GEC Measurements
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E.D RANSOM'S
MASTER COPY

PROTECTION OF INDUSTRIAL POWER SYSTEMS

BY

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BRANCHES IN • SYDNEY • BRISBANE • NEWCASTLE • MELBOURNE • HOBART • ADELAIDE • PERTH

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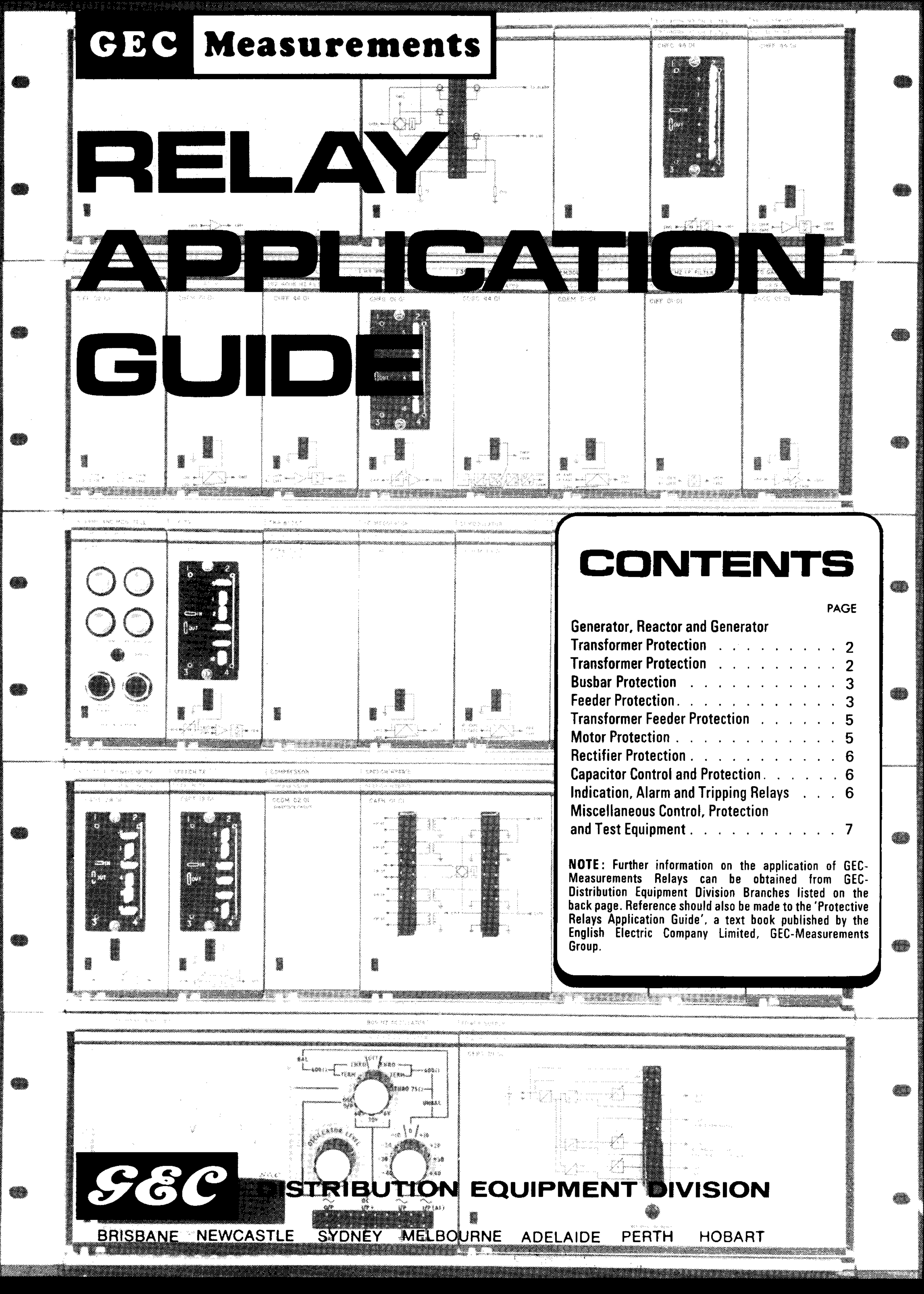
1. Application and Relay List, and Device Identification

GEC Measurements

RELAY APPLICATION GUIDE



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GEC DISTRIBUTION EQUIPMENT DIVISION

BRISBANE NEWCASTLE SYDNEY MELBOURNE ADELAIDE PERTH HOBART

GENERATOR, REACTOR & GENERATOR TRANSFORMER PROTECTION

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Longitudinal Differential	(a) High impedance circulating current system (i) Relay with stabilising resistors (ii) High impedance voltage relay	CAG12 or CAG14 FAC14	MS5078 MS5130 RM5155	Australia & U.K. Australia & U.K. U.K.
Longitudinal Differential (generators & reactors)	(b) Through current biased relay (induction disc)	DDG	MS5155	U.K.
Longitudinal Differential (Generator-transformer)	Overall protection of generator-transformer units – biased induction disc relay.	DDGT	MS5115	U.K.
Long Time Earth Fault	Neutral Earthing resistor back-up protection.	CDG12	MS5091	U.K.
Field Failure	(a) MHO relay for measurement of machine impedance (b) Moving coil undercurrent relay time delay if required	YCGF DBB4 VAT	MS5103 2231-1a (DB2 series) MS5080	U.K. U.K. U.K.
Interlocked Overcurrent	Blindspot protection for faults between CT's and circuit breakers – Polyphase inverse time induction disc relay with control winding.	PDI	RS5137	U.K.
Negative Phase Sequence	Protection against Rotor heating on unbalanced loads. Induction disc relay with negative sequence filter unit. Incorporates an alarm element also.	PGQA4 or CDN	MF455 (PGQA) MS5122	U.K. U.K.
Overcurrent Check	High reset ratio with restraint feature below setting.	DVC4	MF504 (DVC)	U.K.
Overcurrent & Earth Fault	Timed graded for grading with line protection (a) Inverse (i) definite minimum time (IDMT) (ii) very inverse (iii) extremely inverse (b) Definite time (c) Inverse time for system back-up or clearance of close-up faults with restricted generation capacity (i) Voltage controlled (ii) Voltage restrained.	CDG11 or CDG16 CDG13 CDG14 CTU CDV22 CDV21	MS5090 MS5092 MS5093 MS5065 MS5121 MS5163	Australia & U.K. Australia & U.K. Australia & U.K. U.K. Australia & U.K. U.K.
Overvoltage	Protection against overspeed on hydro-machines	VAG	MS5111	Australia & U.K.
Restricted Earth Fault Protection	Instantaneous high impedance relays for generators or transformers with C.T's in neutral as well as lines.	CAG14 or FAC14	MS5130 RM5155	Australia & U.K. U.K.
Rotor Earth Fault	D.C. injection to cover 100% of field winding.	VME	MS5081	U.K.
Rotor Temperature Alarm	Resistance Measurement for temperature alarm by measurement of excitation voltage and current quotient.	DZT4	2231-3 (DZT2)	U.K.
Rotor Temperature Indication	Separate or combined with DZT4 alarm unit, transductor or shunt operated.	DRCR	I-4126	U.K.
Stator Earth Fault	(a) Instantaneous, for generator and transformer low voltage winding where generator solidly earthed or earthed through a resistance. (b) Inverse time induction disc relay for voltage displacement when generator earthed through a voltage transformer – tuned for rejection of 3rd harmonics. (c) Definite time voltage relays	CAG11 or CAG12 VDG14 VAU VAG/VTT	MS5078 MS5078 MS5105 MS5111 On Request	Australia & U.K. Australia & U.K. U.K. U.K. Australia
Reverse Power	(a) Sensitive instantaneous polyphase unit for turbine generators. (b) IDMT unit for engine driven generators. (c) Definite time unit for engine or back-pressure turbine driven generators.	WCD WDG11 WCG	MS5119 RS5124 MS5106	U.K. U.K.* U.K.

TRANSFORMER PROTECTION

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
(A) Earthing Transformer Protection (i) Overcurrent (ii) Standby Earth Fault (iii) Overcurrent	Inverse definite minimum time relays energised from delta connected CT's. Time graded earth fault Instantaneous overcurrent from delta connected CT's.	CDG11 or CDG16 CDG12 CAG34	MS5090 MS5090 MS5091 MS5130	Australia & U.K. Australia & U.K. U.K. Australia & U.K.
(B) Power Transformers Earth Fault Protection	(a) Time Graded (unrestricted) (b) Instantaneous restricted – high impedance unbiased. (c) Long time delay for back-up of earthing resistor.	CDG Range CAG14 or FAC14 CDG12	MS5090 etc. MS5130 RM5155 MS5091	Australia & U.K. Australia & U.K. U.K. U.K.

* Limited stocks available in Australia

TRANSFORMER PROTECTION (Cont)

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Longitudinal Differential				
(i) Biased induction disc	Adjustable inverse time	DDT	MS5116	U.K.
(ii) Biased with harmonic restraint	High speed with 2nd Harmonic restraint, two winding and 3 winding versions.	DMH	MS5227	U.K
(iii) Biased with harmonic restraint	High speed with 2nd harmonic restraint, two winding and 3 winding static version.	DTH	RS5403	U.K.
Neutral Displacement	For transformers earthed through voltage transformers.	VDG12 or VDG14	MS5104 MS5105	U.K. U.K.
(B) Power Transformers Overcurrent Protection	(a) Primary — Inverse time graded overcurrent			
	IDMT	CDG11,CDG16	MS5090	Australia & U.K.
	Very inverse	CDG13	MS5092	Australia & U.K.
	Extremely inverse	CDG14	MS5093	Australia & U.K.
	(b) Primary — instantaneous high set for faults on primary circuit only.			
	(i) Simple attracted armature	CAG13	MS5078	Australia & U.K.
	(ii) High transient stability	CAG17 or CAG19	MS5118 MS5077	U.K. U.K.
	(c) Primary — definite time	CTU CAU	MS5065 On Request	U.K. U.K.
	(d) Secondary — directional overcurrent for two or more transformers in parallel.	CDD	MS5089	U.K.
Winding Temperature Protection	Winding temperature alarms and trip with cooling fan and oil sump control, top oil differential adjustment.	TTT	MS5074	U.K.
Over Fluxing Protection	Volts/Hertz detection for low frequency use during generator and turbine warm-up period.	GTT	RS5407	U.K.
Buchholz Protection	Buchholz alarm & trip for gas accumulation & surge conditions.	OBG	MS5112	U.K.
Gas Accumulation & Gas Surge Auxiliaries	Auxiliary relays for flag indication with alarm and trip contacts — Self reset	VAA21	RS5063	Australia
	Hand reset	VAA23	RS5063	Australia

BUSBAR PROTECTION

APPLICATION	DETAILS	RELAY TYPE	NUMBER	MANUFACTURE
Differential	High impedance (unbiased) instantaneous circulating current. (a) Current setting with external stabilising resistance. (b) Voltage setting	CAG14 FAC14	MS5130 RM5155	Australia & U.K. U.K.
Earth Fault Check	Operated from three residually connected CT's or from one CT in neutral. connection.	CAG11 or CAG12 or DBL4	MS5078 MS5078 MF489 (DBL2)	Australia & U.K. Australia & U.K. U.K.
Frame Earth Fault or Frame Leakage	With switchgear lightly insulated from earth and all cable glands insulated.	CAG11 or CAG12	MS5078 MS5078	Australia & U.K. Australia & U.K.
Interlocked Overcurrent	For tripping of generator or busbars on blindspot protection.	PDI	MS5137	U.K.
Secondary Wiring Supervision	Sensitive voltage time delayed relay for monitoring CT's and secondary wiring, single or 3 phase.	VTX	MS5069	U.K.*

*Limited stocks available in Australia

FEEDER PROTECTION

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Auto Reclose Relays	(a) Single shot, time delayed reclose and lockout.	VAR22 or VTRR	MS5230 On Request	U.K. Australia
	(b) Four shot, time delayed reclose and lockout.	VAR42	MS5230	U.K.
	(c) Many other special schemes also available	VAR	MS5230 & others on request.	U.K.
Circuit Breaker Failure Back-Up	Check relay with fast reset. (a) Set above rated current and with high reset/pick-up ratio.	CAG19	MS5077	U.K.
	(b) Set below rated current and with high withstand rating.	CAG14	MS5130	Australia & U.K.
	(c) As for (b) but high speed static version.	CTIG	RS5135	U.K.
Directional	Polyphase for directional control of overcurrent relays.	PCD	MS5127	U.K.

FEEDER PROTECTION (Cont)

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Distance Protection	(a) Switched three zone phase fault protection scheme incorporating one directional mho unit and overcurrent starters.	SSM3V	MS5222	U.K.
	(b) High speed static scheme giving full 3 phase three zone phase and ground fault (unswitched) protection. Incorporates six directional mho fault detectors together with earth fault compensation unit.	MM3T scheme (YTG relay)	MS5132	U.K.
	(c) Switched 3 zone phase and ground fault protection scheme incorporating a reactance measuring unit, mho directional impedance unit and overcurrent or undervoltage starting.	SSRR3V	MS5133 MS5224	U.K.
	(d) Static mho switched scheme for 3 phase, 3 zone, phase and ground fault protection. Optional features include overcurrent, undervoltage or impedance starting, provision for single pole auto reclose; zone 1 extension, 4th zone timer, power swing blocking, fuse failure and switch-on facility.	SSMM3T (YTS)	RS5404	U.K.
Earth Fault Check	For use in Auto Reclose schemes for earth fault reclose only.	DBL4	MF489 (DBL2)	U.K.
Earth Fault Indicator	Fault location on three phase cables when used with core balance CT's.	CAEF	MS5108	U.K.
Earth Fault Protection	(a) Sensitive relays with high withstand ratings			
	(i) Instaneous	CMG	MS5070	U.K.*
	(ii) Definite time delay	CMU CMTR	MS5101 on request	U.K. Australia
	(iii) Mining application	CMLT	4F001	Australia
	(b) Restricted Earth Fault – instantaneous	CAG14	MS5130	Australia
	(c) Unrestricted Earth Fault – instantaneous	CAG12	MS5078	Australia
Fault Detector	High speed impedance unit used in conjunction with distance relays in high speed carrier blocking systems.	ZTC	MS5125	U.K.
Frequency Relays	Under frequency or overfrequency relay for alarm, trip or load shedding applications	FMG	MS5088	U.K.
	Precision, high performance relay for load shedding application.	FTG	MS5120	U.K.
Fuse Failure Relay	To prevent tripping of distance schemes or relays due to loss of a potential fuse.	VAP or VTP	MS5086 MS5084	U.K. U.K.
High-Set Overcurrent	Instantaneous relay for heavy overcurrents:			
	(a) Standard unit – continuously adjustable.	CAG13	MS5078	Australia & U.K.
	(b) Stabilised, immune to offset in transient currents.	CAG17 or CAG19	MS5118 MS5077	U.K.
Negative Phase Sequence	To detect unbalanced faults on the secondary of small teed-off transformers in high density radial feeder circuits.	CAN	MS5067	U.K.
Sensitive A.C.	Low setting (8-24mA adjustable) for high resistance on arc suppression coil earthed circuits.	NSS4	On request	U.K.
Out-of-Step Blocking	Used in conjunction with distance scheme to prevent tripping during out-of-step conditions.	YTO	RS5136	U.K.
Overcurrent Alarm or Load Shed Control	Adjustable setting with high drop off/pick-up ratio. Not for marine applications (use Vigilarm)	CMQ	MS5066	U.K.
Overcurrent or Earth Fault (Inverse time)	1. Time graded – non directional.			
	(a) Inverse with definite minimum (IDMT)	CDG16 or CDG11	MS5090 MS5090	Australia & U.K. Australia & U.K.
	(b) Very inverse	CDG13	MS5092	Australia & U.K.
	(c) Extremely inverse	CDG14	MS5093	Australia & U.K.
	(d) Definite time	CTU	MS5065	U.K.
	(e) Inverse O/C with instantaneous E/F.	CDAG	CDG+CAG12 or CAG14 E/F	Australia & U.K.
	2. Time graded – directional.			
	(a) IDMT	CDD21	MS5089	U.K.
	(b) Very inverse	CDD23	MS5089	U.K.
	(c) Extremely inverse	CDD24	MS5089	U.K.
	3. As for 1 and 2 but static	SDND	R5176	U.K.
Undercurrent Interlock	Used to prevent isolators being opened with fault current flowing.	CAG19/VAT	MS5077+5080	U.K.
Overpower Relays	Tripping or Alarm for excess power flow conditions. Induction disc inverse time type.	WDG12	MS5124	U.K.
Phase Comparison	Feeder differential h.f. carrier signalling channel.	P10		U.K.

* Limited stocks available in Australia

FEEDER PROTECTION (Cont)

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Pilot Wire Biased Differential Scheme	Static circulating current	SDP	R5326	U.K.
Pilot Wire Biased Differential: (A) Private Pilot Wires (induction disc)	Translay balanced protection of: (a) Plain feeders (b) Teed feeders with quadrature transformer (c) Translay relay as for (a) but tapped to provide adjustment of phase and earth fault settings. (d) Translay balanced protection of fused teed feeders: Fixed setting, adjustable inv. time Adjustable setting, preset inv. time	 HO4 HOA4 HOC4 HT4 HTB4	 RM5145 On request RM5145 On request On request	 U.K.* U.K. U.K. U.K. U.K.
(B) Private Pilot Wires (high speed)	(a) Sensitive biased circulating current scheme. (b) Sensitive biased balanced voltage moving coil relay differential system. Pilot supervision optional. (Refer SJA below) (c) As for DSF7 but for cable circuit protection where line charging currents exceed 1.89% and 5% for resistance and solidly earthed systems respectively. (d) Teed feeder biased balanced voltage moving coil differential system with harmonic restraint.	DMW DSF7 DSE7 DSB7	MS5068 RM5152 On application 2216-2a (DSB5)	U.K. U.K. U.K. U.K.
(C) Rented Pilot Wires (telephone type pilots)	Translay plain feeder protection Plain feeder protection "Stabilay" — high speed, balanced voltage system with pilot supervision.	HM4 or HMB4 DSC7 DSD7	MF445 (HM2,HMB2) 2216-4 (DSC4,DSD3)	U.K. U.K.
Pilot Wire Supervision	Continuous monitoring of protection pilot wires (a) for Translay & DSF7,DSE7 schemes (b) for DSC7 & DSD7 schemes	 SJA SJB	 2221-5 2221-5	 U.K. U.K.

*Limited stocks available in Australia

TRANSFORMER FEEDER PROTECTION

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Pilot Wire Biased Differential	Translay (two element) balanced voltage relay. Teed transformer protection — Translay relay with quadrature transformers.	HHTA4 HHTB4	MF536 (HHTA3) MF244-2a (HHTB)	U.K. U.K.

For all other Protection Application requirements see "Transformer Protection" or "Feeder Protection" as appropriate.

MOTOR PROTECTION

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
(A) SYNCHRONOUS & INDUCTION MOTORS (Above 50 HP)				
Differential Protection	For large motors — approx. 1000 h.p. and over (a) High impedance (unbiased) (b) Biased induction disc	FAC34 or CAG34 DDG11	RM5155 MS5130 MS5115	U.K. Australia & U.K. U.K.
Overcurrent Protection	Time graded overcurrent (IDMT)	CDG etc.	MS5090	Australia & U.K.
Reverse Phase Protection	Induction disc reverse phase and undervoltage relaying.	VDM	MS3028	U.K.*
Thermal Protection	Thermal replica overload with unbalance protection. Versions available with instantaneous balanced, unbalanced and earth units. Versions available for use with Vacuum contactors.	CTM — CTMF	RS5171	U.K.

* Limited stocks available in Australia

MOTOR PROTECTION (Cont)

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Undervoltage Protection	Instantaneous Definite Time Inverse Time — Induction Disc	VAG11 VAU21 VDG13	MS5111 MS5111 MS5113	Australia & U.K. Australia & U.K. Australia & U.K.
(B) ADDITIONAL PROTECTION for SYNCHRONOUS MOTORS				
Field Failure	Moving Coil Undercurrent Relay with separate time delay units.	DBB4/VAT	2231-1a (DB2 series) MS5080	U.K.
Out-of-Step Protection	To protect against damage consequent upon falling out-of-step as a result of low voltage or overloading.	FOS24	RS5161	U.K.*
Overvoltage	To prevent against sudden restoration of supply on motors where power reversal is normal and when there is no load on the motor.	VDG11	MS5104	U.K.
Reverse Power	To protect against sudden restoration of supply on motors which will always rotate in the same direction.	WCD	MS5119	U.K.
Underfrequency	To protect against sudden restoration of supply on loaded motors where power reversal is normal.	FMG	MS5088	U.K.

*Limited stocks available in Australia

RECTIFIER PROTECTION

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Backfire	Reverse current protection on d.c. breaker when two or more rectifiers connected in parallel.	CMG	MS5070	U.K.*
Earth Fault	Instantaneous restricted earth fault high impedance relay for rectifier transformer	CAG14 or FAC14	MS5130 RM5155	Australia & U.K. U.K.
Overload & Short Circuit	(a) Inverse time overcurrent for class I rectifiers, light general or industrial service.	CDG11	MS5090	Australia & U.K.
	(b) Very inverse time overcurrent for class II rectifiers, heavy general or industrial service.	CDG13	MS5092	Australia & U.K.
	(c) Extremely inverse time characteristic for class III rectifiers, CT operated (1A or 5A) or transductor operated for d.c. circuit use.	CTG25	MS5083	U.K.
Short Circuit	Instantaneous high set units on a.c. breaker.	CAG17	MS5118	U.K.

*Limited stocks available in Australia

CAPACITOR CONTROL & PROTECTION

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Capacitor Switching for Power Factor Control	VAr measuring and stepping control: (a) Single step type (b) Multi step types	NJ03 NJ05 NJMA NJMA	2228-6a 2228-6a RM5141 2228-6c	U.K. U.K.* U.K.* U.K.*
Series Capacitor Protection Shunt Capacitor Protection	Split phase differential balance protection per single phase bank. Normally used with definite time delay relays type VTT for alarm and trip.	DTCB11	RS5142	U.K.
Shunt Capacitor Protection	Double star bank residual unbalance (a) Sensitive biased (b) Unbiased	CACB11 CAG12	RS5143 MS5078	U.K. U.K.

*Limited stocks available in Australia

INDICATION, ALARM & TRIPPING RELAYS

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Alarm Cancellation	Check alarm and reset	VAK	MS5114	U.K.
Annunciators (Flags)	Auxiliary flag indicators single or multi-element without repeat contacts	CAF	MS5064	Australia & U.K.
Annunciator Schemes	Multipoint circuit alarm systems	MARK 5	SG283	U.K.

INDICATION, ALARM & TRIPPING RELAYS (Cont)

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Semaphore Indicator	Mimic Diagram application	VAM	MS5095	U.K.
Auxiliary Trip Relay	Multicontact protection auxiliary relays, 2-6 sets contacts a.c. or d.c., self, hand and electrical reset.	CAA VAA	MS5063 MS5063	Australia & U.K. Australia & U.K.
Intertripping (Receive Relays)	Receive relays (d.c.) as follows: (a) Surge-proof up to 5 Amp a.c. using separate pilot circuit (4kV & 15kV insulation) shunt operated. (b) Surge-proof up to 2 Amp a.c. and for connection in series with the protection equipment in a.c. pilot circuit (c) Surge-proof up to 5 Amp a.c. and for connection as in (ii) (d) Interposing signal receive relay 50V d.c. version immune to Operation from 110V 50Hz) (e) Interposing signal receive relay 110V d.c. version immune to 250V a.c.	DBM4 DBS4 DBSA4 VAWA VAA Special	2215-1 (DBA2) 2215-1 (DBS2) 2215-1 (DBSA4) MS5102 On Request	U.K. U.K. U.K. U.K. Australia & U.K.
Intertripping (Send-Receive Relays)	Send & send/receive relays as follows: (a) Providing intertrip pulse of preset duration independent of initiation contact dwell time or an intertrip pulse dependent on initiation dwell time but with preset minimum time. (b) Carrier acceleration send/receive relay to transmit a preset time pulse 0.5 to 3 sec. adjustable and incorporates a receive auxiliary element operated by VF equipment receive output.	VAWJ23 VAWJ34	On request On request	U.K. U.K.
Intertrip Pilot Supervision	A.C. supervision of d.c. pilots	NSS4	On request	U.K.
Tripping (High Speed 10 millisec.)	4 contacts / 8 contacts / 18 contacts } Hand self or electrical reset types with high mechanical stability	VAJ13 VAJ11 VAJ12	MS5109 MS5109 MS5109	Australia & U.K. Australia & U.K. U.K.
Trip Circuit Supervision	Supervision of Circuit Breaker Trip Coils and fused d.c. supplies.	VAX	MS5123	U.K.
V.F. Intertrip	(a) High Security Direct transfer frequency shift trip scheme incorporating security checks to ensure genuine trip tone signals being sent and received before tripping permitted — tripping time less than 30 mS (b) High Speed Frequency shift system providing channel fail alarm with clamp & designed primarily for use with interlocked systems such as high speed permissive intertrip and carrier blocking distance schemes. Operating time less than 15 mS	S25 D12	on request On Request	U.K. U.K.

MISCELLANEOUS APPLICATIONS

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Battery Biasing	Negative Biasing Unit	CD4	DLP0001a(CD2)	U.K.
Battery Earth Fault	D.C. Supply (unearthed). Earth Leakage detector.	CME	MS5071	U.K.
Check Synchronising	Interlock relays to prevent incorrect closure of manually synchronised feeder and generator circuits. Dead bus auxiliary	SK series VAG/VAA	RM5165 MS5111	U.K. Australia & U.K.
D.C. Circuit Protection	Overvoltage / Undervoltage / Overcurrent / Under current / Reverse Current } High versatility, sensitive, balanced moving coil movement Combined O/C & Reverse Current Combined over/under voltage protection	DBA4/DBB4 DBB4	2231-1a (DB2 Series) 2231-1a (DB2 Series)	U.K. U.K.
Frequency Sensitive	See Feeder Protection			
Reclosing Relays	For automatic reswitching of feeder circuit breakers after tripping by protection relays. Single and multishot types some with anti-hunting facilities, operation counters and lockout features for uncleared faults.	VAR	MS5230 MS5096-5099 MS5107	U.K.
Sensitive Measuring	(a) D.C. voltage or current measuring relays having a minimum operating power of 3 milliwatts and high continuous withstand rating of 7 watts. (b) A.C. current measuring relays as in (i) in conjunction with saturating CT's and rectifiers.	CMG or VMG See CMU or CMLT	MS5070 MS5070 MS5101 4F001	U.K. U.K. U.K. Australia

MISCELLANEOUS APPLICATIONS (Cont.)

APPLICATION	DETAILS	PREFERRED RELAY TYPE	PUBLICATION NUMBER	PLACE OF MANUFACTURE
Test Accessories	(a) Test Plugs for use with drawout type relay and meter cases and test blocks (E.E.Co.)	MPB	MS5085	U.K.*
	(b) Test Blocks for use with MPB plug to allow simplified test of meter and relay circuits.	MPG	MS5085	U.K.*
	(c) Tool Kits for relay maintenance and comprising contact bender, contact gauge, torch and light probe, spanner.	–	MS5138	U.K.*
Test Equipment (Portable)	(a) Overcurrent relay test set comprising current control indication, timer impedance matching and contactor switching circuits. Output range 0.05 to 200 Amps. Distortion 1%. Max.	CFB	MS3811	U.K.*
	(b) Distance relay test set comprising all control circuits, adjustable source impedance unit and line impedance unit (1% setting) for rapid dynamic testing of high speed relay system.	ZFB	MS5228	U.K.
Time Delay Relays	(a) A.C. or d.c. induction cup element, with delay on pick-up, drop off or pick-up and drop off.	VAT	MS5080	U.K.
	(b) A.C. or d.c. static relays with delay on pick-up or drop off.	VTT	MS5128	Australia & U.K.
Voltage Regulating	Automatic voltage regulation in a.c. or d.c. circuits by adjustment of on-load tap changers, induction regulators etc.			
	(a) Solenoid element only	AVB4	RM5147	U.K.
	(b) Solenoid type with U/V contacts	AVC4	RM5147	U.K.
	(c) Solenoid type with induction time delay element.	AVE4	RM5147	U.K.*
	(d) A.C. line drop compensator for use with AVE3.	CAD	RM5147	U.K.*
	(e) A.C. Static Relay with inverse time voltage characteristics with adjustable dead band sensitivity of ± 0.5 to ± 3.0% and time delay of 30-120 secs. at 1% outside dead band.	VTJC	MS5129	U.K.
	(f) A.C. line drop compensator for use with the VTJC.	CIJC	MS5129	U.K.

* Limited stocks available in Australia

GEC Measurements

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APPLICATION GUIDE

IEEE-NEMA

DEVICE FUNCTION NUMBERS

FOR

SWITCHGEAR AND AUTOMATIC CONTROL EQUIPMENT

(reference ~~A.S.A. C37.2~~, BS3939.)
ANSI

1. Introduction

In the design of complex control and protection schemes for power generation, distribution and associated control equipment the use of standard methods of referencing devices for similar functions in such schemes facilitates the interpretation of information presented on schematic or elementary diagrams.

The general adoption of a standard method of reference is to be commended but without adequate guidance and access to the device list given in American Standard C37.2 inconsistencies can arise with reduction in the benefits gained by its use.

The device numbering system was originally proposed by the American Institute of Electrical Engineers several decades ago and it was later adopted by NEMA (National Electrical Manufacturers Association). It was also incorporated in an incomplete form in British Standard 108 and is now included in BS3939 but still without application guidance. These device function numbers which have been developed as a result of usage over many years, define either the actual function the device performs in an equipment or they may refer to the electrical or other quantity to which the device is responsive. Where experience has not been gained in the selection of device numbers and their suffix letters (if any), considerable inconsistencies occur throughout the electrical industry. The benefits of using such a system therefore decrease and it is hoped that these notes may assist with the choice of numbers for particular devices hence improve the benefit of the use of such a coding to power system and switchgear equipment for which it was primarily developed.

2. Basis of System

The basis of this system of Device Function Numbers is that in any type of control scheme, the same number denotes a device performing the same function and by consistent use familiarity with these numbers facilitates the identification of apparatus combined with the checking of schematic and wiring connections and rapid review of the protection provided where relay co-ordination is involved.

From the customer's viewpoint these numbers identify similar items from any manufacturer in a universal manner which is independent of particular manufacturer's type designation.

To obtain the maximum benefit from such a system, numbers should appear on all Device Lists, Schematic and Wiring Diagrams, and Instruction Books. They may also be included in any labels and nameplates related to principal items of a control scheme.

Since the title of the device number indicates its function then the number remains the same although the apparatus performing a given function may vary. For example, a master switching device (device No. 1) may be either a contact making device, a switch, a time switch or a controller.

3. Suffix Letters

When there is more than one device on any complete scheme having the same function these devices should be differentiated by the addition of one or more suffix letters, for example : 52 represents a circuit breaker whereas 52CS is the circuit breaker control switch. Capital letters may also be used to distinguish associated and auxiliary devices, example, 52X is an auxiliary contactor used in connection with the circuit breaker 52. Lower case or small letters a, b, c, d etc., may be used to designate circuit breaker or isolator auxiliary switches, example, 52a is an auxiliary contact which closes when the main contacts close. Refer to tables following the numerical list of devices for suffix letters.

Where device numbers are used on schematic and equipment assembly drawings, and in conjunction with other numerical reference data such as Equipment Schedule or Material List item numbers, it has been found of a distinct advantage to underline all device numbers, for example, 52CS.

4. Schematic Diagrams

The most beneficial use of a device numbering scheme is when it is associated with single line system diagrams or fully comprehensive schematic diagrams. If a manufacturer's type designation would assist in further identification, then this can be given briefly in a combined number consisting of the device number which is underlined and the manufacturer's designation written immediately below it, e.g. 51 / CDG11 OR

5. Local Control

The series of numbers and suffixes shown in the following pages may be applied to most schemes when it is not necessary to distinguish between feeder and generation equipment. If, however, it would be an advantage to make such a distinction then the numbers 1-99 may be reserved for generator equipment and a similar series of 101-199, etc., may be used for feeder equipment.

6. Supervisory or Remote Control

A similar series starting with 201 may be used for supervisory or remote control equipment in general cases. If a distinction between machine and feeder equipment is required, then 201-299 series may be reserved for machine equipment and a similar series starting with 301 may be used for feeder equipment.

7. Application Notes with GEC Relay Type References

The following notes must be read in conjunction with the device number list and are produced to assist in the selection of suitable device numbers. Common applications are listed with comments and example relay types are given from the GEC Measurements range where the functions are clearly identifiable. Where the device number definition in the main list is adequately described and/or common applications are not generally applicable to modern practice no notes are offered. Letters underlined in the notes for the first few items indicate the method by which suffix numbers are often chosen. Refer also to BS3939 for abbreviations for guidance if helpful.

IEEE Device Numbers and Functions For Switchgear Apparatus

Manual and Automatic Station Control
Supervisory Systems
Associated Telemetering Equipment

Device Number	Definition and Function	APPLICATION COMMENTS
1	Master Element is the initiating device, such as a control switch, voltage relay, float switch, etc., which serves either directly, or through such permissive devices as protective and time-delay relays to place an equipment in or out of operation.	1PB Master Start/Stop Push Button 1CS Master Start/Stop Control Switch
2	Time-delay starting, or closing, relay is a device which functions to give a desired amount of time delay before or after any point or operation in a switching sequence or protective relay system, except as specifically provided by device functions 62 and 79 described later.	Time delay operate relay, on its own, in automatic circuitry. When included in other composite relays or closely associated with a particular protection function it is more descriptive to use a composite number such as 79/2 which implies an auto-reclose timer. GEC types : VAT, VTT.
3	Checking or interlocking relay is a device which operates in response to the position of a number of other devices, or to a number of predetermined conditions in an equipment to allow an operating sequence to proceed, to stop, or to provide a check of the position of these devices or of these conditions for any purpose.	
4	Master contactor is a device, generally controlled by device No. 1 or equivalent, and the necessary permissive and protective devices, which serves to make and break the necessary control circuits to place an equipment into operation under the desired conditions and to take it out of operation under other or abnormal conditions.	Start relay in automatic scheme. 4/2 Limit timer for starter motor for diesel sets. GEC type VAT, VTT.
5	Stopping device functions to place and hold an equipment out of operation.	Rundown-to-stop controller or stop relay. GEC type VAA.
6	Starting circuit breaker is a device whose principal function is to connect a machine to its source of starting voltage.	Used for synchronous machine or motor starting circuit breaker or contactor, as distinct from a main or running circuit breaker or contactor.
7	Anode circuit breaker is one used in the anode circuits of a power rectifier for the primary purpose of interrupting the rectifier circuit if an arc back should occur.	
8	Control power disconnecting device is a disconnective device – such as a knife switch, circuit breaker or pullout fuse block – used for the purpose of connecting and disconnecting, respectively, the source of control power to and from the control bus or equipment. Note: Control power is considered to include auxiliary power which supplies such apparatus as small motors and heaters.	Isolating device or switch for control or auxiliary power but not for power circuit or mains isolators as described by device 89. 8H Heater switch. *8NE Non essential aux power.*

Dev. No.	Definition & Function	Application Notes
9	Reversing device is used for the purpose of reversing a machine field or for performing any other reversing functions.	
10	Unit sequence switch is used to change the sequence in which units may be placed in and out of service in multiple-unit equipments.	
11	Reserved for future application.	
12	Over-speed device is usually a direct-connected speed switch which functions on machine overspeed.	
13	Synchronous-speed device, such as a centrifugal-speed switch, a slip-frequency relay, a voltage relay, an undercurrent relay or any type of device, operates at approximately synchronous speed of a machine.	A synchronous speed detector, not to be confused with device 56 which is a synchronising relay for initiating field application on synchronous motor starting. The latter relay may also be known as a "slip frequency relay" but is usually given the device number 56.
14	Under-speed device functions when the speed of a machine falls below a predetermined value.	More likely to be a mechanically operated speed switch rather than an underfrequency relay used to initiate load shedding. Refer device 81 for frequency relays.
15	Speed or frequency, matching device functions to match and hold the speed or the frequency of a machine or of a system equal to, or approximately equal to, that of another machine source or system.	May be the speed matching part of an automatic synchroniser. GEC types SV or part of type YP. 15CS Governor load-speed Control Switch.
16	Reserved for future application.	
17	Shunting or discharge switch serves to open or to close a shunting circuit around any piece of apparatus (except a resistor), such as a machine field, a machine armature, a capacitor or a reactor. Note: This excludes devices which perform such shunting operations as may be necessary in the process of starting a machine by devices 6 or 42, or their equivalent, and also excludes device 73 function which serves for the switching of resistors.	Suicide contactor on D.C. drives but not normally used for a D.C. field discharge device on a generator or synchronous motor as this is usually part of the field application contactor or breaker - refer to device 41.
18	Accelerating or decelerating device is used to close or to cause the closing of circuits which are used to increase or to decrease the speed of a machine.	Traction, haulage or mine hoist controller.
19	Starting-to-running transition contactor is a device which operates to initiate or cause the automatic transfer of a machine from the starting to the running power connection.	Transfer initiating device in an autotransformer starter.

Dev. No.	Definition & Function	Application Notes
20	Electrically operated valve is a solenoid- or motor-operated valve which is used in vacuum, air, gas, oil, water, or similar lines. Note: The function of the valve may be indicated by the insertion of descriptive words such as "Brake" or "Pressure Reducing" in the function name, such as "Electrically Operated Brake Valve".	
21	Distance relay is a device which functions when the circuit admittance, impedance or reactance increases or decreases beyond predetermined limits.	All types of distance protection relays. GEC types YTG, SSRR3V, etc. 21R 21Y 21B Phase fault distance relay elements for Red, Yellow and Blue phases. 21E Earth fault distance relay element.
22	Equalizer circuit breaker is a breaker which serves to control or to make and break the equalizer or the current-balancing connections for a machine field, or for regulating equipment, in a multiple-unit installation.	
23	Temperature control device functions to raise or to lower the temperature of a machine or other apparatus, or of any medium, when its temperature falls below, or rises above, a predetermined value. Note: An example is a thermostat which switches on a space heater in a switchgear assembly when the temperature falls to a desired value as distinguished from a device which is used to provide automatic temperature regulation between close limits and would be designated as 90T.	Thermostat.
24	Reserved for future application.	
25	Synchronizing or synchronism-check device operates when two ac circuits are within the desired limits of frequency, phase angle or voltage, to permit or to cause the paralleling of these two circuits.	A synchroniser or synchronism check device. GEC types SRA or part of YP synchronisers, SKA, SKB, SKBA, SKC, SKD, SKE synchronism check relays. 25/15 Automatic synchroniser with speed (and voltage) matcher incorporated. GEC : Complete type SRA/SV scheme or type YP.
26	Apparatus thermal device functions when the temperature of the shunt field or the amortisseur winding of a machine, or that of a load limiting or load shifting resistor or of a liquid or other medium exceeds a predetermined value; or if the temperature of the protected apparatus, such as a power rectifier, or of any medium decreases below a predetermined value.	Temperature limit detecting device, usually direct measuring, e.g. "Thermister". This is not used for bearing overtemperature - refer to device 38. Refer also to device 49, an indirect measuring or replica relay used for thermal protection for trip initiation. eg Motor protection
27	Undervoltage relay is a device which functions on a given value of undervoltage.	Usually reserved for A.C. U/V relays, GEC type VDG13. If no-volt detection also required use 27UV and 27NV. No-volt relay, GEC type VAG. For D.C. (battery) undervoltage device 80 has been used but now reserved for another purpose. Use 27 with appropriate suffix if required. D.C. relays, GEC types DBA4 moving coil or VAG attracted armature type.

Dev. No.	Definition & Function	Application Notes
28	Reserved for future application.	
29	Isolating contactor is used expressly for disconnecting one circuit from another for the purposes of emergency operation, maintenance, or test.	
30	Annunciator relay is a nonautomatically reset device which gives a number of separate visual indications upon the functioning of protective devices, and which may also be arranged to perform a lockout function.	Usually multi-element series or shunt operated flag relay without contacts commonly required in small schemes, example Buchholz indication or for mechanical or environmental abnormality, etc. GEC types VAF, CAF. If these relays also have contacts for audible alarm and/or tripping functions it is general practice to use an auxiliary suffix to the main device number. Refer notes on device 63.
31	Separate excitation device connects a circuit such as the shunt field of a synchronous converter to a source of separate excitation during the starting sequence; or one which energizes the excitation and ignition circuits of a power rectifier.	
32	Directional power relay is one which functions on a desired value of power flow in a given direction, or upon reverse power resulting from arc back in the anode or cathode circuits of a power rectifier.	Used more commonly for reverse power or overpower relay for generators. GEC types : WDG11 reverse power WDG12 over power WCG reverse power WCD sensitive under and reverse power Device 67 is not for power relays but directional current devices.
33	Position switch makes or breaks contact when the main device or piece of apparatus, which has no device function number, reaches a given position.	Could refer to a position or limit switch on a gate or butterfly valve in a liquid or gas flow line.
34	Motor-operated sequence switch is a multi-contact switch which fixes the operating sequence of the major devices during starting and stopping, or during other sequential switching operations.	Master sequence device in multi-unit automatic operation of, for example diesel or water wheel driven generators.
35	Brush-operating, or slip-ring-short-circuiting, device is used for raising, lowering, or shifting the brushes of a machine, or for short-circuiting its slip rings, or for engaging or disengaging the contacts of a mechanical rectifier.	
36	Polarity device operates or permits the operation of another device on a predetermined polarity only.	Could be used in D.C. drives (Ward Leonard) for the device sensing power flow for brake control to prevent overspeed operation.

Dev No.	Definition & Function	Application Notes
37	**Undercurrent or underpower relay is a device which functions when the current or power flow decreases below a predetermined value.**	Undercurrent check relay in fault throwing switch circuit to permit automatic opening of line isolator following remote clearance of fault. GEC type CAU. 37 can also be used as a unit by unit shutdown initiation relay as the demand falls in a multiunit generation plant. GEC types CAU, CMQ or Vigilarm Controller. As a power relay 37 can be used in turbine shutdown schemes. GEC type WCD. However, a WCD would not use 37 if it is used as a reverse power detector often used in synchronous compensator (condenser) schemes or high inertia synchronous motor sets when feedback power could be injected into the supply system following supply line interruption - this application uses device 32.
38	Bearing protective device is one which functions on excessive bearing temperature, or on other abnormal mechanical conditions, such as undue wear, which may eventually result in excessive bearing temperature.	**Usually bearing oil temperature switch.**
39	Mechanical condition monitor is a device which functions upon the occurrence of an abnormal mechanical condition, such as vibration, or seal failure (not including bearing temperature which is covered by Device Function Number 38).	39VB Vibration Monitor 39SF Seal Fail Monitor
40	Field relay is a device that functions on a given or abnormally low value or failure of machine field current, or on an excessive value of the reactive component of armature current in an ac machine indicating abnormally low field excitation.	Field failure detector of A.C. or D.C. machine either by monitoring directly the D.C. current in the field circuit (type DBA4) or indirectly in A.C. machines by monitoring reactive power requirements from the connected system. GEC type YCGF mho type.
41	Field circuit breaker is a device which functions to apply, or to remove, the field excitation of a machine.	This can also apply to a contactor for the same purpose. If the field discharge device is not physically part of the field application breaker or contacts then devices 41M and 41D would be suggested for Main and Discharge units respectively. 41a, 41b Normally open and normally closed auxiliary contacts on for field breaker or contactor.
42	Running circuit breaker is a device whose principal function is to connect a machine to its source of running voltage after having been brought up to the desired speed on the starting connection.	Can also be used for a contactor and would be applied to the final contactor in a reduced voltage motor starting scheme or the only contactor in a DOL (direct on line) starting scheme. Starting contactor(s) would use device 6 (or 6A, 6B, 6C, etc.) and could be those for primary or secondary circuits. Device 42 would be generally reserved for motor circuits and not used for power distribution and feeder circuits where device 52 would be more applicable.

Dev. No.	Definition & Function	Application Notes
43	Manual transfer or selector device transfers the control circuits so as to modify the plan of operation of the switching equipment or of some of the devices.	Most control transfer (or selector) switches for "REMOTE-LOCAL", "AUTO-OFF-MANUAL", "AUTO REMOTE-OFF-AUTO LOCAL" etc. would take this number. Suffixes A, B, C, etc. may be required to distinguish between several switches on the one control scheme. To maintain consistency for synchronising functions it is recommended that synchronising "ON-OFF" or "AUTO-OFF-MANUAL", key operated, control switches should not use the number 43, but 25CS would be appropriate.
44	Unit sequence starting relay is a device which functions to start the next available unit in a multiple-unit equipment on the failure or on the non-availability of the normally preceding unit.	
45	Atmospheric condition monitor is a device which functions upon the occurrence of a predetermined atmospheric condition, such as hazardous explosive atmosphere, smoke, or fire.	This was often selected for D.C. overvoltage use on excitation schemes, but has lately been reserved for new purposes (e.g. smoke detector - refer device list). D.C. overvoltage applications would now take device No. 59 with appropriate suffix letter if required.
46	Reverse-phase, or phase-balance, current relay is a device which functions when the polyphase currents are of reverse-phase sequence, or when the polyphase currents are unbalanced or contain negative phase-sequence components above a given amount.	Negative phase sequence detector, GEC types CDN, PCQA4 for generators, part of CMM motor protection relay, *also CAN*.
47	Phase-sequence voltage relay is a device which functions upon a predetermined value of polyphase voltage in the desired phase sequence.	This relay usually detects reverse phase or loss of phase, GEC type VDM (or AEI PRA3).
48	Incomplete sequence relay is a device which returns the equipment to the normal, or off, position and locks it out if the normal starting, operating or stopping sequence is not properly completed within a predetermined time.	GEC types VAT, VTT, MJDE4.
49	Machine, or transformer, thermal relay is a device which functions when the temperature of an ac machine armature, or of the armature or other load carrying winding or element of a dc machine, or converter or power rectifier or power transformer (including a power rectifier transformer) exceeds a predetermined value.	Most commonly applied to thermal motor protection relays which may also incorporate other features such as instantaneous overcurrent and/or earth fault, etc. For thermal relay only (GEC type CMM21) use device 49 but for relays incorporating instantaneous features use device 49/50, GEC types CMM31, CMM41. NOTE : The CMM relays incorporate phase unbalance (negative sequence) detection circuit which would use 46, but since the relay is basically for thermal and instantaneous overcurrent protection 49/50 would sufficiently describe its main function.

Dev. No.	Definition & Function	Application Notes
50	Instantaneous overcurrent, or rate-of-rise relay is a device which functions instantaneously on an excessive value of current, or on an excessive rate of current rise, thus indicating a fault in the apparatus of circuit being protected	All instantaneous overcurrent relays for fault protection could use this number. Relays detecting current levels for control purposes would generally not use 50 but may use 37. 50E instantaneous earth fault. Overcurrent and earth fault examples could be selected from GEC types CAG11, CAG12, CAG13, CAG14, CAG17, CAG19. Refer also to notes for device 64.
51	Ac time overcurrent relay is a device with either a definite or inverse time characteristic which functions when the current in an ac circuit exceeds a predetermined value.	Commonly applied to all inverse time induction disc type relays with 51 being used for phase fault and 51E being used for earth fault when connected in the residual circuit of a 3 phase CT group. GEC types CDG11, CDG13, CDG14 or individual centre pole elements of a CDG31, CDG33, CDG34. Definite time overcurrent and earth fault relays are most commonly confined to static overcurrent relays GEC type CTU11 and

the sensitive earth fault types CMU21 and CTU15, CTU25 of the balanced armature and static types respectively.

51 is NOT intended for use for thermal overcurrent relays with their inherent time delay as used for motor protection, or instantaneous elements mounted together with inverse time relays in the same case. For example, a CDG21 composed of IDMT element together with a CAG13 or CAG17 instantaneous element could be designated 50/51 or portrayed on a schematic diagram as two separate elements in series and designated 50 and 51 respectively. For the CDG61 3 pole version the principle is the same but where the centre pole is an earth fault element with or without instantaneous element the suffix E is recommended for application distinction, e.g. 51E, 50E/51E respectively. Where the centre pole is an instantaneous earth fault element alone as in the GEC type CDAG relay with CAG12 or CAG14 centre element then this element would use device 50E.

The use of 51I for an instantaneous element in the above examples is not appropriate to the device function. Refer also to notes for device 64.

Dev. No.	Definition & Function	Application Notes
52	Ac circuit breaker is a device which is used to close and interrupt an ac power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions.	This applies to all types of circuit breakers at all voltage levels for distribution, busbar connection and feeder use where the breaker is primarily used for distribution control and fault clearance duty. Where however it is associated with a motor having direct-on-line (DOL), reduced voltage, reactance or secondary resistance starting the device 42 may be more appropriate as it then has a similar function to a motor control contactor. Refer to notes for devices 42 and 6.

Dev. No. — Definition & Function — Application Notes

CB auxiliary devices generally all use the basic number 52 with appropriate suffixes as per the following examples :

52a, 52b respectively, normally open and normally closed auxiliary switches.

52aa, 52bb normally open and normally closed solenoid or spring close mechanism switches.

52c early closing (or late opening) auxiliary contact normally in series with the trip coil.

52d, 52e normally open and normally closed respectively, racking switches on drawout breakers when breaker is "racked out".

52X closing control contactor for solenoid operated units or spring release solenoid for spring closed breakers.

52C or 52CC closing solenoid or air valve solenoid coil.

52T or 52TC shunt trip coil, 52TR, 52TY, 52TB for direct acting AC series trip coils if required.

52CS circuit breaker TRIP-NEUTRAL-CLOSE control switch.

52CS C,AC contact of control switch closed in CLOSE & AFTER CLOSE.

52CS T,AT, 52CS T, 52CS C other control switch contacts closed in TRIP & AFTER TRIP, TRIP & CLOSE respectively. If the control switch contacts are portrayed in tabulation form on a schematic the letters C, AC, T, AT, N etc. would then be used for the closed position indication lines.

52M motor for closing or spring winding mechanism.

Refer also to suffix notes at end of device list table.

The LOCAL-REMOTE control transfer and synchronizing switches often required would use 43 and 25CS respectively and NOT 52 plus suffix designations. Refer notes on device 43.

Dev. No.	Definition & Function	Application Notes
53	Exciter or dc generator relay is a device which forces the dc machine field excitation to build up during starting or which functions when the machine voltage has built up to a given value.	Depending on how the field forcing condition is initiated or detected an A.C. or D.C. relay could be used. A common application is for initiating coarse control of excitation when indirect acting rheostatic types of automatic voltage regulators are used with pilot exciters on A.C. generators.
54	High-speed dc circuit breaker is a device which starts to reduce the current in the main circuit in 0.01 second or less, after the occurrence of the dc overcurrent or the excessive rate of current rise.	This number not now in common use for D.C. breakers and is currently reserved for future use. Refer to 72 for D.C. circuit breaker.

Dev. No.	Definition & Function	Application Notes
55	Power factor relay is a device which operates when the power factor in an ac circuit becomes above or below a predetermined value.	Also VAR measuring relays such as required for capacitor switching control in power factor correction schemes. GEC relays NJMA, NJMB multistep capacitor control *NOVAR* with or without resetting with loss of supply feature, NJPA, NJPB multistep control relay with mechanical resetting feature, ~~NJO3,~~ NJO5 single step control relays.
56	Field application relay is a device which automatically controls the application of the field excitation to an ac motor at some predetermined point in the slip cycle.	GEC relay VTM11 with or VTM12 without point-of-wave switching respectively for synchronous motor starting schemes.
57	Short-circuiting or grounding device is a power or stored energy operated device which functions to short-circuit or to ground a circuit in response to automatic or manual means.	Commonly a transmission line fault throwing switch to initiate remote clearance of a local fault condition. Can also be applied to CT buswire shorting relay in busbar protection scheme, e.g. GEC VAJY hand reset "tripping" relay.
58	Power rectifier misfire relay is a device which functions if one or more of the power rectifier anodes fails to fire.	Also rectification failure relay. GEC type
59	Overvoltage relay is a device which functions on a given value of overvoltage.	For A.C. or D.C. overvoltage application with or without time delay feature. Use appropriate suffixes when required. GEC types VAG, VAU, VDG11.
60	Voltage balance relay is a device which operates on a given difference in voltage between two circuits.	Now for a voltage or current balance relay. Typical application is for rheostat follow-up control in magnetic amplifier types of automatic voltage regulator circuits for larger sizes of generators.* *(*Also neutral current unbalance detection between 2-Y-con. capacitor banks. GEC type CACB11 for biased relay or CAC12 unbiased.)* GEC type DBB4 usually followed by PSE4 timer device 60BT. *This is NOT applied to balanced Voltage type of feeder protection eg Translay, which is a differential scheme using device 87.*
61	Reserved for future application.	Now reserved for future use but has frequently been used for "split phase" protection of parallel windirgs of some generators also known as "transverse differential". Use 87 with appropriate suffix for future similar applications.
62	Time-delay stopping or opening relay is a time-delay device which serves in conjunction with the device which initiates the shutdown, stopping, or opening operation in an automatic sequence.	The complement to device 2. GEC type VAT. *VTT*
63	Pressure switch is a switch which operates on given values, or on a given rate of change, of pressure.	Also for vacuum relay. Common application is for Buchholz transformer gas relay for oil conservator type transformers or the tank pressure relay for sealed transformers. 63GA for gas accumulation alarm contact and 63GS for gas surge or pressure (trip) contact. GEC type OBG range.
64	Ground protective relay is a device which functions on failure of the insulation of a machine, transformer or of other apparatus to ground, or on flashover of a dc machine to ground. Note: This function is assigned only to a relay which detects the flow of current from the frame of a machine or enclosing case or structure of a piece of apparatus to ground, or detects a ground on a normally ungrounded winding or circuit. It is not applied to a device connected in the secondary circuit or secondary neutral of a current transformer, or current transformers, connected in the power circuit of a normally grounded system.	This number is intended for such applications as a generator neutral earth fault detector relay which measures the voltage across the loading resistor in a distribution transformer (high resistance) earthing scheme. It is also used for a generator rotor earth fault detector, excessive earth leakage detection in normally unearthed battery or D.C. supply systems, for example unearthed armature loop of a Ward Leonard system or similar application. It is NOT intended for use in CT secondary circuits when other device numbers would be applicable. Unfortunately the choice of 64 for all earth fault relays is a common misunderstanding in Australian practice which is divergent from the established standard, hence the following recommendations are made for common earth fault relay situations.

50E Instantaneous earth fault often in residual connection of 3 phase CT group. GEC type CAG11, CAG12, CAG13, CAG14, CAG19.

50FE Instantaneous frame earth fault
50CH Instantaneous check relay usually for frame earth fault
} GEC types CAG12, CAG13, CAG14

50SE Instantaneous sensitive earth fault relay without time delay. GEC type CMG.

51E Inverse time earth fault relay usually with residual connection of a 3 phase CT.

51SE Sensitive earth fault relay with time delay. GEC type CMU21, CTU15, CTU25.

51SYE or 51G inverse (long time) standby earth or ground fault relay for back-up protection of a neutral earthing device. GEC type CDG12.

51N or 51BU neutral or backup relay usually in the neutral of a generator or star point earthing connection of a transformer. GEC types CDG11, CDG13, CDG14.

No.	Definition & Function	13 Application Notes
65	**Governor** is the equipment which controls the gate or valve opening of a prime mover.	Governor and servo mechanism only, however <u>15CS</u> or <u>15PB</u> would be the control switch or pushbutton controlling the governor reference when speed or load control is carried out remotely via the governor speeder motor <u>65M</u>. Speed control reference device driven by <u>65M</u> could use <u>65R</u>.
66	**Notching or jogging device** functions to allow only a specified number of operations of a given device, or equipment, or a specified number of successive operations within a given time of each other. It also functions to energize a circuit periodically, or which is used to permit intermittent acceleration or jogging of a machine at low speeds for mechanical positioning.	Also applicable to the step-by-step device in tap changer control schemes.
67	**Ac directional overcurrent relay** is a device which functions on a desired value of ac overcurrent flowing in a predetermined direction.	Directional overcurrent and <u>67E</u> directional earth fault relays, induction disc or instantaneous types, GEC type CDD. For polyphase directional relays controlling separate induction disc units use <u>67</u> for the directional unit, GEC type PCD and its auxiliary, and <u>51</u> for the overcurrent units, GEC type CDG.
68	**Blocking relay** is a device which initiates a pilot signal for blocking of tripping on external faults in a transmission line or in other apparatus under predetermined conditions, or cooperates with other devices to block tripping or to block reclosing on an out-of-step condition or on power swings.	
69	**Permissive control device** is generally a two-position, manually operated switch which in one position permits the closing of a circuit breaker, or the placing of an equipment into operation, and in the other position prevents the circuit breaker or the equipment from being operated.	Safety switch or manually operated lockout device, for example a safety switch located in high voltage switchgear operating cubicle and used during maintenance operations to prevent any attempt to operate a circuit breaker from an out-of-sight position in the control room.
70	**Electrically operated rheostat** is a rheostat which is used to vary the resistance of a circuit in response to some means of electrical control.	Examples are motor operated voltage adjusting rheostat (or "Variac") for voltage regulator, governor or speed control.
71	**Level switch** is a switch which operates on given values, or on a given rate of change, of level.	Liquid or gas level detector for example, unit bearing oil level, either high level (indicating water ingress) or low level indicating oil loss, or both.
72	**Dc circuit breaker** is used to close and interrupt a dc power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions.	Used for traction or mill supplies but <u>not</u> for generator field breaker, which takes device <u>41</u>.

Dev. No.	Definition & Function	Application Notes
73	**Load-resistor contactor** is used to shunt or insert a step of load limiting, shifting, or indicating resistance in a power circuit, or to switch a space heater in circuit, or to switch a light, or regenerative, load resistor of a power rectifier or other machine in and out of circuit.	A contactor commonly used for loading resistors on traction systems and mine hoists, D.C. or A.C., where regenerative braking is involved.
74	**Alarm relay** is a device other than an annunciator, as covered under device No. 30, which is used to operate, or to operate in connection with, a visual or audible alarm.	Commonly used as an audible or visual alarm initiating relay, usually operated from one or more alarm raising contacts in simple alarm schemes and for the audible alarm relay in visual annunciator schemes.
75	**Position changing mechanism** is the mechanism which is used to moving a removable circuit breaker unit to and from the connected, disconnected, and test positions.	Commonly a power operated "racking" mechanism for drawout circuit breakers.
76	**Dc overcurrent relay** is a device which functions when the current in a dc circuit exceeds a given value.	Mainly applied to mill, electrolytic process supplies and D.C. traction schemes, GEC types DBA4 and DBB4 with VAT or VTT timers as required.
77	**Pulse transmitter** is used to generate and transmit pulses over a telemetoring or pilot-wire circuit to the remote indicating or receiving device.	Used in carrier acceleration and carrier blocking schemes with distance or phase comparison protection.
78	**Phase angle measuring, or out-of step protective relay** is a device which functions at a predetermined phase angle between two voltages or between two currents or between voltage and current.	Commonly applied to an out-of-step protection relay for synchronous motors, example GEC type FOS24, but would not be applied to a reactive power measuring or pole slip detector relay indicating field failure in a synchronous generator. The latter would take device <u>40</u> as it would be primarily a field failure detecting device.
79	**Ac reclosing relay** is a device which controls the automatic reclosing and locking out of an ac circuit interrupter.	Provided relay internal details are grouped within a nominal outline on a schematic, lettered device references only need be selected for internal elements. If not grouped together use <u>79</u> with appropriate suffix. Common GEC types VAR11, VAR21, VAR22, VAR42, VAR54, VAR101.
80	**Flow switch** is a switch which operates on given values, or on a given rate of change, of flow.	Now reserved for liquid or gas flow detector such as generator cooling water flow fail but has commonly been applied to undervoltage relays on D.C. station battery schemes and this function should now use device <u>27</u> with an appropriate suffix if necessary.
81	**Frequency relay** is a device which functions on a predetermined value of frequency – either under or over or on normal system frequency – or rate of change of frequency.	GEC types FMG and FTG.

Dev. No.	Definition & Function	Application Notes
82	Dc reclosing relay is a device which controls the automatic closing and reclosing of a dc circuit interrupter, generally in response to load circuit conditions.	Mainly applicable to D.C. traction systems.
83	Automatic selective control or transfer relay is a device which operates to select automatically between certain sources or conditions in an equipment, or performs a transfer operation automatically.	This device is the complement to device 43, the manually operated control selector. As an example, 83 could apply to a device automatically transferring a generator set from peak lopping duty to emergency load supply duty on the loss of a mains supply.
84	Operating mechanism is the complete electrical mechanism or servo-mechanism, including the operating motor, solenoids, position switches, etc., for a tap changer, induction regulator or any piece of apparatus which has no device function number.	Commonly a tap changer or induction regulator complete, whether automatically or manually controlled. 84CS or 84PB Tap change control switch or pushbuttons respectively for manual control of raise and lower functions.
85	Carrier or pilot-wire receiver relay is a device which is operated or restrained by a signal used in connection with carrier-current or dc pilot-wire fault directional relaying.	Commonly a surge-proof (or could be non surge-proof) intertrip receive relay, responsive to a transmitted definite pulse rather than being a voltage or current level detector, GEC types DBM4, DBS4, DBSA4. 85 is NOT applied to the pilot wire protection relays giving unit protection of the balanced voltage or circulating current types. The latter are equivalent to differential relays for feeder use and should, for example, take the number 87F.
86	Locking-out relay is an electrically operated hand or electrically reset device which functions to shut down and hold an equipment out of service on the occurrence of abnormal conditions.	Lockout or master trip relay of non self-reset variety for machine shutdown or as a circuit breaker master trip relay operated by protection relays and when a hand or electrical reset feature is required, GEC types VAJH, VAJE, VAJX or VAJY. (A self-reset tripping relay, example VAJS or VAJZ, commonly given device 94).
87	Differential protective relay is a protective device which functions on a percentage or phase angle or other quantitative difference of two currents or of some other electrical quantities.	Can be used for any circulating current scheme with or without restraint features, or balance voltage schemes, that provide unit protection to transformers, feeders, generators and busbar schemes, etc. Where a number of unit protection schemes exist on one project appropriate suffixes may be required, for example, for those already mentioned 87T, 87F, 87G, 87B would be appropriate. GEC types - 87T : DDT, DMH or DTH or HHTA4 87F : HO4, HT4, DS7, DSF7, DSB7, DSE7 or DMW 87G : CAG34, FAG34, DDG31 87B : CAG34, FAC34 87RE : Restricted Earth Fault Protection, types FAC14, CAG14.
88	Auxiliary motor or motor generator is one used for operating auxiliary equipment such as pumps, blowers, exciters, rotating magnetic amplifiers, etc.	

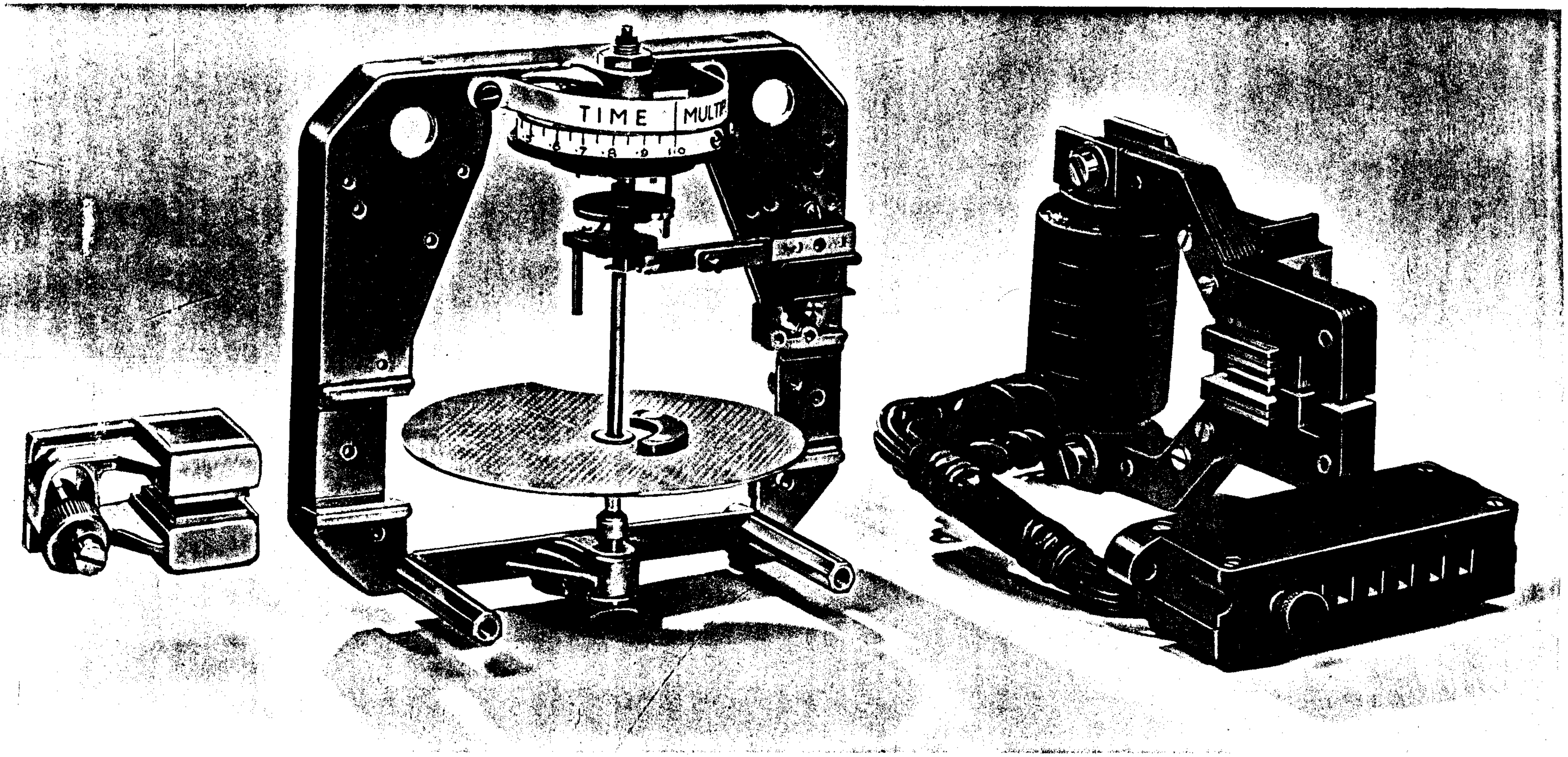
No.	Definition & Function	Application Notes
89	Line switch is used as a disconnecting or isolating switch in an ac or dc power circuit, when this device is electrically operated or has electrical accessories, such as an auxiliary sw switch, magnetic lock, etc.	Power supply isolator or earthing switch. Suggested suffixes when required are 87L for Line Isolator, 89B1 for Bus 1, 89B2 for Bus 2, etc., 89E for Earth Switch. Auxiliary switches would take suffixes a and b as in 89a, 89b, or 89La, 89Lb for normally open and normally closed contacts respectively when the isolator is open.
90	Regulating device functions to regulate a quantity, or quantities, such as voltage, current, power, speed, frequency, temperature, and load, at a certain value or between certain limits for machines, tie lines or other apparatus.	Commonly an automatic voltage regulator for generator or tap changer use.
91	Voltage directional relay is a device which operates when the voltage across an open circuit breaker or contactor exceeds a given value in a given direction.	
92	Voltage and power directional relay is a device which permits or causes the connection of two circuits when the voltage difference between them exceeds a given value in a predetermined direction and causes these two circuits to be disconnected from each other when the power flowing between them exceeds a given value in the opposite direction.	A relay for detecting correct polarity between a D.C. machine and the bus before paralleling, also it can relate to the relay used to initiate connection and disconnection of loading resistors in traction or haulage systems where regenerative braking may cause rectifier trouble or overspeed of prime movers of generators. It may also refer to a reverse current relay required for D.C. machines and/or rectifiers operating in parallel.
93	Field changing contactor functions to increase or decrease in one step the value of field excitation on a machine.	Field Forcing device.
94	Tripping or trip-free relay is a device which functions to trip a circuit breaker, contactor, or equipment, or to permit immediate tripping by other devices; or to prevent immediate reclosure of a circuit interrupter, in case it should open automatically even though its closing circuit is maintained closed.	Also an anti-pumping relay where required in automatic control schemes.
95 96 97 98 99	Used only for specific applications on individual installations where none of the assigned numbered functions from 1 to 94 is suitable.	

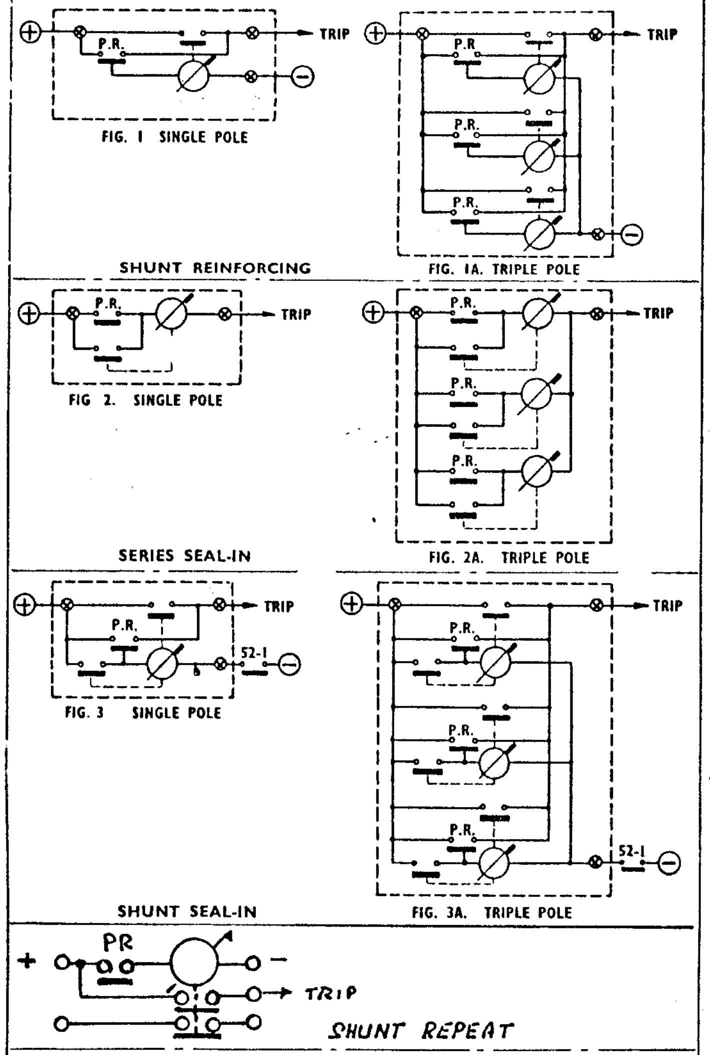
Note: A similar series of numbers, starting with 201 instead of 1, shall be used for those device functions in a machine, feeder, or other equipment when these are controlled directly from the supervisory system.

Typical examples of such device functions are 201, 205, and 294.

E. D. RANSOM

2. Induction Disc Overcurrent and Earth Fault Relays Types CDG11/CDG14


TIME
MULTIP



DIAGRAMS OF CONNECTIONS FOR COMBINED OPERATION INDICATORS AND SHUNT REINFORCING, SERIES SEAL-IN, OR SHUNT SEAL-IN *& shunt repeat.*

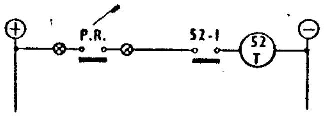


FIG. I
SINGLE CONTACT WITH A MECHANICAL OPERATION INDICATOR

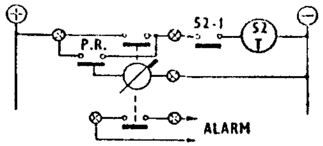


FIG. 3
TWO ELECTRICALLY SEPARATE CONTACTS ON A COMBINED OPERATION INDICATOR AND SHUNT REINFORCING UNIT.

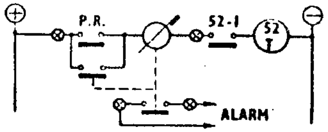


FIG. 4
TWO ELECTRICALLY SEPARATE CONTACTS ON A COMBINED OPERATION INDICATOR AND SERIES SEAL-IN UNIT.

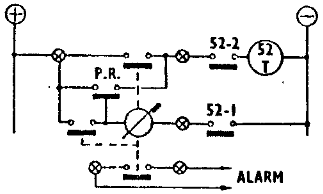


FIG. 5
TWO ELECTRICALLY SEPARATE CONTACTS ON A COMBINED OPERATION INDICATOR AND SHUNT SEAL-IN UNIT.

KEY TO SYMBOLS

- P.R. PROTECTIVE RELAY.
- 52T CIRCUIT-BREAKER TRIP COIL
- 52-1 & 52-2 CIRCUIT-BREAKER AUX., SWITCH CLOSES BEFORE CIRCUIT-BREAKER CLOSES.
- 86 HIGH-SPEED TRIPPING RELAY.
- 86-1 & 86-2 HIGH-SPEED TRIPPING RELAY' CONTACTS.
- ⊗ RELAY CASE TERMINAL.
- NORMALLY-OPEN CONTACT.
- NORMALLY-CLOSED CONTACT.
- MECHANICAL OPERATION INDICATOR.
- COMBINED OPERATION INDICATOR AND REINFORCING, SERIES SEAL-IN, OR SHUNT REPEAT UNIT.

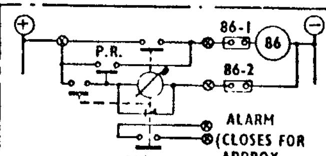
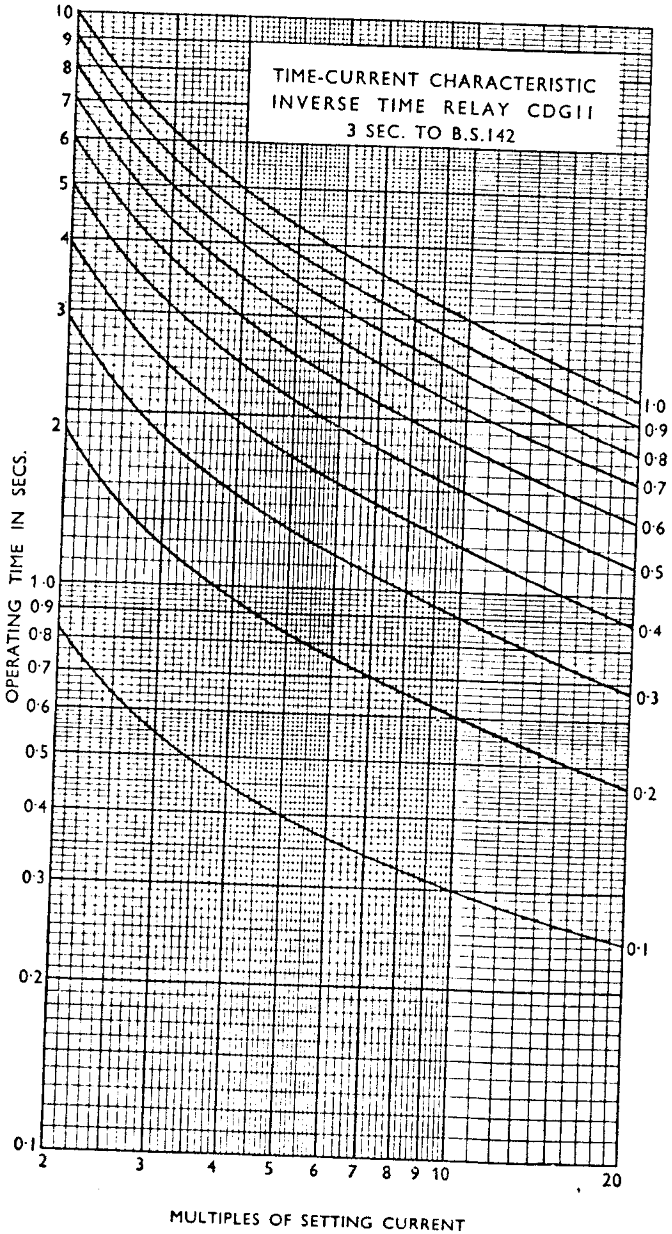


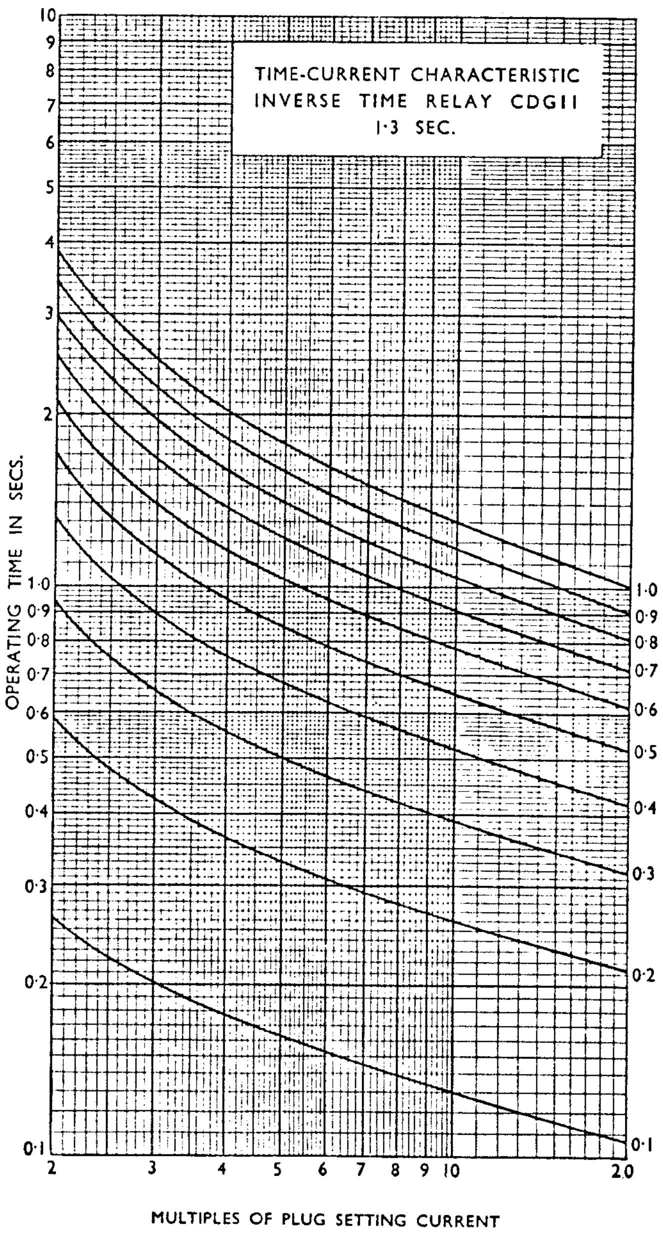
FIG. 6
DELAYED SHUNT SEAL-IN ALTERNATIVE CONNECTION FOR FIG. 5

STANDARD TRIPPING CIRCUITS

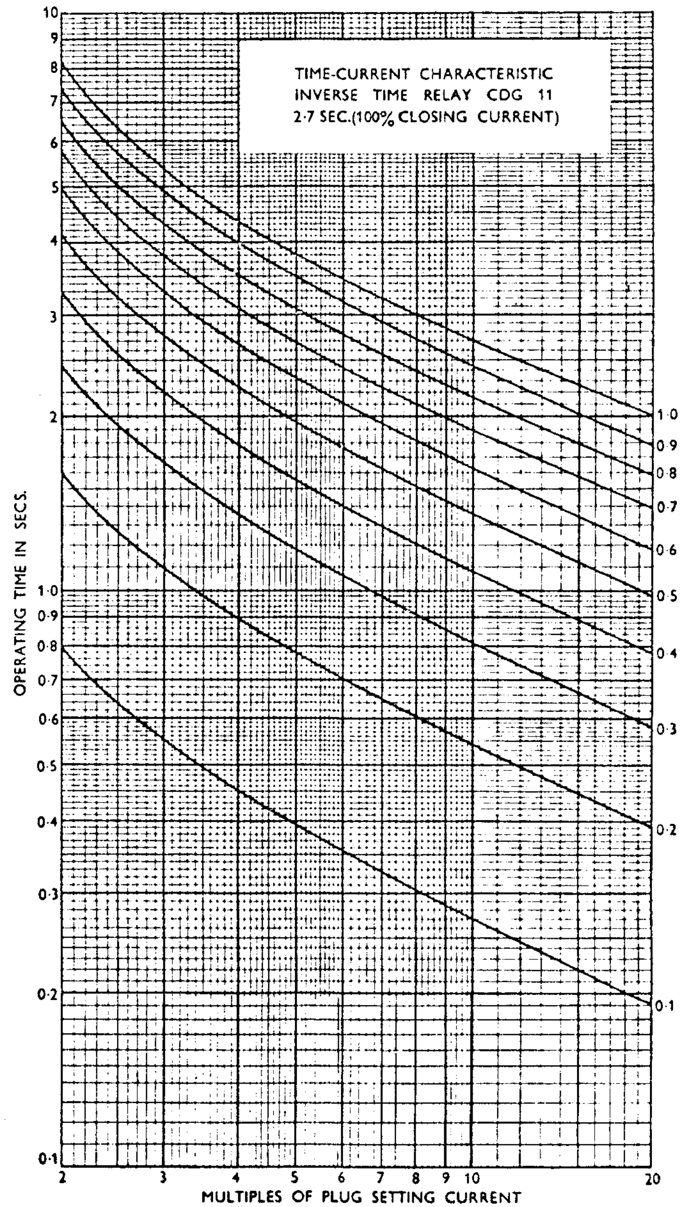
(FOR CONTACT ARRANGEMENTS POSSIBLE ON A PARTICULAR RELAY SEE ORDERING INFORMATION SECTIONS)



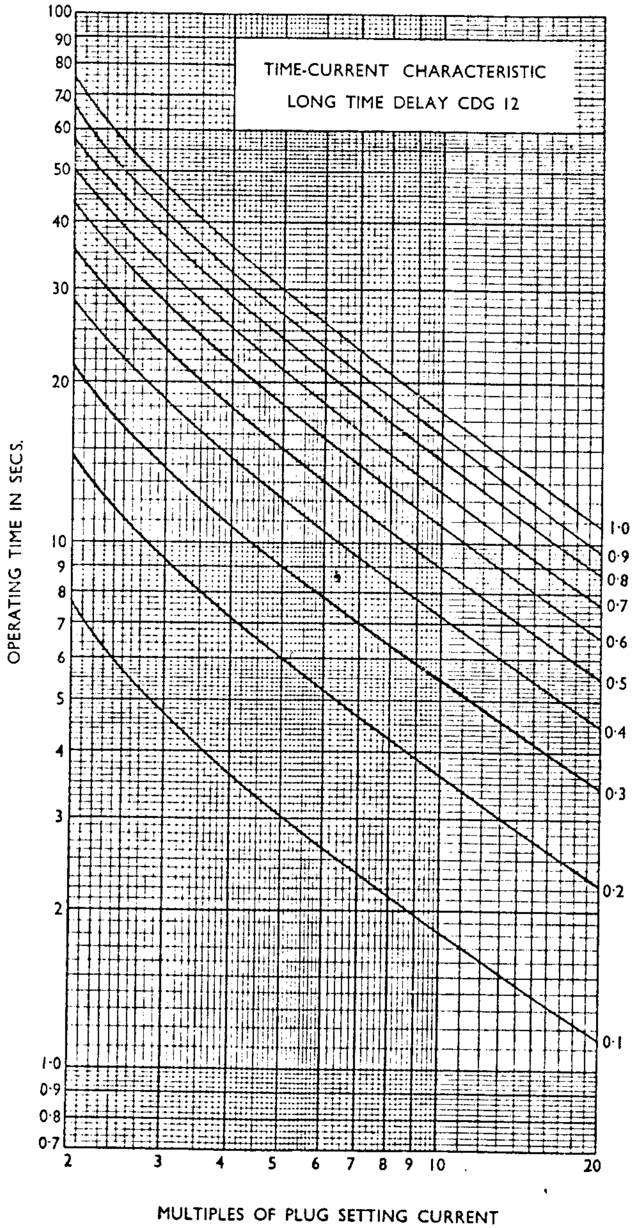
TIME-CURRENT CHARACTERISTIC
INVERSE TIME RELAY CDG11
3 SEC. TO B.S.142
OPERATING TIME IN SECS.
MULTIPLES OF SETTING CURRENT

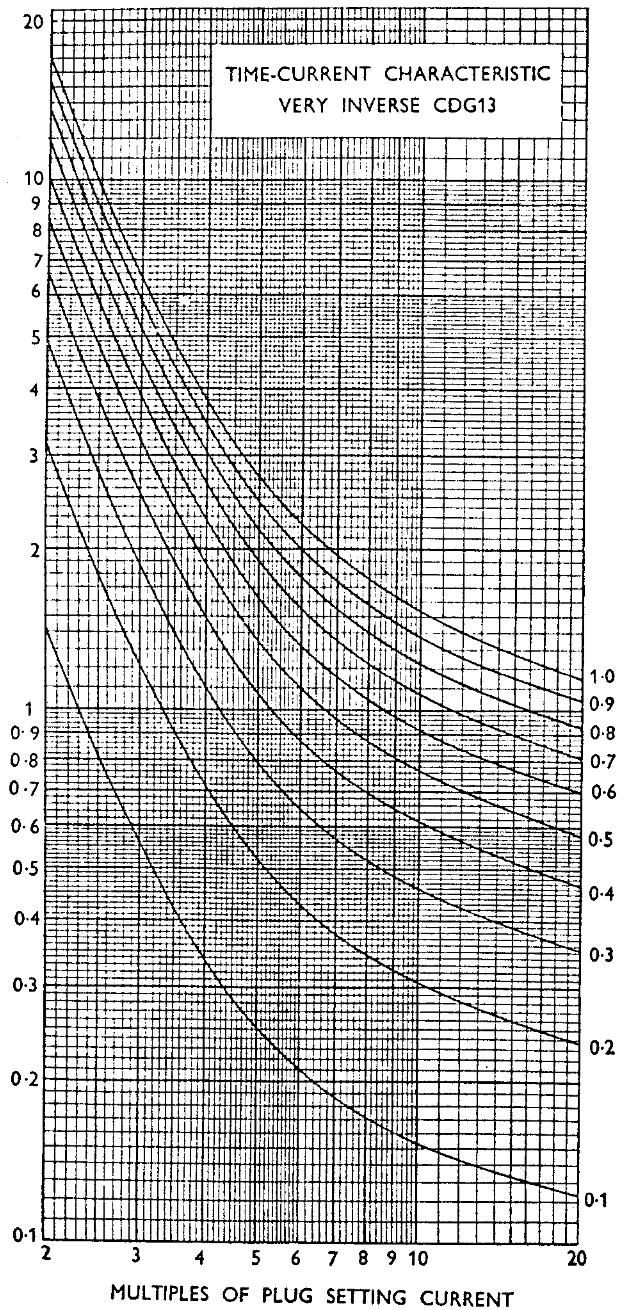


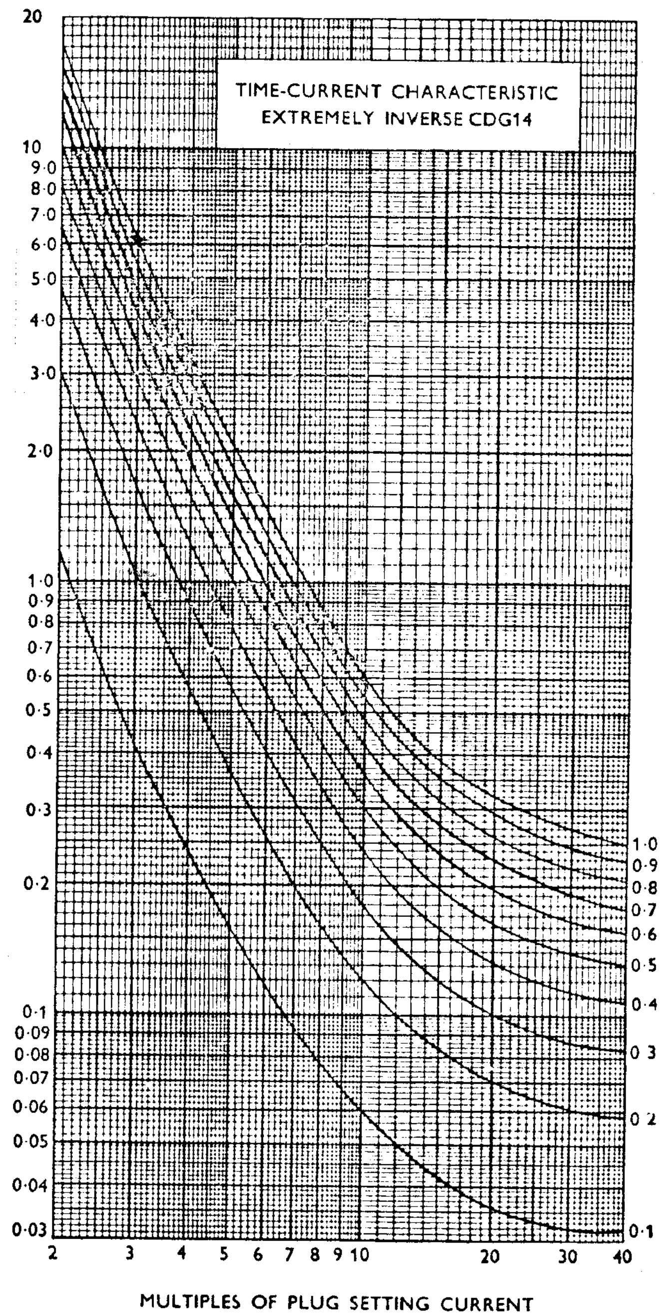
TIME-CURRENT CHARACTERISTIC
INVERSE TIME RELAY CDG11
1·3 SEC.
OPERATING TIME IN SECS.
MULTIPLES OF PLUG SETTING CURRENT



TIME-CURRENT CHARACTERISTIC
INVERSE TIME RELAY CDG 11
2·7 SEC.(100% CLOSING CURRENT)
OPERATING TIME IN SECS.
MULTIPLES OF PLUG SETTING CURRENT


TIME-CURRENT CHARACTERISTIC
LONG TIME DELAY CDG 12
OPERATING TIME IN SECS.
MULTIPLES OF PLUG SETTING CURRENT
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1


TIME-CURRENT CHARACTERISTIC
VERY INVERSE CDG13
MULTIPLES OF PLUG SETTING CURRENT
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1


TIME-CURRENT CHARACTERISTIC
EXTREMELY INVERSE CDG14
MULTIPLES OF PLUG SETTING CURRENT
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0 3
0 2
0·1

$\Omega = \frac{VA}{I^2}$

50 – c/s

RANGE: - 0.1 - 0.4 AMP

TAP SETTING VALUE	V. A. BURDEN AT: TIMES TAP VALUE			
	1.0	3.0	10.0	20.0
0.1	2.3	14	90	250
0.15	2.4	15	100	310
0.2	2.4	15	110	390
0.25	2.6	16	130	490
0.3	2.6	17	140	530
0.35	2.7	17	160	610
0.4	2.8	18	180	680

Phase angle at current setting 59°
1 sec. rating any tap 14 amp.
3 sec. rating any tap 8 amp.

RANGE: - 0.2 - 0.8 AMP

TAP SETTING VALUE	V. A. BURDEN AT: TIMES TAP VALUE			
	1.0	3.0	10.0	20.0
0.2	2.2	14	90	250
0.3	2.4	14	100	310
0.4	2.4	15	110	400
0.5	2.6	16	120	450
0.6	2.6	17	140	540
0.7	2.7	18	150	590
0.8	2.8	19	170	670

PHASE Angle at current setting 61°
1 sec. rating any tap 28 amp.
3 sec. rating any tap 16 amp.

[illegible]

50 – c/s

RANGE: - 0.5 - 2.0 AMP

TAP SETTING VALUE	V. A. BURDEN AT : TIMES TAP VALUE			
	1.0	3.0	10.0	20.0
0.5	2.4	14	85	260
0.75	2.5	15	90	310
1.0	2.5	15	110	380
1.25	2.6	16	130	480
1.5	2.7	17	150	570
1.75	2.8	18	160	640
2.0	2.9	19	180	720

Phase angle at current setting 61°
1 sec. rating any tap 69 amp.
3 sec. rating any tap 40 amp.

RANGE: - 1.0 - 4.0 AMP

TAP SETTING VALUE	V. A. BURDEN AT: TIMES TAP VALUE			
	1.0	3.0	10.0	20.0
1.0	2.2	12	90	260
1.5	2.4	13	100	340
2.0	2.4	15	110	420
2.5	2.5	16	130	450
3.0	2.6	17	150	560
3 [illegible]	2.9	19	160	630
4.0	2.9	19	190	700

Phase angle at current setting 60°
1 sec. rating any tap 138 amp.
3 sec. rating any tap 80 amp.

CDG11 (INVERSE) 3 V.A.

50 – c/s

RANGE: - 1.5 - 6.0 AMP

TAP SETTING VALUE	V. A. BURDEN AT: TIMES TAP VALUE			
	1.0	3.0	10.0	20.0
1.5	2.2	14	90	260
1.8	2.2	14	90	300
2.25	2.2	14	100	350
3.0	2.3	16	120	420
3.6	2.6	17	130	480
4.5	2.7	18	160	600
6.0	2.9	22	210	800

Phase angle at current setting 56°
1 sec. rating any tap 208 amp.
3 sec. rating any tap 120 amp.

RANGE: - 2.5 - 10.0 AMP

TAP SETTING VALUE	V. A. BURDEN AT: TIMES TAP VALUE			
	1.0	3.0	10.0	20.0
2.5	2.5	14	98	320
3.75	2.7	15	120	440
5.0	2.8	17	140	520
6.25	3.0	19	160	630
7.5	3.0	31	190	740
8.75	3.2	23	210	850
10.0	3.6	26	240	960

Phase angle at current setting 57°
1 sec. rating any tap 346 amp.
3 sec. rating any tap 200 amp.

CDG11 (INVERSE) 3 V.A.

50 – c/s

RANGE: - 4.0 - 16.0 AMP

TAP SETTING VALUE	V. A. BURDEN AT: TIMES TAP VALUE			
	1.0	3.0	10.0	20.0
4.0	2.4	14.4	100	326
4.8	2.6	15	100	380
6.0	2.7	16	130	470
8.0	2.9	19	160	630
9.6	3.0	21	180	700
12.0	3.3	25	220	800
16.0	4.0	31	260	1000

Phase angle at current setting 49°
1 sec. rating any tap 555 amp.
3 sec. rating any tap 320 amp.

CDG13 (Very Inverse) I.V.A.

50 - c/s

RANGE:- 0.1 - 0.4 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
0.1	.7	6.5	52	135
0.12	.72	6.7	55	150
0.15	.75	6.8	59	170
0.2	.81	7.1	65	210
0.24	.85	7.5	71	235
0.3	.91	8.0	80	280
0.4	1.05	9.3	(98)	390

Phase angle at tap setting 55°.

RANGE:- 0.2 - 0.8 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
0.2	0.7	6.4	55	130
0.24	0.72	6.6	57	150
0.3	0.76	6.8	60	170
0.4	0.82	7.2	64	210
0.48	0.86	7.6	70	230
0.6	0.91	8.2	78	270
0.8	1.06	9.0	96	380

Phase angle at tap setting 55°

CDG13 (Very Inverse) I.V.A.

50 - c/s

RANGE:- 0.5 - 2.0 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
0.5	0.7	6.6	49	140
0.6	0.72	6.8	52	150
0.75	0.74	7.0	57	170
1.0	0.8	7.5	66	210
1.2	0.84	7.8	72	240
1.5	0.91	8.5	82	300
2.0	1.05	9.6	100	400

Phase angle at tap setting value 55°

RANGE:- 1 - 4 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
1.0	0.81	6.6	58	180
1.2	0.83	7.2	62	200
1.5	0.85	7.7	66	230
2.0	0.92	8.4	78	270
2.4	1.00	9.0	86	300
3.0	1.1	9.8	100	370
4.0	1.3	11.0	130	500

Phase angle at top setting value 50°

CDG13 (Very Inverse) I.V.A.

50 - c/s

RANGE:- 2.5 - 10 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
2.5	0.76	6.8	56	170
3.0	0.78	7.1	61	190
3.75	0.84	7.5	68	220
5.0	0.93	8.4	82	290
6.0	1.03	9.1	96	350
7.5	1.2	11.0	120	440
10.0	1.6	14.0	160	580

Phase angle at tap setting value 43°

RANGE:- 1.5 - 6 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
1.5	0.71	6.5	51	160
1.8	0.75	6.8	56	170
2.25	0.79	7.2	62	210
3.0	0.89	8.1	74	260
3.6	0.98	8.9	65	300
4.5	1.1	10.0	102	360
6.0	1.35	12.5	123	440

Phase angle at tap setting value 49°

CDG13 (Very Inverse) I.V.A.

50 - c/s

RANGE:- 4 - 16 AMPS

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
4.0	0.85	8.4	72	240
4.8	0.91	8.9	79	260
6.0	1.0	9.7	93	320
8.0	1.2	11.6	116	400
9.6	1.35	13.5	134	480
12.0	1.68	16.0	160	580
16.0	2.3	21.5	215	780

Phase angle at tap setting value 27.5°

CDG14 (Extremely Inverse) I.V.A.

50 - c/s

RANGE:- 0.1 - 0.4 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
0.1	0.35	3.1	35	140
0.12	0.37	3.2	38	150
0.15	0.4	3.5	41	160
0.2	0.47	4.2	47	190
0.24	0.53	4.8	54	210
0.30	0.61	5.5	69	250
0.40	0.76	6.9	80	325

Phase angle at tap setting 33.5°

RANGE:- 0.5 - 2.0 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
0.5	0.33	3.0	35	140
0.6	0.35	3.2	37	150
0.75	0.38	3.5	41	160
1.0	0.46	4.3	48	190
1.2	0.52	4.8	55	220
1.5	0.62	5.7	65	260
2.0	0.79	7.1	84	330

Phase angle at tap setting value 33.5°

CDG14 (Extremely Inverse) I.V.A.

50 c/s

RANGE:- 0.2 - 0.8 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
0.2	0.36	3.2	35	140
0.29	0.39	3.4	39	150
0.3	0.42	3.6	41	160
0.4	0.48	4.2	47	190
0.48	0.55	4.8	53	210
0.6	0.6	5.4	72	250
0.8	0.72	6.7	77	320

Phase angle at tap setting value 41.5°

RANGE:- 1.5 - 6.0 AMPS

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
1.5	0.38	3.4	39	150
1.8	0.41	3.8	43	170
2.25	0.47	4.4	48	190
3.0	0.58	5.4	60	250
3.6	0.67	6.2	70	290
4.5	0.82	7.8	88	270
6.0	1.13	10.5	125	500

Phase angle at tap setting value 30°

CDG14 (Extremely Inverse) I.V.A.

50 - c/s

RANGE:- 2.5 - 10 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
2.5	0.4	3.6	42	160
3.0	0.44	4.0	45	180
3.75	0.51	4.6	50	200
5.0	0.66	6.0	68	280
6.0	0.79	7.1	83	340
7.5	1.01	9.2	105	440
10.0	1.45	13.0	155	640

Phase angle at tap setting value 30°

RANGE:- 4 - 16 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
4.0	0.56	5.0	58	230
4.8	0.62	5.8	64	260
6.0	0.76	6.9	76	320
8.0	0.98	9.0	105	430
9.6	1.20	11.0	130	540
12.0	1.6	14.0	170	700
16.0	2.3	21.0	250	1000

Phase angle at tap setting value 22°

CDG14 (Extremely Inverse) I.V.A.

50 - c/s

RANGE:- 1 - 4 AMP

TAP SETTING VALUE	V.A. BURDEN AT: TIMES TAP VALUE 1.0	3.0	10.0	20.0
1.0	0.41	3.9	42	160
1.2	0.44	4.2	45	180
1.5	0.48	4.6	50	200
2.0	0.58	5.4	60	250
2.4	0.65	6.0	69	290
3.0	0.79	7.2	84	340
4.0	1.02	9.4	110	450

Phase angle at tap setting value 34°

Sect 1 of 7.

CT REQUIREMENTS FOR

CDG11, CDG13 and CDG14

OVERCURRENT AND EARTH FAULT RELAYS

Because of electromagnet saturation effects with increasing overcurrent factors, using a nominal 3VA burden "at tap value" as a basis for determining element impedance at all overcurrent factors (OCF) will, in some instances, produce excessive CT voltage requirements. It is therefore more satisfactory to use the actual VA requirements at any OCF and tap value combination to be considered.

By examination of burden curves for various typical taps and OCF's, it will be seen that no hard-and-fast rule or formula can be established to produce a common output voltage requirement to suit all possible relay setting combinations. Several examples of setting combinations and fault conditions must be examined and the results of the most onerous case used to determin the CT class requirement.

For single Ø-E/F conditions the main CT voltage requirement is based on a current level equal to 20 x the E/F element setting and will include, in the burden, the loop lead resistance of the CT-to-relay connection pilots.

For Ø-Ø fault conditions the current level used must equal 20 x O/C relay setting and since 2 CT's and 2 relay elements will be involved, it is only necessary to consider one relay and half the loop lead resistance of the connections.

Now as $VA = I^2 Z$ then $Z = \frac{VA}{I^2}$

Ignoring the effect of phase angles of the voltages across each burden:

CT output volts = sum of volt drops across all burdens in series, lead burden included.

= current level chosen x (sum of burdens, in ohms, of each element + lead burden).

FOR E/F

i.e. $$V_{CT} = \text{E/F tap} \times \text{OCF} \left[\frac{VA_{E/F}}{(\text{E/F tap} \times \text{OCF})^2} + \frac{VA_{O/C}}{(\text{O/C tap} \times \text{OCF})^2} + \text{Lead Burden} \right]$$

Example 1: CDG31 3VA nominal burden, 2.5A O/C setting 0.5A E/F setting, Ø-E fault condition (no high set elements).

Assume an OCF of 20 for E/F setting, i.e., fault current of 20 x 0.5A. This is equivalent to an OCF, for the O/C element settings of $\frac{0.5}{2.5} \times 20 = 4$.

Refer to VA burden tables or impedance curves for values at the appropriate OCF to include in the CT voltage output formula.

Note however, that as we are considering only the CT output voltage and not the kneepoint voltage (V_{kp}) the burden of the CT secondary winding in ohms is omitted from the formula.

$$V_{CT} = 20 \times \text{E/F setting} \left[\text{Burden of E/F relay} + \text{Burden of O/C relay} + \text{Lead Burden} \right]$$

$$V_{CT} = 0.5 \times 20 \left[\frac{260}{(.5 \times 20)^2} + 0.2325 \text{ ohms} \div \frac{20 \text{ ft.}}{3000 \text{ ft.}} \times 5.6 \text{ ohms} \right]$$

$$= 10 \left[2.6 + 0.2325 + 0.0373 = 2.8698 \text{ ohms} \right]$$

$$= 28.7 \text{ volts} \quad \text{(for 20ft. loop lead of 7/.029)}$$

To illustrate that the actual VA requirements at any given OCF produce a more economical CT, consider that if the burden was based on 3VA "at tap value" and the assumption that the impedance remains substantially constant up to 20 x tap value then,

$$V_{CT} = 10 \left[\frac{3}{0.5^2} + \frac{3}{2.5^2} + .0373 \right]$$

$$= 10 \left[12 + .48 + 0.0373 = 12.5173 \text{ ohms} \right]$$

= <u>125.2 volts</u> – an unnecessarily high requirement.

Example 2: for 10A O/C setting and 2 Amps E/F setting (Ø-E fault condition)

$$V_{CT} = 2 \times 20 \left[\frac{720}{40^2} + 0.025 - 0.0373 \right]$$

$$= 40 \times 0.5123$$

$$= 20.5 \text{ volts}$$

Example 3: for 10A O/C setting and 0.5A E/F setting (Ø-E fault condition)

$$V_{CT} = 0.5 \times 20 \left[\frac{260}{10^2} + 0.035 + 0.0373 \right]$$

$$= 10 \times 2.6723$$

$$= 26.7 \text{ volts}$$

Example 4: for 10A O/C setting and Ø-Ø fault only

Ignore E/F relay

$$V_{CT} = 10 \times 20 \left[\frac{960}{200^2} + \frac{0.0373}{2} \right]$$

$$= 200(.024 + .01865)$$

$$= 200(0.04265)$$

$$= 8.5 \text{ volts}$$

If this was based on 3VA "at tap setting" then

$$V_{CT} = 200(.03 + 0.01865)$$

$$= 200(0.04865)$$

$$= 9.7 \text{ volts}$$

Example 5: 2.5A O/C setting and Ø-Ø fault only

$$V_{CT} = 2.5 \times 20 \left[\frac{320}{50^2} + \frac{0.0373}{2} \right]$$

$$= 50(0.128 + 0.01865)$$

$$= 50(0.14665)$$

$$= 7.3 \text{ volts}$$

If this was based on 3VA "at tap setting" then

$$V_{CT} = 50(.48 + 0.01865)$$

$$= 50(0.49865)$$

$$= 24.9 \text{ volts}$$

The most onerous cases for 20ft. lead loop and based on actual VA burdens require:

28.7 volts for E/F condition and

8.5 volts for phase fault condition

Hence, the minimum CT class required would be 10P30 for E/F conditions and 10P10 for O/C conditions only.

In practice, and because the lead burden is usually unknown at the time of job design and other considerations that must be allowed for such as: relay burden tolerances, it is usual to recommend 10P40 or 50 for O/C and E/F relay, and 10P30 for O/C only. Where lead burden is within the bounds of the examples above 10P30 and 10P15 could be used. However, to allow freedom of choice between 3-O/C relays and 2-O/C and E/F combinations, one does not generally recommend using less than 10P30 in any metalclad switchgear situations.

Effect of Burden of Long CT Leads

For 300ft. loop of 7/.029 having burden of 0.56 ohms the results of the above examples become:

Example 1: 2.5A O/C + 0.5A E/F: $V_{CT} = 33.55$ volts

Example 2: 10A O/C + 2A E/F: $V_{CT} = 41.4$ volts

Example 3: 10A O/C + 0.5A E/F: $V_{CT} = 31.95$ volts

Example 4: 10A O/C and Ø-0 fault: $V_{CT} = 60.8$ volts

For "3VA at tap setting": $V_{CT} = 200 \times 0.31$

$= 62$ volts

Also if lead loop is reduced to the following:

200ft.: $V_{CT} = 42.1$ volts

180ft.: $V_{CT} = 38.9$ volts

100ft.: $V_{CT} = 23.5$ volts

Example 5: 2.5A O/C and Ø-Ø fault: $V_{CT} = 20.4$ volts

For "3VA at tap setting": $V_{CT} = 50 \times 0.76$

$= 38$ volts

The most onerous case for 300ft. loop leads and based on actual VA burdens require: 41.4 volts for E/F condition and 60.8 volts for phase fault conditions. Hence, we would require 10P60 CT's and the best best loop length that can be tolerated with commonly recommended 10P40 would be approximately 180ft. loop of 7/.029

It will be seen above that for E/F conditions the effect of the CT lead length is small compared with the burden of the E/F element, but for Ø-Ø fault conditions the effect of the CT lead length can be quite considerable.

CDG61 3VA Relay Including CAG13 High Set Elements

The addition of CAG13 elements has a minimal effect on CT requirements as shown by typical impedances as follows:

10 - 40A unit: 0.7VA at lowest tap

$$= \frac{0.7}{10^2}$$

$$= 0.007 \text{ ohms}$$

Since the relay is spring controlled and has no taps, the ohmic burden (ignoring saturation effects) is substantially constant for all settings for 20 - 80A unit:

$$Z = \frac{0.7}{20^2}$$

$$= 0.00175 \text{ ohms}$$

Adding these levels of impedances to those in examples 1 - 5 above have negligible effect on the V_{CT} figures.

Where a CAG12 or CAG14 E/F elements are used as in CDAG51, the impedances will change with the taps selected, but again, the effect is relatively small.

For CDG33 1VA Nominal Burden

O/C and E/F combinations similar examples are worked as follows:

Example 1: 2.5A O/C + 0.5A E/F settings (no high sets)

$$V_{CT} = 10A\left(\frac{140}{100} + 0.12 + 0.0373\right)$$

$$= 15.57 \text{ volts} \quad \text{(for 20ft. loop leads)}$$

Example 2: 10A O/C + 2A E/F

$$V_{CT} = 40A\left(\frac{400}{40^2} + 0.016 + 0.0373\right)$$

$$= 12.13 \text{ volts}$$

Example 3: 10A O/C + 0.5A E/F -

$$V_{CT} = 10(1.4 + 0.121 + 0.0373)$$

$$= 15.58 \text{ volts}$$

Example 4: 10A O/C, Ø-Ø fault only

$$V_{CT} = 200\left(\frac{580}{200^2} + \frac{0.0373}{2}\right)$$

$$= 200(0.03315)$$

$$= 6.63 \text{ volts}$$

Example 5: 2.5A O/C setting, Ø-Ø fault

$$V_{CT} = 50\left(\frac{170}{50^2} + \frac{0.0373}{2}\right)$$

$$4.33 \text{ volts}$$

The most onerous condition would require 10P20 5A secondary CT's for E/F conditions and 10P10 for O/C only.

For 300ft. Loop Leads

The following examples are given:

Example 1: 2.5A O/C and 0.5A E/F settings

$$V_{CT} = 20.8 \text{ volts}$$

Example 2: 10A O/C and 2A E/F settings

V_{CT} = 33 volts

Example 3: 10A O/C and 0.5A E/F settings

V_{CT} = 20.8 volts

Example 4: 10A O/C and 0.5A E/F settings

V_{CT} = 58.9 volts

for 200ft. loop V_{CT} = 40 volts

for 150ft. loop V_{CT} = 30 volts

Example 5: 2.5A O/C setting and Ø-Ø fault

V_{CT} = 17.4 volts

The most onerous E/F condition would require 10P35 5A CT's and for phase fault only 10P60.

For CDG34 combinations the burden conditions are similar to those for CDG33 and would produce approximately the same results.

GEC Measurements — THE GENERAL ELECTRIC COMPANY LIMITED, ST LEONARDS WORKS, STAFFORD

DRG. No. ADZ002-41

STANDARD CIRCUIT & WIRING DIAGRAM. CDG

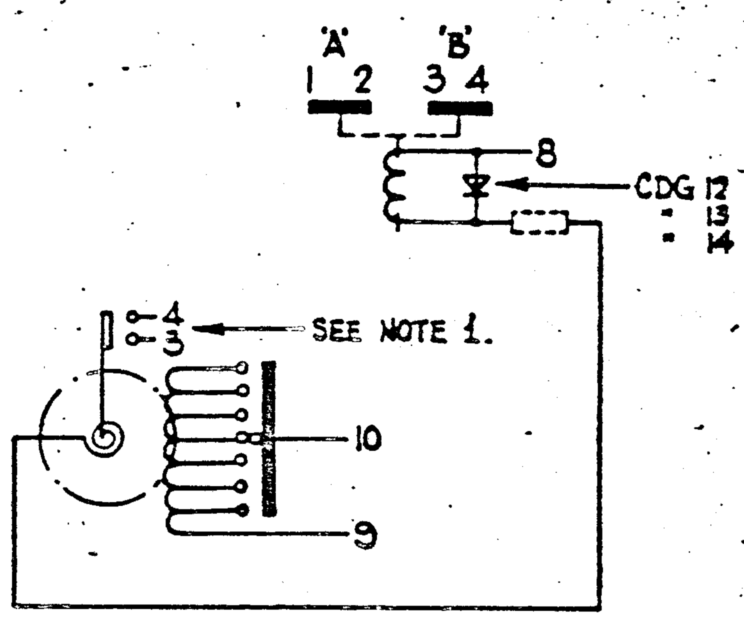
CONTACT ARRANGEMENTS.

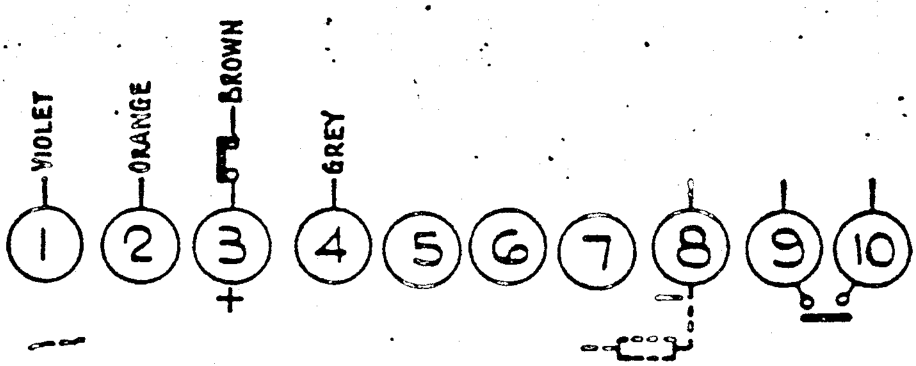
SELF RESET		HAND RESET	
NORMALLY OPEN	NORMALLY CLOSED	NORMALLY OPEN	NORMALLY CLOSED
A & B	—	—	—
B	A	—	—
B	—	A	—
B	—	—	A
—	—	A & B	—
—	—	B	A

NOTES:- 1. PROTECTIVE RELAY CONTACT CONNECTED TO TERMINAL 3 MUST MAKE BEFORE CONTACT CONNECTED TO TERMINAL 4.

2. CDG COIL HAS TWO TAPS ONLY FOR CDG 12.

CDG with Shunt reinforcing Aux Unit





(VIEWED FROM FRONT)

DRAWN	S.D.B.	A	N	RETRACED. NOTES RE-ARRANGED. NOTE 2 AND CONTACT ARRANGMENT ADDED.	O	(TT) RESISTOR (WHEN FITTED) ADDED TO TERMINAL 8.
	A.L.R.	DATE 26·11·57	N.T.C. 3·9·74		N.T.C. 4·8·76	

O/No | CUSTR

THIRD ANGLE PROJECTION

DIMENSIONS ARE IN mm

DO NOT SCALE

ST LEONARDS WORKS
STAFFORD

No. AD2002-49[illegible]

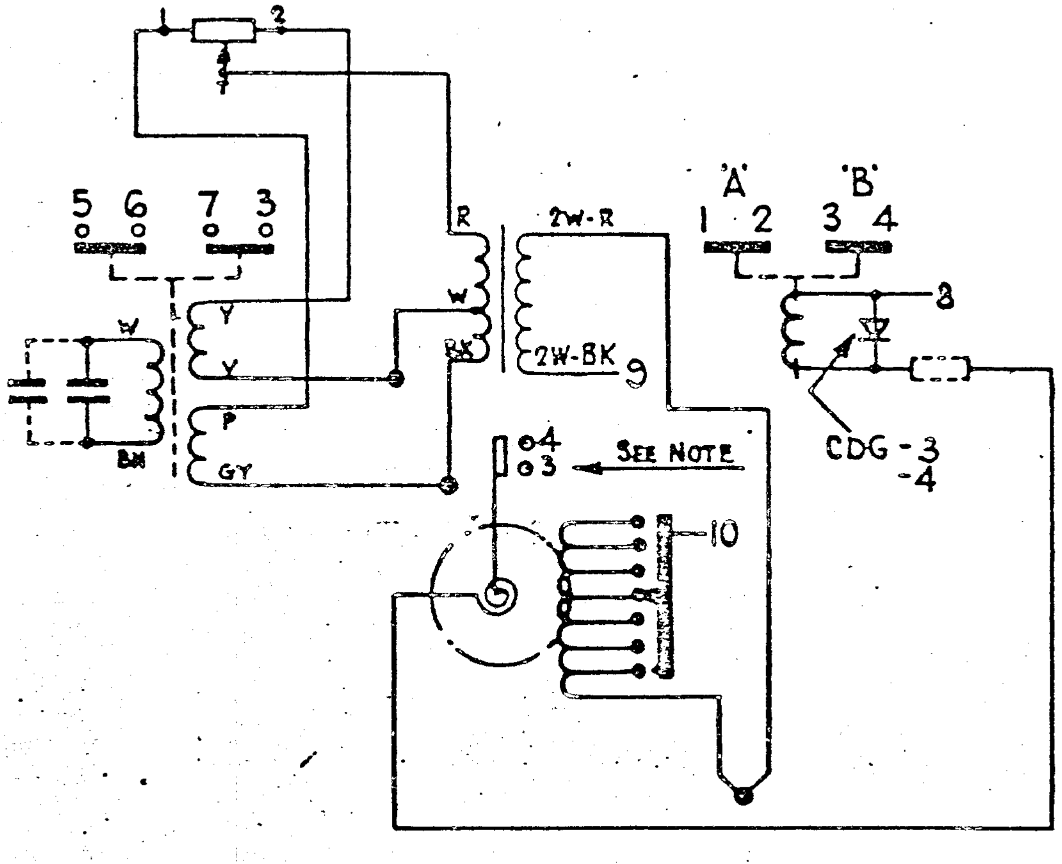
CATEGORY 2 CIRCUIT & WIRING DIAGRAM. CAG17/CDG

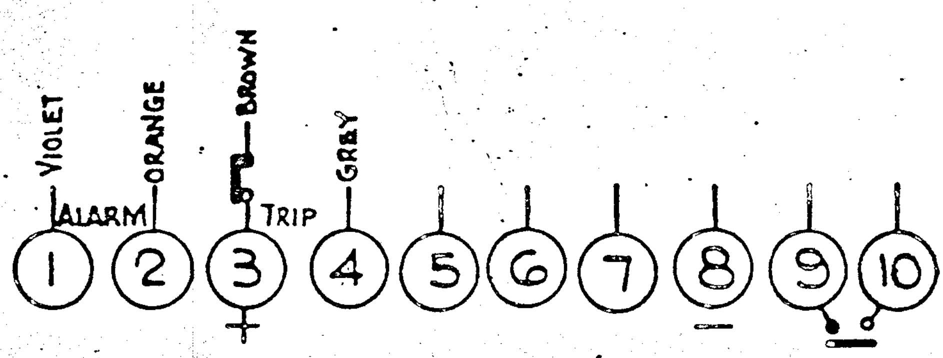
NOTE:- PROTECTIVE RELAY CONTACT CONNECTED TO TERMINAL 3 MUST MAKE BEFORE CONTACT CONNECTED TO TERMINAL 4

CONTACT ARRANGEMENTS

SELF RESET		HAND RESET	
MAKE	BREAK	MAKE	BREAK
A & B	—	—	—
B	A	—	—
—	—	A & B	—
—	—	B	A
B	—	A	—
B	—	—	A

CDG11 + CAG17
IDMT Hi Set.





(VIEWED FROM FRONT)

THIRD ANGLE PROJECTION

DIMENSIONS ARE IN mm

DO NOT SCALE

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CUSTR

DRAWN R.M. P.W.	A ORIGINAL ISSUE	F	RETRACED
CHECKED	DATE 15.4.66	H.T.C 23.3.81	

C.D.W Ltd 770

CDG & CDD OVERCURRENT RELAY CHARACTERISTICS

In accordance with the requirements of BS142, relay characteristic curves are usually only plotted between the plug setting multiplier limits of 2x and 20x. However, for certain grading studies it is useful to have an estimate of nominal characteristics of inverse time relays for Plug Setting Multiplier factors of less than 2x. The following table sets out, with check figures for 2x, the relevant figures for each Time Multiplier Setting for each of the CDG types common to Australian practice :

T.M.S.	3VA & 1VA CDG11, CDD21						CDG13, CDD23 Very Inverse			CDG14, CDD24 Extremely Inverse		
	3 Sec. IDMT			1.3 Sec. IDMT								
	P.S.M.			P.S.M.			P.S.M.			P.S.M.		
	1.3x	1.5x	2.0x	1.3x	1.5x	2.0x	1.3x	1.5x	2.0x	1.3x	1.5x	2.0x
1.0	33.0	18.0	10.0	11.2	6.7	3.9	87.0	43.0	17.0	117.0	51.0	17.2
0.9	30.0	17.0	9.1	9.9	6.0	3.4	78.0	39.0	15.3	103.0	45.0	15.6
0.8	28.0	15.0	8.1	8.6	5.2	3.0	70.0	34.0	13.5	94.0	40.0	13.8
0.7	25.0	13.0	7.1	7.4	4.4	2.5	61.0	30.0	11.8	84.0	35.0	12.0
0.6	21.0	11.5	6.0	6.1	3.6	2.1	52.0	25.0	10.1	74.0	30.0	10.2
0.5	18.0	9.6	5.0	4.8	2.9	1.7	43.0	21.0	8.4	64.0	25.0	8.4
0.4	14.0	7.6	4.0	3.6	2.2	1.31	34.0	17.0	6.6	51.0	20.0	6.5
0.3	11.0	5.6	2.9	2.4	1.5	0.94	25.0	12.0	4.9	38.0	14.8	4.8
0.2	7.00	3.6	1.9	1.3	0.88	0.58	17.0	7.8	3.1	25.0	9.2	3.0
0.1	2.7	1.5	0.83	0.50	0.38	0.26	8.0	3.5	1.42	9.40	3.6	1.19

Extension of CDG11, CDD21 curves beyond 20x at T.M.S. 1.0.

	P.S.M.			
	25x	30x	35x	40x
3 sec. Relay	2.00	1.84	1.72	1.62
1.3 sec. Relay	0.93	0.88	0.83	0.80

EDR271172

025-1

TAP CURRENT AND TAP POSITIONS ON PLUG SETTING BOARD FOR CDG OVERCURRENT RELAYS

PREFERRED Taps in Amps — Tap 4 is "Rated Tap" — CDG13, CDG14

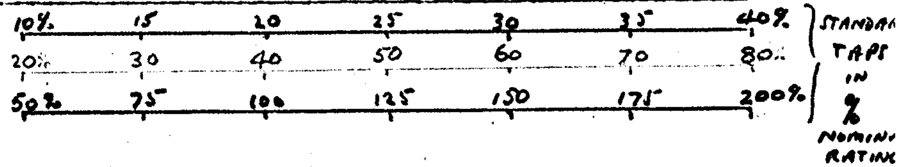
Setting Range Amps	1	2	3	4	5	6	7
0.05- 0.2	0.05	0.06	0.075	0.1	0.12	0.15	0.20
0.1 - 0.4	0.1	0.12	0.15	0.20	0.24	0.30	0.40
0.2 - 0.8	0.2	0.24	0.3	0.4	0.48	0.60	0.80
0.25- 1.0	0.25	0.3	0.375	0.5	0.6	0.75	1.0
0.5 - 2.0	0.5	0.6	0.75	1.0	1.2	1.5	2.0
1.0 - 4.0	1.0	1.2	1.5	2.0	2.4	3.0	4.0
1.5 - 6.0	1.5	1.8	2.25	3.0	3.6	4.5	6.0
2.5 -10	2.5	3.0	3.75	5.0	6.0	7.5	10.0
4.0 -16	4.0	4.8	6.0	8.0	9.6	12.0	16.0

CAG14 RANGE (0.05–0.2 to 1.0–4.0)

0·025 0·0375 0·05 0·0625 0·075 0·0875 0·1

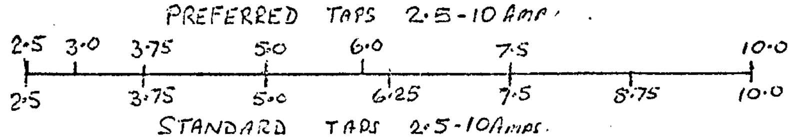
CDG11 — STANDARD (BS142) Taps in Amps — Tap 3 is "Rated Tap"

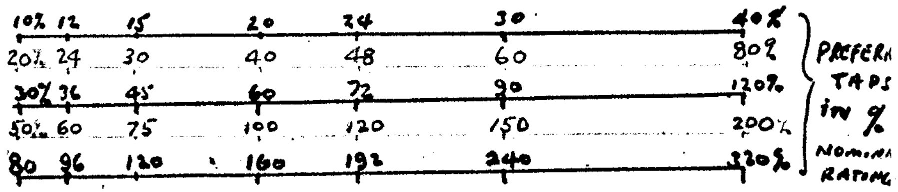
Setting Range Amps	1	2	3	4	5	6	7
0.05- 0.2	0.05	0.075	0.10	0.125	0.15	0.175	0.2
0.1 - 0.4	0.1	0.15	0.2	0.25	0.3	0.35	0.4
0.2 - 0.8	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.25- 1.0	0.25	0.375	0.5	0.625	0.75	0.875	1.0
0.5 - 2.0	0.5	0.75	1.0	1.25	1.5	1.75	2.0
1.0 - 4.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0
1.5 - 6.0	–	–	–	–	–	–	–
2.5 -10	2.5	3.75	5.0	6.25	7.5	8.75	10.0
4.0 -16	–	–	–	–	–	–	–

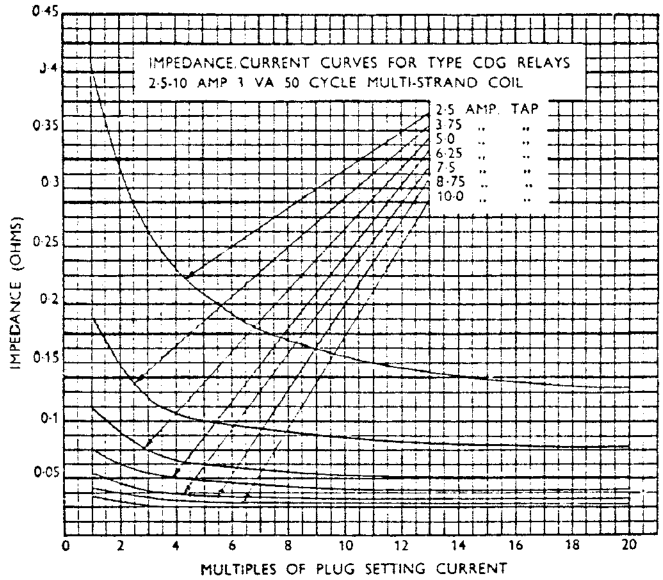


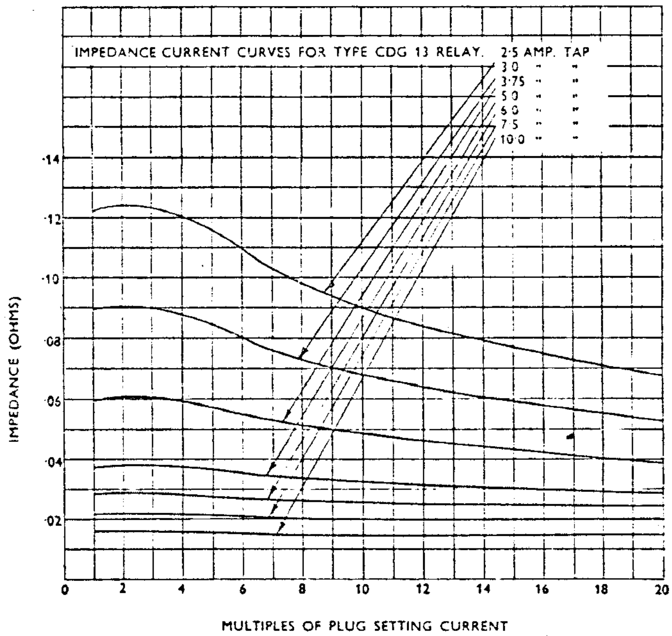
Common PER CENT Ranges for CT Secondary Ratings

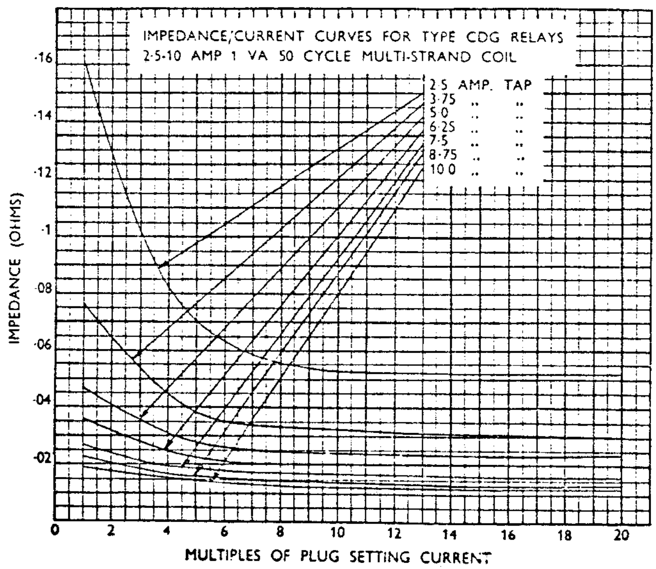
Setting Range Amps	0.5A CT	1A CT	2A CT	5A CT
0.05- 0.2	10-40%			
0.1 - 0.4	20-80%	10-40%		
0.2 - 0.8	--	20-80%	10-40%	
0.25- 1.0	50-200%	--	---	
0.5 - 2.0		50-200%	--	10-40%
1.0 - 4.0			50-200%	20-80%
1.5 - 6.0				30-120%
2.5 -10				50-200%
4.0 -16				80-320%

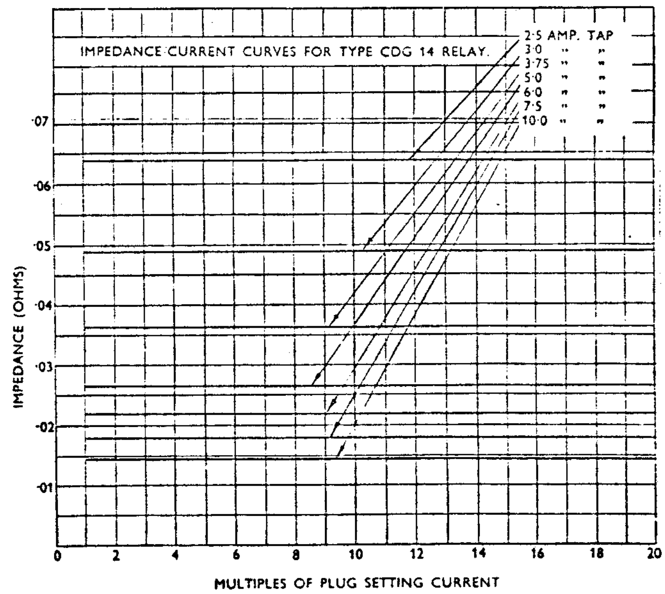




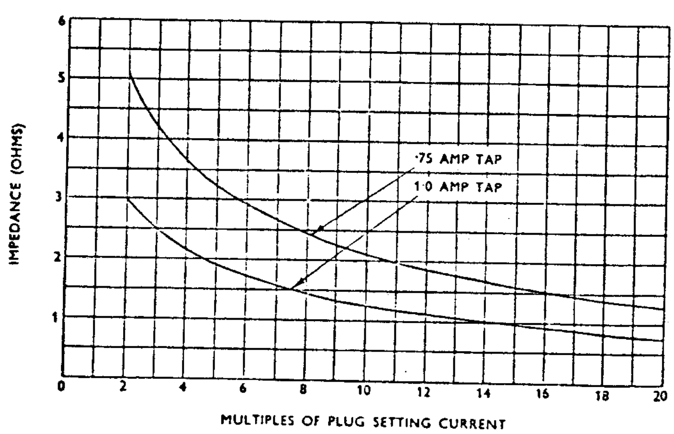




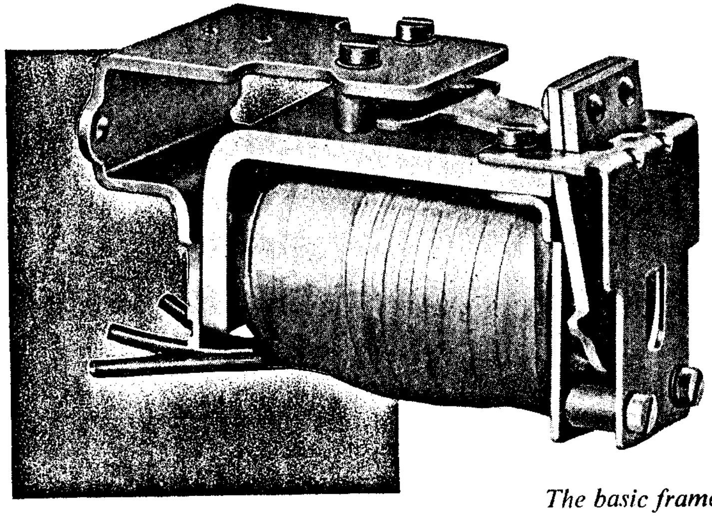




IMPEDANCE CURRENT CURVES FOR TYPE CDG 12 RELAY

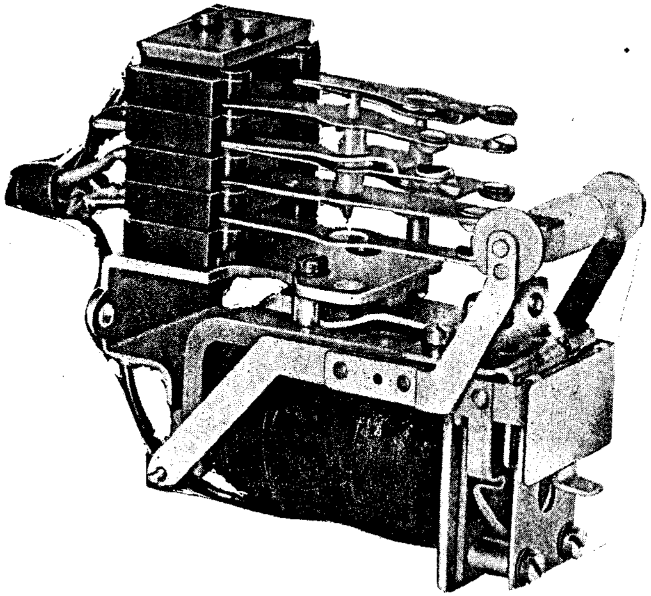


3. Attracted Armature Relays
Types CAG11, 12, 13 and CAG17



- Here are some of the classes in our range
- A.C. or D.C. relays
- Multi-contact relays
- Plug in relays
- Sensitive measuring relays
- Slugged relays
- Semaphore relays

The basic frame, armature and coil assembly.



A typical hand-reset relay.

GEC Measurements

INSTANTANEOUS OVERCURRENT RELAYS

Types CAG11, 12, 13

These relays are attracted armature units designed for instantaneous phase or earth fault protection, instantaneous high set overcurrent protection, or definite time overcurrent protection when used with a timer. The relays are of simple and robust construction and have a positive action without chatter.

According to the type, the relays have settings which are fixed (CAG11), variable in seven equal steps (CAG12) by a plug tapping bridge, or continuously variable (CAG13) by a knurled knob against a calibrated scale. Relays type CAG31, 32, and 33 are respective triple pole versions.

Instantaneous high set overcurrent relays are used to rapidly clear heavy short circuits which can occur near power sources where inverse time overcurrent relays have the longest time settings. The instantaneous relay trip and alarm contacts are parallelled with those of the inverse time overcurrent relays.

CURRENT SETTINGS

CAG11	Fixed settings up to 20 amps a.c. or d.c.
CAG12	10–40%, 20–80% or 50–200% of 0·5, 1·0 or 5 amps a.c. (C.T. ratings), adjustable in seven equal steps 30–120% of 5 amps a.c. (C.T. rating) adjustable in seven equal steps 80–320% of 5 amps a.c. (C.T. rating) adjustable in seven equal steps
CAG13	100–400%, 200–800% or 400–1600% of 0·5, 1·0 or 5 amps a.c. (C.T. ratings), continuously adjustable

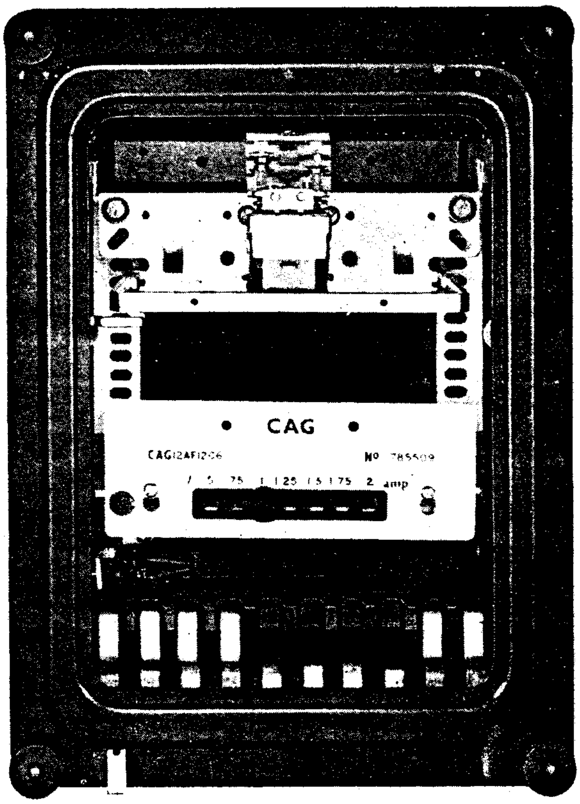
CAG13 relays are also available for d.c. operation with a setting variation of 1 : 2 up to a maximum range of 20 to 40 amps.

A.c. relays are available for use on supply frequencies of 50 or 60 Hz.

CONTINUOUS COIL RATINGS

CAG11 and CAG12	Up to approximately twice any current setting
CAG13	Single contact relay; up to twice minimum current setting Double contact relay; up to 1·5 times minimum current setting

Short time ratings are considerably higher and heavy fault currents can normally be passed for the duration of the tripping time.



Type CAG12 relay in size 1 drawout case

BURDENS

CAG11	A.C. relay; 0·5VA at setting current D.C. relay; 0·1 watt at setting current
CAG12	0·7VA at setting current
CAG13	Single contact a.c. relay; 0·7VA at lowest setting current to 10VA at highest setting Double contact a.c. relay; 1·4VA at lowest setting current to 18VA at highest setting Single contact d.c. relay; 0·1 watt at lowest setting current to 0·4 watt at highest setting

These figures are applicable to all setting ranges.

CONTACTS

The relays are fitted with self reset silver/copper alloy contacts. CAG11 and CAG12 relays have one normally open and one normally closed, or two normally open contacts. CAG13 relays have one normally open or two normally open contacts.

CONTACT RATINGS

Normally open contacts are rated as follows:—

	Make and Carry Continuously	Make and Carry for 0·5 second	Break
a.c.	1250VA with maxima of 5 amps and 660 volts	7500VA with maxima of 30 amps and 660 volts	1250VA with maxima of 5 amps and 660 volts
d.c.	1250 watts with maxima of 5 amps and 660 volts	7500 watts with maxima of 30 amps and 660 volts	100 watts resistive, 50 watts inductive, with maxima of 5 amps and 660 volts

The 'make and carry for 0·5 second' rating of a normally closed CAG relay contact is 3750VA with maxima of 15 amps and 660 volts.

OPERATING TIME

0·010 seconds at 5 times current setting

OPERATION INDICATOR

A hand reset operation indicator is fitted as standard.

CASES

CAG relays are available in drawout (D-type) and moulded non-drawout (N-type) cases as follows:

Relay	Case Types and Sizes
CAG11 (single-pole)	½D 1D ¼N
CAG31 (triple-pole)	½D 1D ½D (Horiz.)
CAG12 (single-pole)	½D 1D ½N (Vert.)
CAG32 (triple-pole)	1D
CAG13 (single-pole)	½D 1D ¼N
CAG33 (triple-pole)	½D 1D ½N (Horiz.)

CAG13 relays can be accommodated in the same case as an inverse time relay type CDG.

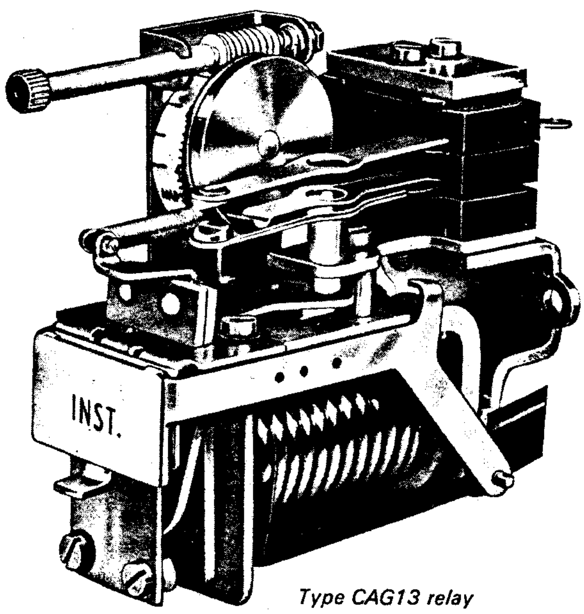
Case	Maximum Overall Dimensions					
	Height		Width		Depth*	
	in.	mm	in.	mm	in.	mm
½D	6 1/16	154	6 11/16	170	7 13/16	198
1D	9 3/16	233	6 11/16	170	7 3/4	197
¼N	4 5/8	118	4 1/8	105	4 1/2	115
½N (Vert.)	6	153	4 7/8	124	5 1/8	130
½N (Horiz.)	4 7/8	124	6	153	5 1/8	130

*Add 2 in. (51 mm) for maximum length of 2BA terminal studs.

Dimensioned drawings of case outlines, panel cut-outs and mounting details are available on request.

INSULATION

The relay will withstand 2·5 kV 50 Hz for one second between all terminals connected together and the case, between all terminals not intended to be connected together and 1·25 kV 50 Hz for one second between all normally open contacts.



Type CAG13 relay

All cases are finished phenolic black as standard and are available for flush or projecting mounting.

Relays for use in exceptionally severe environments can be finished to BS.2011:20/50/56 at extra cost; standard relays are finished to BS.2011:20/40/4 and are satisfactory for normal tropical use.

The drawout case offers many advantages including ease of maintenance and testing. The case is fitted with a contact which short circuits the current transformer on withdrawal of the relay. A filter is fitted to equalise pressures inside and outside the case without admitting dust.

INFORMATION REQUIRED WITH ORDER

Relay type
Current setting
Current rating (C.T. secondary)
Supply frequency
Number and type of contacts
Operation indicator and inscription if required
Case size, type and mode of mounting

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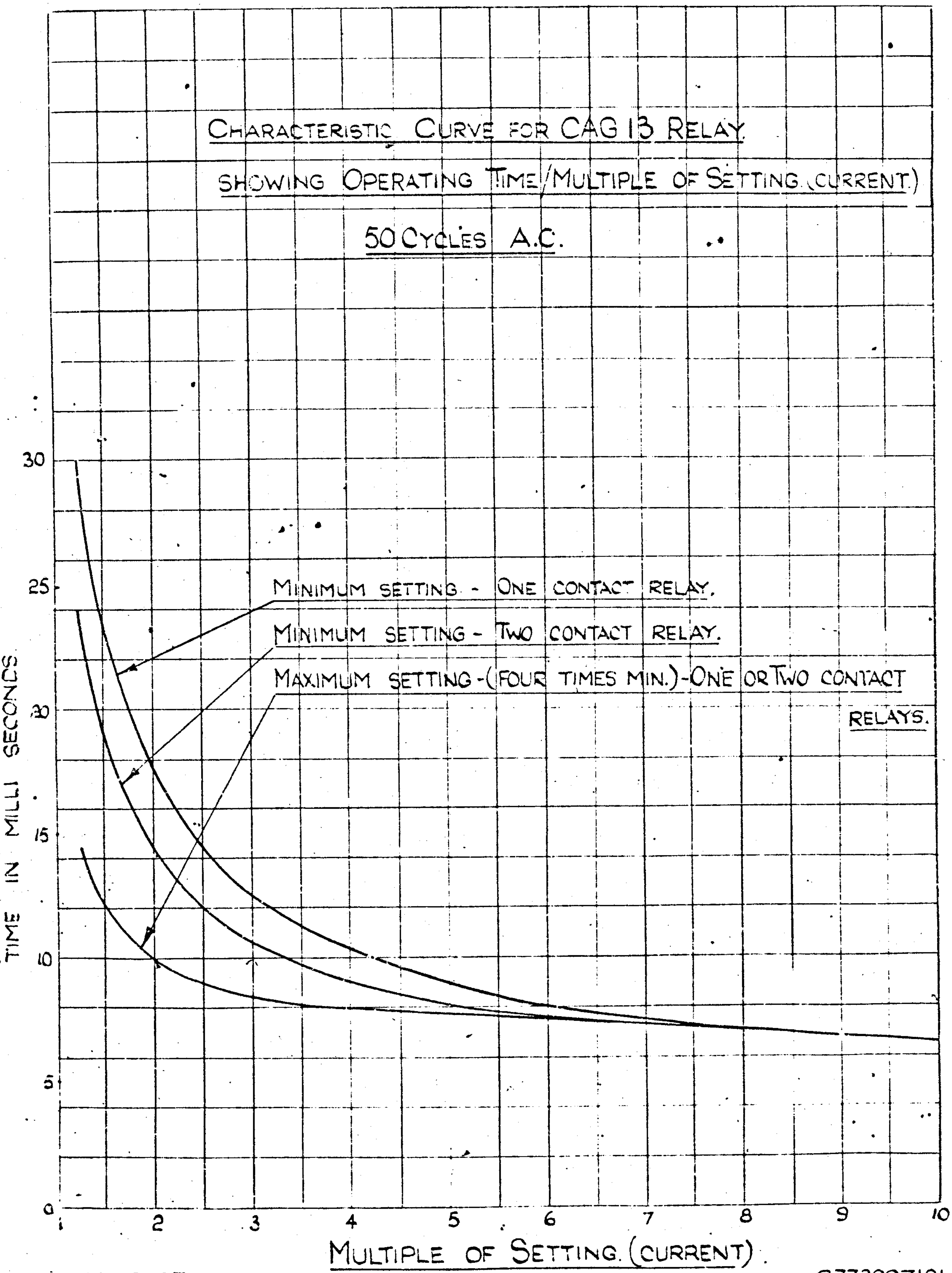

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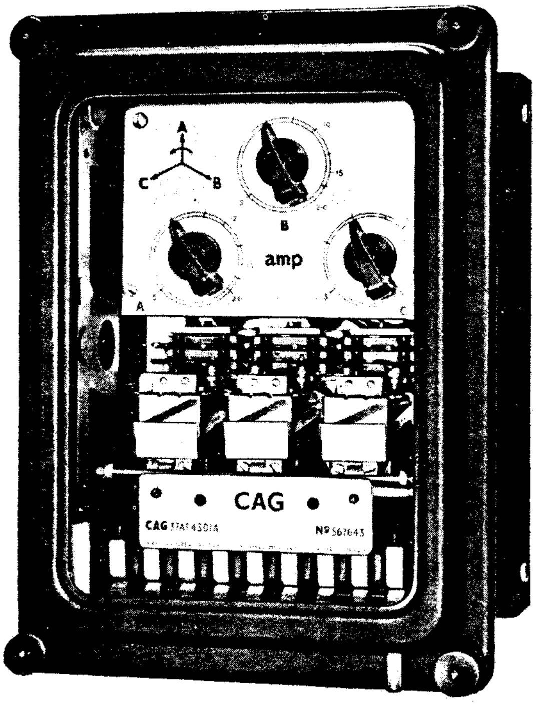
GEC Measurements

INSTANTANEOUS OVERCURRENT RELAY

Type CAG17

The type CAG17 relay (triple pole CAG37) is a high set instantaneous overcurrent unit with low transient overreach and a high drop off/pick up ratio.
Because of its infinitely variable setting and immunity to offset transients, this relay has special advantages for protection of transformer feeders and feeders connected to high MVA sources.
Where lines are fed from high MVA sources, the impedance of the line causes a sharp reduction in fault current as the distance between the fault and the source increases. Conventional instantaneous overcurrent protection gives good discrimination and economy on these lines, but a relay set to detect symmetrical faults at the far end will overreach and cause tripping for offset faults which are outside the protected zone; the overcurrent setting must therefore be raised in proportion to the overreach of the relay, with consequent loss of coverage for symmetrical faults at the far end of the line.
The CAG17 can be accurately set to cover all feeder faults up to the transformer secondary bushings, and ensures correct discrimination at high speed under maximum offset fault conditions.



Type CAG37 relay

OPERATION

The relay consists of an attracted armature unit, a setting potentiometer, an auxiliary transformer and associated components.
The attracted armature unit has three windings, one of which is tuned to the supply frequency by a shunt capacitor. The inductance of the winding varies with the position of the armature, and by correct choice of tuning capacitor the pull characteristic is made to follow the restraint characteristic closely and give an improved drop off/pick up ratio.
Because the initial armature pull is derived from a tuned circuit, the relay is insensitive to d.c. and will respond only to the a.c. component of an offset waveform.

CHARACTERISTICS

Current settings are continuously adjustable between 200%–800%, 500%–2000% or 1000%–4000% of the current rating which may be 1 or 5 amps (C.T. secondary) at 50 or 60 c/s.

Transient Overreach—less than 5% for system angles up to 80 degrees on any setting. The overreach is considerably lower for smaller system angles as shown overleaf.

Drop off/pick up ratio—greater than 90%

Thermal Rating—the relay will withstand:
Minimum setting current continuously, subject to a maximum of 20A.

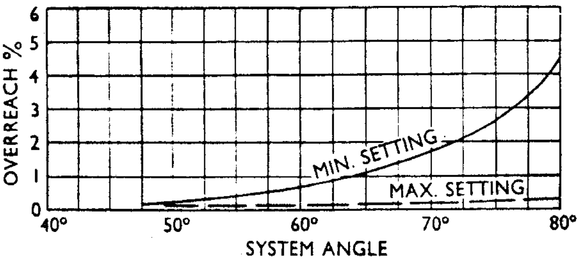
BURDEN

	200/800% version		500/2000% version	
	200%	800%	500%	2000%
At rated current	0·64 VA	0·11 VA	0·1 VA	0·02 VA
At setting current	2·5 VA	8·0 VA	2·5 VA	8·0 VA

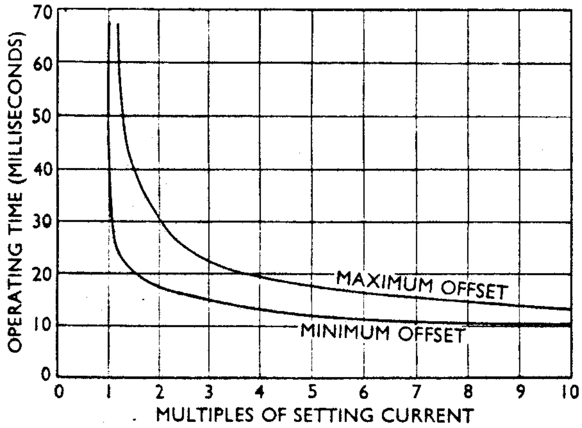
CONTACTS

Two pairs of normally open self reset contacts are provided. Each pair is rated as follows:—

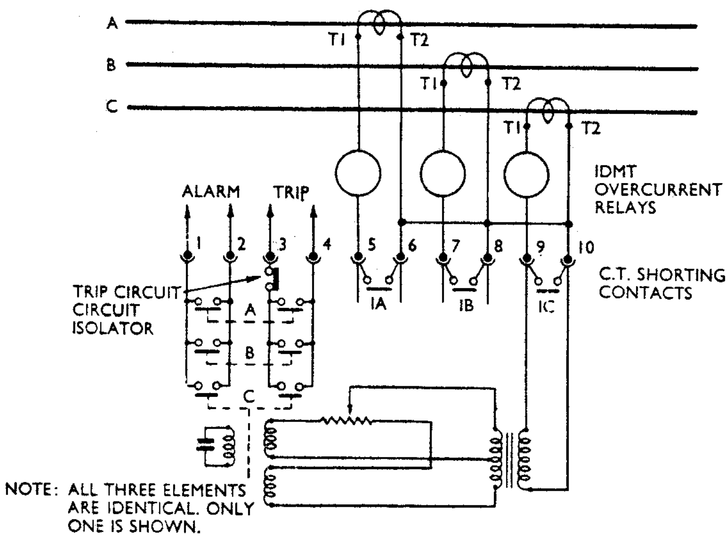
	Make and carry continuously	Make and carry for 3 seconds	Break
a.c.	1250 VA with maxima of 5 amps and 660 volts	7500 VA with maxima of 30 amps and 660 volts	1250 VA with maxima of 5 amps and 660 volts
d.c.	1250 watts with maxima of 5 amps and 660 volts	7500 watts with maxima of 30 amps and 660 volts	100 watts (resistive) 50 watts (inductive) with maxima of 5 amps and 660 volts



Variation of overreach with system angle



Operating time/current characteristic



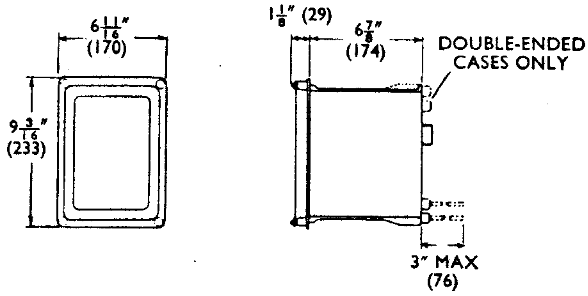
Typical connection and application diagram for CAG37 relay (delete connections to terminals 5–8 and contacts A and B for CAG17 internal connections)

OPERATION INDICATOR

A hand reset operation indicator is fitted as standard.

CASES

Single pole (CAG17) and triple pole (CAG37) relays are supplied in a size 1 drawout case available for flush or projecting mounting and finished phenolic black.
Alternatively, units may be mounted in the same case as I.D.M.T. relays. Both cases are available for flush or projecting mounting.
Relays for use in exceptionally severe environments can be finished to B.S. 2011 : 20/50/56 at extra cost; standard relays are finished to B.S. 2011 : 20/40/4 and are satisfactory for normal tropical use.



Case outline details

INFORMATION REQUIRED WITH ORDER

Single or triple pole (CAG17 or CAG37)

Current setting

Frequency

Case finish and mode of mounting

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Publication R-5118 B

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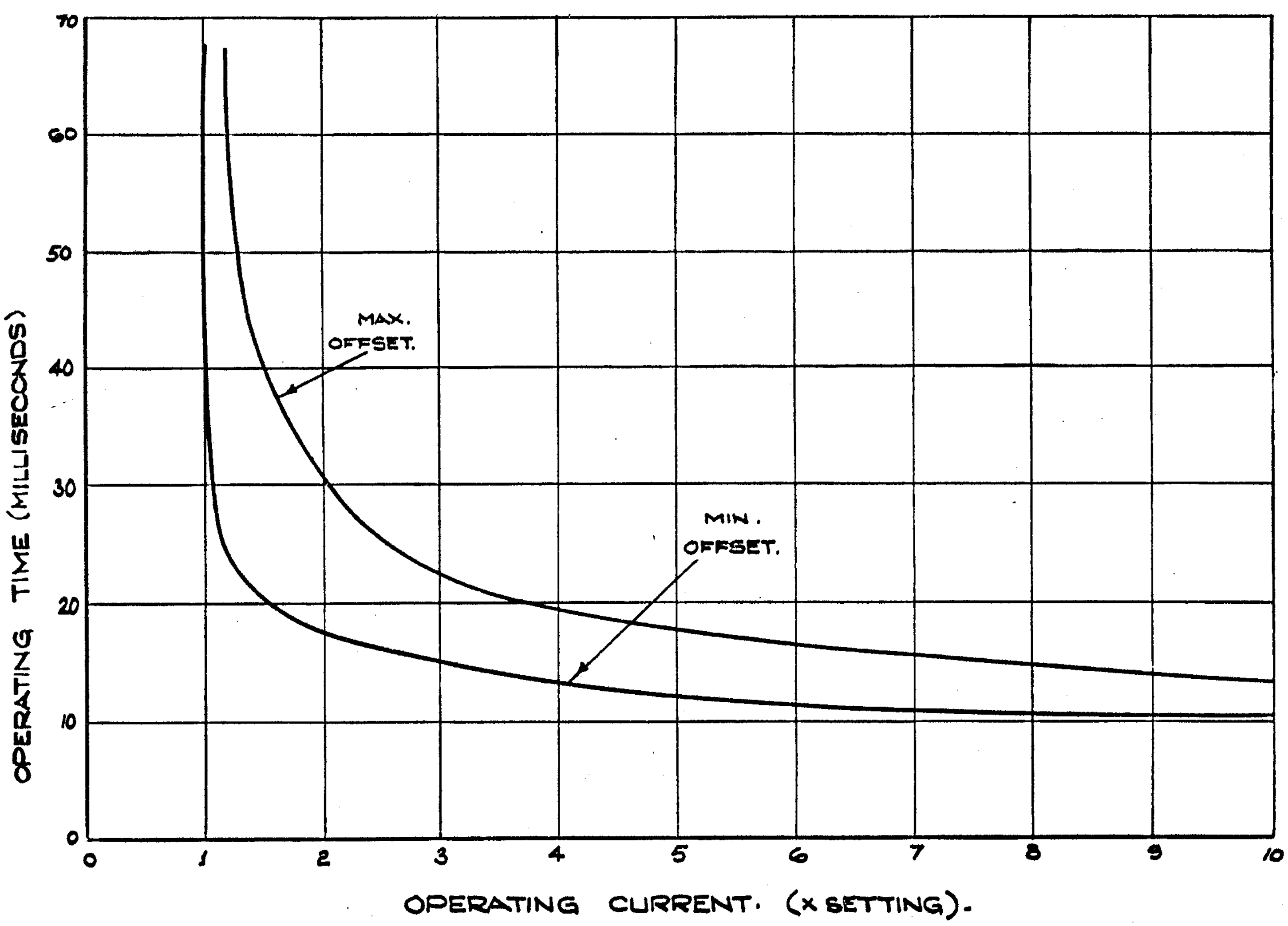


TYPE CAG 17 RELAY.

OPERATING TIME / OPERATING CURRENT.

4. High Impendance Differential Relays
Type CAG14/34 and FAC14/34

GEC Measurements

HIGH STABILITY CIRCULATING CURRENT RELAY

Type CAG14

When circulating current protection schemes are subjected to heavy through faults, the sudden, and often asymmetrical growth in the system current can cause the protective current transformers to approach or even reach saturation level. Because of the variations in the magnetising characteristics of the transformers a high unbalance current may result.

To ensure stability under these conditions, it is modern practice to use a voltage operated, high impedance relay, set to operate at a voltage slightly higher than that developed by the current transformers under maximum external fault conditions.

The CAG14 relay, used with a stabilising resistor, is designed for applications where sensitive settings with stability on heavy through faults are required, and is recommended for balanced and restricted earth fault, bus-zone and certain forms of differential protection of generators, auto-transformers, reactors and motors.

The total impedance of the relay and series stabilising resistor is usually low enough to prevent the current transformers developing voltages over 2kV during maximum internal faults, but in some applications a non-linear resistor is required to limit this voltage.

Types CAG14 and CAG34 relays are single and triple pole, respectively.

CONSTRUCTION AND OPERATION

The relay is basically a standard attracted armature unit of simple and robust construction. The operating coil of this unit is connected in series with a small choke and capacitor, forming a series resonant circuit. These components are energised from an auto-transformer which is tapped to provide seven current settings.

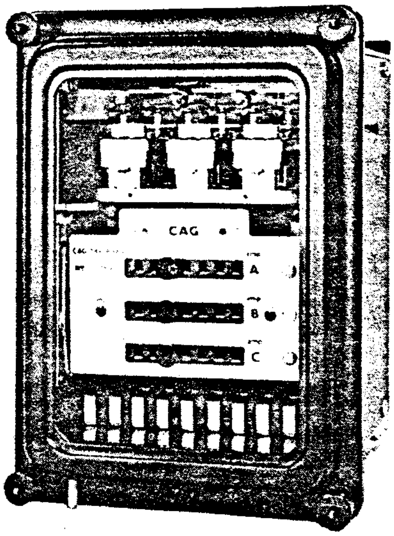
The relay circuit, tuned to the supply frequency rejects the harmonics produced by C.T. saturation. A slight time delay on operation helps to provide stability on heavy external faults and is obtained by allowing the auto-transformer to saturate above the relay setting. This limits the current supplied, and the attracted armature unit operates only on the slower part of its time-current curve.

STANDARD CURRENT SETTINGS

5–20%, 10–40% or 20–80% of 0·5 or 1 amp (C.T. secondary)
10–40% or 20–80% of 5 amps (C.T. secondary) at 50 or 60Hz, adjustable by plug setting bridge in seven equal steps.

OPERATING TIME

0·025 second at 5 times setting current (see curve overleaf).



Type CAG34 relay

BURDEN

0·9VA at current setting on lowest tap
1·0VA at current setting on highest tap

Current Transformer Knee-point Voltage

The knee-point voltage is defined as the point on the magnetisation curve at which a 10% increase in excitation voltage produces a 50% increase in excitation current. The minimum knee-point voltage (Vk) and maximum excitation current (Ie) are calculated as follows:

$$Vk = 2If\,(Rs + Rp)$$

$$Ie = \frac{Is - Ir}{n}$$

where If = equivalent secondary pilot current of maximum fault current
Is = effective fault setting expressed in secondary amps
Ir = relay setting current
Rs = C.T. secondary winding resistance
Rp = maximum loop lead resistance between C.T.'s and relay
n = 3 for restricted earth fault protection on delta windings (3 C.T.'s)
n = 4 for restricted earth fault protection on star windings (4 C.T.'s)
n = 2 for machine or transformer differential protection
n = number of C.T. groups forming the protected zone for bus-zone differential protection

STABILISING RESISTANCE

Externally mounted continuously variable resistors of 400, 200 and 50 ohms for 0·5, 1 and 5 amp C.T. secondaries respectively are supplied as standard. Non-standard resistance values and non-linear voltage limiting devices are available.

The approximate value of series resistance (Rsr) required to ensure stability is calculated as follows:—

$$Rsr = \frac{\frac{Vk}{2} - \frac{VA}{Ir}}{Ir}$$

where Vk = minimum knee-point voltage
VA = relay burden
Ir = relay setting current

CONTACTS

Two pairs of electrically separate normally open self reset contacts are provided and are rated to make and carry 7,500VA for 0·5 second with maxima of 30 amps and 660 volts a.c. or d.c.

An attracted armature auxiliary unit (VAA) can be fitted in the same case as type CAG14 relays, to provide an additional four pairs of electrically separate contacts in any combination of normally open or normally closed hand or self reset.

Standard auxiliary voltages are 30, 110, 125 and 220 volts d.c. or 110, 240 and 440 volts a.c. 50/60Hz.

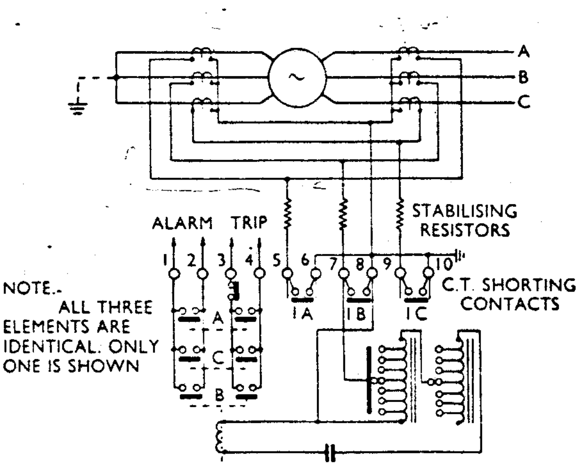
OPERATION INDICATOR

A hand reset operation indicator can be fitted to the CAG unit or the auxiliary unit as required.

CASES

Single pole relays (CAG14) are supplied in size ½ moulded non-drawout cases (½N) or size 1 drawout cases (1D).

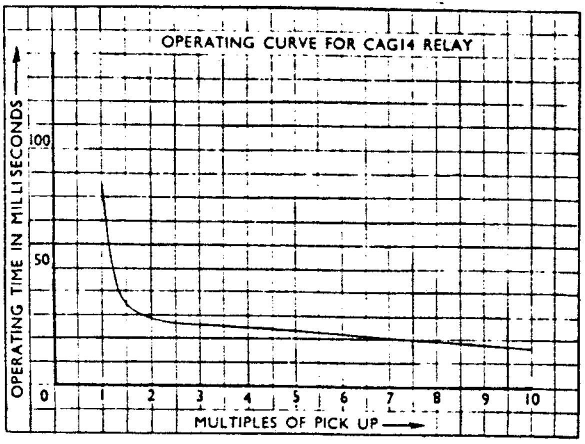
Triple pole relays (CAG34) are supplied in size 1 drawout cases only. Cases are finished in phenolic black as standard, and are available for flush or projecting mounting.



Internal and external circuit diagram for unbiased differential protection for generators, reactors and synchronous motors using type CAG34 relay.

INSULATION

The relay will withstand 2·0kV 50Hz for one minute, between all live parts and earth, and between all circuits not intended to be connected together. It will also withstand 1kV 50Hz for one minute between all normally open contacts.



Time/current characteristic

The drawout case has the advantage of ease of maintenance and testing, and is fitted with a filter which equalises pressure inside and outside without admitting dust. A contact is fitted to short circuit the current transformer when the unit is withdrawn from the case.

All cases are finished bright black as standard. Relays for use in exceptionally severe environments can be finished to B.S.2011:20/50/56 at extra cost; standard relays are finished to B.S.2011:20/40/4 and are satisfactory for normal tropical use.

Case	Maximum Overall Dimensions					
	Height		Width		Depth*	
	ins.	mm	ins.	mm	ins.	mm
1D	9 3/16	233	6 11/16	170	7 3/4	197
½N vertical	6	153	4 7/8	124	5 1/8	130
Stabilising Resistor	1 5/8 ins. (41 mm) diameter × 10 3/4 ins. (273 mm) long					

*Add 2 ins. (51 mm) for maximum length of 2BA terminal studs.

Dimensioned drawings of case outlines, panel cut-outs and mounting details are available on request.

INFORMATION REQUIRED WITH ORDER

Relay type (CAG14 or CAG34)
Current transformer secondary rating
Frequency
Current setting range
Auxiliary voltage and contact combination of auxiliary unit (when fitted)
Operation indicator and inscription (if required)
Case size, type and mode of mounting

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401 R

TITLE

STANDARD CIRCUIT & WIRING DIAGRAM. CAG34

= 3×CAG14

PART	CONTACT ARRANGEMENT NORMALLY OPEN	CONTACT ARRANGEMENT NORMALLY CLOSED			
1	A TO F	—			
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
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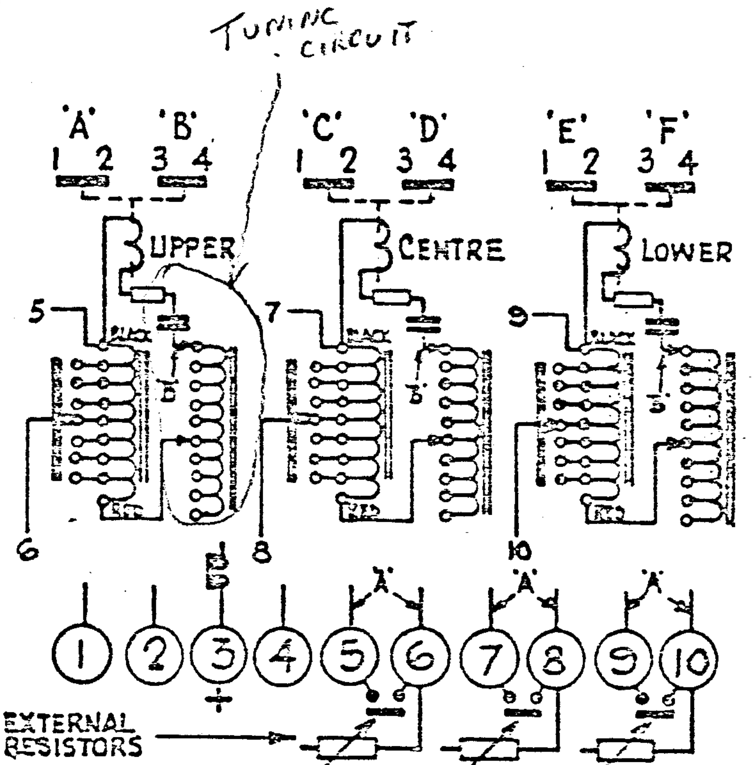
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					

TRANSFORMER COLOUR CODE

TAP		
TAP	0	RED
"	1	WHITE
"	2	BROWN
"	3	PINK
"	4	GREY
"	5	YELLOW
"	6	VIOLET
"	7	BLUE
"	9	BLACK

NOTE :- THE AUTO TRANSFORMER TAPS SHOULD BE CONNECTED TO THIER CORRESPONDING NUMBERS ON THE TAP CHANGE PLUG-BOARD.



(DRAWOUT CASES)

COIL LEADS ARE SUPPLIED WITH THE UNITS. LEADS MARKED. DEPENDING ON THE COIL RATING ARE TO BE ONE OF THE FOLLOWING:- RATINGS FROM 0·1/0·4 TO ·5/2 AMPS 24/0,20mm RATINGS 1/10.50/0,25mm & RATINGS 8/15 AND 4/16 AMPS 56/0,30mm TINNED COPPER FLEX. ALL OTHER LEADS TO BE 1/1,13mm TINNED COPPER FLEX EXCEPT LEADS MARKED 'B' WHICH ARE TO BE 13/0,20mm. ALL LEADS TO BE COVERED WITH BLACK INSULATION SLEEVING.

NON-DRAWOUT CASES

TERMINAL POSITIONS VIEWED FROM FRONT

THIRD ANGLE PROJECTION

DIMENSIONS ARE IN mm

DO NOT SCALE

CUSTR. No

DRAWN S.D.B. | A ORIGINAL ISSUE | J | RETRACED.

E.B.

CHECKED | DATE 11.4.'57 | M.T.C 23.6.'78

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210 x 297

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THE GENERAL ELECTRIC COMPANY LIMITED
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STAFFORD

DRG. No. FDZ001-97

TITLE
STANDARD CIRCUIT & WIRING DIAGRAM. CDG.

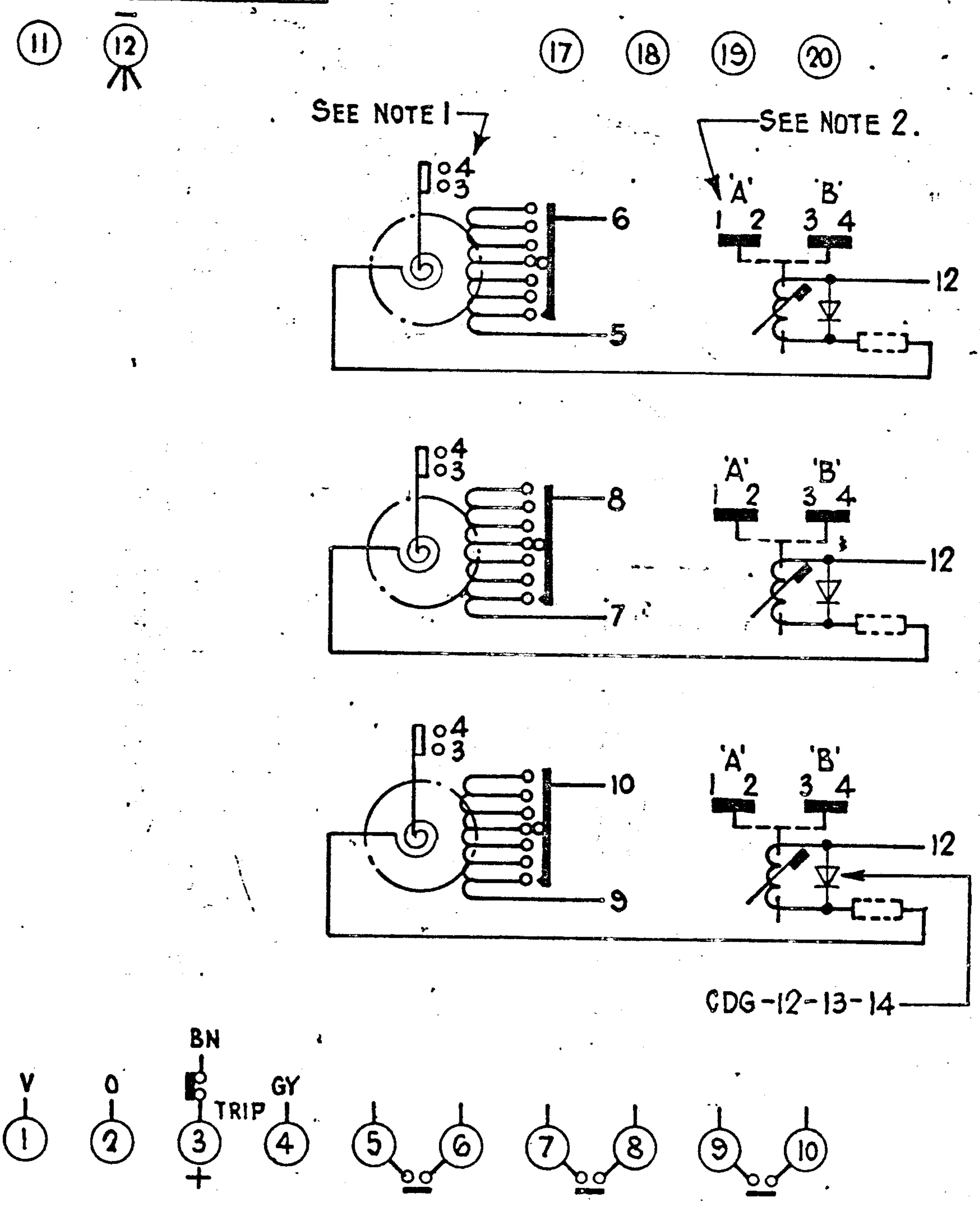
O/No.
CUSTR.

CONTACT ARRANGEMENTS.			
SELF RESET		HAND RESET	
NORMALLY OPEN	NORMALLY CLOSED	NORMALLY OPEN	NORMALLY CLOSED
A & B	—	—	—
B	A	—	—
B	—	A	—
B	—	—	A
—	—	A & B	—
—	—	B	A

NOTE:- 1. PROTECTIVE RELAY CONTACT CONNECTED TO TERMINAL 3 MUST MAKE BEFORE CONTACT CONNECTED TO TERMINAL 4.

2. WHEN LEFT HAND CONTACTS ON AUXILIARY UNITS ARE NORMALLY CLOSED THEY ARE TO BE WIRED IN SERIES, AND WHEN NORMALLY OPEN IN PARALLEL.

3 Pole O/C or 2-O/C + 1-E/F
all in 3 pole Vertical Case.



(VIEWED FROM FRONT)

THIRD ANGLE PROJECTION

DIMENSIONS ARE IN mm.

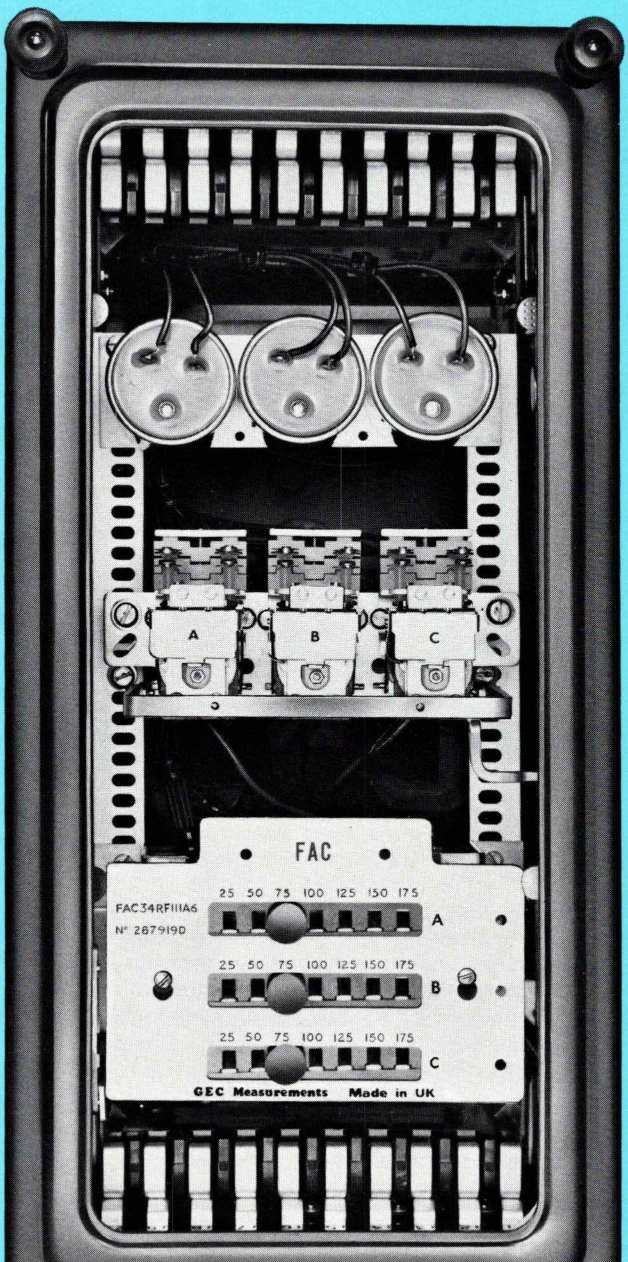
DO NOT SCALE

DRAWN	S.D.B. A.L.R.	A ORIGINAL ISSUE	M	RETRACED. CDG-14 ADDED TO DIODES. NOTES REWRITTEN CONTACT ARRANGEMENTS ADDED	N	WIRING TAGS DELETED FROM TERMINALS 17, 18, 19 & 20 WERE SHOWN IN ERROR
CHECKED		DATE 2.12.57	M.T.C. 9.2.77		M.T.C. 14.3.77	

GEC Measurements

Type FAC

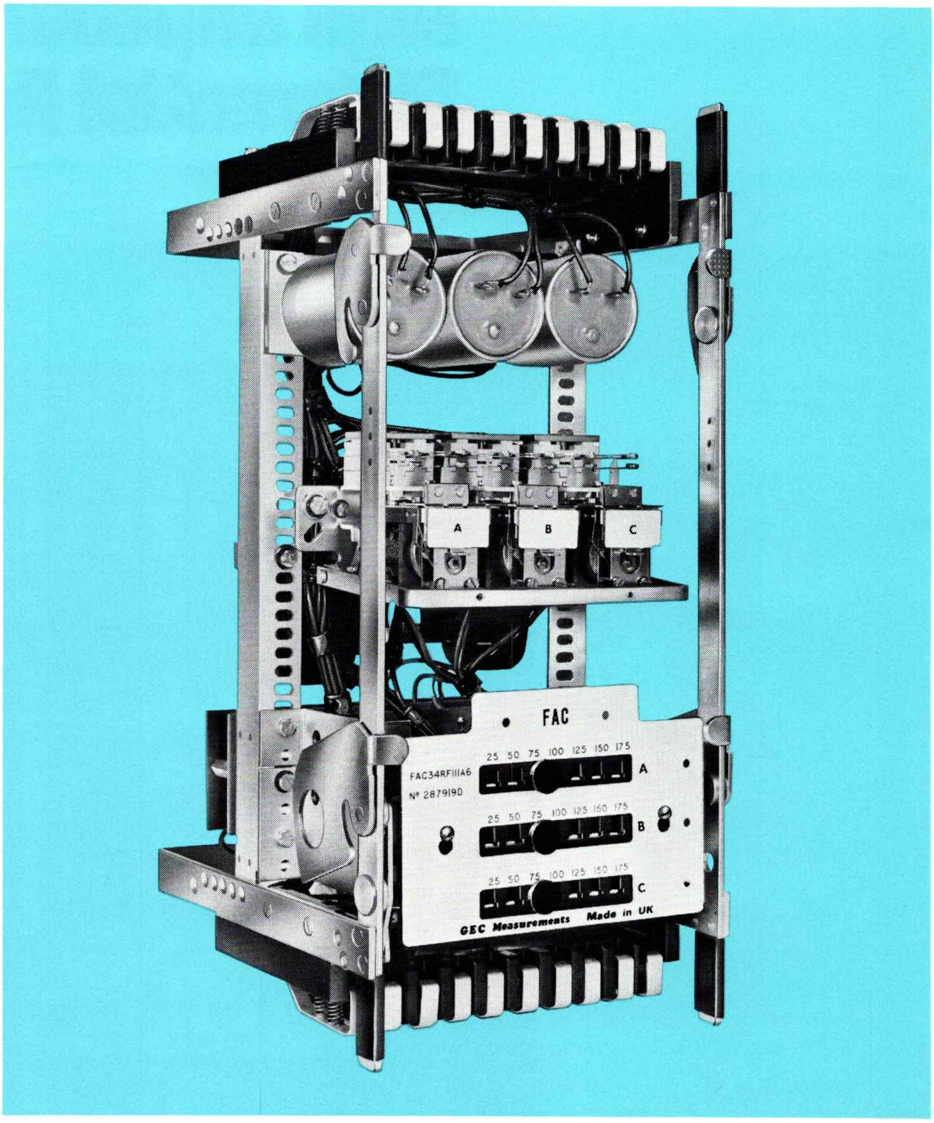
High Impedance Differential Relay



Type FAC

FEATURES

* High speed operation
* Wide range of settings
* Simple application technique
* Determinate operation and stability performance
* Compact robust design



APPLICATION

When circulating current protection schemes are subjected to through faults, the sudden and often asymmetrical growth in the system current can cause the line current transformers to reach saturation. In this condition, variation in transformer magnetising characteristics can cause large ratio errors with a consequent circuit unbalance and maloperation of the protective relays.

To ensure stability, it is modern practice to employ high impedance relays set to operate at a slightly higher voltage than that developed in the worst theoretical case of this condition for a given through fault current. On a balanced earth fault system for example, this is when one transformer of a group is saturated whilst the others remain unaffected. The saturated transformer presents a low impedance path in parallel with the relay and limits the voltage applied. On internal faults this limitation does not exist and voltages of twice the settings are easily reached.

Type FAC relays provide high speed differential protection for various items of power system plant including generators, reactors, busbars, motors and the individual windings of power transformers.

The single element version, Type FAC14, is applied when protection is required for earth faults only. Applications for protecting power transformer windings are shown typically in Figure 1.

The three element version, Type FAC34, provides both phase and earth fault protection. A typical application for generator protection is shown in Figure 2.

An external 'Metrosil' unit having a non-linear resistance characteristic is provided for each relay element, to limit the peak voltage appearing across the secondary differential circuits under internal fault conditions.

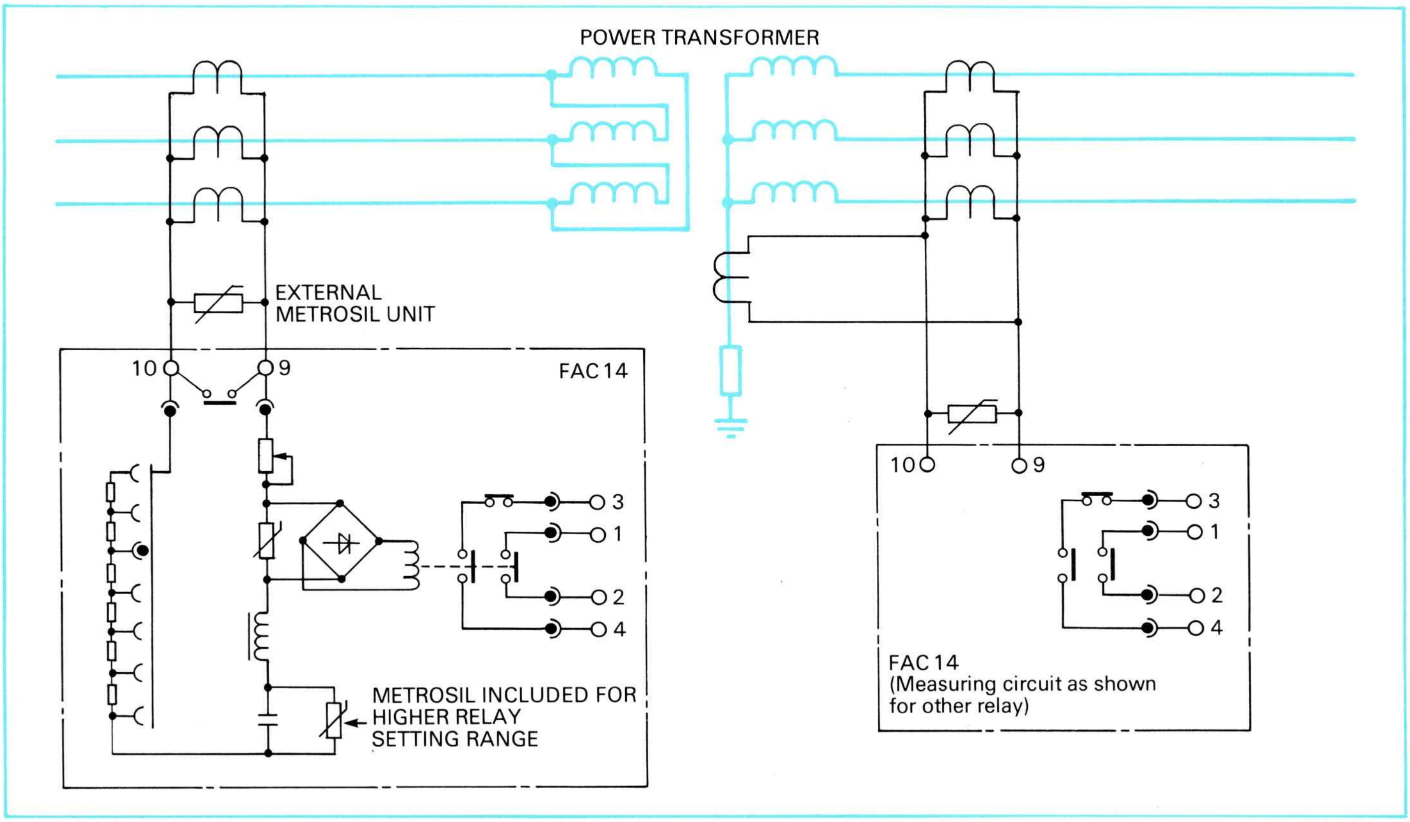


Figure 1 TYPE FAC 14 RELAYS APPLIED FOR RESTRICTED EARTH FAULT PROTECTION OF POWER TRANSFORMER WINDINGS

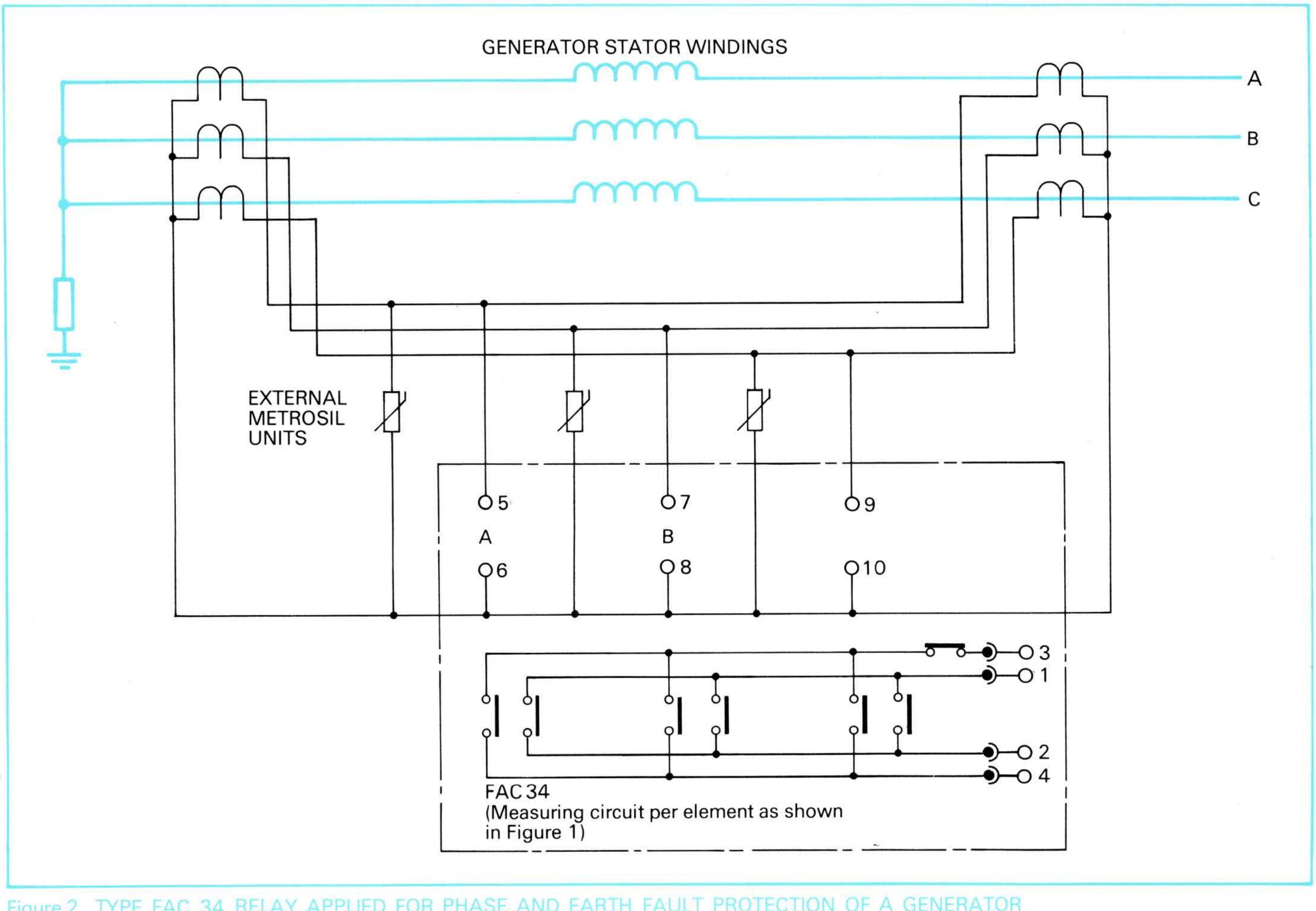


Figure 2 TYPE FAC 34 RELAY APPLIED FOR PHASE AND EARTH FAULT PROTECTION OF A GENERATOR

CONSTRUCTION AND OPERATION

Relay

The relay measuring element is basically an attracted armature unit of simple and robust construction, supplied from a bridge rectifier.

By means of a number of resistors connected in series with each element, the relay setting can be varied within each of the two alternative setting ranges available, by selecting a plug position in a seven way plug setting bridge.

A capacitor is connected in series with the operating coil to make the relay insensitive to the d.c. component of fault current. The setting voltage can thus be calculated in terms of r.m.s. alternating quantities without regard for the degree of offset produced by the point-on-wave at which the fault occurs. A reactor connected in series with the capacitor forms a resonant circuit tuned to the relay rated frequency.

External 'Metrosil' units

Single element or three element 'Metrosil' units are provided with single element or three element relays respectively.

The type of Metrosil characteristic differs for each of the alternative relay setting ranges.

The nominal characteristic for a Metrosil unit is conventionally of the form $V = CI^{\beta}$, with the voltage (V) and the current (I) specified in d.c. quantities for convenience in some applications and also to facilitate testing in manufacture. The constant (C) and the index (β) are nominally fixed for a particular Metrosil design.

For a.c. applications a modified equation $V' = 0{\cdot}84C\,(I')^{\beta}$ can be used to determine an approximate a.c. characteristic, where
V' = voltage (V r.m.s., sinusoidal)
I' = current (A r.m.s.)
Details of the alternative 'Metrosil' designs used with FAC relays are given in the Technical Data section.

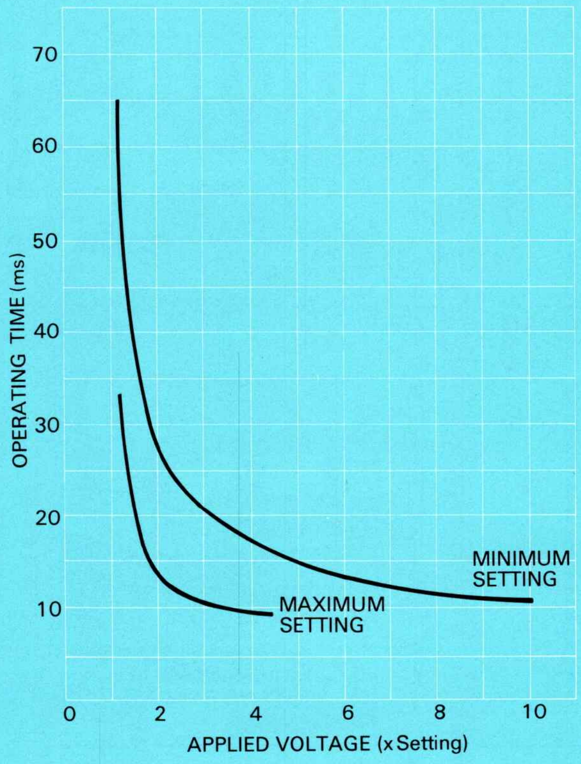


Figure 3 TYPICAL OPERATING TIME CHARACTERISTICS

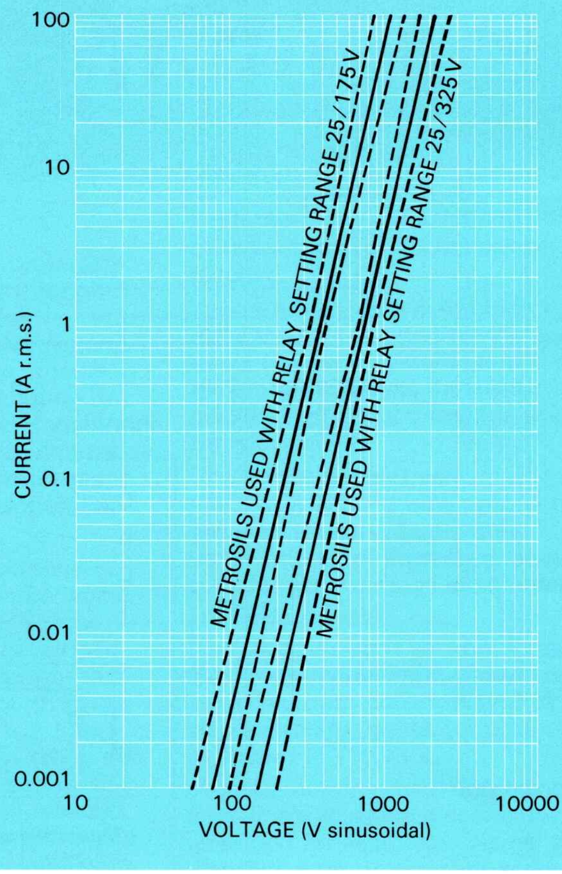


Figure 4 NOMINAL & EXTREME A.C. CHARACTERISTICS OF EXTERNAL METROSILS FOR USE WITH FAC RELAYS

TECHNICAL DATA

Setting ranges

Either 25V to 175V in seven equal 25V steps, or 25V to 325V in seven equal 50V steps.
The operating current of the relay alone on any setting is 19 mA nominally.

Rated frequency

50 Hz or 60 Hz.

Operation time

The operation time characteristics are shown in Figure 3.

'Metrosil' characteristics

Relay setting range	Nominal characteristics	
	C	β
25V to 175V 25V to 325V	450 900	0·25 0·25

Each characteristic is shown graphically in detail in Figure 4.

Thermal withstand ratings

Continuous ratings – Relay alone

Setting range 25–175V			Setting range 25–325V		
Setting	Continuous rating		Setting	Continuous rating	
V	X Setting	V	V	X Setting	V
25	2	50	25	2·0	50
50	2	100	75	1·7	128
75	2	150	125	1·7	213
100	2	200	175	1·7	297
125	2	250	225	1·7	383
150	2	300	275	1·6	440
175	2	350	325	1·5	487

Continuous ratings – 'Metrosil' unit
(Standard, with single 6 in. disc per element)

'C' Characteristic	Continuous rating (V)
450	225
900	400

Short-time rating — Relay alone
0·75A for 3s
Short-time rating — Metrosil unit

Metrosil arrangement	'C' Characteristic	Short time rating
Standard (Single 6 in. disc per element)	450	22A for 3s 30A for 2s
	900	17A for 3s 30A for 1·5s
Special (Each element comprising two standard C=450 discs in series)	900	22A for 3s 30A for 2s
Special (Each element comprising two special discs in parallel)	900	30A for 3s

The 'Metrosil' unit is the limiting component with respect to short time rating.

Where higher ratings are required, special 'Metrosil' units can be provided with more discs in parallel per element, to suit a particular application.

Operation indicator

A hand reset operation indicator is fitted to each element as standard.

Contacts

Two pairs of normally open self-resetting contacts are provided on each element as standard.

In three element relays the contacts are connected in parallel, as shown in Figure 2, or brought out to separate case terminals if required.

Other contact arrangements, including hand resetting contacts, are available if required, within the limit of 20 terminals total. An auxiliary follower element is included in such arrangements.

Contact ratings

Current	Make and carry continuously	Make and carry for 3 seconds	Break
a.c.	1250 VA with maxima of 5A and 660V	7500 VA with maxima of 30A and 660V	1250 VA with maxima of 5A and 660V
d.c.	1250W with maxima of 5A and 660V	7500W with maxima of 30A and 660V	100W (resistive) 50W (inductive) with maxima of 5A and 660V

Insulation

The relay will withstand 2·0kV r.m.s. 50 Hz for one minute between all live parts and earth and between all circuits not intended to be connected together. It will also withstand 1kV r.m.s. 50Hz for one minute across open contacts.

CURRENT TRANSFORMERS

Type FAC relays are suitable for use with 0·5A, 1A and 5A current transformers, at 50H or 60Hz. Since selection of the optimum relay setting is based on the loop resistance of the secondary circuit, there are advantages in using current transformers with either of the lower secondary ratings.

The current transformers used in circulating current differential protection systems must be of equal turns ratio and have reasonably low secondary winding resistance. The knee-point voltage is defined as the point on the magnetisation curve at which a 10% increase in excitation voltage produces a 50% increase in excitation current. For use with type FAC relays the knee-point voltage (V_k) should be at least twice the voltage setting, thus $V_k = 2V_s$ actual.

SELECTION OF OPTIMUM RELAY SETTING

The required voltage setting (V_s) is calculated using the formula

$$V_s = \frac{I_f}{n}(R_{ct} + 2R_w) \text{ volts}$$

where I_f = Maximum primary through fault current for which stability is required (A r.m.s.)

n = Current transformer turns ratio

R_{ct} = Current transformer secondary winding resistance (ohms)

R_w = Resistance of each lead between the relay and current transformer (ohms)

A value of V_s is calculated for each current transformer circuit in the differential system, and the relay setting finally chosen (V_s actual) is made equal to, or nearest above the highest of these calculated values.

EFFECTIVE PRIMARY OPERATING CURRENT

During internal fault conditions, the relay and 'Metrosil' current and the magnetising current of all connected current transformers is supplied from fault current. The primary operating current is given by:

$$I_{OP} = n\,(I_R + NI\mu)$$

where I_R = Relay operating current and 'Metrosil' current at setting voltage, as given in the table below (A).

$I\mu$ = Current transformer magnetising current at setting voltage. (A)

N = Number of connected current transformers

n = Current transformer turns ratio

Setting range		V	25	50	75	100	125	150	175
I_R	Nominal	A	0·019	0·019	0·02	0·023	0·027	0·036	0·053
	Limits	A	0·018–0·020	0·018–0·020	0·018–0·023	0·019–0·028	0·020–0·039	0·024–0·060	0·033–0·095
Setting range		V	25	75	125	175	225	275	325
I_R	Nominal	A	0·019	0·019	0·020	0·022	0·024	0·031	0·044
	Limits	A	0·018–0·020	0·018–0·020	0·018–0·022	0·019–0·025	0·019–0·033	0·022–0·048	0·028–0·076

Should the natural effective operating current after applying the above formula be lower than desired, it can be raised to the required level by adding a shunt resistor across the differential relay input circuit.

CASES

Type FAC14 (single element) and FAC34 (three element) relays are supplied in size 1D and 1½D drawout cases respectively, shown in Figure 5. Both cases are available for flush and projection mounting and finished phenolic black as standard.

Standard relays are finished to BS.2011:20/40/4 and are satisfactory for normal tropical use.

Relays for use in exceptionally severe environments can be finished to BS.2011:20/50/56 at extra cost.

The standard relays in either case size have single terminal blocks (numbers 1 to 10). Cases with both upper and lower terminal blocks (numbers 1 to 20) are required for special contact arrangements.

The outline dimensions and mounting arrangements for the external 'Metrosil' units are shown in Figure 6.

INFORMATION REQUIRED WITH ORDER

Single or three element relay

Setting range

Rated frequency

Contact arrangement

External 'Metrosil' short-time rating, if non-standard

Case mounting

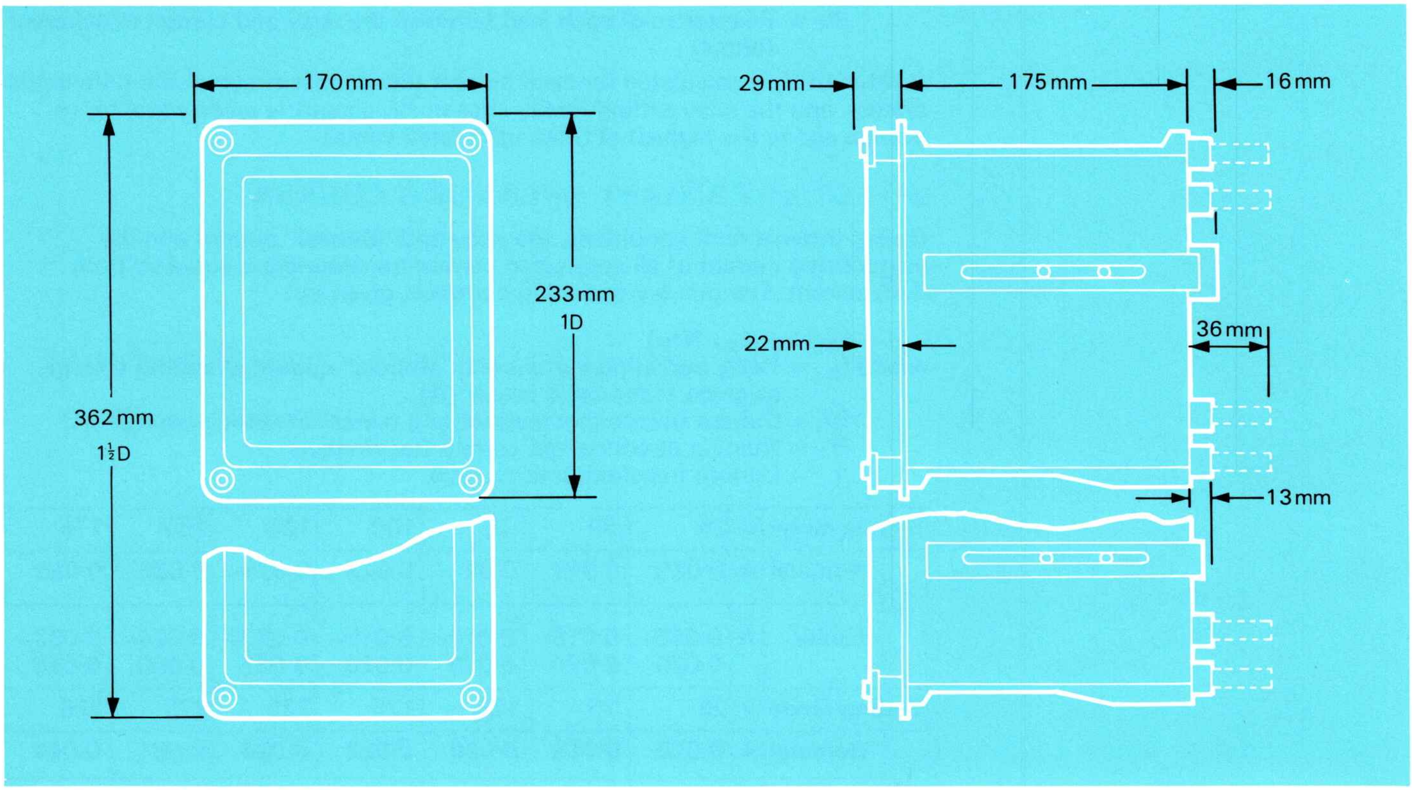


Figure 5 OUTLINES: RELAY CASES

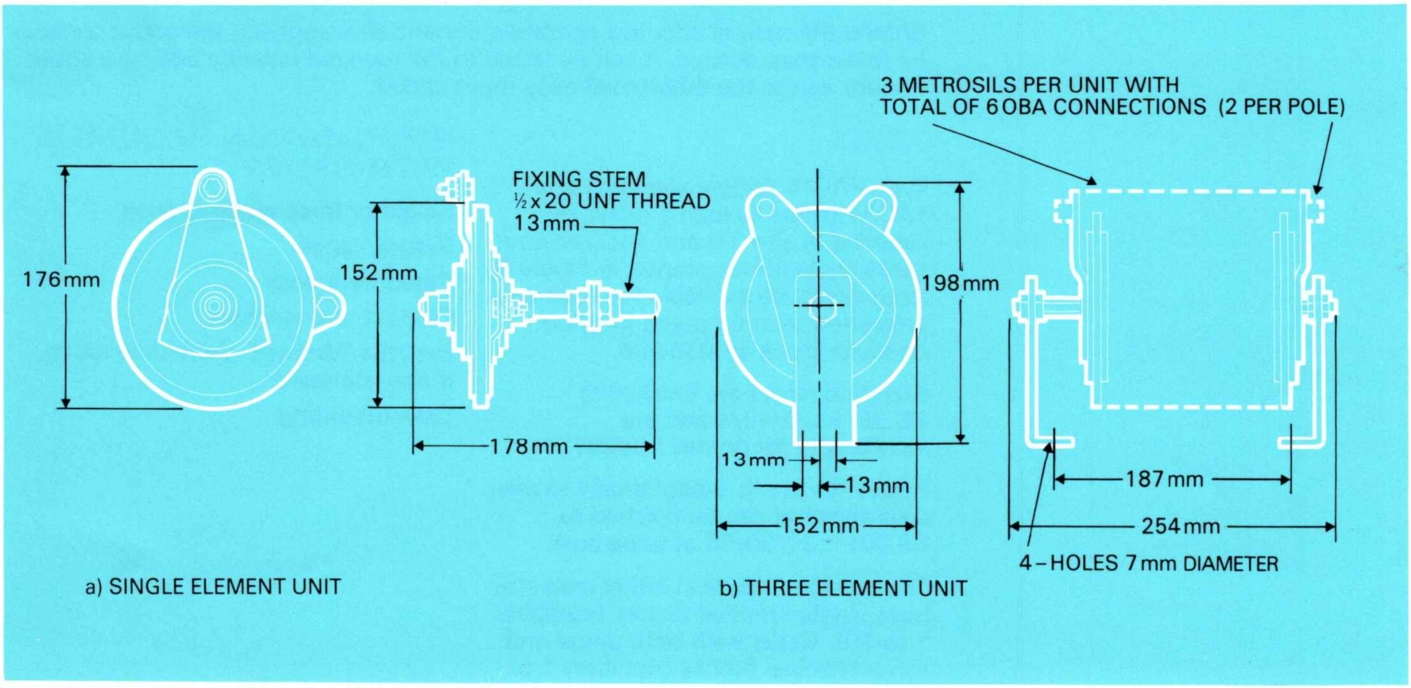


Figure 6 OUTLINES: EXTERNAL METROSIL UNITS

GEC Measurements

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NOTES ON COORDINATION OF CAG14/CAG34 RELAYS WITH CT REQUIREMENTS

A. General Requirements

On full differential and restricted earth fault applications, it is common to supply each CAG14 element with a 10 - 40% settings range based on the CT nominal secondary rating, to set the relay on the 10% tap and adjust the stabilising resistor to suit the application. Other settings may be used if an advantage.

$V_s = I_f(R_{ct} + 2R_w)$ and $V_k \geq 2V_s$ (refer note 1)

$I_e = \dfrac{I_s - I_r}{n}$

For stability at relay setting:

V_s = IR drop of resistor + IR drop of relay

$= \dfrac{VA}{I_r} + I_r \times R_{stab}$ $\quad \therefore R_{stab.} = \dfrac{V_s - \dfrac{VA}{I_r}}{I_r}$

V_s = Voltage setting for relay and resistor combination

V_k = minimum knee-point secondary voltage

I_e = maximum excitation current at relay voltage setting (V_s)

I_f = the equivalent CT secondary current for the maximum through fault conditions considered

R_{ct} = the CT secondary winding resistance

$2R_w$ = the maximum loop lead resistance (R_L) between CT's and relay

I_s = the effective fault setting experienced in secondary amps where CT's already exist.

VA = the relay burden at setting (approx 1VA)

I_r = relay setting im amps

R_{stab} = stabilising resistor setting in ohms

n = No. of CT's in parallel per relay element.

Notes

1. A factor of 2 is provided in the V_k formula to give adequate speed to the relay operation.

2. For transmission element protection such as busbar, short feeder, reactor and auto transformer differential etc., I_f is derived from the CT ratio and the maximum through fault current based on the MVA fault rating of the protected equipment.

3. For rotating machines and in the absence of any other criteria, I_f is derived from the CT ratio and the machine current contribution to an external fault. It is based on the subtransit reactance (X''_d) of the machine. For motors, an estimate may be made from the initial value of current obtained from the direct on line start (neglecting magnetizing inrush).

4. If CT's are being specified and a given primary sensitivity is required then the maximum excitation current permitted at relay voltage setting must be specified. If an economical CT size is required then, in addition to providing the CT maker with the ratio and V_k formula, it should be stated that "CT's shall have the least possible magnetising current consistent with economical design." The resultant overall primary sensitivity in this latter case should not exceed 30% but generally values down to 15 - 20% may be achievable with the relay set at 10%.

5. If it is proposed to use the relays with existing CT's it is recommended that a stabilising resistor setting claculation be carried out before ordering to ensure that an appropriate value of resistor is supplied. In the absence of a specified resistor range, 50 ohm or 200 ohm adjustable resistors will be provided for 5A and 1A CT applications respectively.

B. Metrosil Non-Linear Resistor Application

If the voltage across the CT terminals V_p with maximum through fault current, exceeds 2500V peak, shunt **Metrosils** should be applied. From Matthews text book on CT's:

$V_p = 2\sqrt{2V_k(V_f - V_k)}$ where,

V_p = CT peak voltage $\not>$ 2500V

V_t = fault voltage across CT terminals

i.e. = $I_f(R_{ct} + 2R_w + R_r)$ where,

R_r = total resistance of relay + R_{stab}

Generally, a 6 inch (152mm) diameter Metrosil with a constant C = 450 should be satisfactory. If in doubt, full details of the application should be submitted for comment.

Publication R-5776

TYPES CAG14 & CAG34
TYPES FAC14 & FAC 34
HIGH IMPEDANCE RELAYS
FOR DIFFERENTIAL PROTECTION

APPLICATION NOTES

THE APPLICATION OF HIGH IMPEDANCE RELAYS

The application of the CAG14 and FAC14 relays to the protection of machines, power transformers and bus-bar installations is based on the high impedance voltage differential principle, requiring stability for any type of fault occurring outside the protected zone and satisfactory operation for faults within the zone.

A high impedance relay is defined as a relay or relay circuit whose voltage setting is not less than the calculated maximum voltage which can appear across its terminals under the assigned maximum through fault current condition.

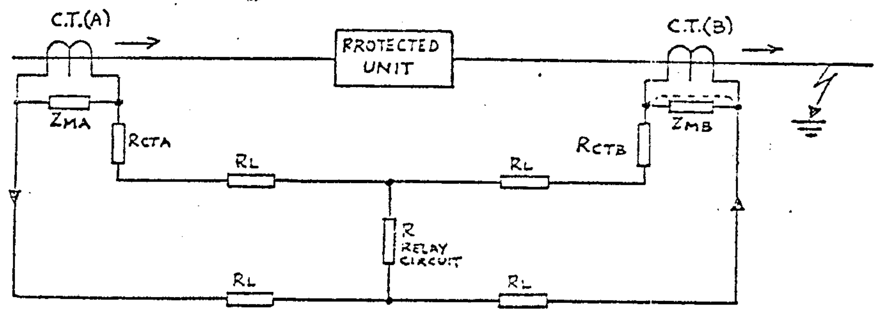


FIGURE 1.

It can be seen from figure 1 that during an external fault the through fault current should circulate between the c.t. secondaries and the only current that can flow through the relay circuit is that due to any difference in the c.t. outputs for the same primary current. Magnetic saturation will reduce the output of a c.t. and the most extreme case of error will be if one c.t. is completely saturated and the other unaffected. This condition can be approached in bus bar installations, due to the multiplicity of infeeds and extremely high fault level, but is unlikely on machines or power transformers due to the limitation of through fault level by the protected units impedance, and the fact that the comparison is made between a limited number of c.t.'s.

However it is this extreme case which is considered and for it a c.t. at one end can be considered fully saturated with its magnetising impedance ZMB short circuited, the c.t. at the other end being unaffected delivers its full current output which will then divide between the relay and the saturated c.t. This division will be in the inverse ratio of $R_{RELAY\ CIRCUIT}$ and $R_{CT_B} + 2R_L$ and obviously if $R_{RELAY\ CIRCUIT}$ is high compared with $R_{CT_B} + 2R_L$ then the relay will be prevented from undesirable operation as most of the current will pass through the saturated c.t.

To express the current transformer requirements for this type of protection it is then necessary to calculate the voltage appearing across the relay circuit V_R, equivalent to $I_f\ (R_{CT} + 2R_L)$.

where I_f = maximum through fault secondary current.
R_{CT} = current transformer secondary winding resistance.
R_L = maximum lead resistance from the current transformer to the relay tapping point.

Then to ensure satisfactory operation of the relay under internal fault conditions the current transformer knee point voltage should be not less than twice the relay voltage setting i.e. $V_K \geqslant 2V_R$.

The knee point voltage of a current transformer marks the upper limit of the roughly linear portion of the secondary winding excitation characteristic and is defined exactly in British practice as that point on the excitation curve where a 10% increase in exciting voltage produces a 50% increase in exciting current.

The current transformers should be of equal ratio and magnetic characteristics and of low reactance construction. In cases where low reactance c.t.'s are not available and high reactance ones must be used it is essential to use in the calculations for the voltage setting, the reactance of the current transformer and express the current transformer impedance as a complex number in the form $R_{CT} + jX_{CT}$ and also to ensure that the exciting impedance of the c.t. is large in comparison with its secondary ohmic impedance at the relay voltage setting.

APPLYING THE CAG14

As the CAG14 is a current calibrated relay with setting ranges of :

0.025 – 0.100A
0.050 – 0.200A
0.100 – 0.400A
0.200 – 0.800A
0.500 – 2.00A
2.00 – 4.00A

and with a fixed burden of approximately 1VA at setting current, its impedance varies with the setting current used and therefore to comply with the definition for a high impedance relay, it is necessary in most applications to utilise an externally mounted stabilising resistor in series with the relay coil.

The standard ratings of the stabilising resistors normally supplied with the relay are 400, 200 and 50 ohms for 0.5, 1.0 and 5.0A current transformer secondaries respectively. In applications such as busbar protection, where higher values of stabilising resistor are often required to obtain the desired relay voltage setting, non standard resistor values can be supplied. The standard resistors are wire wound, continuously adjustable and have a continuous rating of 120 watts.

The recommended relay current setting is usually determined by the minimum fault current available for operation of the relay and whenever possible it should not be greater than 30% of the minimum fault level.

The relay effective setting is also determined by the number of current transformers in parallel with the relay and is given by the expression :

$$I_P = N\ (I_R + n\ I_e)$$

where N = current transformer ratio.
I_R = relay setting current.
n = number of current transformers in parallel with the relay.
I_e = current transformer exciting current at the relay voltage setting.

The required value of stabilising resistor to be used with the relay for a given application can easily be calculated once the relay voltage and current settings are known. It is given by the expression :

$$R_{ST} = \frac{V_R}{I_R} - \frac{V_A}{I_R^2}$$

where V_R = relay voltage setting.
I_R = relay current setting.
V_A = relay volt-amperes burden.

APPLYING THE FAC14

As the FAC14 is a voltage calibrated relay with setting ranges of 25-175V or 25-325V it is inherently a high impedance relay requiring no external resistors.

Its operating current for the various voltage settings is as follows, (including the metrosil current) :

Setting Volts	25	50	75	100	125	150	175
I_R (mA)	19	19	20	23	27	36	53

Setting Volts	25	75	125	175	225	275	325
I_R (mA)	19	19	20	22	24	31	44

The relay effective setting can be calculated in the same manner as described for the CAG14.

USE OF METROSIL NON LINEAR RESISTORS – CAG14

When the maximum through fault current is limited by the protected circuit impedance such as in the case of generator differential and power transformer restricted earth fault protection, it is generally found unnecessary to use metrosil non-linear resistors. However, when the maximum through fault current is high such as in bus-bar protection, it is always advisable to use non-linear resistors across the relay circuit (relay and stabilising resistor) in order to limit the peak voltage developed by the current transformers under internal fault conditions, to a value below the insulation level of the current transformers, relay and interconnecting pilots which are normally designed to withstand 3000V peak. A formula that can be used to determine the approximate voltage developed by a current transformer under internal fault conditions is given by the expression :

$$V_P = 2\sqrt{2\ V_K\ (V_f - V_K)}$$

where V_P = peak voltage developed by the c.t. under internal fault conditions.

V_K = current transformer knee-point voltage.

V_f = maximum volts that would be produced if the current transformer did not saturate and it were equal to $I_f\ (R_{CT} + 2R_L + R_{ST} + R_R)$

where I_f = maximum through fault secondary current.
R_{CT} = current transformer secondary winding resistance.
R_L = maximum lead burden from current transformers to relay.
R_{ST} = relay stabilising resistor.
R_R = relay ohmic impedance at the relay current setting.

When the value given by the formula is greater than 3000 volts peak, the use of non linear resistors is recommended. These non-linear resistors are effectively connected across the relay circuit or phase to neutral of the A.C. buswires and serve the purpose of shunting the secondary current output of the current transformer from the relay in order to prevent the current transformers being driven into saturation and thereby producing very high and peaky secondary voltages.

These non-linear resistors are externally mounted and take the form of annular discs, of 6 inches diameter and approx. ⅜" thickness. Their operating characteristics follow the expression :

$$V = K\ I^{0.25}$$

where V = peak volts applied to the metrosil.
K = constant of the metrosil.
I = current through the metrosil. This current has an r.m.s. value of 0.52 times the value given by the above formula. This is due to the fact that the current waveform through the metrosil is not sinusoidal but appreciably distorted.

For satisfactory application of the non-linear resistors the characteristic should be such that it complies with the following requirements :

i) At the relay voltage setting, the metrosil current is as low as possible but no greater than approx. 30mA r.m.s. for 1A current transformers and approx. 100mA r.m.s. for 5A current transformers.

ii) At the maximum secondary current, the metrosil cut-off point should not be greater than 1500V r.m.s. or 2120V peak.

The metrosils normally recommended for the CAG14 are as follows :

For secondary currents up to 50A, the type 600A/S1 with a constant of 900.

For secondary currents up to 100A, the type 600A/S2/P with a constant of 620/740.

For secondary currents up to 150A, the type 600A/S3/P with a constant of 620/740.

USE OF METROSIL NON-LINEAR RESISTORS – FAC14

Due to the high impedance of the FAC14 relay the use of a shunting metrosil is always recommended and the type 600A/S1 with a constant of 900 for secondary current levels of up to 50A r.m.s. is supplied as a standard. For higher secondary current ratings, metrosils similar to those specified for the CAG14 are recommended.

TYPICAL EXAMPLE OF CAG14/FAC14 APPLICATION

The correct application of high impedance relaying can best be illustrated by taking the case of 1000 KVA power transformer of ratio 11kV/415V for which restricted earth fault protection is required on the L.V. winding.

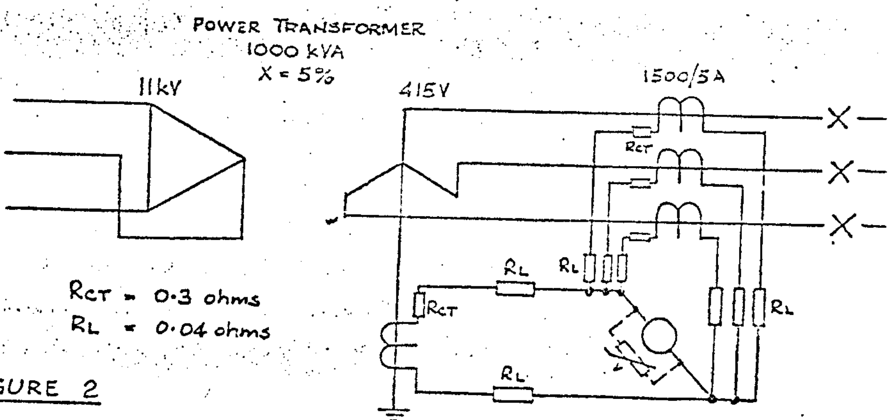


FIGURE 2

The power transformer full load current $= \frac{1000 \times 10^3}{\sqrt{3} \times 415} = 1395A$

Maximum through fault level (ignoring source impedance) $= \frac{100}{5} \times 1395$

i) VOLTAGE SETTING

∴ The required relay voltage setting, assuming one c.t. to saturate

$= I_f \ (R_{CT} + 2R_L)$

$= 27900 \times \frac{5}{1500} \quad (0.3 + 0.08).$

$= 35.3V.$

A 50V setting should be used on the FAC14.

ii) STABILISING RESISTOR FOR THE CAG14

Assuming that the relay effective setting for a solidly earthed power transfor[mer] is approx. 30% of full load, we can therefore, choose a relay current setting [of] 20% of 5A i.e. 1A. On this basis the required value of stabilising resistor is

$R_{ST} = \frac{35.3}{1} - \frac{1}{1^2}$

$= 34.3$ ohms

iii) CURRENT TRANSFORMER REQUIREMENTS FOR THE CAG14 AND FAC14

The minimum current transformer knee point voltage $V_K = 2V_R$.

Requiring 2 x 35.3 = 70.6V for the CAG14.

and 2 x 50 = 100V for the FAC14.

The exciting current to be drawn by the current transformers at the relay voltage setting $= \frac{I_S - I_R}{n}$

where I_S = relay effective setting $= \frac{30}{100} \times 1395 \times \frac{5}{1500} = 1.4A$

I_R = relay current setting.

$= \frac{20}{100} \times 5 = 1A$ for the CAG14.

= 20mA for the FAC14 (relay and metrosil).

n = number of current transformers in parallel with the relay = 4.

Therefore for the CAG14 the current transformer exciting current at 35.3V = $\frac{1.4 - 1}{4} = 0.1A.$

and for the FAC14 at 50V $= \frac{1.4 - 0.02}{4} = 0.346A.$

APPLICATION OF METROSIL NON-LINEAR RESISTORS FOR THE CAG14

If the peak voltage, appearing across the relay circuit, under maximum internal fault conditions exceeds 3000V peak then a suitable non-linear resistor, externally mounted, should be connected across the relay and stabilising resistor, in order to protect the insulation of the current transformers, relay and inter-connecting pilots. In the present case the peak voltage can be estimated by the formula :

$$V_P = 2\sqrt{2 \quad V_K\,(V_f - V_K)}$$

where V_K = 70.6V (assumed value). In practice this shall be the actual current transformer knee point voltage, obtained from the current transformer magnetisation curve.

$V_f = 27900 \times \frac{5}{1500} \quad (0.3 + 0.08 + 34.3 + 1)$

$= 93 \times 35.68$

= 3320 volts.

Therefore substituting these values for V_K and V_f in the above formula it can be seen that the peak voltage developed by the current transformer is :

$$V_P = 2\sqrt{2 \times 70.6 \times (3320 - 70.6)}$$

$= 2.82 \times 8.4 \times 57$

= 1350 volts.

This value is well below the maximum of 3000 volts peak and therefore no metrosils are required with the relay. If on the other hand the peak voltage V_P given by the formula had been greater than 3000V peak, a non linear resistor would have to be connected across the relay circuit and the recommended metrosil type would have been chosen in accordance with the maximum secondary current of $27900 \times \frac{5}{1500} = 93A.$

Therefore the metrosil reference would have been the 600A/S2/P with a constant of 620/740.

Attached are sketches of the various applications for high impedance relaying for incorporation in the leaflet.

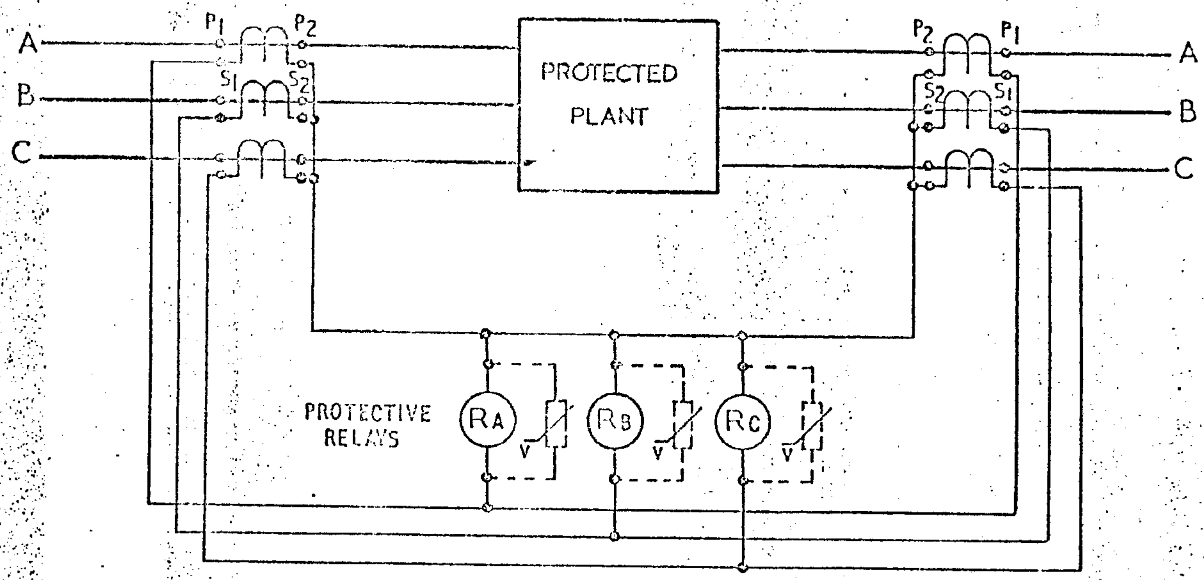


Figure 3 PHASE AND EARTH FAULT DIFFERENTIAL PROTECTION FOR GENERATORS, MOTORS OR REACTORS

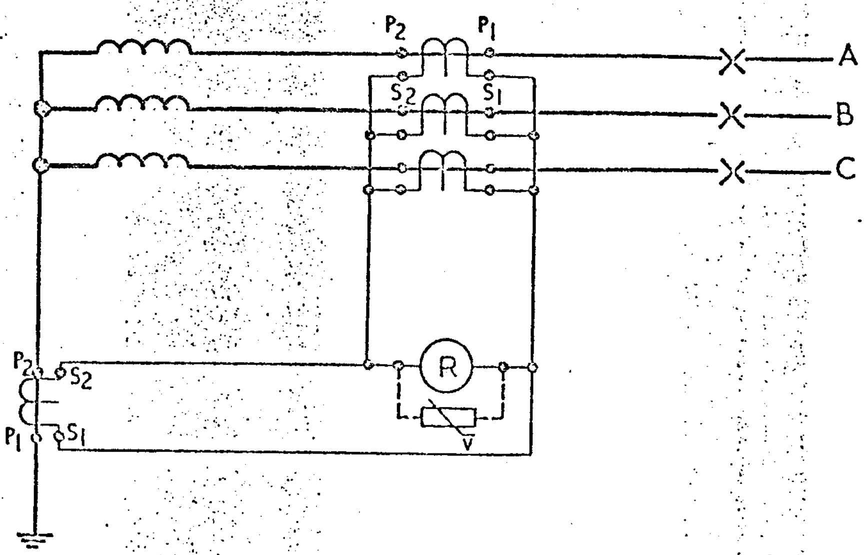


Figure 4 RESTRICTED EARTH FAULT PROTECTION 3PHASE 3 WIRE SYSTEM APPLICABLE TO STAR CONNECTED GENERATORS OR POWER TRANSFORMER WINDINGS

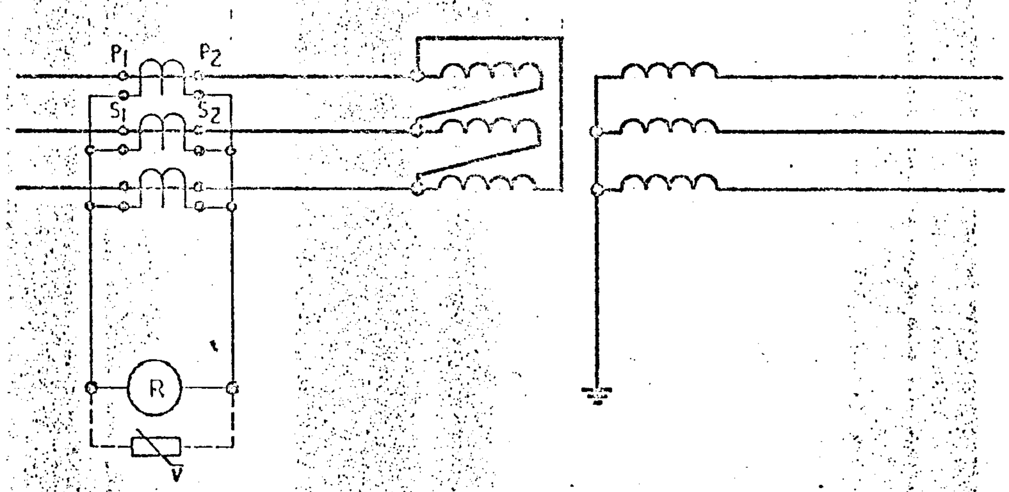


Figure 5 BALANCED OR RESTRICTED EARTH FAULT PROTECTION FOR DELTA WINDING OF A POWER TRANSFORMER WITH SUPPLY SYSTEM EARTHED.

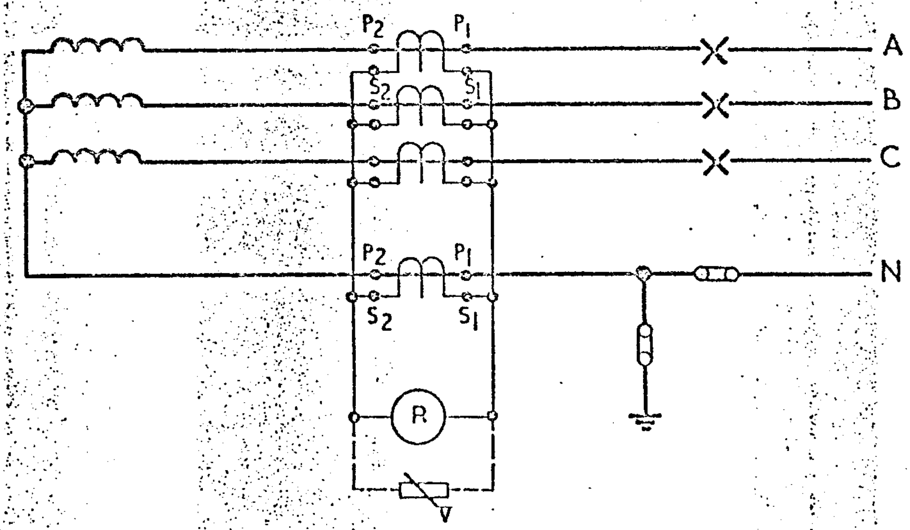


Figure 6 RESTRICTED EARTH FAULT PROTECTION FOR 3 PHASE, 4 WIRE SYSTEM - APPLICABLE TO STAR CONNECTED GENERATORS OR POWER TRANSFORMER WINDINGS WITH NEUTRAL EARTHED AT SWITCHGEAR

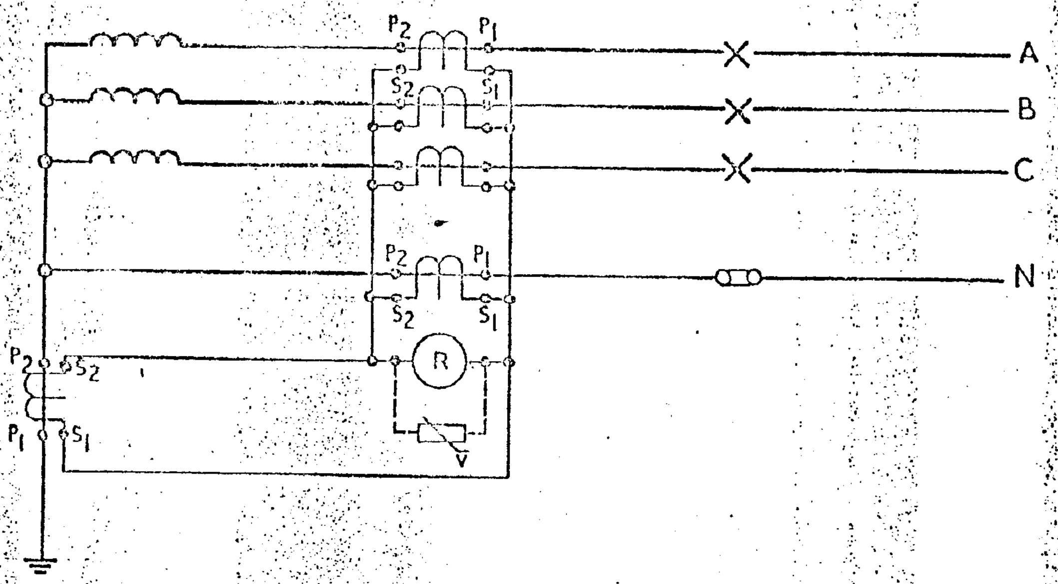


Figure 7 RESTRICTED EARTH FAULT PROTECTION FOR 3 PHASE, 4WIRE SYSTEM APPLICABLE TO STAR CONNECTED GENERATORS OR POWER TRANSFORMER WINDINGS EARTHED DIRECTLY AT THE STAR POINT.

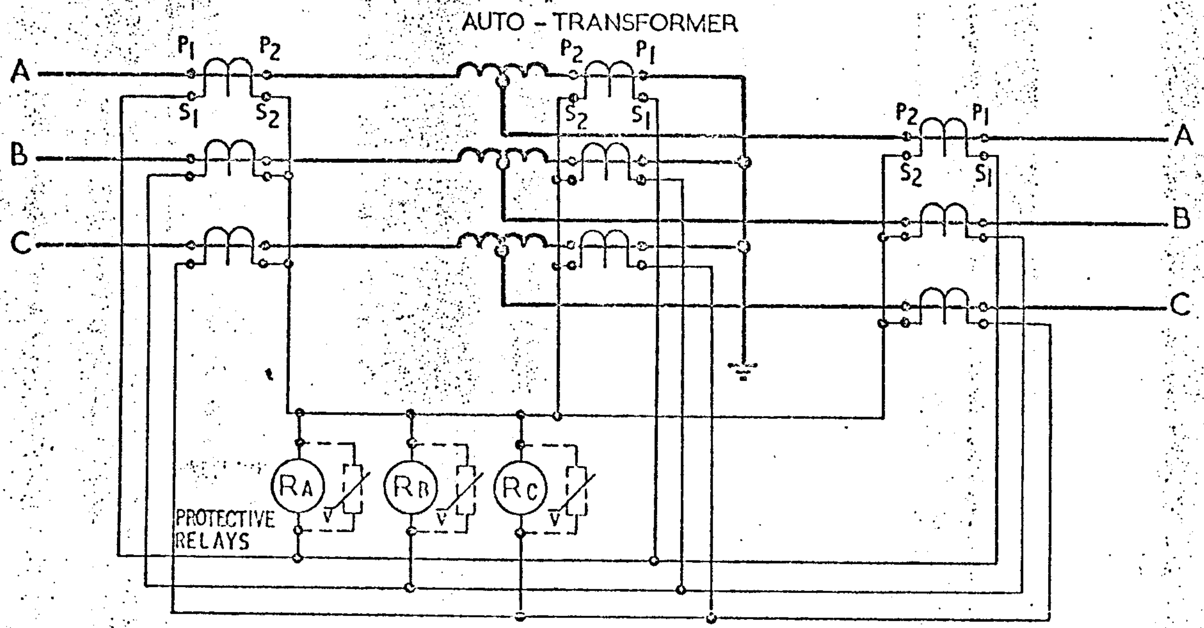


Figure 8 PHASE AND EARTH FAULT DIFFERENTIAL PROTECTION FOR AN AUTO-TRANSFORMER WITH C.T.'s AT THE NEUTRAL STAR POINT.

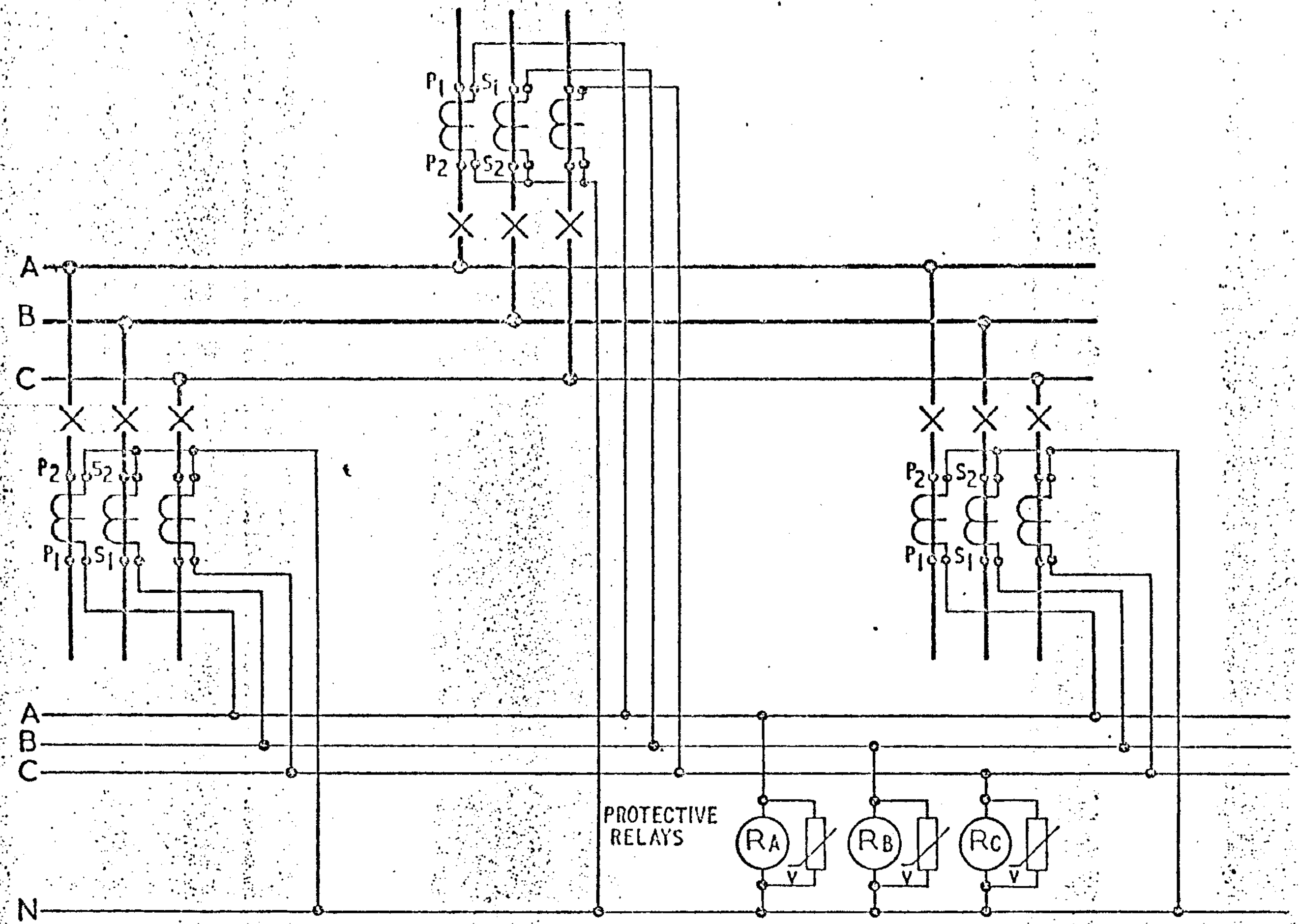


Figure 9 BUSBAR PROTECTION - SIMPLE SINGLE ZONE PHASE & EARTH FAULT SCHEME

5. Transformer Differential Protection Relays Types DDT32 and DTH31/32

GEC Measurements

TRANSFORMER PERCENTAGE BIASED DIFFERENTIAL RELAY

Type DDT

The type DDT relay is a medium or high bias-slope differential unit designed for protection of two-winding power transformers over about 1 MVA rating against internal phase and earth faults. Basically the relay is an induction disc unit with a pair of bias or restraint coils (in addition to an operating coil) to prevent operation by external faults. Types DDT12 and DDT32 are single and triple pole versions respectively.

OPERATION

The relay is connected in a Merz-Price configuration to corresponding matched current transformers on either side of the protected transformer. The C.T. secondaries provide a through current in the relay restraint coils which produce a continuous torque on the disc in the contact opening direction. The differential of the C.T. secondary currents flows in the relay operating coil.

Under normal load conditions the C.T. secondary currents are equal and no current flows in the operating coil. If these currents become unequal due to a fault in the transformers, the resulting differential current energises the operating coil which produces a torque on the disc in the contact closing direction. The contacts close when the ratio of the differential current to the through current exceeds the slope of the relay operating characteristic determined by the turns ratio of the operating and restraint coils.

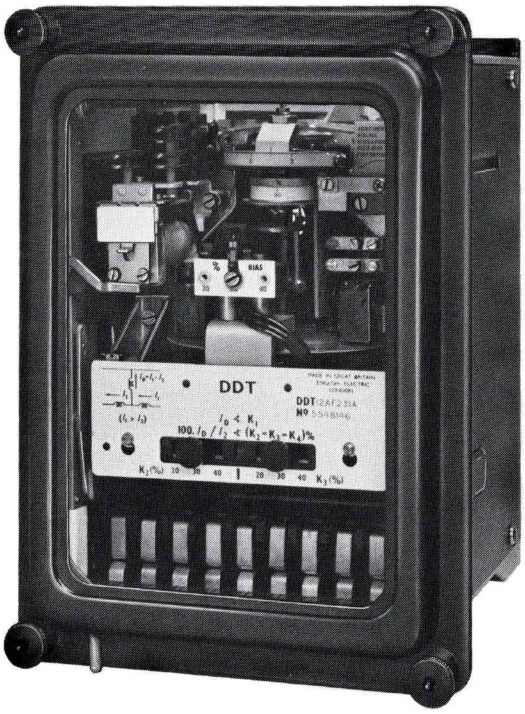
The bias slope is chosen so that the relay is insensitive to unbalanced external lead burdens which normally give a lower ratio of differential current to through current than an internal fault. In addition a fairly high bias slope is required to prevent maloperation by C.T. differential currents arising from:

(a) tap changing on transformers giving mismatch of the C.T.'s.

(b) different C.T. ratios and hence saturation levels giving differential currents under through fault conditions.

(c) magnetising inrush giving secondary currents in one set of C.T.'s only.

To prevent maloperation by magnetising inrush the relay function is delayed by a selected time until the initial current peaks have decayed to a tolerable level (determined by the percentage bias).



Type DDT12 relay

The minimum operating current of the relay is determined by the tension of the disc control spring and can be adjusted by rotating a knurled moulded disc against a graduated scale.

CURRENT SETTING

40–100% (adjustable) of 0·5, 1·0 or 5·0 amps (C.T. secondary) 50 or 60 c/s

PERCENTAGE BIAS

20%, 30% or 40% (selected by taps)

The percentaged bias is defined at the minimum current setting (40%) as $\frac{\text{spill current}}{\text{through current}} \times 100$

OPERATING TIME

0·10 second to 0·25 second (adjustable) at 5 times current setting (see characteristic)

BURDENS

Bias coil		
Bias	Burden (C.T.) at rated current	
	50 c/s	60 c/s
20%	0·2 VA	0·3 VA
30%	0·35 VA	0·4 VA
40%	0·4 VA	0·5 VA

Operating coil		
Current setting	Burden (C.T.) at current setting	
	50 c/s	60 c/s
40%	0·6 VA	0·7 VA
100%	3·7 VA	4·5 VA

Operating Coil Impedance

At the rated current, the operating coil impedance does not exceed 0·182 ohms and is 0·08 ohms at saturation.

Current Transformer Knee-point Voltage

The knee point is defined as the point on the magnetisation curve at which a 10% increase in excitation voltage produces a 50% increase in excitation current. The minimum knee-point voltage is calculated as follows:

$$V_k = 2 I_f (R_s + R_b + R_r) \text{ (star connected C.T.'s)}$$

$$\text{or } V_k = (2/\sqrt{3})\, I_f [R_s + 3(R_b + R_r)] \text{ (delta connected C.T.'s)}$$

where I_f = Maximum fault current (C.T. secondary amps)

R_s = C.T. secondary resistance (ohms)

R_r = Lead resistance between C.T.'s and relay (ohms)

R_b = Impedance of one half of relay bias winding (ohms)

$$= \frac{\text{bias winding burden (VA)}}{2 \times (\text{rated current})^2}$$

AUXILIARY UNITS AND OPERATION INDICATORS

An auxiliary attracted armature unit with a hand reset operation indicator for either shunt (seal in) or series seal in is fitted as standard.

Standard Coil Ratings

Voltage operated (shunt) auxiliary units are available with nominal ratings of 30, 110, 125 or 220 volts d.c.

Current operated (series) auxiliary units:

Minimum operating current in amps (two taps)	0·5 second current rating in amps	Coil resistance in ohms
0·1 and 0·3	18 and 22	9·2 and 2·1
0·2 and 2·0	22 and 92	6·0 and 0·125
0·6 and 2·4	92 and 188	0·29 and 0·031

Other coil ratings can be supplied for both types of auxiliary unit.

Contacts

Two pairs of electrically separate normally open self or hand reset contacts are fitted and will make and carry 7500 VA for 3s with maxima of 30 A and 660 V a.c. or d.c.

CASES

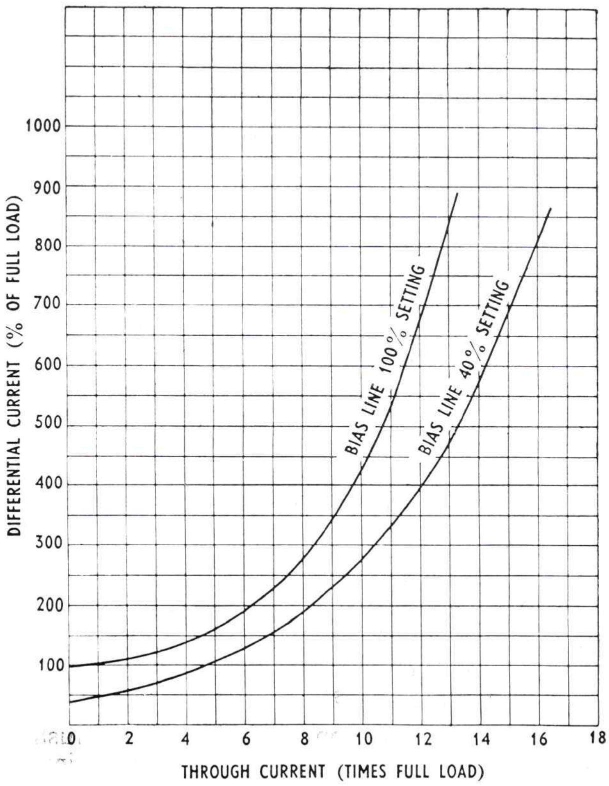
The relays are supplied in drawout cases available for either flush or projecting mounting and finished in phenolic black.
Standard relays are finished to BS.2011:20/40/4 and are suitable for normal tropical use; relays for use in exceptionally severe environments can be finished to BS.2011:20/50/56 at extra cost.

The drawout case offers many advantages including ease of maintenance and testing, and is fitted with contacts which short circuit the associated current transformers on withdrawal of the unit. A filter is fitted to equalise the pressure inside and outside the case without admitting dust.

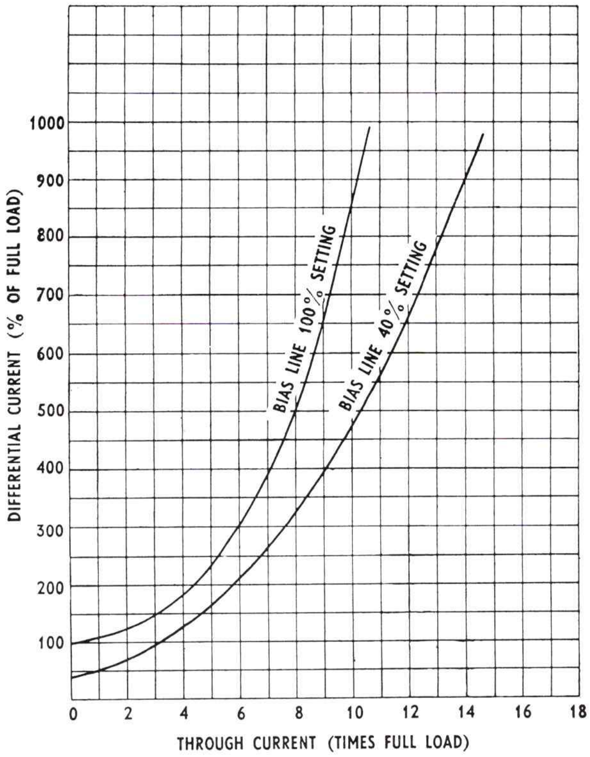
Relay	Case	Maximum Overall Dimensions					
		Height		Width		Depth*	
		ins	mm	ins	mm	ins	mm
DDT 12 (Single Pole)	1D	9 3/16	233	6 11/16	170	7 3/4	197
DDT 32 (Triple Pole)	3D (Vert.)	20 5/8	524	6 11/16	170	7 3/4	197
	3D (Horiz.)	9 1/4	235	17 7/8	454	7 3/4	197

*Add 3 ins (76 mm) for maximum length of 2 BA terminal studs.

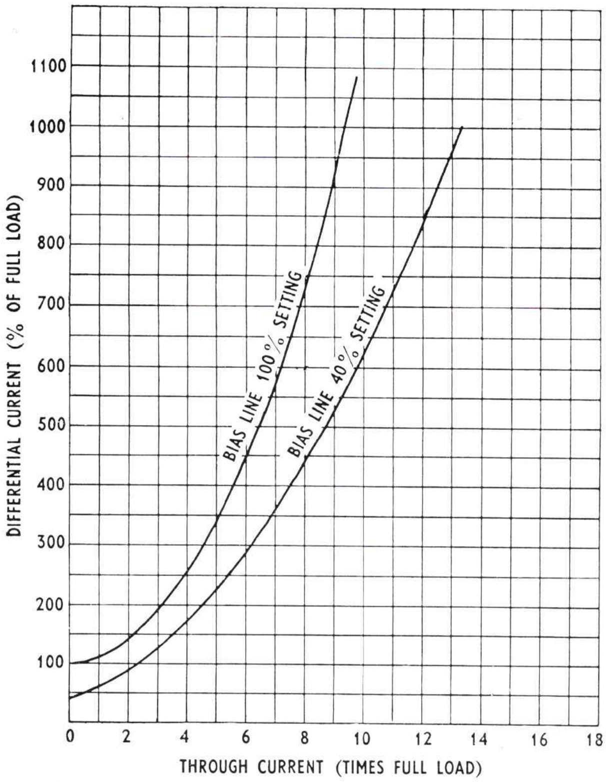
Dimensioned drawings of case outlines, panel cut-outs and mounting details are available on request.



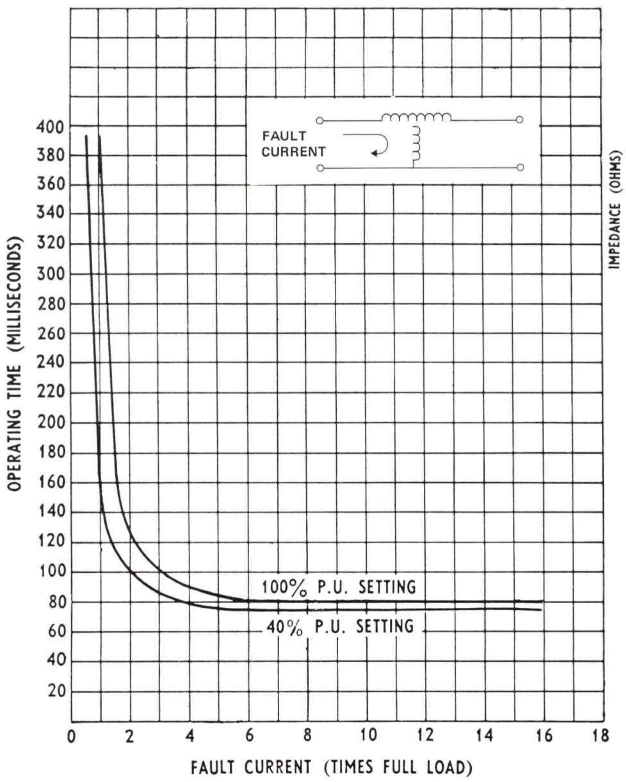
Operating characteristics (20% bias tap)



Operating characteristics (30% bias tap)



Operating characteristics (40% bias tap)

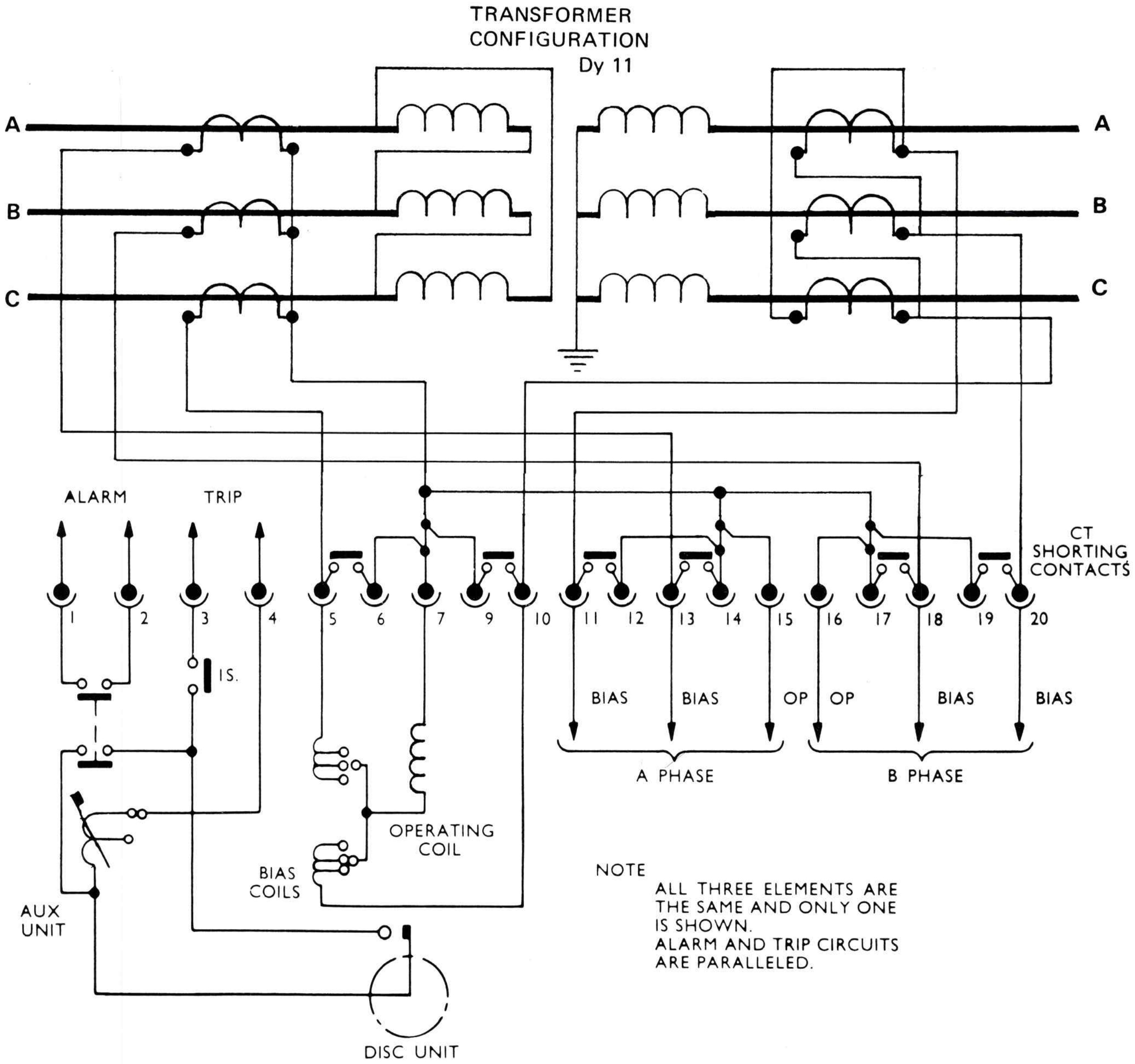


Time current characteristics at 30% bias,
time multiplier setting 1·0

Differential circuit impedance characteristic

INFORMATION REQUIRED WITH ORDER

Relay type
Current transformer secondary rating
Frequency
Trip circuit (series seal in or shunt reinforcing)
Trip circuit current (series seal in)
Trip circuit voltage (shunt reinforcing)
Operation indicator inscription if required
Auxiliary contacts (hand or self reset)
Case finish and mode of mounting



Typical application and internal circuit diagram of type DDT32 relay with series seal in

EARTHING ARRANGEMENTS

Although not included in the diagram, it is assumed that secondary C.T. and/or V.T. circuits will be earthed as necessary in compliance with standard safety requirements and determined by the switchgear contractor or user. If in doubt, please consult GEC Measurements for advice.

Our policy is one of continuous product development and the right is reserved to supply equipment which may vary slightly from that described.

GEC Measurements **The General Electric Company Limited of England**

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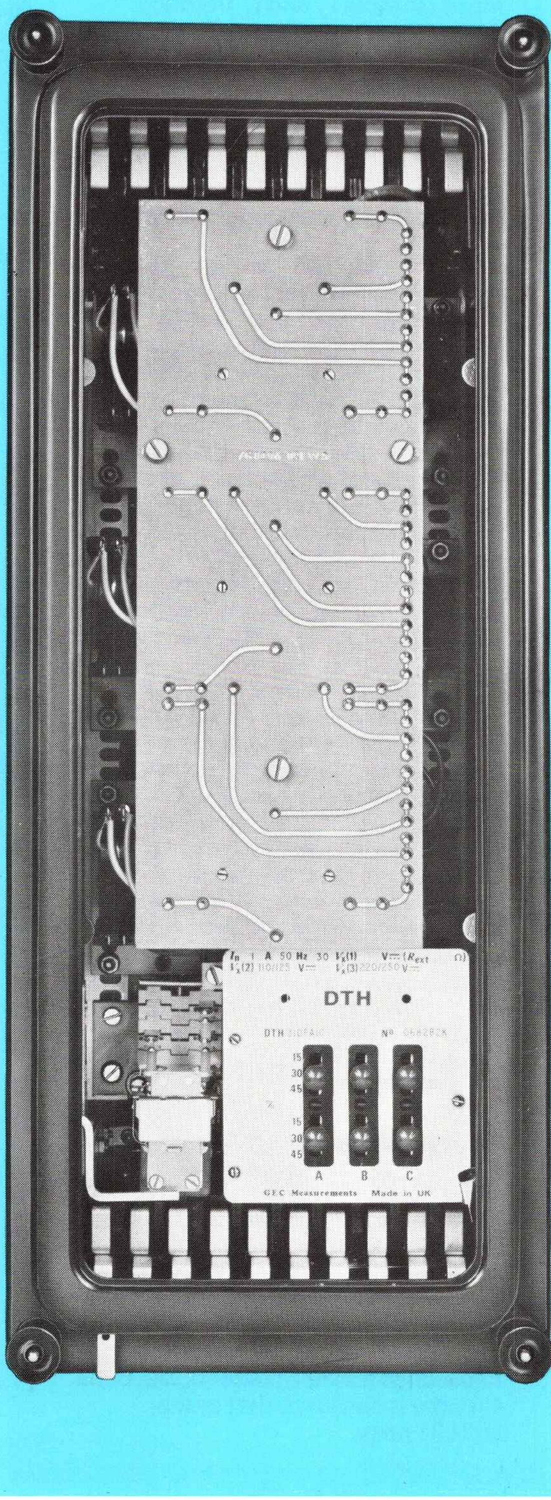
GEC Measurements

High Speed Biased Differential Relays

Types DTH31 and DTH32



Types DTH31 and DTH32

APPLICATION

The DTH 31 and 32 are high speed biased differential relays designed for use with large three phase power transformers to protect against internal faults. Biased to provide stability during heavy through faults, the relays utilise second harmonic restraint to prevent operation by normal magnetising inrush currents produced when the transformer is first energised.

According to type, the relays are for use with two winding transformers, DTH 31, or three winding transformers, DTH 32.

In addition DTH relays can be used effectively for the protection of auto transformers and large generator transformer units where high speed clearance of internal faults is required of the differential protection.

Extremely low burdens are achieved by the use of input devices which convert current to voltage (transactors). Static circuitry is employed throughout, and a single attracted armature unit provides the output. The relays have the advantage of small dimensions and increased reliability over electromechanical equivalents.

Ideally, the CT primary rating should agree with the protected power transformer full load rating, and with the transformation ratio. This ensures the secondary currents flowing in the interconnecting pilots are balanced and matched with the relay rating. Consequently, for a 60 MVA star/delta two winding transformer ratio 132/33 kV the CT ratios are selected as follows:

132 kV winding full load = 263A
33 kV winding full load = 1050A

Therefore transformation ratio = 4

The calculation assumes that interposing CT's are not used.

Using standard primary current ratings, and a differential relay rated at 5A, the ideal CT ratios are:
132 kV side: 300/2.89A, with secondary windings delta-connected,
33 kV side : 1200/5A, with secondary windings star-connected.

When the main CT's on both sides of a star/delta transformer have a 5A or 1A secondary, those on the star side of the power transformer should be star connected. Three separate single phase star/delta interposing CT's should be used with a suitably matched current ratio so that the pilot currents are balanced.

DESCRIPTION AND OPERATION

DTH 31

Figure 1, Block Schematic Diagram shows a typical application with a three-phase, two-winding transformer.

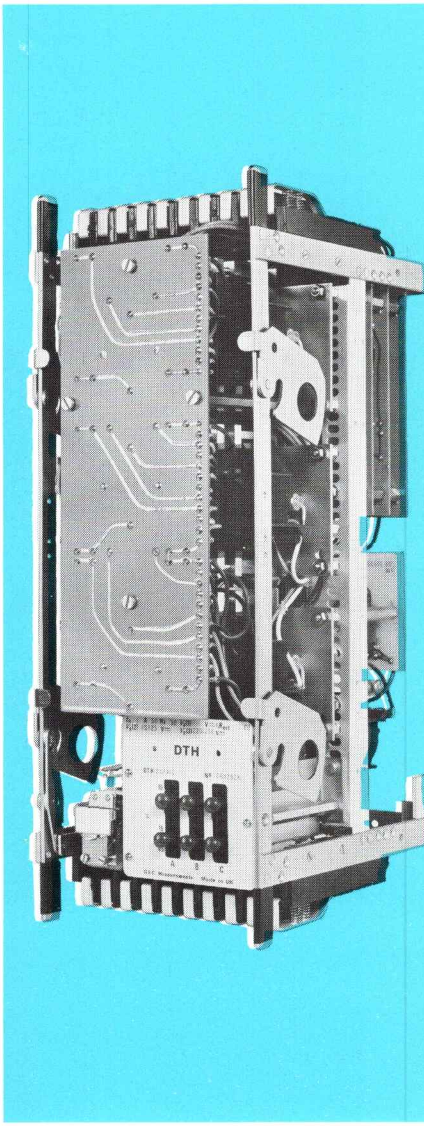
Input currents I_2 and I_1 from the power transformer line CT's are added vectorially in the centre tapped restraint bias transactor T1. Three taps in each half of the transactor primary enable bias settings of 15%, 30% and 45% to be obtained. The output of T1 is full wave rectified and smoothed to obtain the restraint bias voltage level V_B.

The centre tap of T1 is connected to the differential circuit which comprises transactors T2, T3 and current transformer T4 connected in series. A tuned circuit, which includes the secondary of T2, is arranged to resonate at the 2nd harmonic frequency. The output of this circuit is rectified and smoothed to obtain the harmonic restraint voltage level V_H. In addition, outputs of transactor T3 and current transformer T4 are rectified and smoothed to obtain the differential voltage level V_D and the high-set voltage level V_O respectively.

The greater of the two restraining voltage levels V_B and V_H is detected in one comparator and compared in magnitude with the differential operate voltage level V_D in a second comparator stage. When the operate voltage exceeds the restraining voltage by more than a preset amount, the second comparator produces an output to operate the common relay drive circuit. The highset voltage level V_O operates the relay drive circuit if the differential current exceeds ten times the rated current.

DTH 32

Figure 3, Block Schematic Diagram shows an application with a three-phase, three-winding transformer. Because current reversal is possible, the three inputs I_1, I_2 and I_3 cannot be added vectorially. Consequently, inputs to the DTH 32 are fed to separate transactor/rectifier circuits, and the d.c. voltage outputs added to produce a bias voltage V_B. All other circuitry is similar to that of the DTH 31 relay.



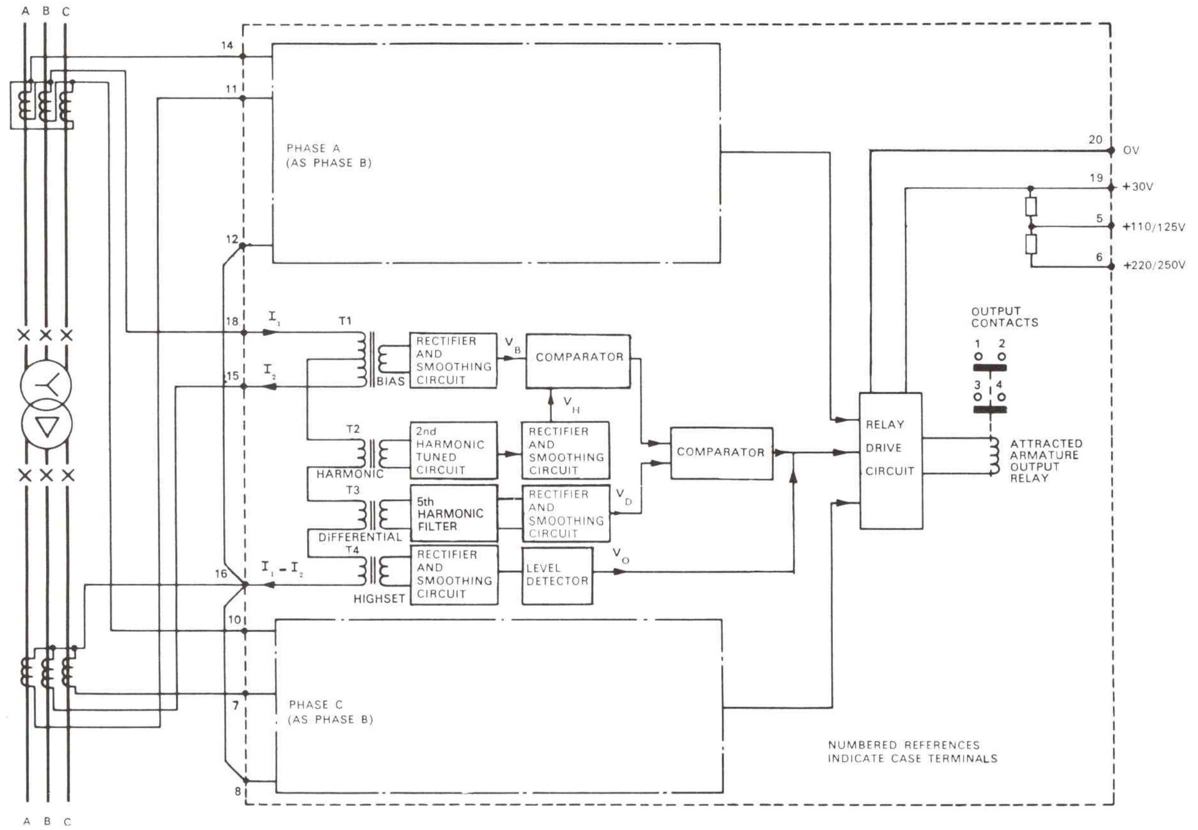


Figure 1 BLOCK SCHEMATIC DIAGRAM TYPE DTH 31 RELAY

TECHNICAL DATA

Current ratings
1A, 2A or 5A each at 50 Hz or 60 Hz.

Current settings
Operate — Differential current is greater than 15% of rated current (fixed).
Bias — 15%, 30% and 45% adjustable by plugboard taps.

Thermal ratings
The relay will withstand twice rated current continuously, 40 times rated current for 3 seconds, 100 times rated current for 1 second.
Limiting value, 170 times rated current. The limiting value must not be exceeded and can be withstood for a maximum period of 0.25 seconds.

Operating times
See Figure 2
For differential currents above twice rated:
Less than 45 ms for auxiliary supplies of 110/125V d.c. and 220/250V d.c.
Less than 60 ms for an auxiliary supply of 30V d.c.

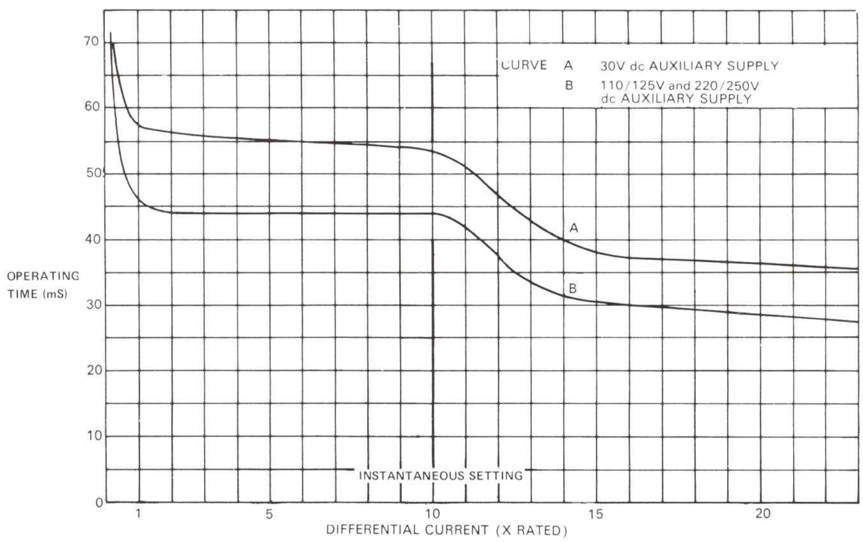


Figure 2 OPERATING TIME CHARACTERISTICS, TYPE DTH RELAY

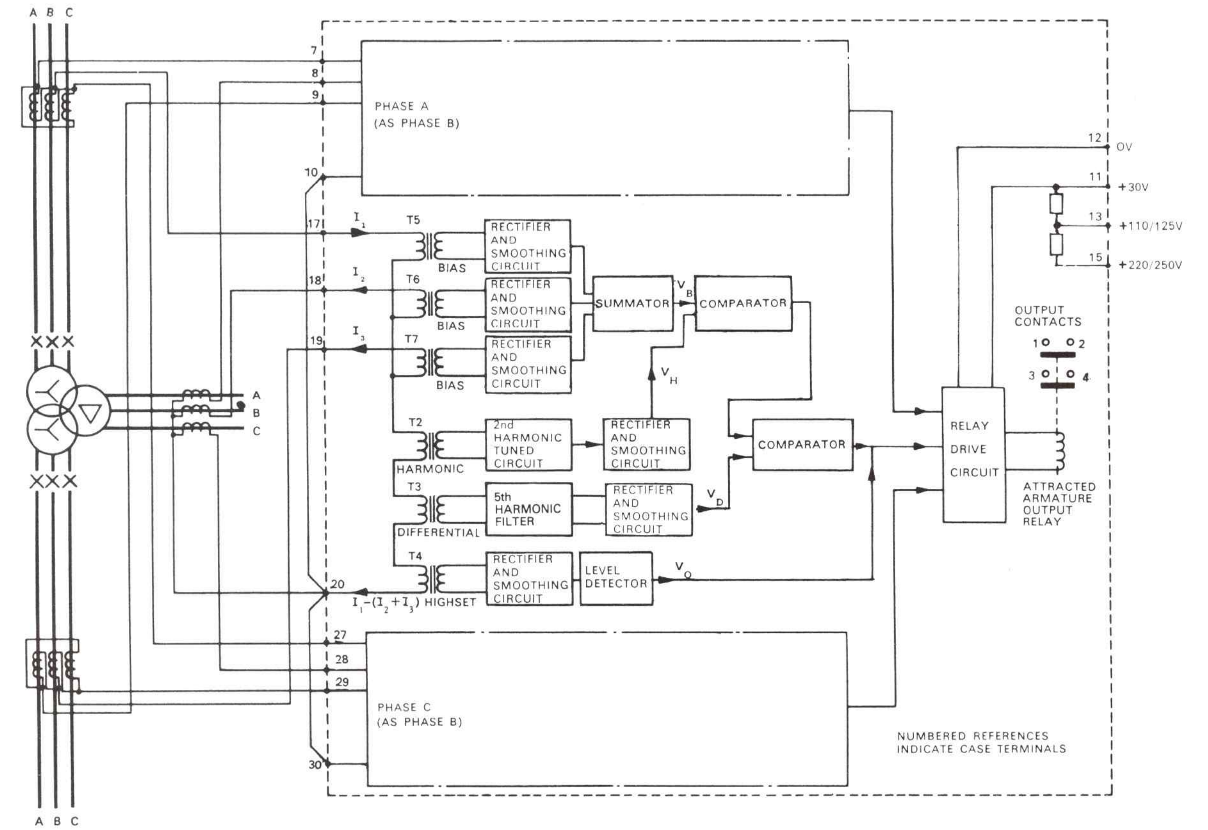


Figure 3 BLOCK SCHEMATIC DIAGRAM DTH 32

Stability
The relay is stable for through faults of up to 15 times full load current.

Harmonic restraint
Operation is prevented when the second harmonic content of the differential current exceeds 20%.

Burdens

DTH 31
1A rated relay—0.33 VA per phase at rated current.
5A rated relay—1.00 VA per phase at rated current.

DTH 32
1A rated relay—0.39 VA per phase at rated current.
5A rated relay—1.2 VA per phase at rated current.

Highset
The highset circuit operates when the differential current exceeds 10 times the rated current.

Contacts
Two pairs of normally open self reset contacts rated to make and carry 7500 VA for 0.5 seconds with maxima of 30A and 660V.

Auxiliary supply
Voltage
30, 110/125, 220/250V d.c.

Current consumption unoperated
15, 34/39, 37/42 mA.

Current consumption operated
39, 44/51, 41/47 mA.

CT requirements
Star connected and delta connected current transformers must have a knee point voltage given by

$$V_K = 40I(R_{CT} + 2R_L)$$

where

V_K = Current transformer knee point voltage (V)

I = relay rated current (A)

R_{CT} = resistance of CT secondary winding (ohms)

R_L = resistance of each pilot from the relay to the CT's (ohms)

CASES

According to type the relays are supplied in two pole double ended, or three pole single ended, drawout cases. See Figures 4 and 5. These are available for flush or projecting mounting and are finished phenolic black as standard.

INFORMATION REQUIRED WITH ORDER

Differential relay type DTH 31 or DTH 32.
Relay current rating: 1A, 2A or 5A
Supply frequency 50 Hz or 60 Hz.
Case finish and mode of mounting.

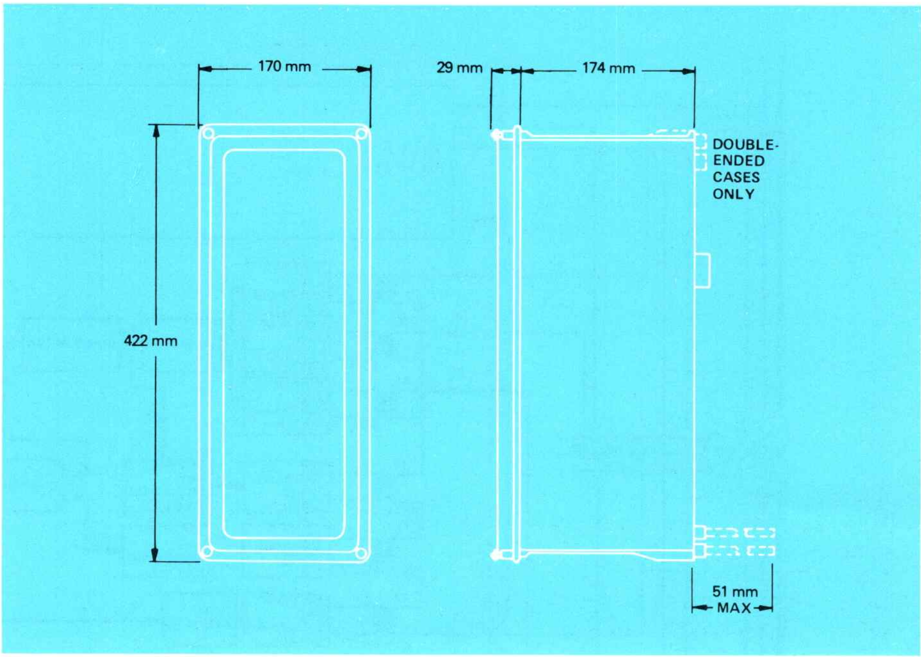


Figure 4 DTH 31 SIZE 2D VERTICAL CASE

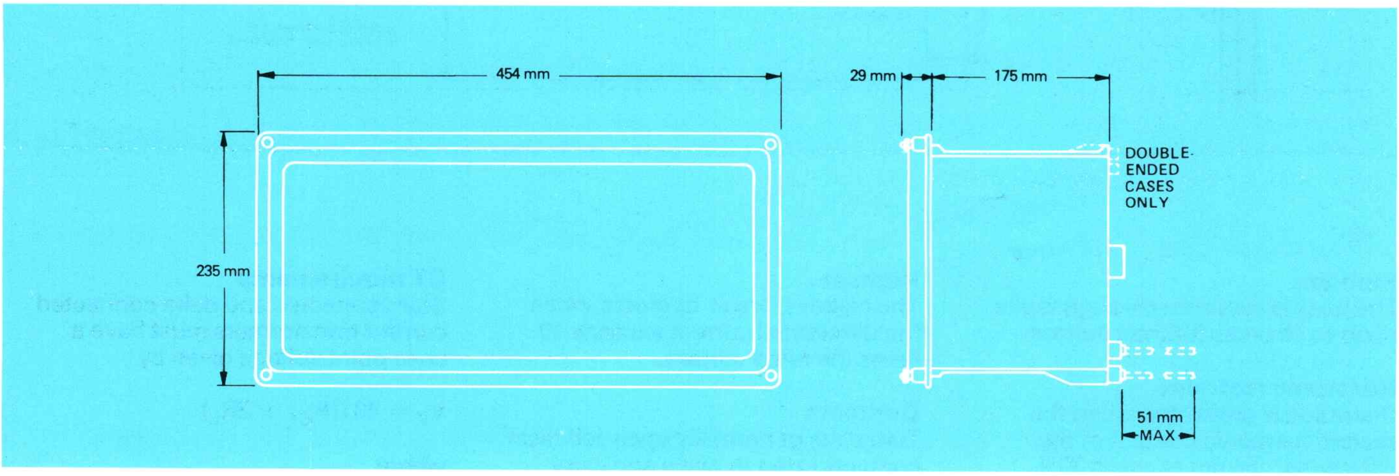


Figure 5 DTH32 SIZE 3D HORIZONTAL CASE

More detailed dimensional drawings and mounting arrangements with panel cut-outs are available on request.

GEC Measurements **The General Electric Company Limited of England**

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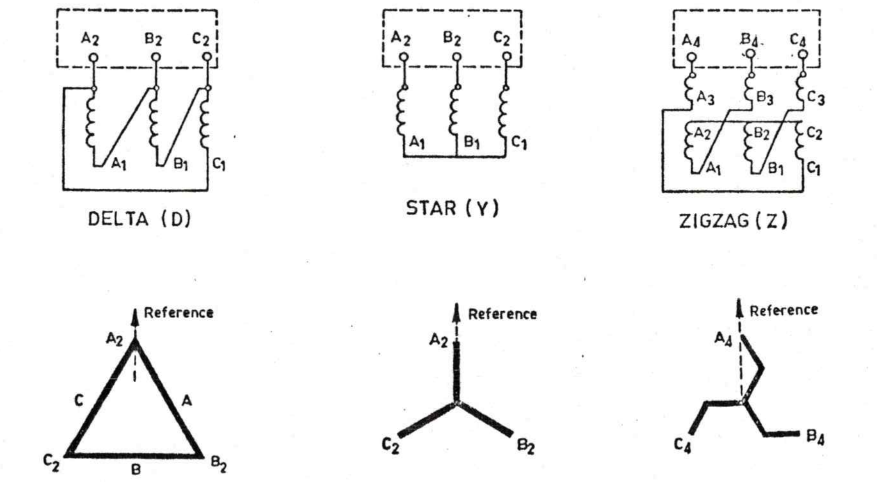


Fig. 6A. ILLUSTRATION OF HV VECTOR REFERENCE (VECTOR OF ORIGIN)

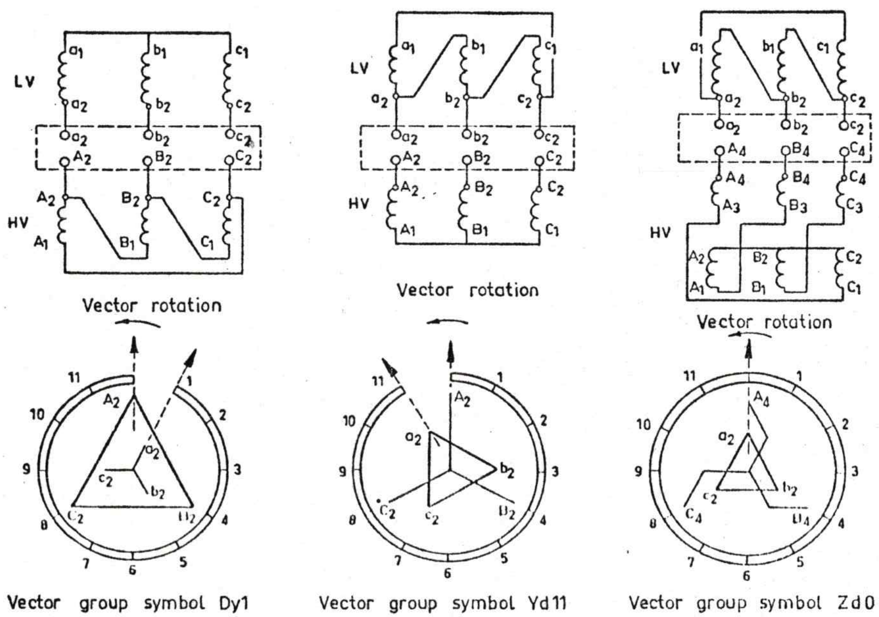
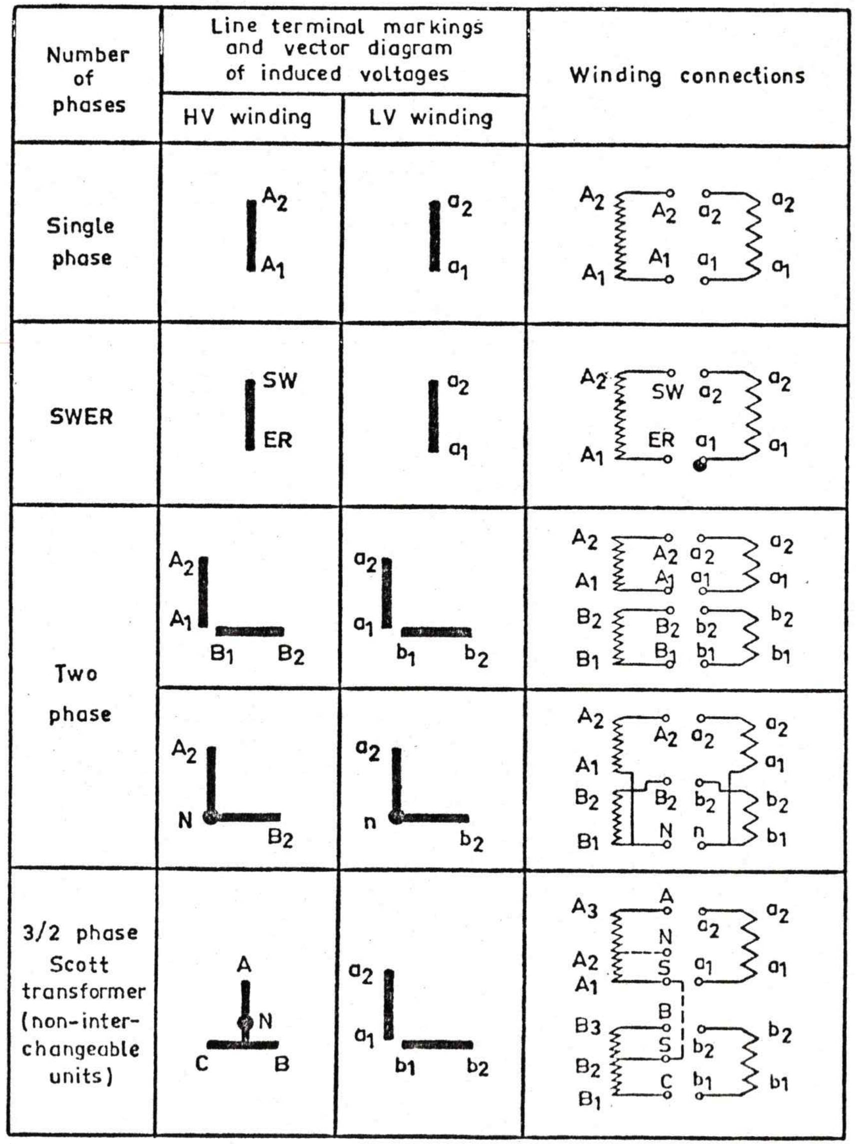
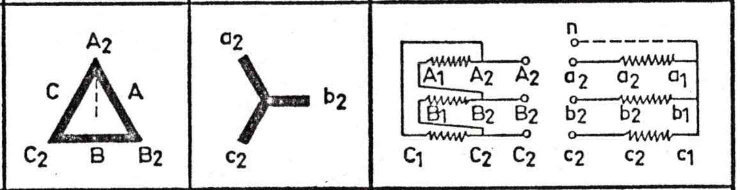
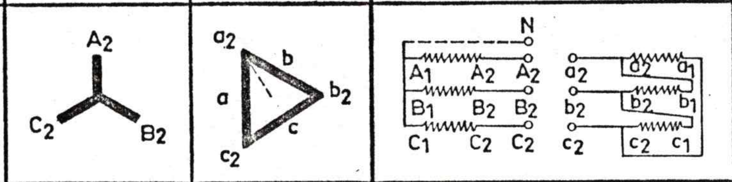
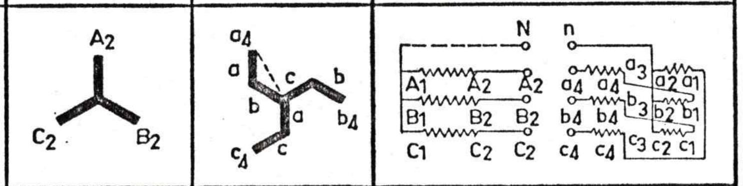
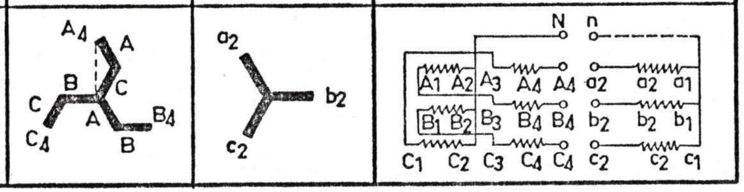


ILLUSTRATION OF USE OF CLOCK-HOUR FIGURE IN VECTOR SYMBOLS



VECTOR DIAGRAMS FOR SINGLE-PHASE, SWER, TWO-PHASE AND 3/2-PHASE TRANSFORMERS

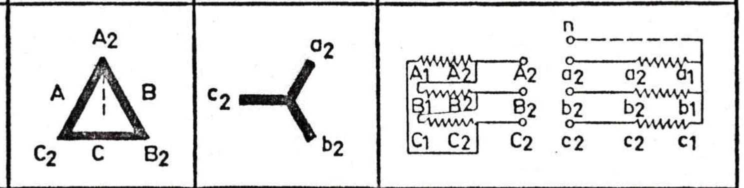
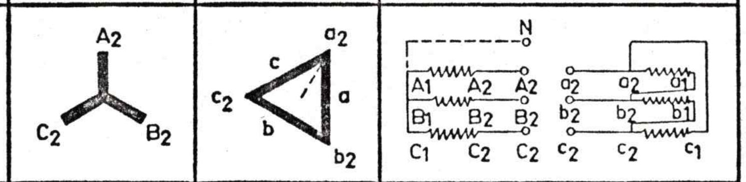
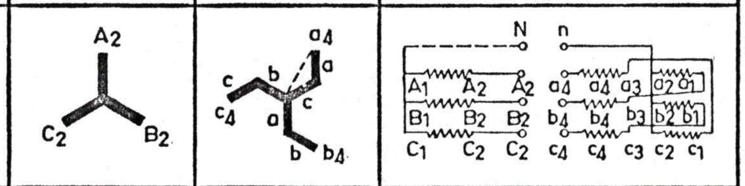
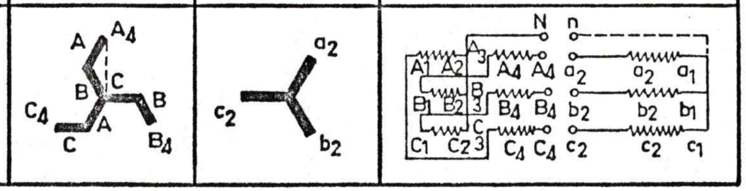
PHASE DISPLACEMENT = PLUS 30°
CLOCK-HOUR FIGURE = 11

Vector symbols	Line terminal markings and vector diagram of induced voltages: HV winding / LV winding — Winding connections
Dy 11	
Yd 11	
Yz 11	
Zy 11	

NOTE: In these diagrams the vector rotation is counter-clockwise

VECTOR DIAGRAMS FOR THREE-PHASE TRANSFORMERS

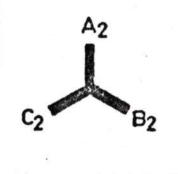
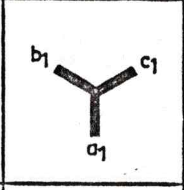
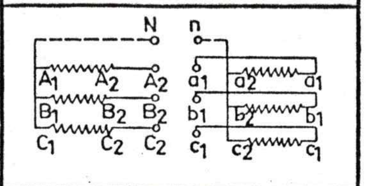
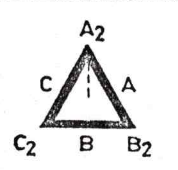
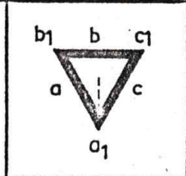
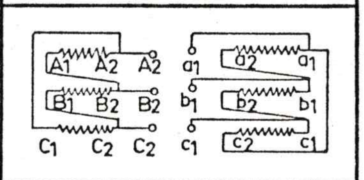
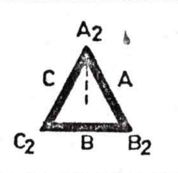
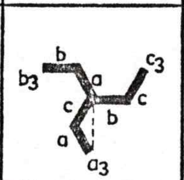
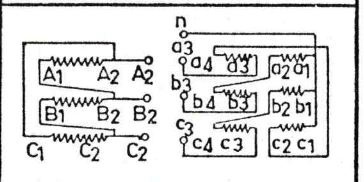
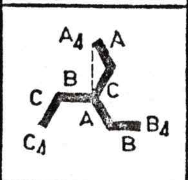
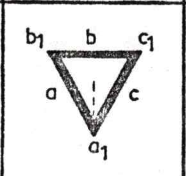
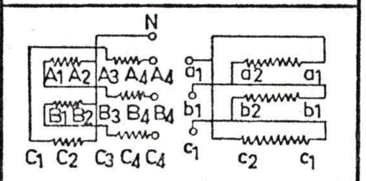
PHASE DISPLACEMENT = MINUS 30°
CLOCK-HOUR FIGURE = 1

Vector symbols	Line terminal markings and vector diagram of induced voltages: HV winding / LV winding — Winding connections
Dy 1	
Yd 1	
Yz 1	
Zy 1	

NOTE: In these diagrams the vector rotation is counter-clockwise

VECTOR DIAGRAMS FOR THREE-PHASE TRANSFORMERS

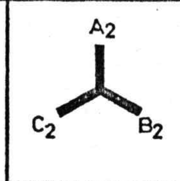
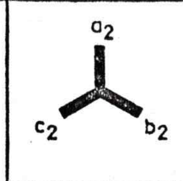
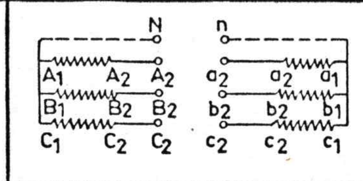
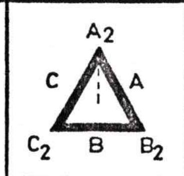
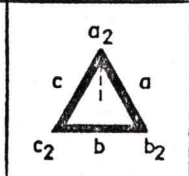
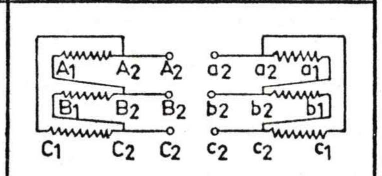
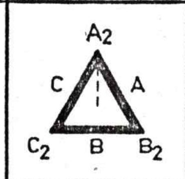
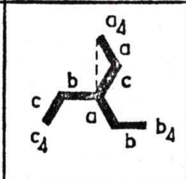
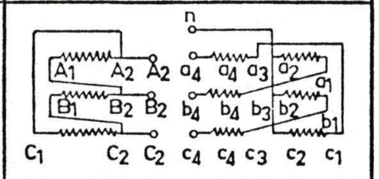
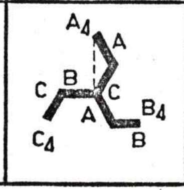
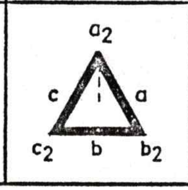
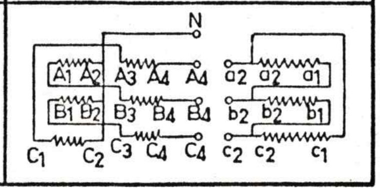
PHASE DISPLACEMENT = 180°
CLOCK-HOUR FIGURE = 6

Vector symbols	Line terminal markings and vector diagram of induced voltages: HV winding	LV winding	Winding connections
Yy 6			
Dd 6			
Dz 6			
Zd 6			

NOTE: In these diagrams the vector rotation is counter-clockwise

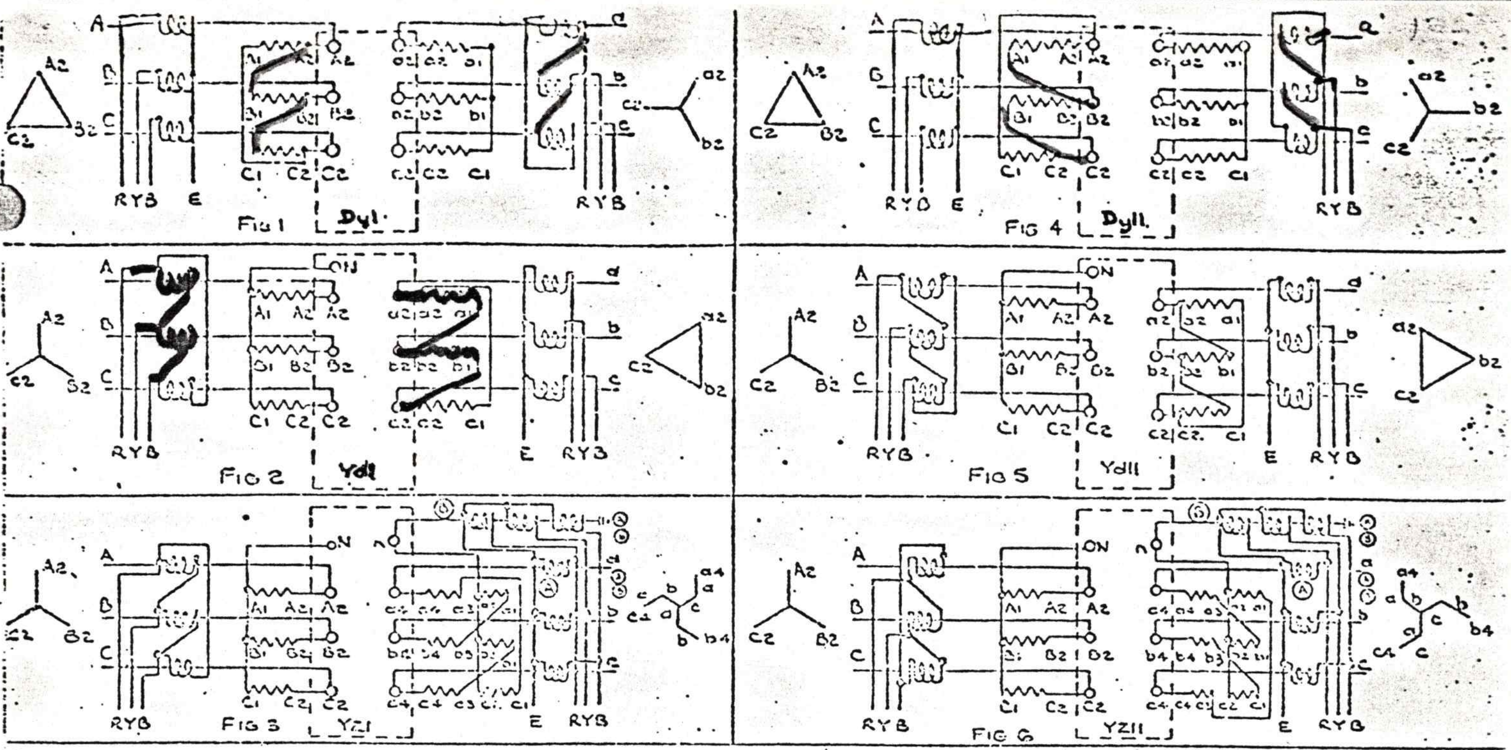
VECTOR DIAGRAMS FOR THREE-PHASE TRANSFORMERS

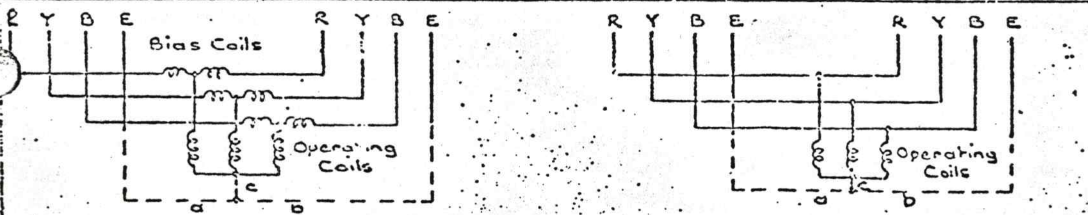
PHASE DISPLACEMENT = 0°
CLOCK-HOUR FIGURE = 0

Vector symbols	Line terminal markings and vector diagram of induced voltages: HV winding	LV winding	Winding connections
Yy 0			
Dd 0			
Dz 0			
Zd 0			

NOTE: In these diagrams the vector rotation is counter clockwise

VECTOR DIAGRAMS FOR THREE-PHASE TRANSFORMERS





Connections for Biased Relays eg. DG2, DT2, PBD2, PBG2

Connections for Unbiased Relays eg. PBO, FRM

NOTE

Omit Connection a or b when corresponding CTs are delta connected. When both sets are delta connected omit a,b & c.

NOT TRANSLAY

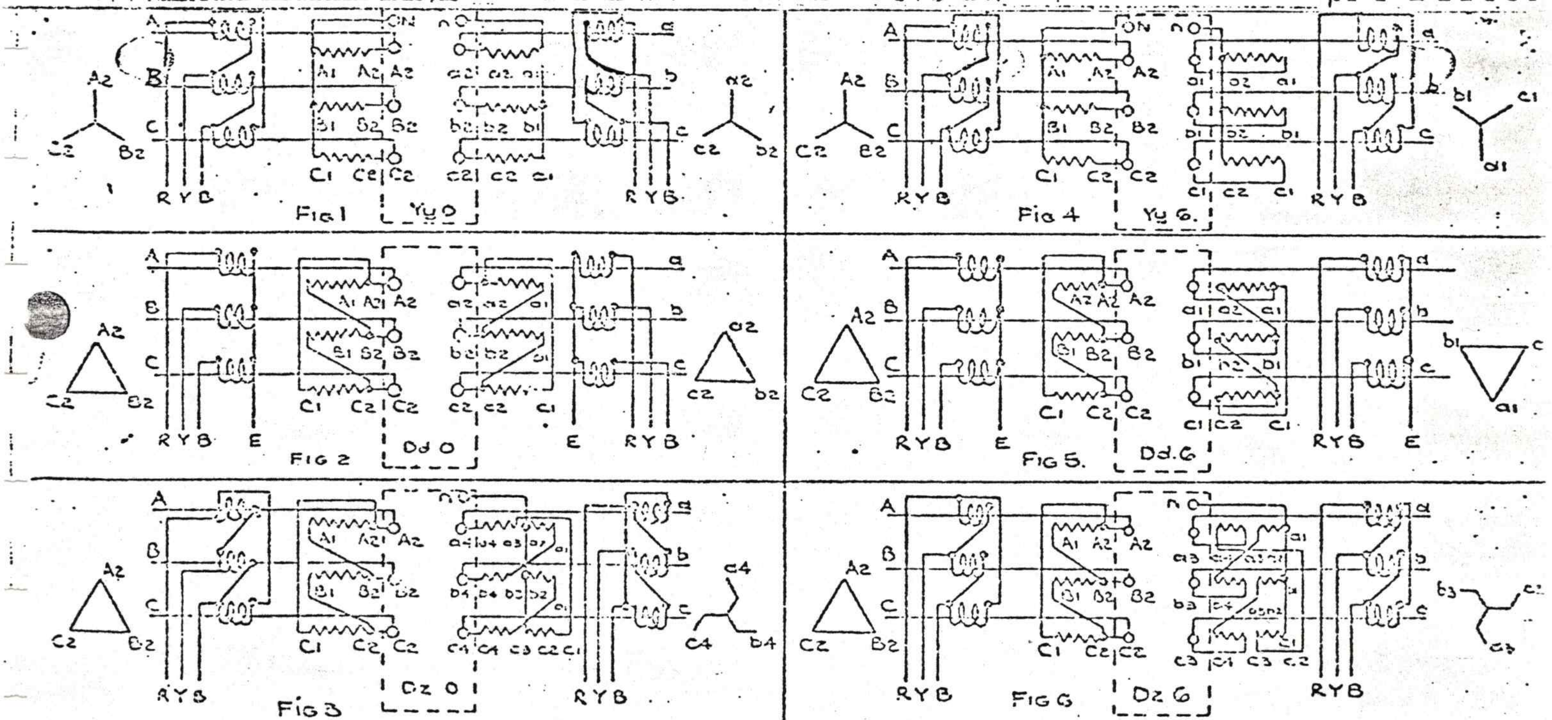
Vector Group Nos BSS 171 (1959)

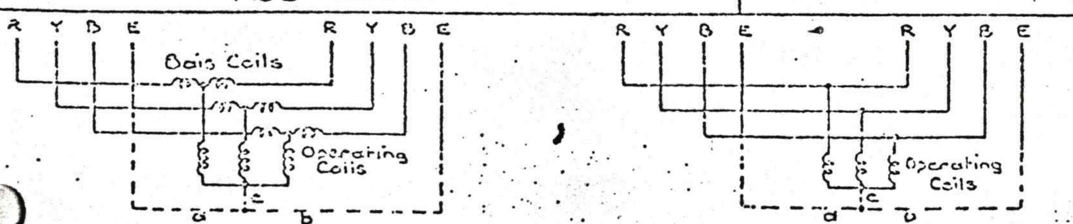
CT CONNECTIONS FOR TRANSFORMER PROTN.

CIRCULATING CURRENT SYSTEM

D.5116645

Dwg. Iss. by P.B.S.M. Dep





Connections for Biased Relays eg. DG2, DT2, PBD2, PBG2.

Connections for Unbiased Relays eg. PBO, FRM.

NOTE

Omit Connection a or b when corresponding CT's are delta connected. When both sets ar delta connected omit a, b & c.

NOT TRANSLAY

C.T. CONNECTIONS FOR TRANSFORMER PROTN.

CIRCULATING CURRENT SYSTEM

Group Nos BSS 171 (1959).

D.5116646

Dwg. Issued by. P.P.S.M.C.

Meter File, SwGr. D.O.

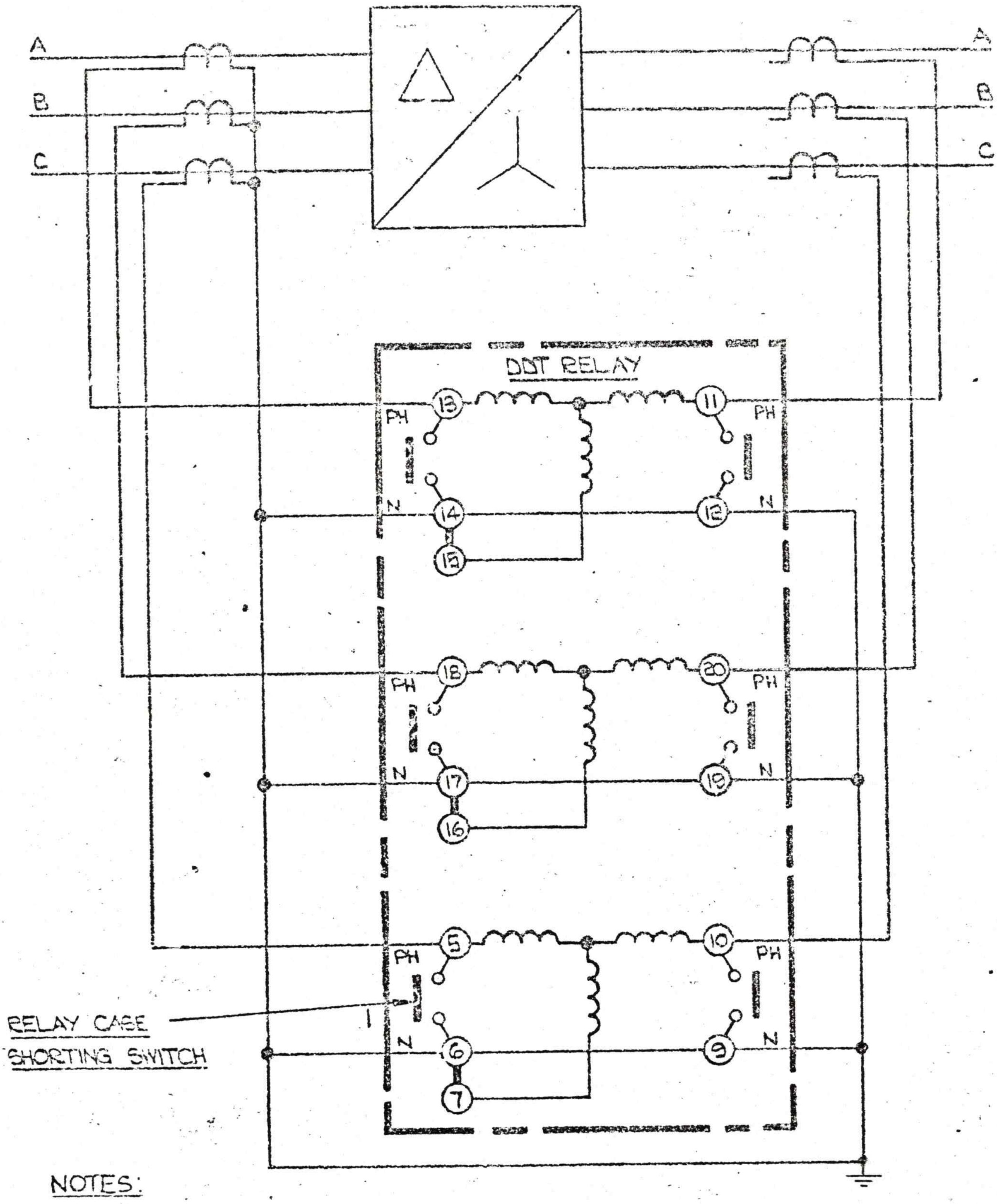
GEC Measurements | THE GENERAL ELECTRIC COMPANY LIMITED, ST. LEONARDS WORKS, STAFFORD | DRG. No. 595Z0119

TITLE: CONNECTIONS FOR TRIPLE DDT RELAY.

DEPT.

SCALE

D/No. CUSTR.



NOTES:

1. TO ENSURE THAT CURRENT TRANSFORMERS ARE SHORT CIRCUITED AND EARTHED WHEN THE RELAY CRADLE IS REMOVED IT IS ESSENTIAL TO COMMON TOGETHER TERMINALS 14, 17 AND 6 AND ALSO TERMINALS 12, 19 AND 9 AS SHOWN IN THE DIAGRAM.
2. FOR DETAILS OF CURRENT TRANSFORMER CONNECTIONS REFER TO 595F0120

THIRD ANGLE PROJECTION

DIMENSIONS ARE IN mm.

DO NOT SCALE

DRAWN BDM	A ORIGINAL ISSUE	B	REDRAWN CT CONNS CORRTD	C M.T.	NOTES 1 ADDED
CHECKED	DATE 18 1 72	BDM 24 5 72		20. 8. 75	

E. D. W. Ltd 770

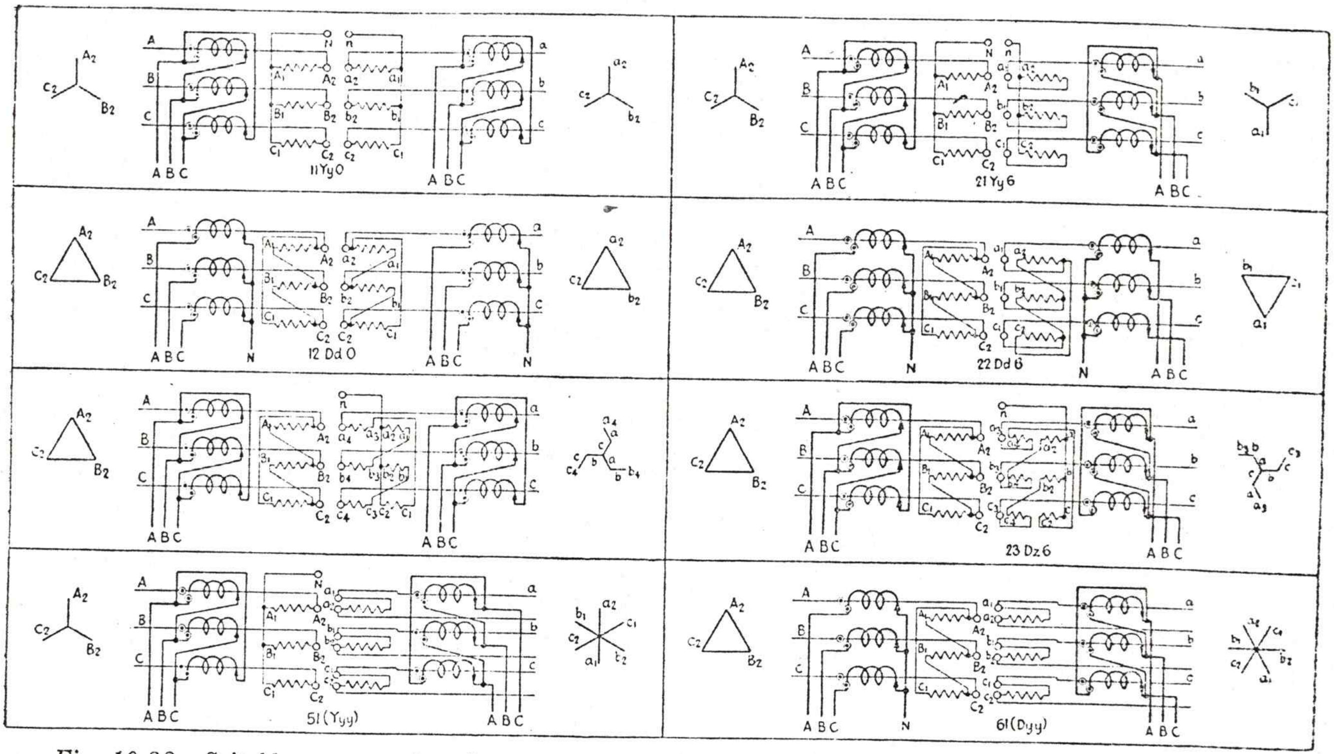


Fig. 10.23. Suitable c.t. connexions for overall balanced-voltage protection of transformers using Translay relays

C.T. polarities are indicated thus: —⊕(coil symbol)— Relays are connected as shown in Fig. 10.24. Star-connected c.t.s have a secondary rating of I, which may be 5, 1 or 0·5 A. Delta-connected c.t.s have a secondary rating of $I\sqrt{3}$. The relay rated current is I.

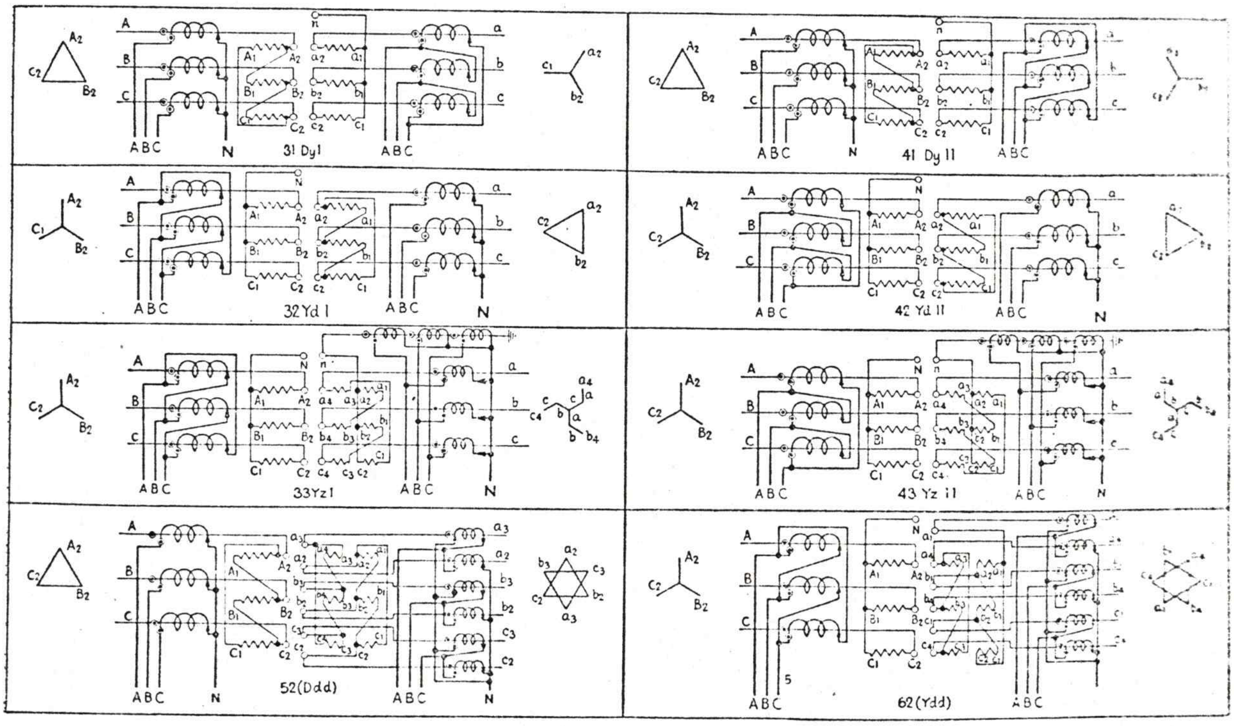


Fig. 10.23. contd.

6. Directional Overcurrent and Earth Fault Relays Type CDD21

GEC Measurements

DIRECTIONAL INVERSE TIME OVERCURRENT OR EARTH FAULT RELAY

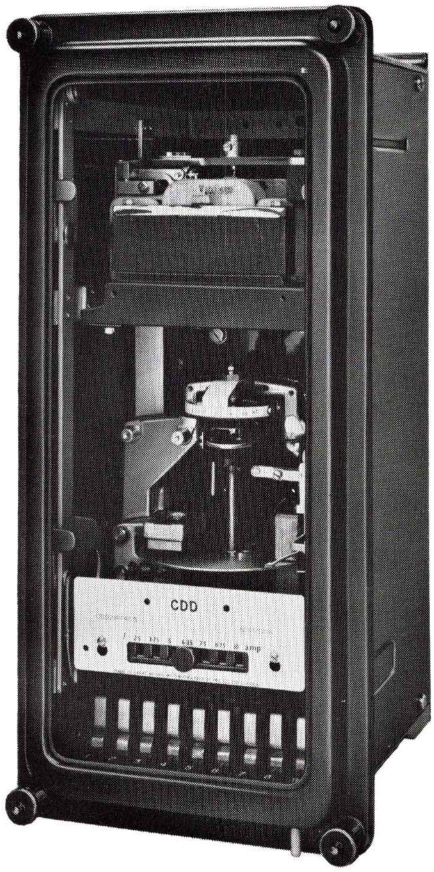
Type CDD

The type CDD21, 23 and 24 relays are directional overcurrent protection units with inverse, very inverse and extremely inverse time/current characteristics. The relays are respectively identical to types CDG11, 13 and 14 described in publications R5090, R5092 and R5093 except for the addition of a high speed directional unit. CDD relays are available only as single pole units.

An auxiliary seal in unit and a high set instantaneous overcurrent unit type CAG can be accommodated in the same case.

The relays are used for either phase or earth fault overcurrent protection when directional characteristics are required in addition to inverse time/current characteristics and are suitable for protection of ring mains, parallel transformers, transformer feeders and parallel feeders.

The directional unit is a high speed four pole induction cup movement with current coils (connected in series with the operating coil of the inverse time relay), voltage or current polarising coils and a pair of contacts which are connected across the shading winding of the inverse time unit. The inverse time unit will not operate until there is current flow in the correct direction for tripping when the directional unit contacts are closed to short circuit the shading winding.



MAXIMUM TORQUE PHASE ANGLES

Phase Fault

30° or 45° current leading. The relays are normally intended for a 90° system connection and this will result in system characteristic angles of 60° and 45° respectively where the line current lags the phase to neutral voltage.

Earth Fault

14° current lag for resistance earthed system or, 45° or 60° current lag for solidly earthed system using a 3 phase V.T. tertiary winding for supply to polarising coil.

OPERATING TIME

The directional unit operates in less than 10 milliseconds which is small compared with the overall operating time of a CDD relay.

COIL RATINGS

Current Coil

0·5, 1, 2 or 5 amps a.c. (C.T. secondary)
The rating is selected as close as possible to the centre tap current setting of the induction disc unit.

The maximum continuous current in either direction for the relay is limited by the coil of the induction disc unit given in the following table.

Operating Coil Tap	1	2	3	4	5	6	7
Max. continuous current (times current setting)	4·5	3·7	3·2	2·7	2·6	2·4	2·2

Voltage polarising coil

63·5 or 110 V a.c. (continuous rating 200 V a.c.)

Current polarising coil

Where there is a power transformer with an earthed neutral the voltage polarising coil can be replaced by a current polarising coil (available with ratings of 0·5, 1, 2 or 5 amps a.c.) which is fed by a current transformer in the neutral line.

BURDENS

Current coils

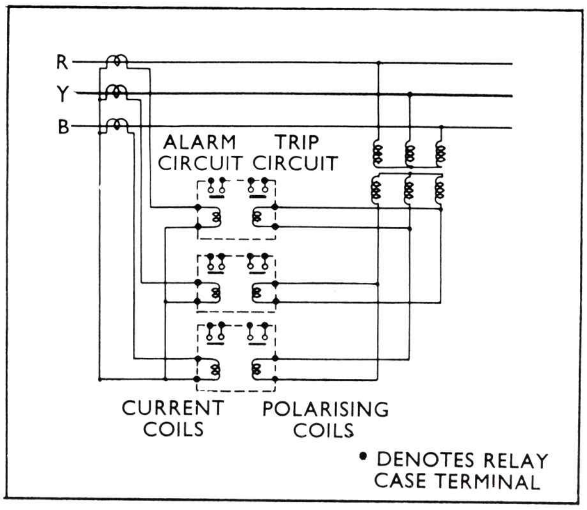
Relay	CDD21	CDD23	CDD24
At minimum setting	2·25 VA	1·0 VA	0·6 VA
At maximum setting	7·5 VA	6·0 VA	6·0 VA

Voltage polarising coils

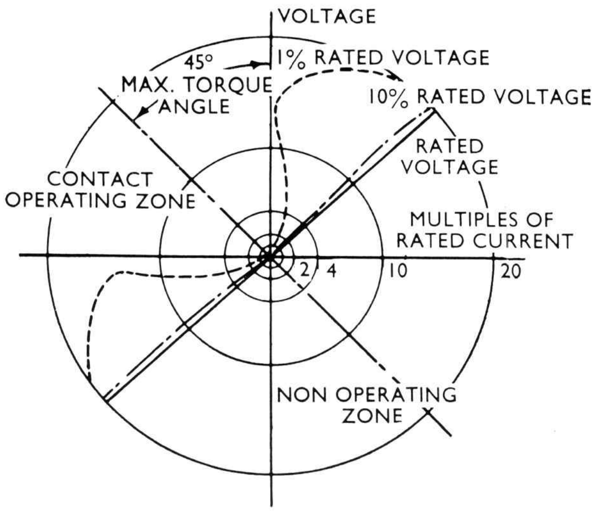
9 VA or 4·5 watts (110 V a.c. coil)
3 VA or 1·5 watts (63·5 V a.c. coil)

Current polarising coils

1·0 VA at rated current



Three CDD relays connected for phase fault protection (voltage polarised)

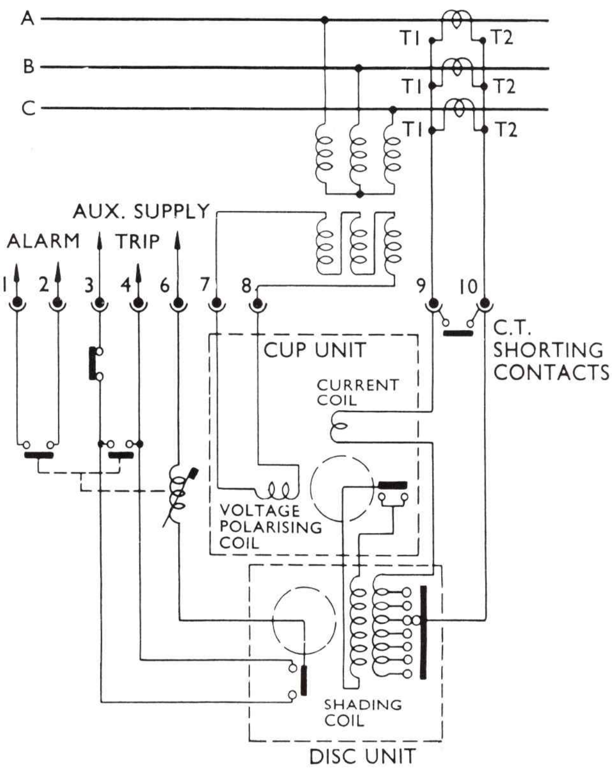


Characteristic of directional unit with 45° maximum torque angle

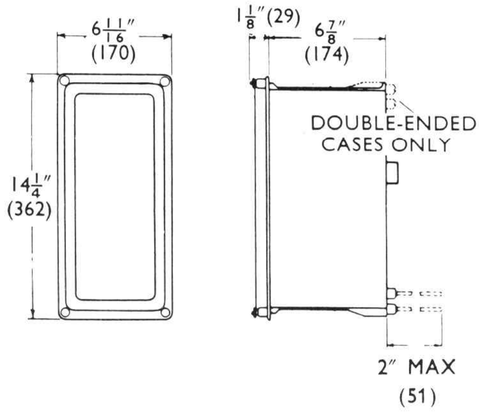
DIRECTIONAL DISCRIMINATION

Down to approximately 1% of normal voltage with from 1 to 15 times rated current

Down to approximately 3% of normal voltage with from 0·4 to 40 times rated current



Internal and external diagram of CDD relay for earth fault protection (voltage polarised)



Drawout case outline — size $1\frac{1}{2}$

EARTHING ARRANGEMENTS

Although not included in the diagram, it is assumed that secondary C.T. and/or V.T. circuits will be earthed as necessary in compliance with standard safety requirements and determined by the switchgear contractor or user. If in doubt, please consult GEC Measurements for advice.

CASES

The relays are supplied in a size 1½ drawout case available for flush or projecting mounting, finished phenolic black.

Relays for use in exceptionally severe environments can be finished to BS.2011:20/50/56 at extra cost; standard relays are finished to BS.2011:20/40/4 and are satisfactory for normal tropical use.

INFORMATION REQUIRED WITH ORDER

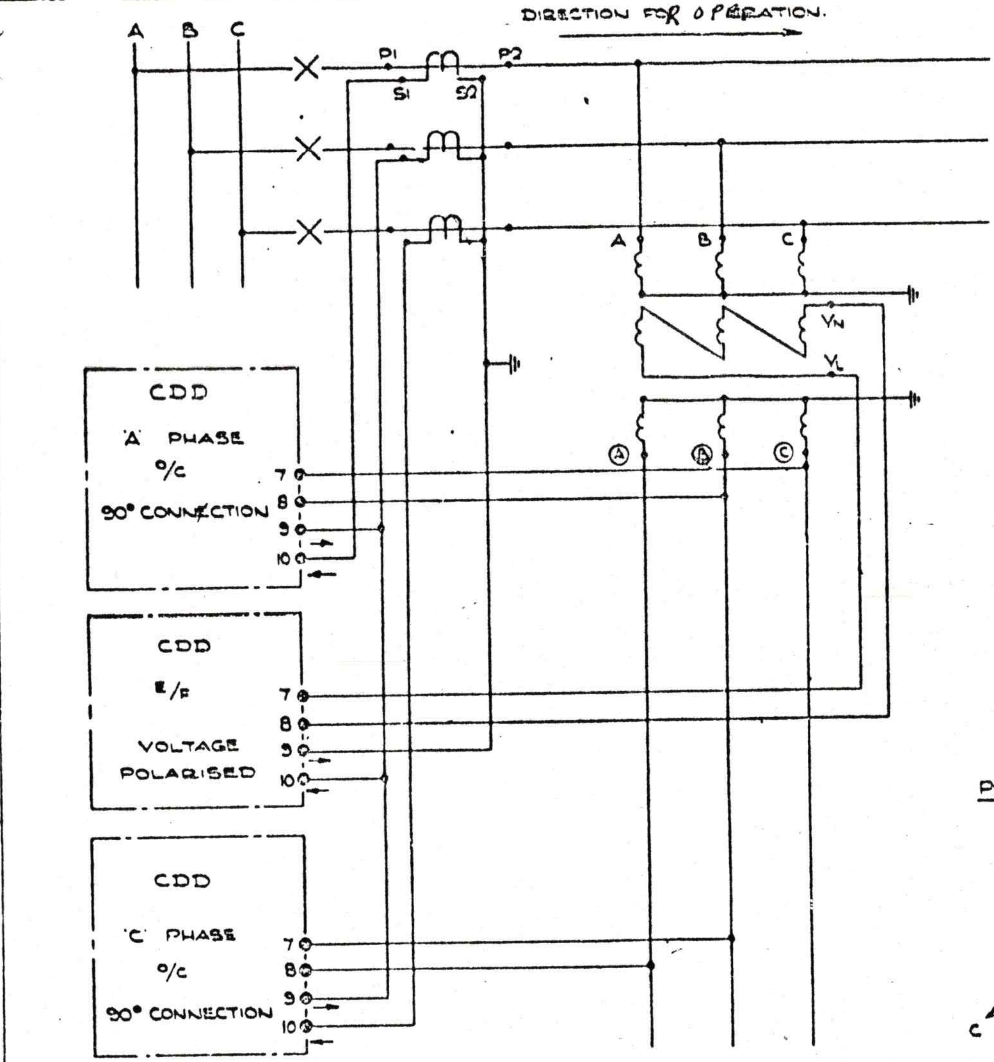
Relay type
IDMT relay data (see R5090)
Details of instantaneous high set unit, if required
Maximum torque angle
Polarising coil rating (voltage or current)
Current coil rating
Case finish and mode of mounting

GEC Measurements The General Electric Company Limited of England

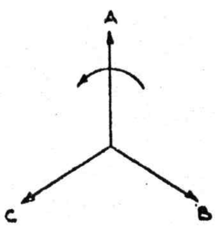
St. Leonards Works Stafford ST17 4LX England
Telephone: 0785 3251 Telex: 36240 Cables: Measurements Stafford Telex

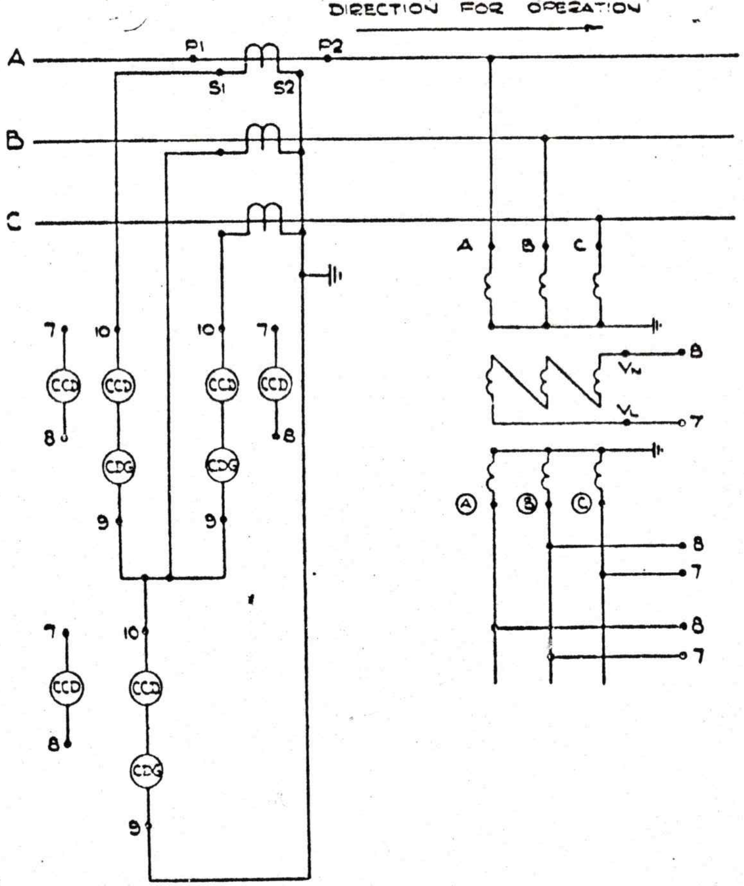
Publication R-5089C

048050GSP *Printed in England*



PHASE ROTATION





NOTE :- FOR RELAY OPERATION TERMINALS 7 AND 9 MUST HAVE THE SAME RELATIVE POLARITIES

CURRENT COIL CONNECTIONS FOR OPERATION.
CURRENT FLOW INTO TERMINAL 10 OUT OF TERMINAL 9.

VOLTAGE COIL (O/C ELEMENTS)
WITH REFERENCE TO THE CURRENT VECTOR TERMINAL 7 MUST BE CONNECTED TO THE LEADING VOLTAGE PHASE AND TERMINAL 8 TO THE LAGGING VOLTAGE PHASE

VOLTAGE COIL (E/F ELEMENT)
TERMINAL 8 MUST BE CONNECTED TO TERMINAL VN ON V.T. BROKEN DELTA.
TERMINAL 7 MUST BE CONNECTED TO TERMINAL VL ON V.T. BROKEN DELTA.

GEC Measurements — ST. LEONARDS WORKS STAFFORD

TITLE: CONNECTIONS FOR CDD DIRECTIONAL OVERCURRENT AND EARTH FAULT RELAYS.

SCALE	
DRG. No.	595S0104
DRAWN	M.C.
TRACED	P.W.
CHECKED	
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A	B	C	D	E
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WHEN QUOTING THE DRAWING NUMBER PLEASE STATE THE LATEST LETTER OF ISSUE

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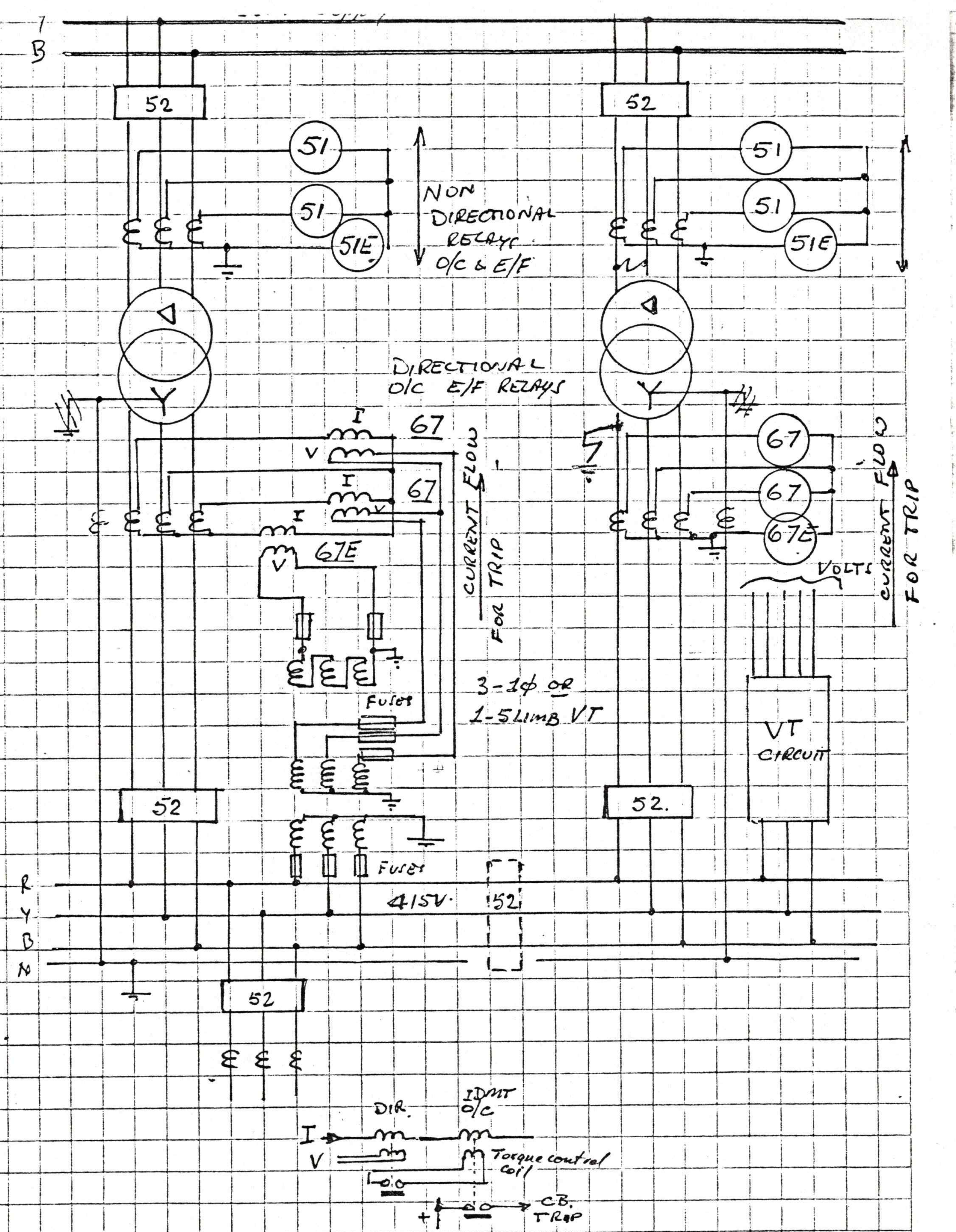
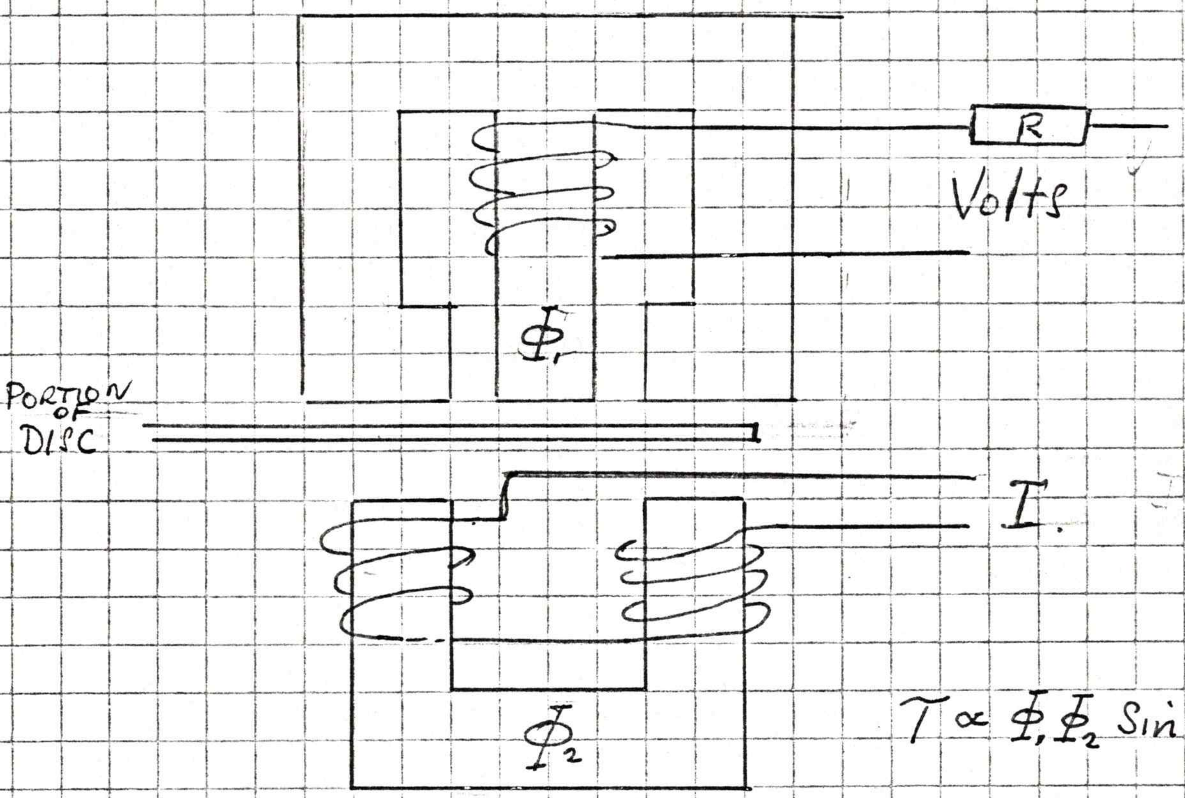


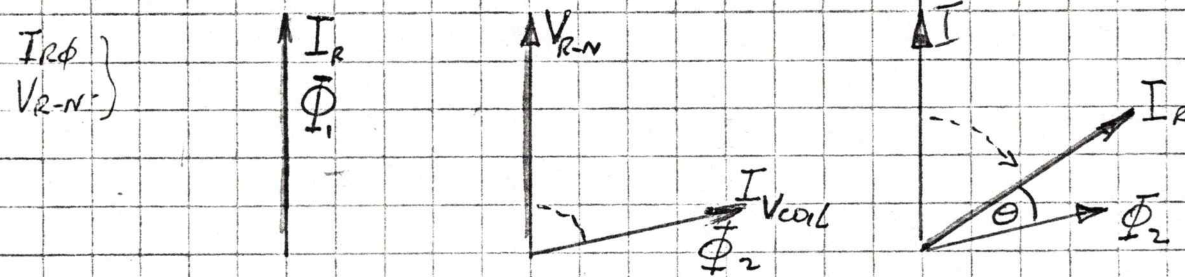
DIRECTIONAL CONTROL OF INV. TIME RELAY

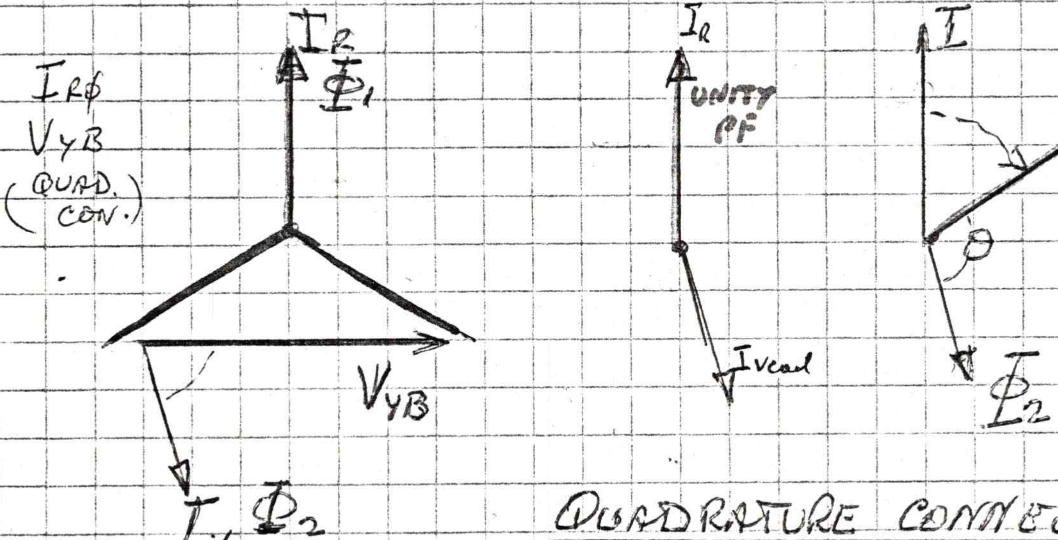
correct direction *must* be established before Inv. time relay starts timing out.

Very early relays had contacts in series allowing inv. time relay to time out — for currents in wrong direction (for downstream faults) which when cleared caused the directional unit to "bounce" off the back stop & touch its contacts hence causing a CB trip unnecessarily.

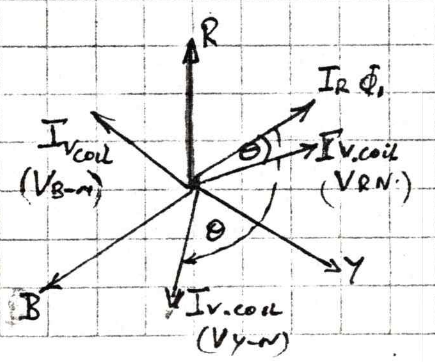


$T \propto \Phi_1 \Phi_2 \sin\theta$





QUADRATURE CONNECTION.



Adjusted to give Max Torque at 45° current Lag.

7. Reverse Power Relays
Type WDG11, WCD11

GEC Measurements

DIRECTIONAL INVERSE TIME OVERCURRENT OR EARTH FAULT RELAY

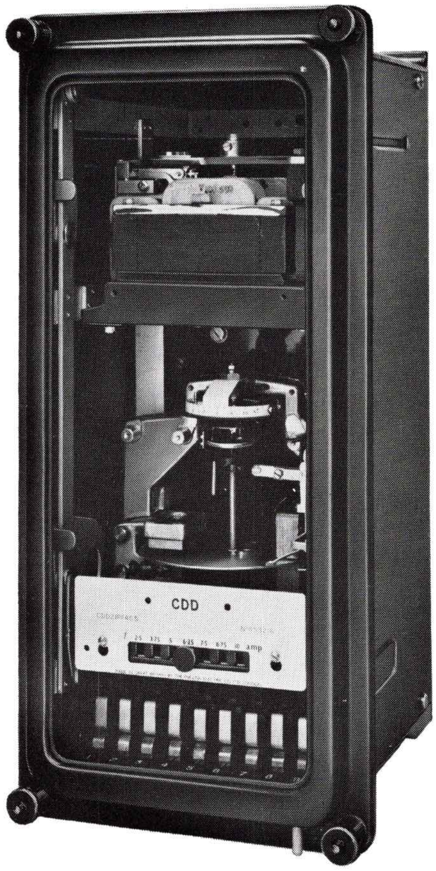
Type CDD

The type CDD21, 23 and 24 relays are directional overcurrent protection units with inverse, very inverse and extremely inverse time/current characteristics. The relays are respectively identical to types CDG11, 13 and 14 described in publications R5090, R5092 and R5093 except for the addition of a high speed directional unit. CDD relays are available only as single pole units.

An auxiliary seal in unit and a high set instantaneous overcurrent unit type CAG can be accommodated in the same case.

The relays are used for either phase or earth fault overcurrent protection when directional characteristics are required in addition to inverse time/current characteristics and are suitable for protection of ring mains, parallel transformers, transformer feeders and parallel feeders.

The directional unit is a high speed four pole induction cup movement with current coils (connected in series with the operating coil of the inverse time relay), voltage or current polarising coils and a pair of contacts which are connected across the shading winding of the inverse time unit. The inverse time unit will not operate until there is current flow in the correct direction for tripping when the directional unit contacts are closed to short circuit the shading winding.



MAXIMUM TORQUE PHASE ANGLES

Phase Fault

30° or 45° current leading. The relays are normally intended for a 90° system connection and this will result in system characteristic angles of 60° and 45° respectively where the line current lags the phase to neutral voltage.

Earth Fault

14° current lag for resistance earthed system or, 45° or 60° current lag for solidly earthed system using a 3 phase V.T. tertiary winding for supply to polarising coil.

OPERATING TIME

The directional unit operates in less than 10 milliseconds which is small compared with the overall operating time of a CDD relay.

COIL RATINGS

Current Coil

0·5, 1, 2 or 5 amps a.c. (C.T. secondary)
The rating is selected as close as possible to the centre tap current setting of the induction disc unit.

The maximum continuous current in either direction for the relay is limited by the coil of the induction disc unit given in the following table.

Operating Coil Tap	1	2	3	4	5	6	7
Max. continuous current (times current setting)	4·5	3·7	3·2	2·7	2·6	2·4	2·2

Voltage polarising coil

63·5 or 110 V a.c. (continuous rating 200 V a.c.)

Current polarising coil

Where there is a power transformer with an earthed neutral the voltage polarising coil can be replaced by a current polarising coil (available with ratings of 0·5, 1, 2 or 5 amps a.c.) which is fed by a current transformer in the neutral line.

BURDENS

Current coils

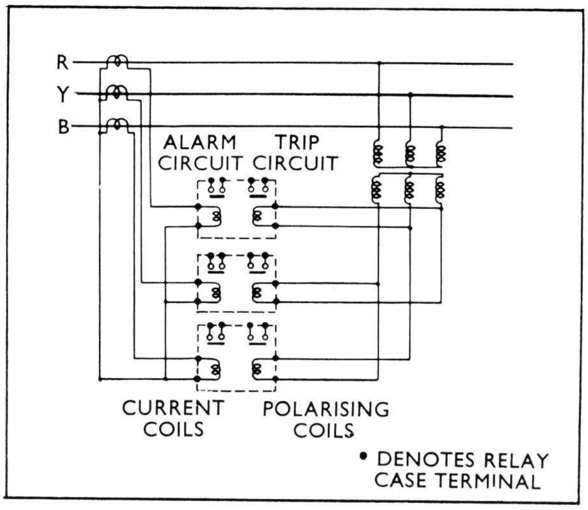
Relay	CDD21	CDD23	CDD24
At minimum setting	2·25 VA	1·0 VA	0·6 VA
At maximum setting	7·5 VA	6·0 VA	6·0 VA

Voltage polarising coils

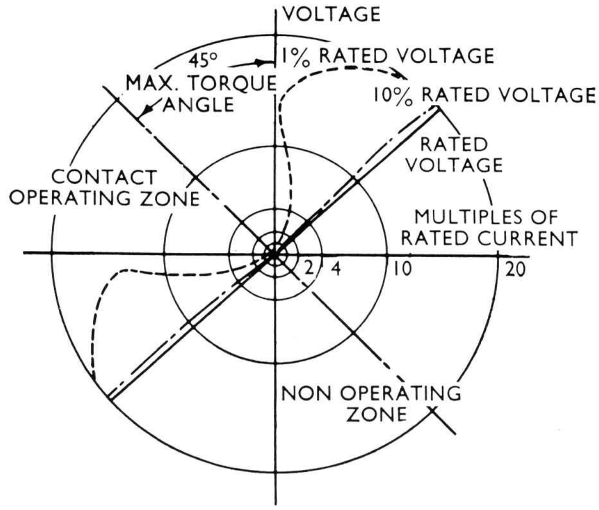
9 VA or 4·5 watts (110 V a.c. coil)
3 VA or 1·5 watts (63·5 V a.c. coil)

Current polarising coils

1·0 VA at rated current



Three CDD relays connected for phase fault protection (voltage polarised)

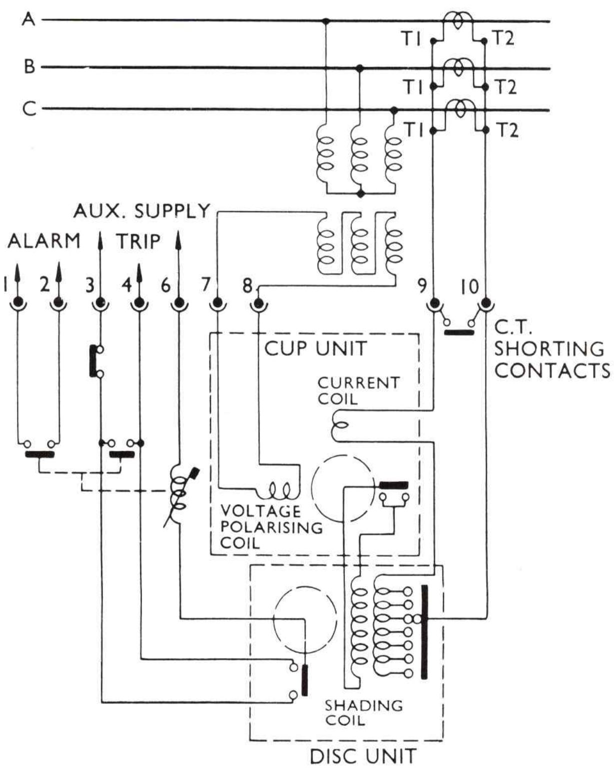


Characteristic of directional unit with 45° maximum torque angle

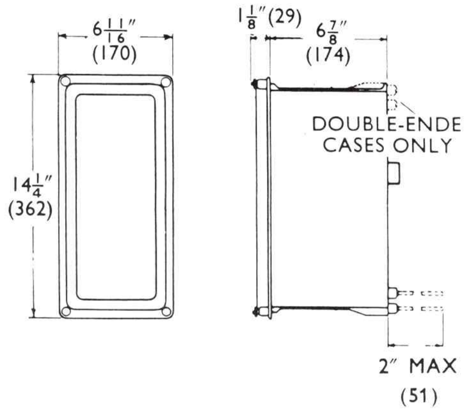
DIRECTIONAL DISCRIMINATION

Down to approximately 1% of normal voltage with from 1 to 15 times rated current

Down to approximately 3% of normal voltage with from 0·4 to 40 times rated current



Internal and external diagram of CDD relay for earth fault protection (voltage polarised)



Drawout case outline — size $1\frac{1}{2}$

EARTHING ARRANGEMENTS

Although not included in the diagram, it is assumed that secondary C.T. and/or V.T. circuits will be earthed as necessary in compliance with standard safety requirements and determined by the switchgear contractor or user. If in doubt, please consult GEC Measurements for advice.

CASES

The relays are supplied in a size 1½ drawout case available for flush or projecting mounting, finished phenolic black.

Relays for use in exceptionally severe environments can be finished to BS.2011:20/50/56 at extra cost; standard relays are finished to BS.2011:20/40/4 and are satisfactory for normal tropical use.

INFORMATION REQUIRED WITH ORDER

Relay type
IDMT relay data (see R5090)
Details of instantaneous high set unit, if required
Maximum torque angle
Polarising coil rating (voltage or current)
Current coil rating
Case finish and mode of mounting

Our policy is one of continuous product development and the right is reserved to supply equipment which may vary slightly from that described.

GEC Measurements **The General Electric Company Limited of England**

St. Leonards Works Stafford ST17 4LX England
Telephone: 0785 3251 Telex: 36240 Cables: Measurements Stafford Telex

Publication R-5089C

048050GSP *Printed in England*

GEC Measurements

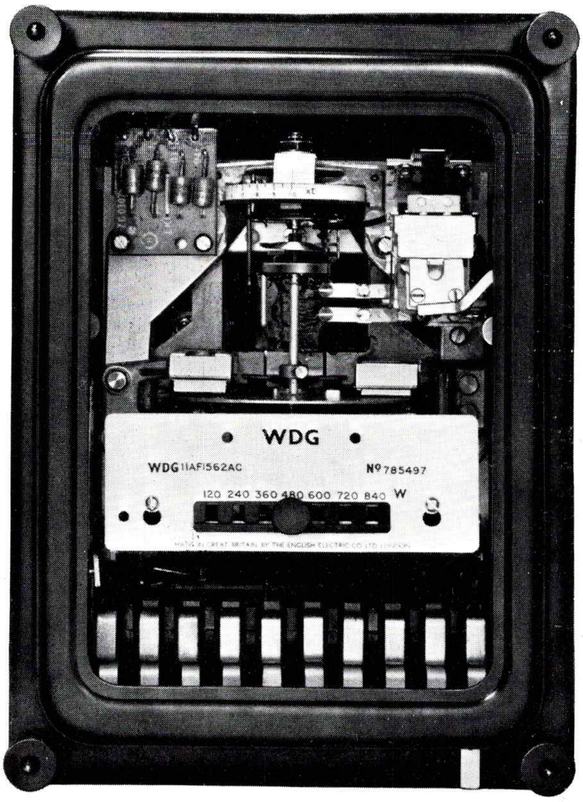
INVERSE TIME POWER RELAY

Type WDG

Type WDG11 relays detect reversal of power flow and are used to give time graded IDMT protection against 'motoring' to diesel and gas turbine driven alternators and to large pass-out turbo alternators, when the 'motoring' power available is greater than 6% of rated power. For condenser-evacuated sets, where the 'motoring' power is less than 3% of rated power, the more sensitive polyphase relay type WCD is recommended. Reverse power protection can also be given to interconnected feeders. Relays suitable for phase-neutral (type A) and phase-phase (type B) connection are available with either standard or sensitive settings

Type WDG12 power relays detect power increases. Typical applications include the separation of power systems when the flow from one system to another exceeds a safe value and time-graded IDMT protection of unattended generating plant against overload.

A single relay is sufficient for balanced conditions on three phase, three or four wire systems, but a relay must be employed on each phase for unbalanced conditions. A triple pole relay WDG31 is available.



Type WDG11 relay

CONSTRUCTION AND OPERATION

The relay is basically a wattmetric induction disc movement and seven equal taps are provided on a small auxiliary current transformer to obtain the desired power setting. The relay measures true watts down to 50% of normal voltage and 0·5 power factor.

Adjustment of the time setting is made by rotating a knurled moulded disc against a graduated time multiplier scale.

TECHNICAL INFORMATION

Relay			WDG11 type 'A'			WDG11 type 'B'			WDG12	
Application			Reverse power			Reverse power			Over power	
Connection			Phase to neutral			Phase to phase			Phase to phase	
Maximum torque angle			0°			30° lead			30° lead	
Frequency Hz			50		60	50		60	50	60
Current coil rating (C.T. secondary) amps			1 or 5		1 or 5	1 or 5		1 or 5	1 or 5	1 or 5
Voltage coil rating (V.T. secondary) volts			63·5	240	66·5	110	440	115	110	115
Settings 5 amp rated relay*	Sensitive	Single phase watts	6–42	24–168	6–42	—	—	—	—	—
		3 phase watts	—	—	—	18–126	72–504	18–126	—	—
	Standard	Single phase watts	30–210	120–840	30–210	—	—	—	—	—
		3 phase watts	—	—	—	90–630	360–2520	90–630	450–1800	450–1800
Burdens	Voltage coil VA at rated volts		10·6		9·0	13·9		10·5	13·9	10·5
	Current coil VA at rated current	Sensitive	11·5–0·4		13·5–0·3	11·5–0·4		13·5–0·3	—	—
		Standard	3·5–0·07		4·5–0·1	3·5–0·07		4·5–0·1	0·14–0·003	0·18–0·004

*For settings of 1 amp rated relay divide figures given by 5

THERMAL RATING

The relays will withstand twice rated current continuously or 20 times rated current for three seconds, and 110% rated voltage continuously.

AUXILIARY UNITS AND OPERATION INDICATORS

An auxiliary attracted armature unit with a hand reset operation indicator for either shunt reinforcing or series seal in is fitted as standard.

Standard coil ratings

Voltage operated (shunt) auxiliary units: 30, 48, 50, 110, 125, 220 and 250 volts d.c. at a nominal burden of 3 watts continuously rated or 110, 240 and 440 volts a.c. at a nominal burden of 3·5 VA continuously rated.

Current operated (series) auxiliary units:

Minimum operating current in amps d.c. (two taps)	0·5 second current rating in amps d.c.	Coil resistance in ohms
0·1 and 0·3	18 and 22	9·2 and 2·1
0·2 and 2·0	22 and 92	6·0 and 0·125
0·6 and 2·4	92 and 188	0·29 and 0·031

Other coil ratings can be supplied for both types of auxiliary unit.

Contacts

Two pairs of self or hand reset contacts in any combination of normally open or normally closed are fitted which will make and carry 7500 VA for 0·5 second with maxima of 30 amps and 660 volts a.c. or d.c.

INSULATION

The relay will withstand 2·0 kV 50 Hz for one minute between all terminals connected together and the case, together and 1·0 kV 50 Hz for one minute between all normally open contacts.

CASES

The relays are supplied in drawout cases, and can be either flush or projecting mounted. Standard case finish is phenolic black. Relays for use in exceptionally severe environments can be finished to B.S.2011: 20/50/56 at extra cost. Standard relays are finished to B.S.2011: 20/40/4 and are satisfactory for normal tropical use.

CASE DIMENSIONS

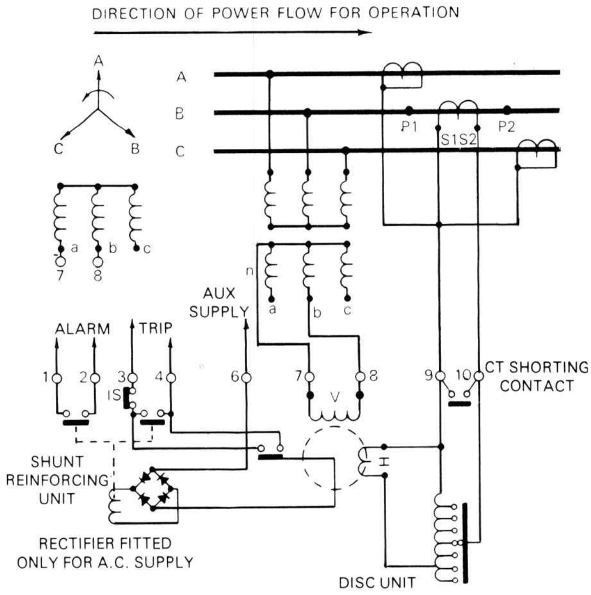
Relay	Case	Maximum overall dimensions					
		Height		Width		Depth*	
		in.	mm	in.	mm	in.	mm
WDG11 WDG12	1D	9 3/16	233	6 11/16	170	7¾	197
WDG31	3D (horiz)	9¼	235	17 7/8	454	7¾	197

*Add 2 in. (51 mm) for maximum length of 2 BA terminal studs.

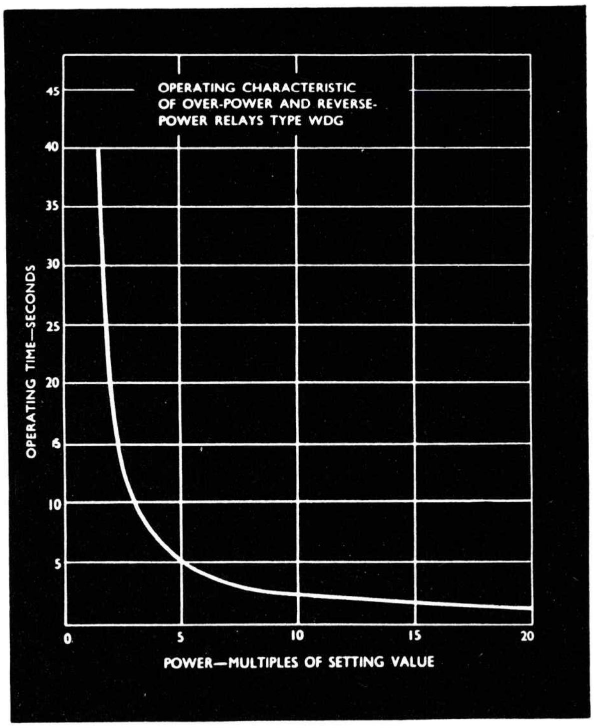
Dimensioned drawings of case outlines, panel cut-outs and mounting details are avilable on request.

EARTHING ARRANGEMENTS

Although not included in the diagram, it is assumed that secondary C.T. and/or V.T. circuits will be earthed as necessary in compliance with standard safety requirements and determined by the switchgear contractor or user. If in doubt, please consult GEC Measurements for advice.



Typical application and simplified internal circuit diagram of WDG11 type 'A' reverse power relay with shunt reinforcing. Alternative V.T. secondary connection for type 'B' relay is shown. Overpower relays are connected in the same way but will restrain for power flow in the direction shown.



Time/power characteristic

INFORMATION REQUIRED WITH ORDER

Relay type
Power setting range
Current (C.T. secondary)
Voltage (V.T. secondary)
System frequency
Trip circuit voltage (shunt reinforcing)
Trip circuit current (series seal in)
Case mounting

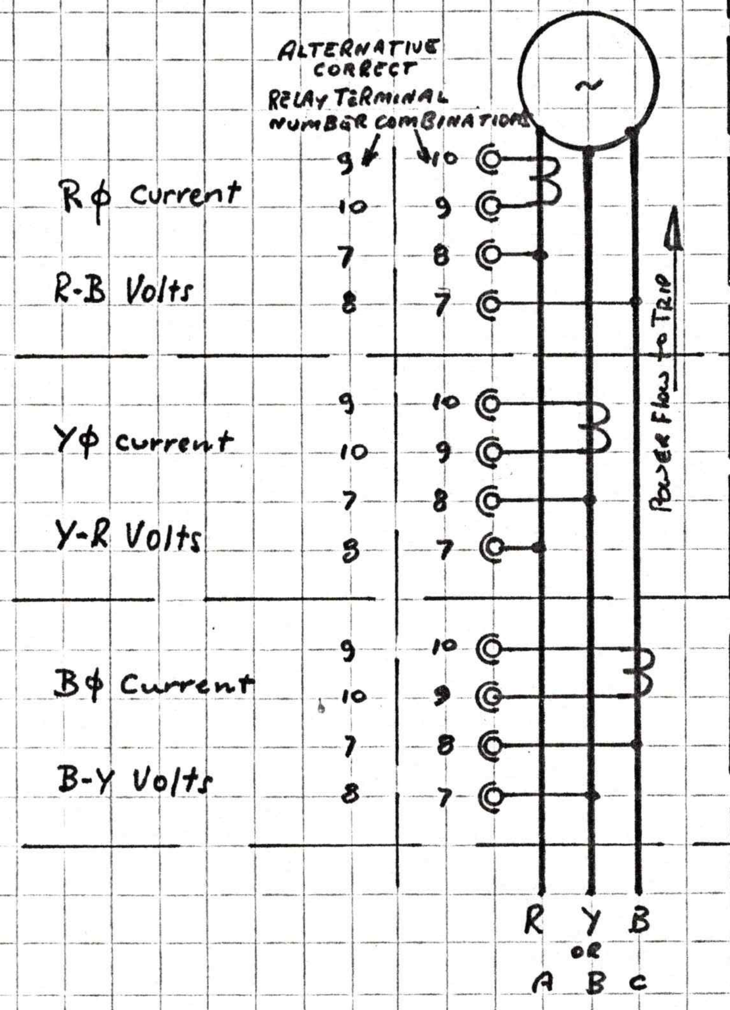
Our policy is one of continuous product development and the right is reserved to supply equipment which may vary slightly from that described.

GEC Measurements The General Electric Company Limited of England

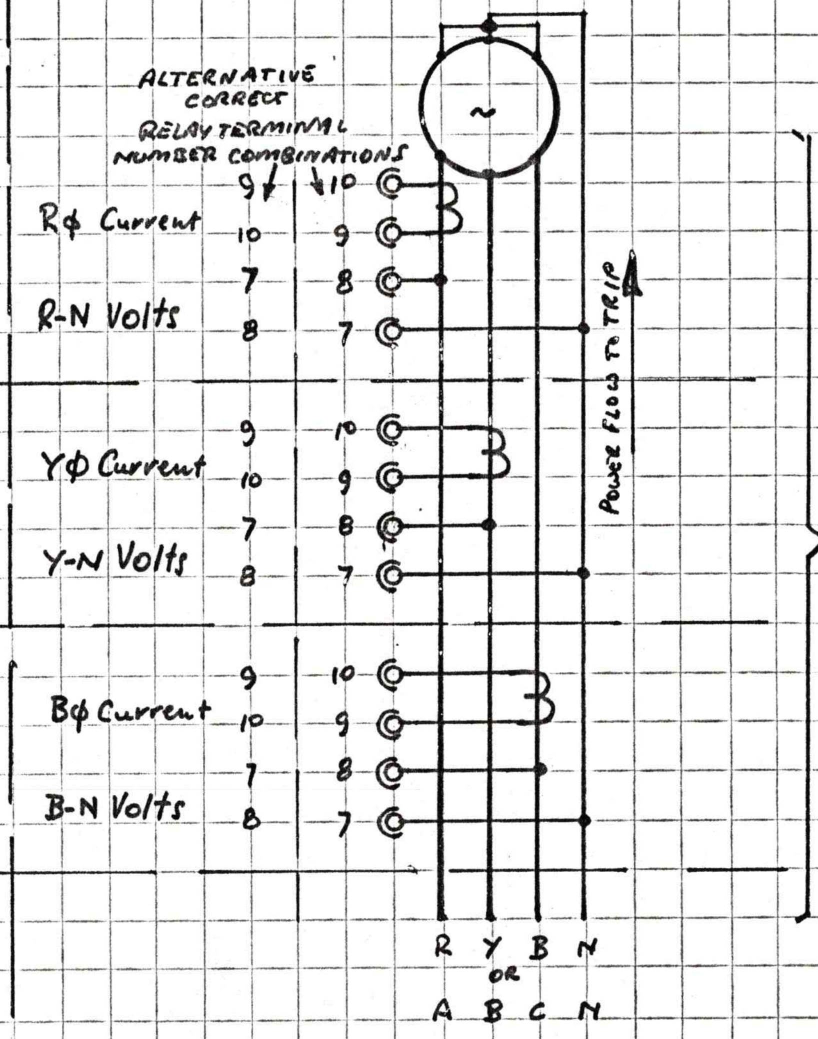
St. Leonards Works Stafford ST17 4LX England
Telephone: 0785 3251 Telex: 36240 Cables: Measurements Stafford Telex

Publication R-5124D

108050GSP *Printed in England*



WDG11 TYPE B RELAY
for
Phase - Phase Volts



WDG11 Type A RELAY
for
Phase - Neutral Volts

ALTERNATIVE CORRECT CONNECTIONS DEPENDENT ON CT PHASE LOCATION.

NOTES:

1. All test links fuses & earthing recommendations have been omitted from this diagram.
2. Relays for φ-φ voltage connections will not suit φ-N circuits & vice versa.
3. GEC Regents Park NSW stock items are:
   Type B Sensitive range units
   (a) 415/440V. 5A 50HZ.
   (b) 110V 5A 50HZ (VTs required)

CURRENT & VOLTAGE SUPPLIES FOR GEC TYPE WDG11 REVERSE POWER RELAYS FOR USE WITH AC GENERATORS

EDR15117B

GEC Measurements

SENSITIVE POWER RELAY

Type WCD

The type WCD power relay is a sensitive polyphase induction cup unit intended to provide reverse or under power interlocking. When a turbo-generator set is shut down in an emergency, there is a risk of overspeed if the circuit breaker opens before the steam valves are completely closed. Even if these actions are simultaneous, steam trapped in the casing of a large turbine may be sufficient to cause overspeed. A sensitive power relay retains the generator on load until the onset of 'motoring' and then operates to open the circuit breaker.

To prevent operation due to power swings when the machine is being synchronised, it is desirable to employ a definite time delay unit (VAT).

CONSTRUCTION

The electrical quantities are fed to windings on the eight poles of a laminated stator with a central fixed core. The moving contact is carried on a cup-shaped aluminium rotor which turns on jewel bearings in the air gap between stator and core. Only a small travel is needed to close the contacts, and with the low inertia of the rotor and unusually large operating torque, a high speed of operation is ensured.

CHARACTERISTICS

Current Rating 1 or 5 amps (C.T. secondary at 50 or 60 Hz

Voltage Rating 110 volts at 50 Hz or 115 volts at 60Hz

Thermal Rating The relay will withstand twice rated current continuously or 20 times rated current for three seconds and 110% of rated voltage continuously.

Sensitivity Less than 0·5% of rated power at unity power factor and less that 1·0% of rated power at 75° phase angle

Operating Time 35 milliseconds at 5·0% of rated power

Directional Stability The relay remains unoperated at forward powers of over five times rated power.

BURDENS

Phase	Burden at rated current and voltage (VA)	
	Current	Voltage
Red ..	6·5	9·0
Yellow ..	3·6	9·0
Blue ..	2·8	18·0

AUXILIARY UNIT

The induction cup unit contact energises an attracted armature auxiliary unit (VAA).

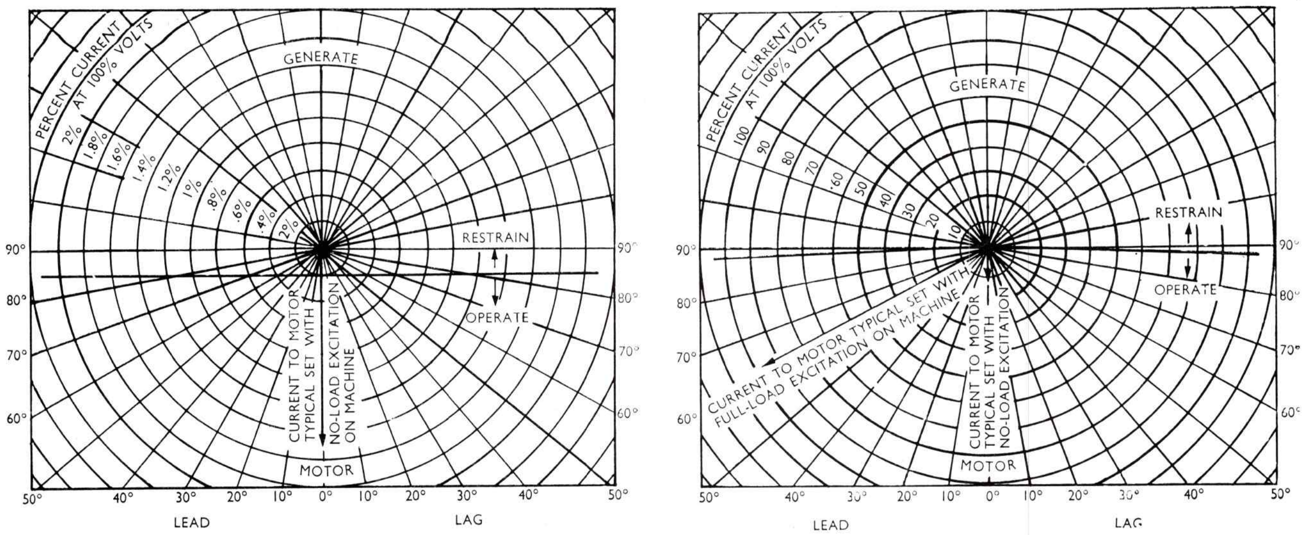
Contacts Up to four pairs of electrically separate self reset contacts in any combination of normally open or normally closed can be provided. Each pair is rated as follows:—

	Make and carry continuously	Make and carry for 3 seconds	Break
a.c.	1250 VA with maxima of 5 amps and 660 volts	7500 VA with maxima of 30 amps and 660 volts	1250 VA with maxima of 5 amps and 660 volts
d.c.	1250 watts with maxima of 5 amps and 660 volts	7500 watts with maxima of 30 amps and 660 volts	100 watts (resistive) 50 watts (inductive) with maxima of 5 amps and 660 volts

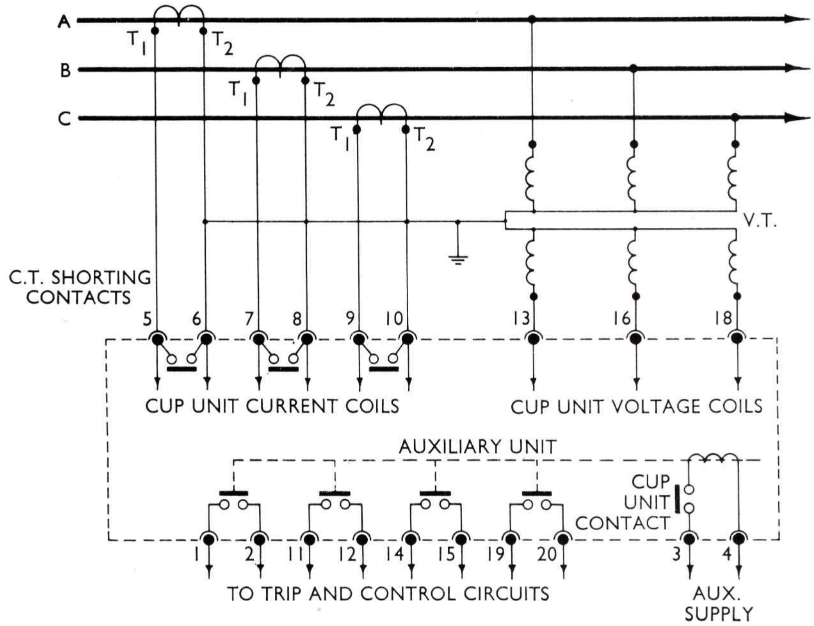
Standard Voltages 30, 110, 125 or 220 volts d.c. at 3 watts. Other voltage ratings either a.c. or d.c. can be supplied.

CASE

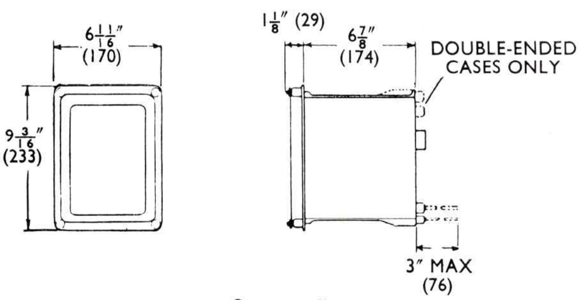
The relay is supplied in a size 1 double ended drawout case which is available for either flush or projecting mounting finished phenolic black.
Relays for use in exceptionally severe environments can be finished to B.S. 2011 : 20/50/56 at extra cost; standard relays are finished to B.S. 2011 : 20/40/4 and are satisfactory for normal tropical use.



Typical operating characteristics showing (left) *performance at very low current and* (right) *performance at large currents*



Typical application and internal diagram



Case outline

INFORMATION REQUIRED WITH ORDER

Current rating
Voltage rating
Frequency
Auxiliary supply voltage
Number and arrangement of auxiliary contacts
Case finish and mode of mounting

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GEC Measurements The General Electric Company Ltd

St. Leonards Works Stafford ST17 4LX England
Telephone: 0785 3251 Telex: 36240 Cables: Measurements Stafford Telex

Publication R-5119B

117630GSP *Printed in England*

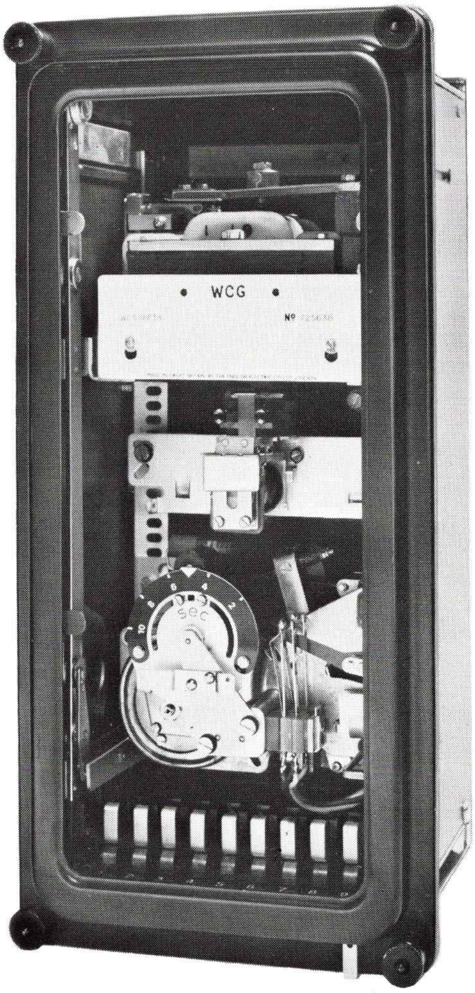
GEC Measurements

DEFINITE TIME REVERSE POWER RELAY

Type WCG

The type WCG definite time reverse power relay provides a sensitive and economical means of detecting motoring conditions in diesel alternators and back pressure turbines. Faster clearance times can be obtained for lower values of reverse power than are possible with inverse definite minimum time delay relays.

Basically the relay is a high speed induction cup unit (type CCD). On a reverse power condition the contacts close to energise an auxiliary attracted armature unit (type VAA). The contact of the attracted armature unit initiates an electro-mechanical timing unit (type VAT) with contacts for alarm and trip duties which are independently adjustable over a given time range.



RATINGS

Current: 1 or 5 amps (C.T. secondary) at 50 or 60 Hz

Voltage: 110 volts (V.T. secondary) at 50 or 60 Hz

OVERLOAD

The relay will withstand twice rated current continuously or 20 times rated current for three seconds and 110% rated voltage continuously.

MAXIMUM TORQUE ANGLE

When connected as shown overleaf, the relay develops maximum torque when the applied voltage lags the applied current by 30°. This corresponds to unity power factor on the system.

SENSITIVITY

The relay is directional down to approximately 1% of rated voltage with 1 to 15 times rated current or down to approximately 3% of rated voltage with 0·4 to 40 times rated current. The nominal power setting is fixed at less than 3% of the rated single phase power.

A.C. BURDENS

Current Coils: 1VA at rated current

Voltage Coils: 9VA at rated voltage

OPERATING TIME

The standard definite time delay unit is continuously adjustable from 2 to 10 seconds. Other time ranges are available covering from 0·5 to 120 seconds.

AUXILIARY SUPPLY

Standard auxiliary voltage ratings are 30, 110, 125 and 220 volts d.c. Other voltages a.c. and d.c. can be accommodated.

D.C. Burden: 13 watts on operation

Satisfactory operation is maintained at between 50% and 120% of rated auxiliary voltage.

CONTACTS

Two pairs of electrically separate self reset contacts in any combination of normally open or normally closed are provided.

OPERATION INDICATOR

A hand reset mechanical operation indicator is provided on the definite time delay unit.

CONTACT RATING

	Make and carry continuously	Make and carry for 3 seconds	Break
a.c.	1250 VA with maxima of 5 amps and 440 volts	7500 VA with maxima of 30 amps and 440 volts	1250 VA with maxima of 5 amps and 440 volts
d.c.	1250 watts with maxima of 5 amps and 440 volts	7500 watts with maxima of 30 amps and 440 volts	50 watts (resistive) 25 watts (inductive) with maxima of 5 amps and 440 volts

INSULATION

The relay will withstand 2kV r.m.s. 50 Hz for 1 minute between all live parts and earth and between all circuits not intended to be connected together. It will also withstand 1 kV r.m.s. 50 Hz for 1 minute across open contacts.

CASE

The relay is supplied in a size $1\frac{1}{2}$ drawout case which is available for either flush or projecting mounting finished phenolic black as standard. Relays for use in exceptionally severe environments can be finished to B.S.2011 : 20/50/56 at extra cost; standard relays are finished to B.S.2011: 20/40/4 and are satisfactory for normal tropical use.

Fully dimensioned drawings of case outline, panel cut-outs and mounting details are available on request

INFORMATION REQUIRED WITH ORDER

Current rating

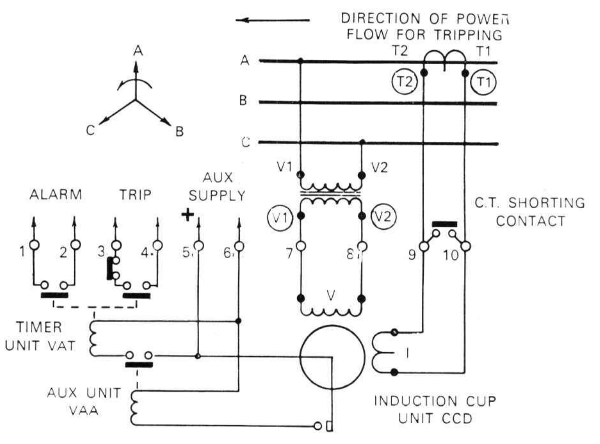
Supply frequency

Operating time range

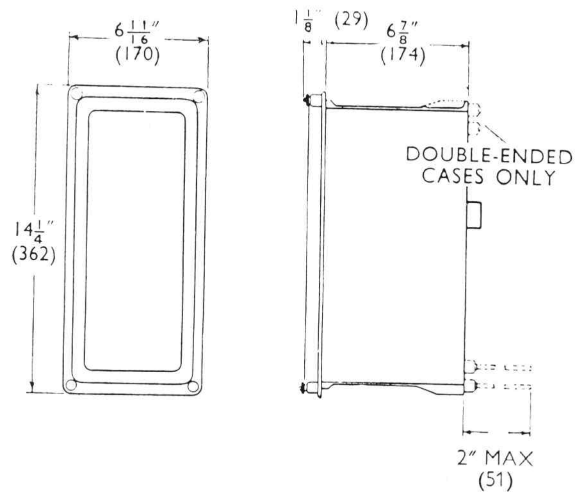
Contact combination

Auxiliary supply

Case mounting



Typical application and internal circuit diagram



Case outline

Our policy is one of continuous product development and the right is reserved to supply equipment which may vary slightly from that described.

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St. Leonards Works Stafford ST17 4LX England

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Publication R-5106A

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8. Field Failure Protection Relays
Type YCGF

GEC Measurements

FIELD FAILURE RELAY

Type YCGF

The type YCGF relay detects loss of field supply or reduction in the field current of synchronous generators beyond the stability limits of the machine.

Loss of field supply to a synchronous generator can be caused by a fault in the excitation circuits or by incorrect opening of the field circuit breaker. On loss of field, the machine operates as an induction generator excited by reactive power drawn from the system to which it is connected. This could result in instability of power in the system and overheating of the rotor, especially if the machine is of the cylindrical rotor type without damping windings in the pole faces.

The circular mho characteristic has its centre on the —X axis of the RX diagram and is offset from the origin. This offset is adjustable so that undesirable operation of the relay on power swings or loss of synchronism not accompanied by loss of field, is avoided. The diameter of the circle is also adjustable, independent of the offset.

To avoid mal-operation due to synchronising surges and transient conditions, the relay is used with a simple definite time delay relay type VAT11 and arranged to initiate alarm, tripping or load shedding if adverse field conditions persist longer than a safe period.

When used with generators designed for line charging which can operate at rotor angles in excess of 90°, the diameter of the circle characteristic must be set small. At this setting, the impedance locus of the machine, on loss of field, can enter and leave the relay circle characteristic at intervals depending mainly on load conditions prior to the fault. To ensure correct operation in these conditions, it is necessary to use a type VAT51 time delay relay. This arrangement is standard for turbo-alternator sets installed by the Central Electricity Generating Board.

CONSTRUCTION AND OPERATION

The relay is basically a low inertia, high speed four pole induction cup unit of simple construction having operating, polarising and restraint coils.

With the relay connected as shown, the phase to neutral field impedance of the machine, in terms of secondary ohms, is measured. If the field supply fails, the locus of the machine terminal impedance moves inside the relay characteristic and the contacts close immediately.

RATINGS

Current: 1 or 5 amps (C.T. secondary) at 50 or 60 Hz

Voltage: 110 volts (V.T. secondary) at 50 Hz
115 volts (V.T. secondary) at 60 Hz

SETTINGS

Circle diameter

1 amp rating: 25–250 ohms } adjustable in 5% steps
5 amp rating: 5– 50 ohms }

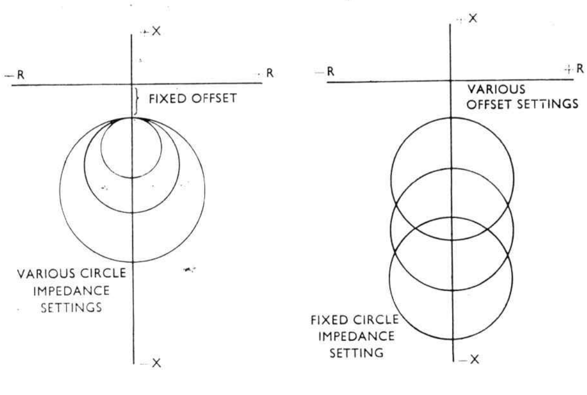
The value usually chosen is the direct axis synchronous reactance of the generator.

Offset

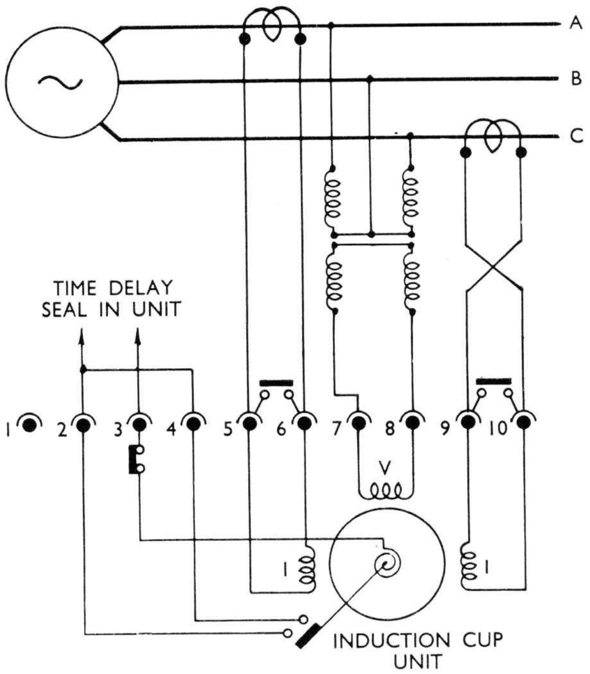
1 amp rating: 2·5–20 ohms adjustable in 2·5 ohm steps

5 amp rating: 0·5– 4 ohms adjustable in 0·5 ohm steps

The value usually chosen is half the direct axis transient reactance of the generator.



Characteristics of type YCGF relay



Typical application and simplified internal circuit diagram

BURDENS

Voltage circuit: 5·0–7·7 VA } at 50 or
Current circuit: 1·7–2·8 VA per phase } 60 Hz

The burden depends on the relevant ohmic setting and the magnitude and phase angle of the load current.

CONTACTS

A light duty normally open three-point contact is fitted to the induction cup unit and is rated to make, break and carry for 30 seconds, 10 watts inductive or 20 watts resistive with maxima of 250 volts and 5 amps d.c.

INSULATION

The relay will withstand 2 kV, 50 Hz for 1 minute between all circuits not intended to be connected together and between all live parts and earth. It will also withstand 1 kV, 50 Hz for 1 minute between normally open contacts.

CASE

The relays are supplied in drawout cases available for flush or projecting mounting finished phenolic black as standard. Relays for use in exceptionally severe environments can be finished to B.S.2011:20/50/56 at extra cost. Standard relays are finished to B.S.2011:20/40/4 and are suitable for normal tropical use. A filter breather is fitted which equalises the pressure inside and outside the case without admitting dust.

CASE DIMENSIONS

Relay	Case	Maximum Overall Dimensions					
		Height		Width		Depth*	
		ins.	mm	ins.	mm	ins.	mm
YCGF and VAT11	1D	$9\frac{3}{16}$	233	$6\frac{11}{16}$	170	$7\frac{3}{4}$	197
VAT51	2D	$16\frac{5}{8}$	422	$6\frac{11}{16}$	170	$7\frac{3}{4}$	197

*Add 2 ins. (51 mm) for maximum length of 2BA terminal studs

Dimensioned drawings of case outlines, panel cut-outs and mounting details are available on request.

INFORMATION REQUIRED WITH ORDER

Current rating

Supply frequency

Case mounting

Details of definite time delay

GEC Measurements **The General Electric Company Limited of England**

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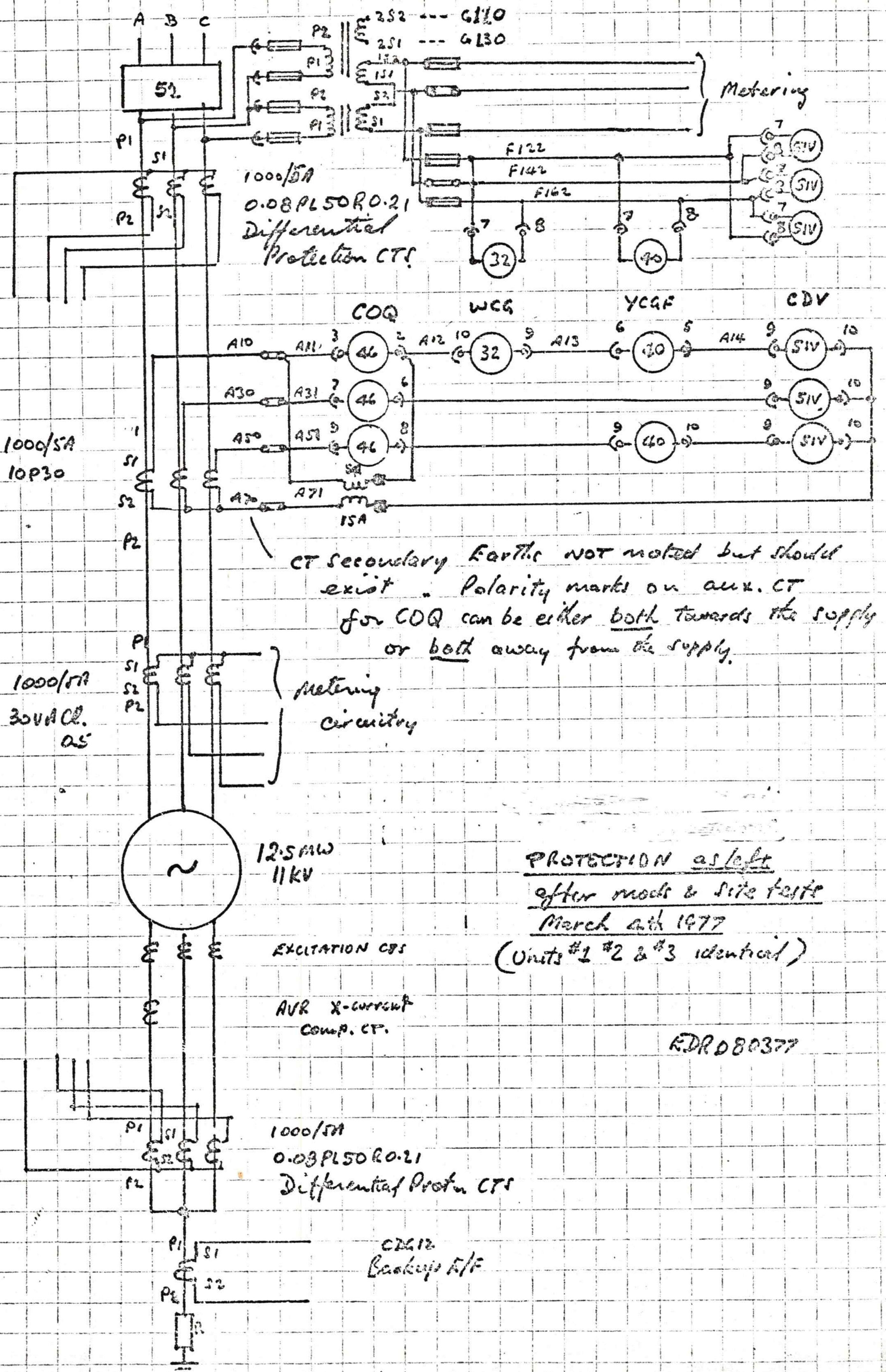
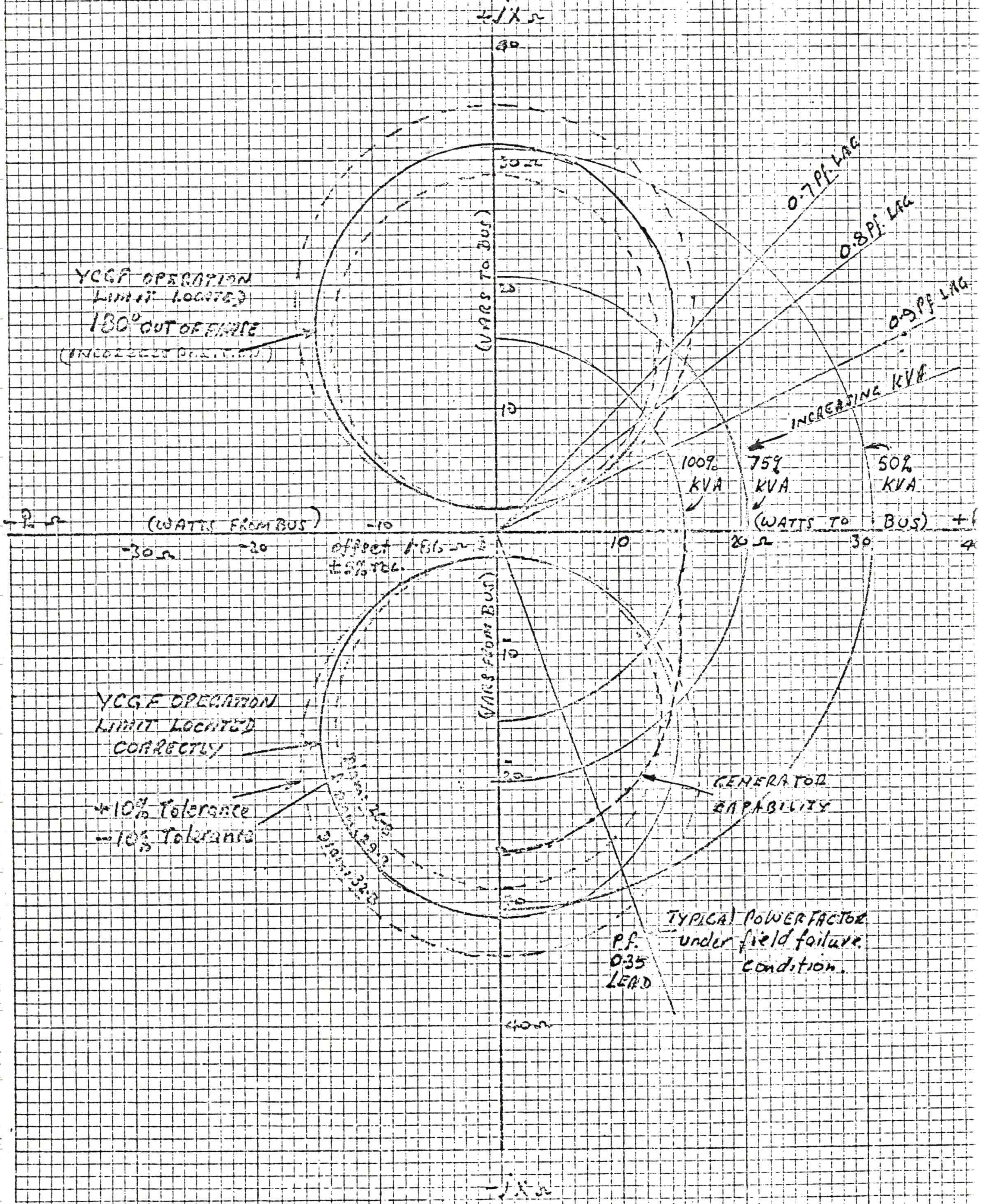
Telephone: 0785 3251 Telex: 36240 Cables: Measurements Stafford Telex

Publication R-5103A

067950GSP *Printed in England*

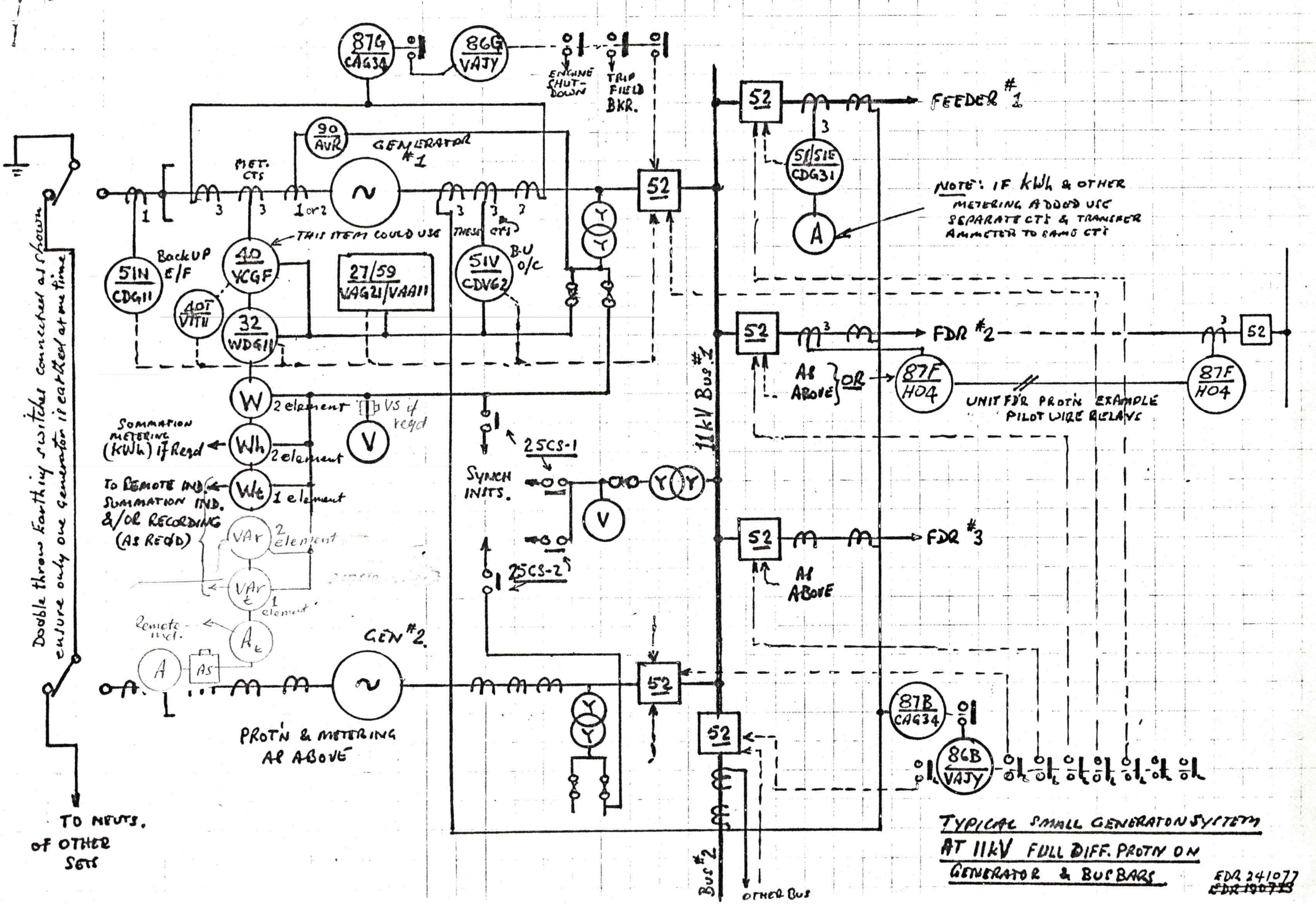


A B C
52
2S2 --- G110
2S1 --- G130
P2
P1
1S2
1S1
S2
S1
Metering
F122
F142
F162
7
8
51V
32
40
P1
S1
P2
S2
1000/5A
0.08PL50R0.21
Differential Protection CT'S
COQ
WCG
YCGF
CDV
A10
A11
A12
A13
A14
46
30
A30
A31
A50
A51
A70
A71
15A
1000/5A
10P30
CT secondary Earths NOT noted but should exist. Polarity marks on aux. CT for COQ can be either both towards the supply or both away from the supply.
1000/5A
30VA CL. 0.5
Metering circuitry
12.5MW
11KV
PROTECTION as left after mods & site tests March 8th 1977
(Units #1 #2 & #3 identical)
EXCITATION CTS
AVR X-current comp. CT.
EDR080377
1000/5A
0.03PL50R0.21
Differential Protn CTS
CDG12
Backup E/F



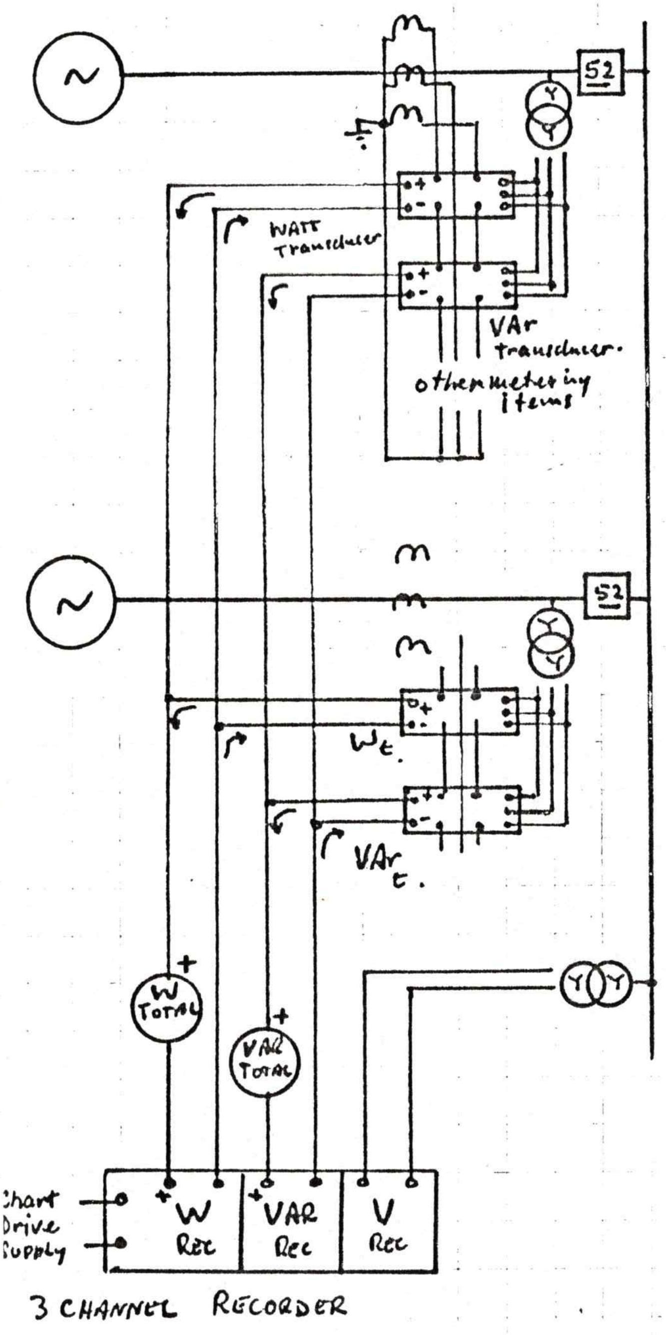
Typ. YCGF Field Failure Relay Setting & Generator Capability Superimposed in leading power factor quadrant only

9. Typical Protection and Metering Recommendations for small generation systems at 3.3kV and above



TYPICAL SMALL GENERATON SYSTEM AT 11kV FULL DIFF. PROTN ON GENERATOR & BUSBARS

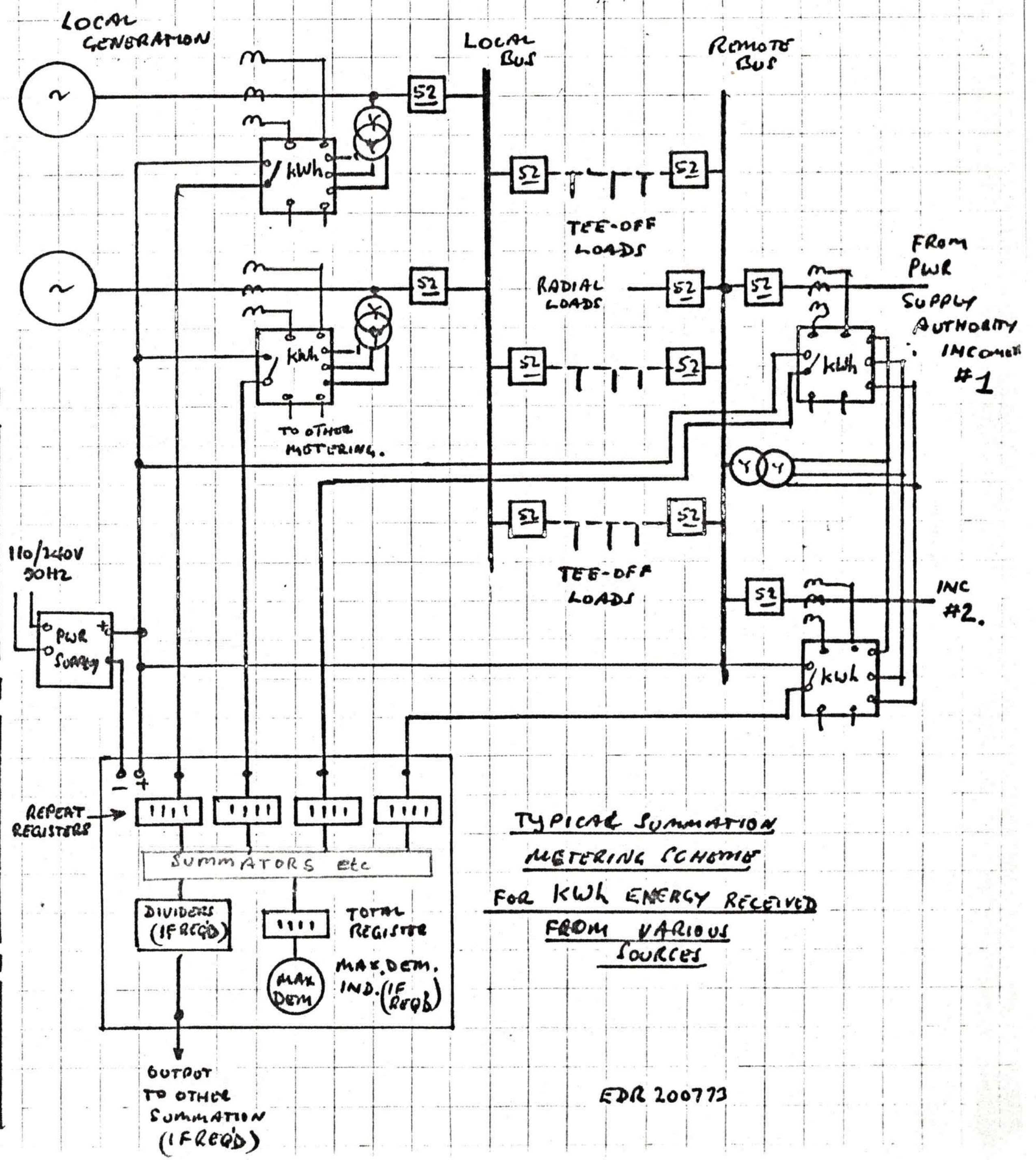
EDR 241077



TYPICAL GENERATION SUMMATION & RECORDING SCHEME.

(3φ3W UNBALANCED LOAD (2 element) TRANSDUCERS SHOWN.)

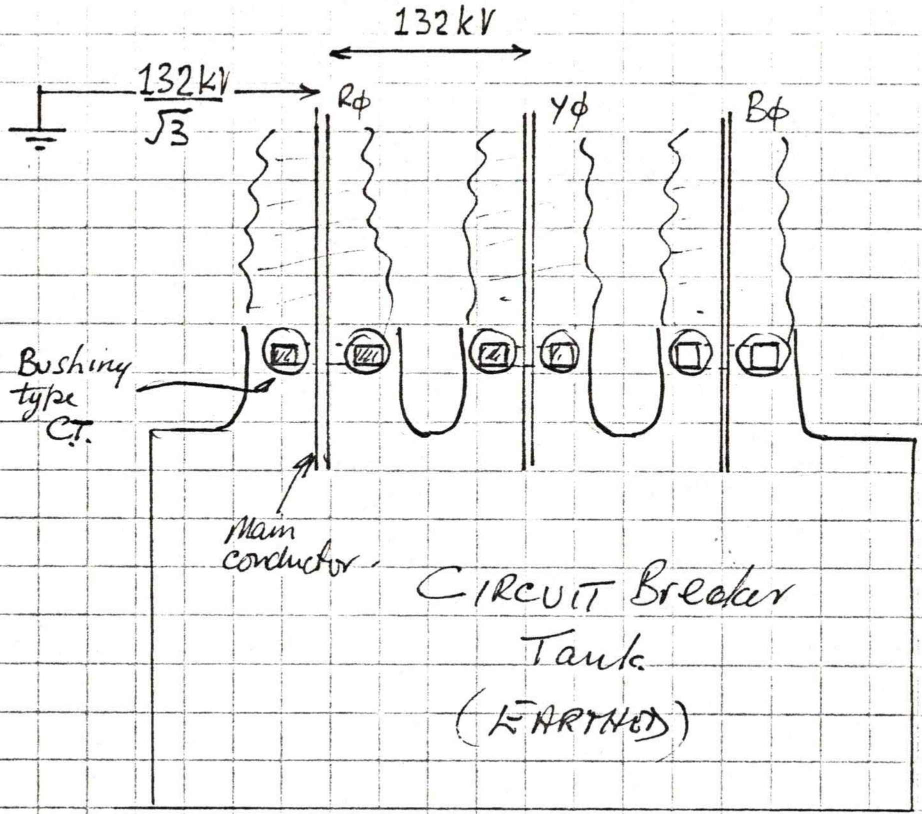
(Single element balanced load measurement could be used.)



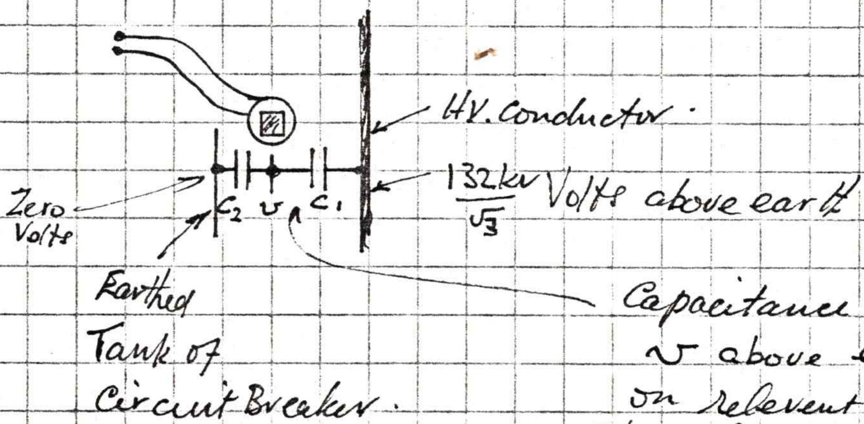
TYPICAL SUMMATION METERING SCHEME FOR KWh ENERGY RECEIVED FROM VARIOUS SOURCES

EDR 200773

10. C.T. Connections and Neutral Displacement Detection



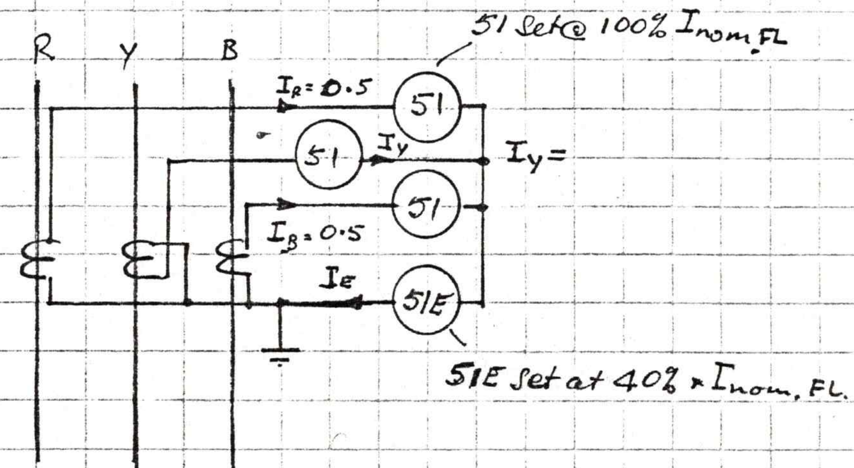
WHY CT & VT CIRCUITS SHOULD BE EARTHED



Capacitance V. Divider.
v above earth is dependent on relevent values of C_1 & C_2.
The value of v could be dangerous & in excess of the insulation rating of the CT secondary circuit – Normally withstands 2kV 50Hz for 1 minute.

Hence – if we earth the whole of the CT secondary circuit v becomes Zero & the CT circuit is safe as a whole to both insulation & personnel.

All secondary circuits for CTs & VTs should be earthed <u>at one point only</u> for each respective circuit. Even circuits downstream from interposing transformers should be earthed as a matter of principle even if not considered vitally necessary.
For busbar protection involving many sets of CTs, the earthing point should be common to all CTs and at one point only.



Q.. Up to what value of Load as a percentage of I_{FL} does this relay & CT system remain stable i.e. no trip or relay operation.

Reversed CT Connections

If the initial load after commissioning is low compared with the projected plant load and the CT primary rating chosen, then the CT connection error may not be noticed until the load increases.
If this system supplies a 3φ 4W system subject to unbalanced neutral loads then the E/F element setting may have been set initially at 10% then increased to 40% in the belief that the neutral current was exceeding the setting. If 40% is the max E/F relay setting and tripping still occurs as the total load is increased it may not be evident to the consumer that it is a CT connection problem & not neutral unbalance.

2 Overcurrent & E/F Connections to 3-pole CDG Relays

As the centre element has a 0.5 – 2 Amp setting range (well below the nominal 5A output of the CTs) it will operate on a moderate load current if connected as shown in figure 1. Fig 2 is the correct connection for 2-O/C+E/F. Fig. 3 shows why the leads C30 & C70 must be reversed.

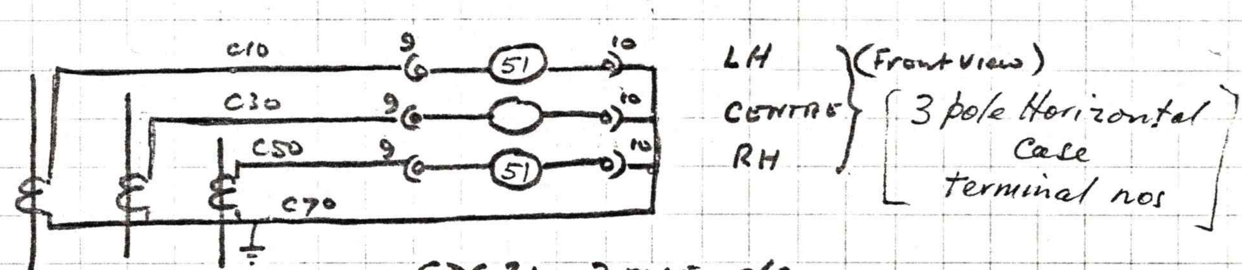


FIG 1 CDG 31 3 pole O/C APPLICATION. (CT circuit only)

The centre element is measuring Y ϕ current directly.

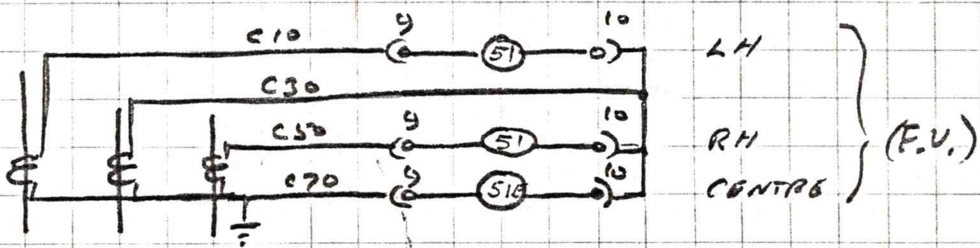


FIG 2 CDG 31 2 - O/C + 1 - E/F APPLICATION

The centre element only measures the unbalance in the 3 phases hence for a 4 wire circuit the E/F relay setting must be above the max expected unbalance due to 1 ϕ loads. For a 3 wire circuit any unbalance represents some fault involving Earth.

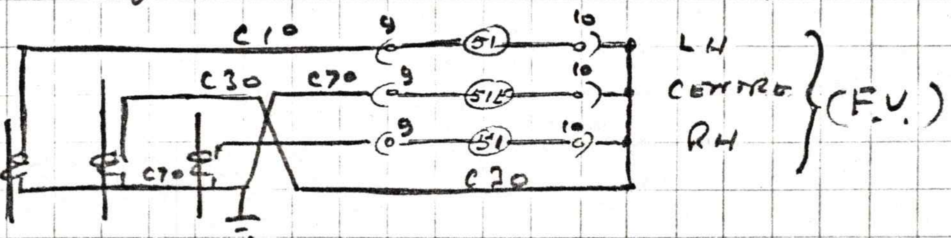
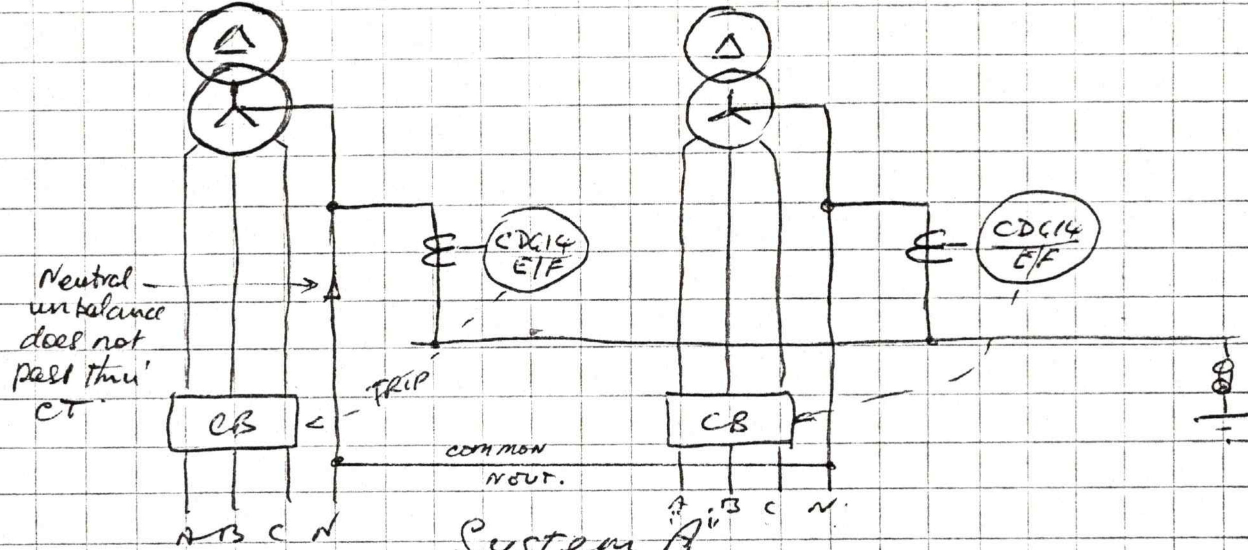


FIG 3 CDG 31 2 - O/C + 1 - E/F alternative method of drawing the diagram

Ref. W/O 566 F-6786

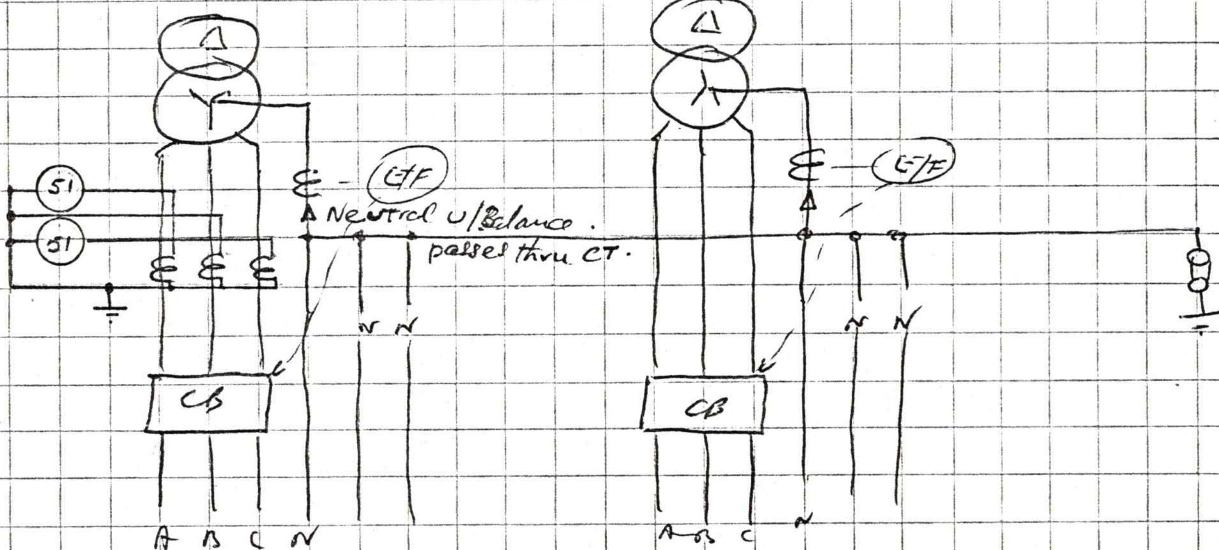
[signature]

Jan 16/76



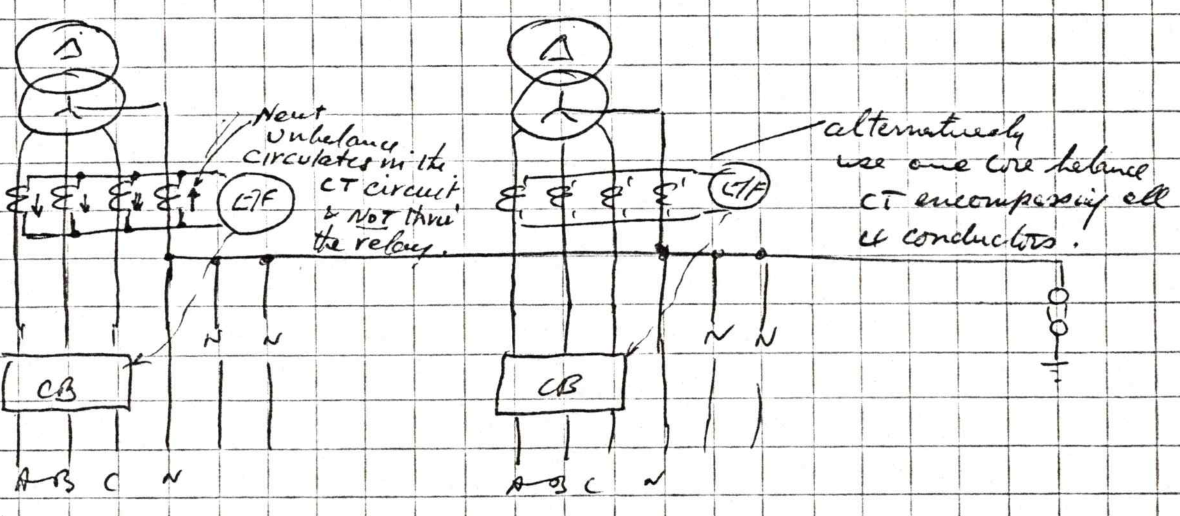
System 'A'

GOOD SENSITIVITY POSSIBLE
& NOT SUBJECT TO 1φ UNBALANCE.



System 'B'

SENSITIVITY DEPENDENT ON
MAX 1φ UNBALANCE



System 'C'

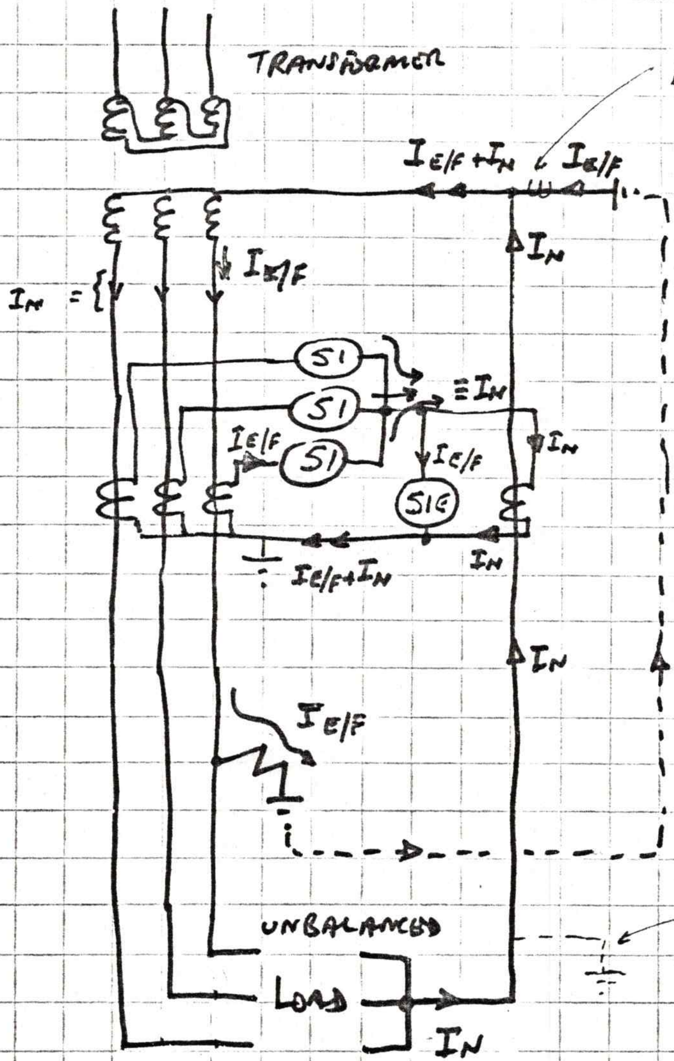
GOOD SENSITIVITY POSSIBLE
NOT SUBJECT TO 1φ UNBALANCE

KJR 250277

EARTH FAULT RELAYS ON
3PH 4 WIRE SYSTEMS

3 CTs or 4 CTs for E/F Protection of 3 PH 4 WIRE Systems ?

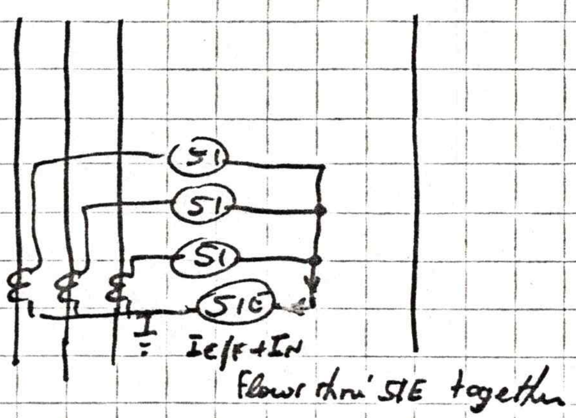
Alt. position for E/F detection relay & CT



51E can be set to detect E/F current irrespective of level of standing neutral current

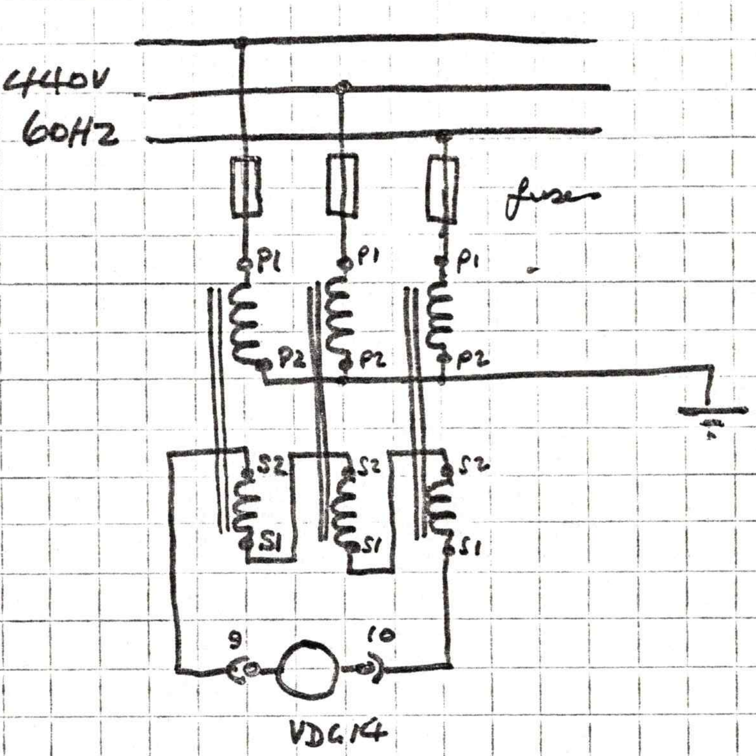
if Neut. was earthed here then 51E would be generally ineffective

I_N is standing neut. current



alternative scheme
51E has to be set to a higher level

EDR 260280



3-VT's each 440/110V 60HZ single phase 20VA indoor type, 660V insulation for back of panel mounting.

NOTE: Ratio given is equivalent to:

$$\frac{440}{\sqrt{3}} \Big/ \frac{110}{\sqrt{3}}$$

i.e. 254/63.5V.

} but 440V rating primary must be used, as if 1 bus becomes solidly earthed the remaining VT primaries will have 440V applied to them.

NEUTRAL DISPLACEMENT DETECTION ON UNEARTHED SYSTEMS

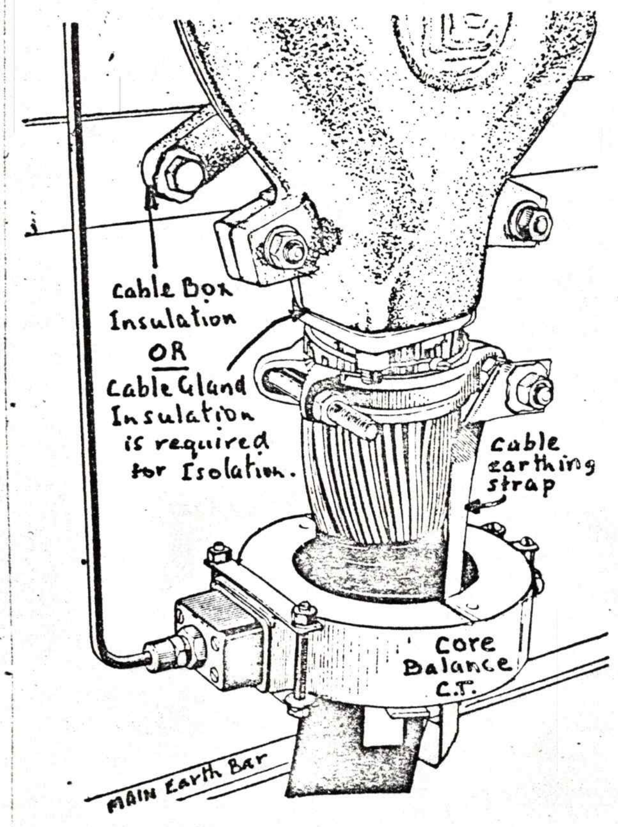
EDR 060380

11. Core Balance Earth Fault Relays for Mining Applications etc.

NOTES ON THE USE OF CORE BALANCE CT FOR EARTH FAULT MEASUREMENT

To prevent spurious operation or cancelling of the unbalance flux, stray currents in the cable sheath must be diverted past the current transformer. The cable gland or complete cable box assembly must be effectively insulated from the switchgear and/or other earthed equipment. The cable armouring and/or sheath is bonded to the main earth bar by a copper strap which passes back through the core balance current transformer as shown in the attached sketch hence cancelling any cable sheath currents and ensuring stability of the earth fault measuring relay.

Where core balance current transformers are used with three phase four wire systems, then, to prevent unwanted operation due to normal unbalance of single phase loading, the neutral conductor must be passed through the core balance transformer together with all phase conductors.

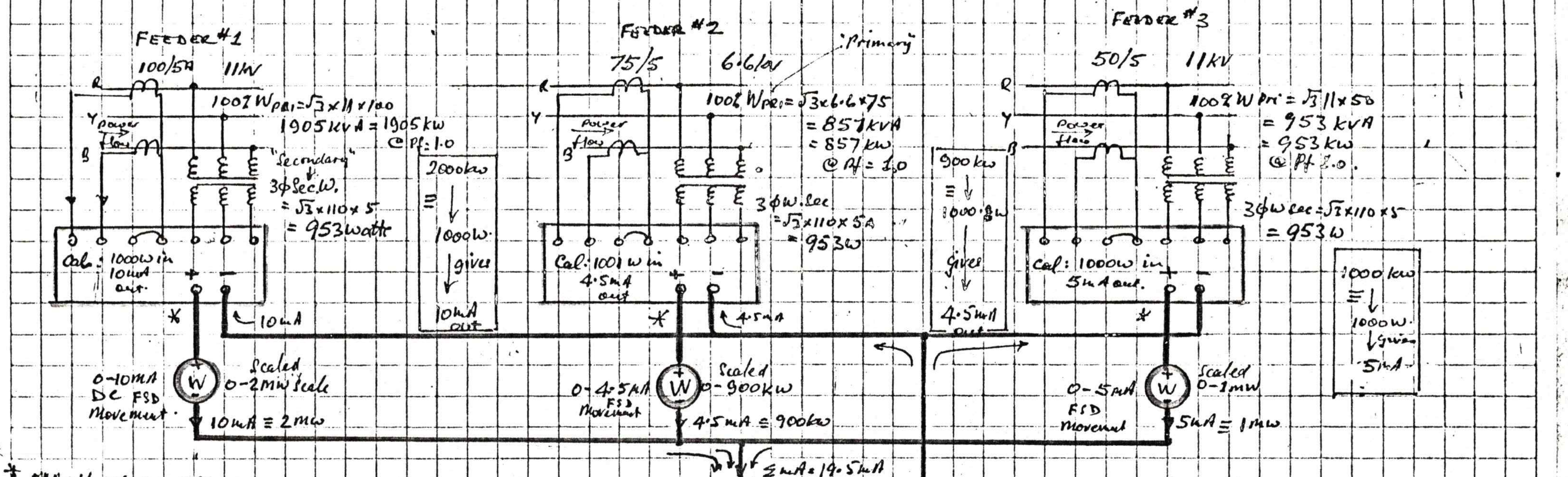


. *Method of connecting earth bonding strap*

CBEF

EDR 060372

12. Summation of power in multi-circuit systems. Indication and Recording



$\Sigma MW = 2 + 0.9 + 1 = 3.9\,MW \times \frac{20}{19.5} = 4\,MW$

∴ Scale of Total MW indicator & Recorder is 0–4MW. Scales dont have to be exactly equiv. to primary or total nominal watts but the conversion ratio must be maintained

* MA × Volts across transducer output terminals is limited & this needs checking with the supplier.

Note: Watts transducers must be ordered to suit same overall conversion ratio if they are to be used in a summation indication &/or recording system. Always choose a convenient ratio based on the highest primary rating of all circuits included in the scheme eg for above sample: 2MW / 10mA is chosen. All transducer outputs are less than 10mA.

Typical MW Summation Scheme using transducers of the current output type.
(MVAr systems would be identical.)
If power flow in one or more circuits could be reversed, centre zero or offset centre zero instruments & recorder would be req'd & the indicated total watts is the Nett power flow of all circuits in the chosen +ve direction. 10mm.   EDR.1

SPECIFICATION OF CONVERSION RATIOS FOR USE WITH TRANSDUCERS OPERATED EITHER DIRECTLY OR VIA CT'S AND VT'S

1. Wattmetric Types

(a) Conversion covering Transducer Input to Output

Whether connected direct to the main supply or via instrument transformers, single and polyphase transducers may be arranged to give full d.c. output (say 10mA) when the Watts, measured at unity power factor, correspond to the rated current input together with nominal voltage of the transducer. For example, for 5A and 110V inputs, 550 Watts single phase (or 951.5 3-phase Watts as applicable) can be arranged to produce an output of 10mA (or as appropriate to the transducer rating).

(b) Conversion covering System Input to Transducer Output

As an alternative, and a more common application, if the nominal CT primary rating does not correspond exactly to the feeder full load rating in Watts at nominal line Volts, transducers may be adjusted during manufacture to give a full output corresponding to the actual full load primary Watts. For example, for an 11kV circuit with 11kV/110V VT and using 200/5A CT's, and having a 3-phase full load rating of 3.5MW at unity power factor (which corresponds to a current of 183.9 Amp) 3.5MW primary can be arranged to produce a 10mA output from the transducer. There are, however, limits to the adjustment range of approximately $\pm$ 5% of nominal value, depending on the VT and CT ratios chosen. Special accommodation outside these limits may be available, but data should be submitted for comment.

In the first case it would be necessary to specify the input rating at the transducer terminals and conversion ratio in terms of the nominal input Watts (at unity power factor) and 10mA output. In the second case the CT and VT ratios must be specified together with the overall conversion ratio in primary Watts that are to correspond to 10mA output.

In calculating the conversion ratios one can assume the power factor is unity as any variations will only reduce output below rating and not increase it.

(c) Polyphase Balanced Load Measurement

Where balanced loads exist on a 3-phase system, a single element transducer may be used to measure 3-phase power and it is only necessary to specify the conversion ratio in 3-phase Watts to milliamps d.c. As component selection and factory adjustment automatically take care of the 3 or $\sqrt{3}$ factor that may enter calculated values, it is not necessary to specify a conversion ratio adjusted for the fact that a single element unit using L-N Volts or L-L Volts is required to give an output proportional to 3-phase power.

(d) Connections

A number of standard alternative methods of connection are available for the use of current and voltage supplies when applying single or multi-element polyphase transducers, but where supplies with unsuitable phase relationships only are available, phase shifting devices can usually be made to suit the supplies available and the transducer selected. Phase shifters will usually be housed in separate boxes.

2. VArmetric Types

For VAR transducers the same comments apply but calculations would be based on zero power factor conditions.

3. Bidirectional & Biassed Outputs

The above examples have been based on transducers giving unidirectional outputs, however the same philosophy may be applied to bidirectional or biased (offset zero) outputs or for transducers having 0-1 or 1-0-1mA outputs.

4. Current and Voltage Types

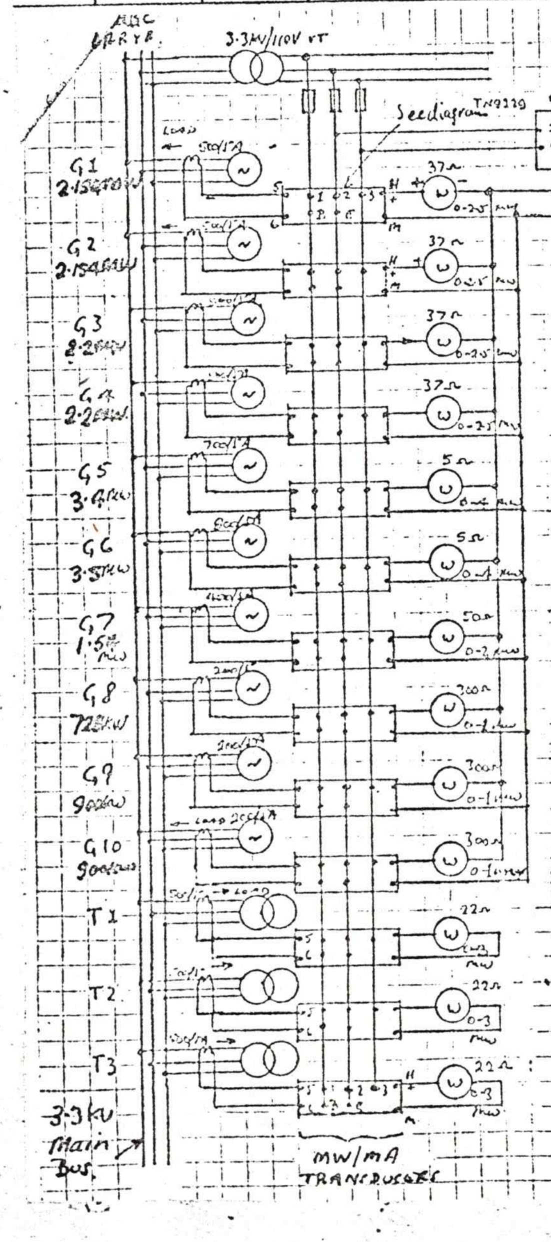
As for the Watt and VAr types, the current and voltage types can be supplied either with the nominal input rating corresponding to the nominal d.c. output rating or varied by factory setting, to suit fully rated feeder conditions which vary slightly from that determined by the CT or VT primary rating or ratios.

e.g. For 600/5A CT ratio and a 0-750A scale the transducer can be arranged to give 10mA output with 6.25A input.

E.D. Ransom
Senior Sales Engineer - Projects
GEC Measurements Section

SUMMATION MW INDICATION SCHEME

Unit No.	Nom MW Rtg.	110% Nom. MW	Inst FSD MW	mA out @ 110% Rtg.	mA @ FSD	Practical Transducer details: all to suit 3300/110V 3PH with CT & conversion Ratios given below, All to Diagram TN9229
1	2.154	2.3694	2.5			) 500/5A CT
2	2.154	2.3694	2.5			) 2.5MW/3.125 mA dc.
3	2.2	2.42	2.5			) 500/5A
4	2.2	2.42	2.5			) 2.5MW/3.125 mA
5	3.4	3.74	4			700/5A 4MW/5 mA
6	3.5	3.85	4			800/5A 4MW/5 mA
7	1.54	1.694	2			400/5A 2MW/2.5 mA
8	0.728	0.8008	1			) 200/5A
9	0.9	0.99	1			) 1MW/1.25 mA
10	0.9	0.99	1			)
	Σ MW = 19.676	Σ MW = 21.6476	Σ MW = 23	Σ mA =	Σ mA =	Σ mA = 28.75 ≡ 23MW
		∴	20MW	≡		≡ 25 mA



Notes:

1. As the total load never exceeds 20MW and some machines will always be on standby, then the summated MW at F.S.D of the total indicator & recorder is less than the sum of the installed capacity of the power station.

2. Transducers are all of the current output type (proportional to input watts)

Hence for summation schemes the outputs are in parallel & all transducers must have the same conversion ratio

3. T1 T2 T3 are all transformer feeders fed from the generator bus hence not included in the summation scheme.

TYPICAL SUMMATION OF MW LOAD for a MINE POWER STATION.

Measurements	THE GENERAL ELECTRIC COMPANY LIMITED ST LEONARDS WORKS STAFFORD	DRG. No. TN9229	SHEET NUMBER	NEXT SH. NUMBER

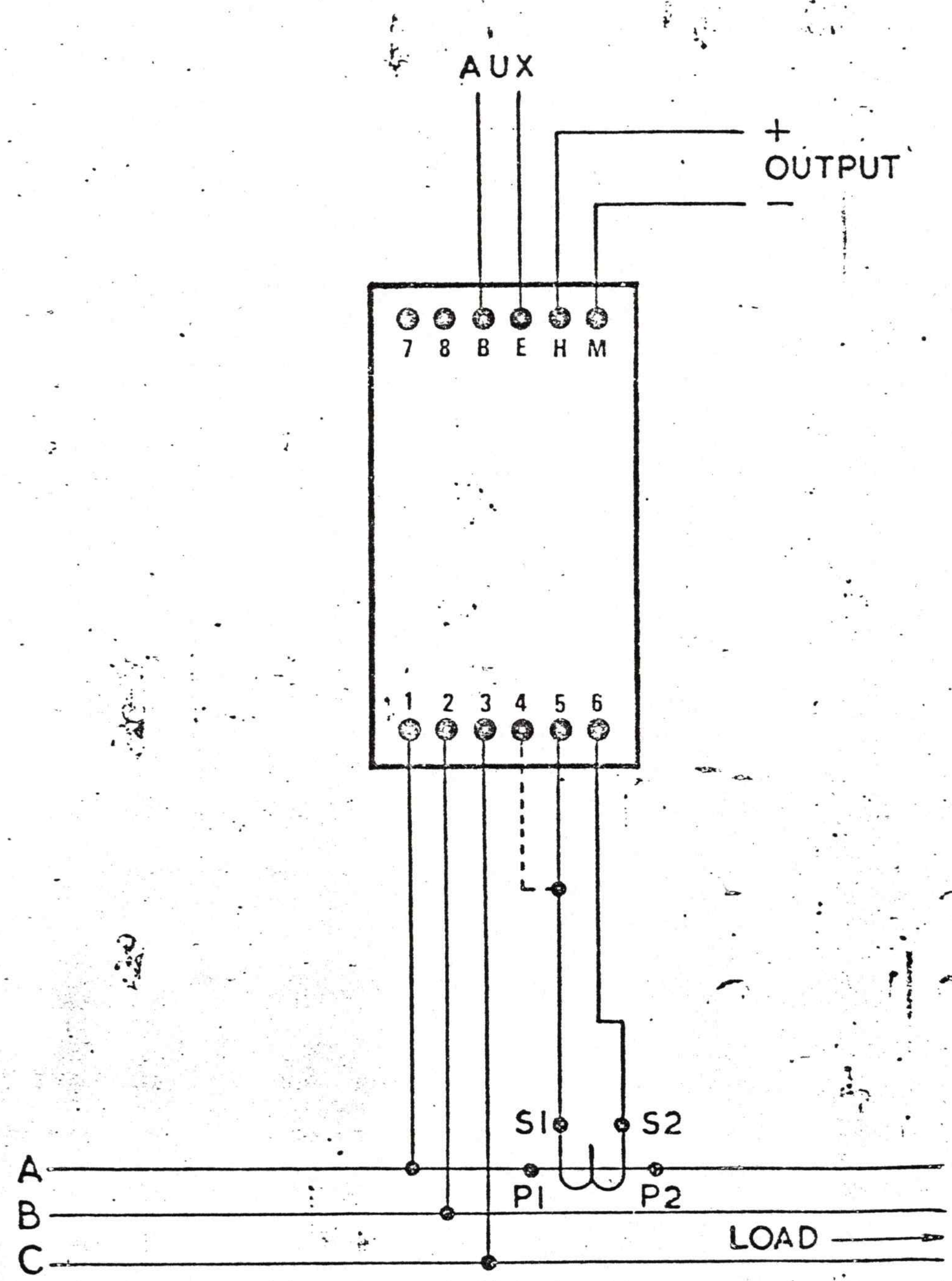
TITLE

EXTERNAL WIRING DIAGRAM ISTAT TRANSDUCER

DEPT.

SCALE

3PHASE 3WIRE BAL.LOAD WATTS OR PHASE ANGLE



NOTE:

ON DOUBLE RANGE TRANSDUCERS

FOR HIGH RANGE CONNECT C.T. AS DRAWN

FOR LOW RANGE CONNECT C.T. TO

TERMINALS 4 & 6

THIRD ANGLE PROJECTION

DIMENSIONS ARE IN mm.

DO NOT SCALE

J/No. CUSTR

DRAWN	A	B	ISTAT WAS MK II
ERJ/JS	ORIGINAL ISSUE		
CHECKED	DATE 11.4.75	16.2.76	

494

GEC Measurements

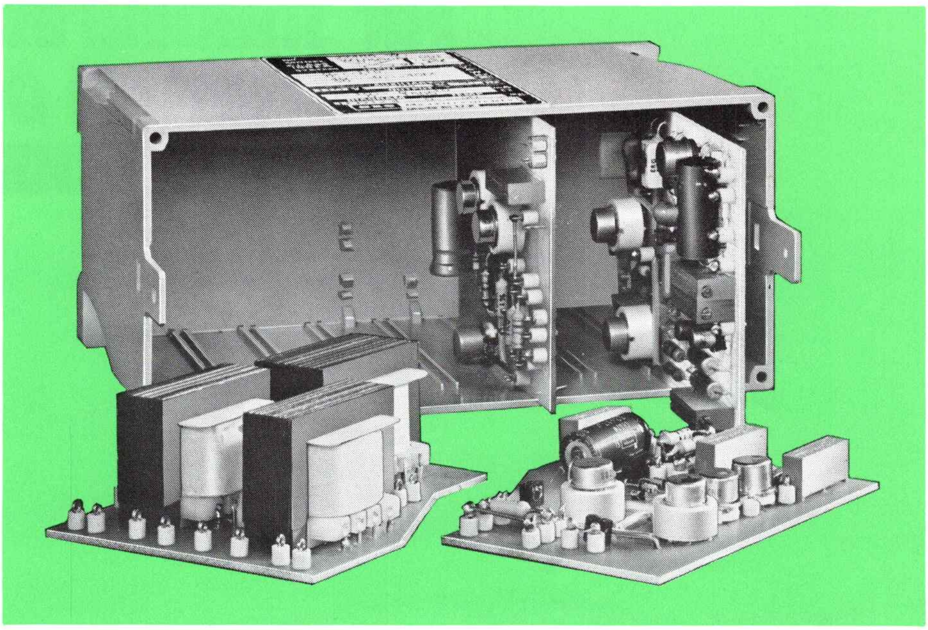
'ISTAT' 200 Transducers

For Measurement and Control of Electrical Quantities

'ISTAT' 200 Transducers

FEATURES

* Advanced static circuit design gives high accuracy
* Wide range of current and voltage outputs meets national and international requirements.
* Programmable conversion ratios on power transducers.
* Housed in moulded flame retardant polycarbonate enclosures for DIN rail mounting.
* Can be mounted singly or in groups.
* Low burdens imposed on measuring transformers.
* Component selection and quality control procedures ensure high reliability factor.



POWER TRANSDUCER CONSTRUCTION

INTRODUCTION

GEC Measurements introduced its first transducer range in 1960. Since then it has been engaged in a continuous programme of improvement and development to satisfy the ever increasing number of applications for the product.
The 'Istat' 200 range is the latest generation of GEC Measurements transducers. It has been designed, both electrically and physically, to meet the technical specifications demanded by national and international markets.
The advanced static circuit design is the result of long experience and accrued knowledge of market requirements.

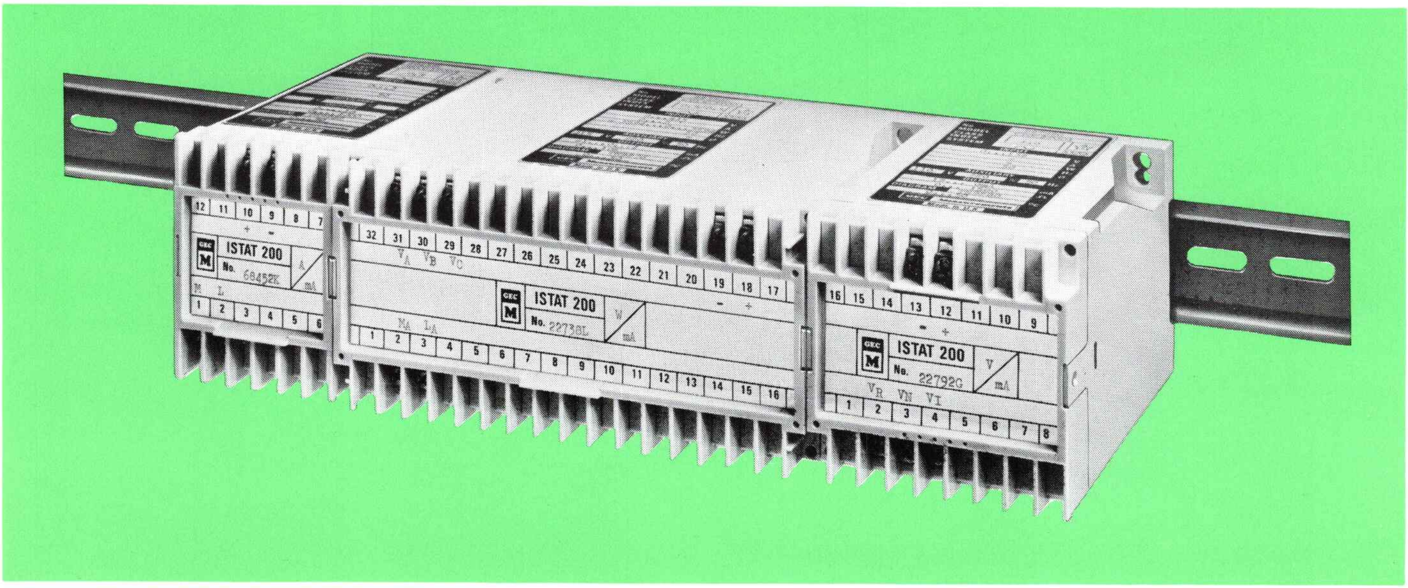
APPLICATION

Transducers now have a very important role in the field of measurement and control. Used in conjunction with conventional moving coil instruments or recorders, these units are convenient for local and remote indication, and can provide reductions in primary installation and operating costs. Modern techniques using microprocessor based central control and indication functions, rely heavily on the use of suitable transducers.
The range offered includes transducers for the following measurements:

* Current (mean sensing or r.m.s.)
* Voltage (mean sensing or r.m.s.)
* Power (active or reactive)
* Phase angle
* Frequency
* Suppressed zero voltage
* Linear inverse voltage (mainly for synchronising applications)

Output quantities

A transducer can be provided with a current output, or alternatively a voltage output. The voltage output is offered for the few applications where the receiving device(s) require a true voltage input and in consequence current is consumed. Transducers with a true current output compensate automatically for variations in total loop



resistance, for example, changes in pilot wire resistance due to temperature changes and/or changes in the receiving equipment. Consequently, transducers with a current output are more commonly used in practise to ensure accuracy of the system up to the specified maximum resistance.

Connections

Transducers are connected to the circuit to be monitored in a similar manner to that of a conventional indicating instrument, that is, either directly or through measuring transformers, depending upon the magnitude of the quantity being measured. The transducers provide a d.c. analogue signal which is proportional to the function of the input being measured. Transducer units can be mounted close to the measured source and the signal can be sent via lightweight pilot cables to a remote point for display purposes or for processing. As shown in Figure 1, the receiving devices can be connected anywhere within the output loop.

Switching and summation of outputs

As shown in Figures 2 and 3, current outputs can be conveniently switched and summated.

The summation application in Figure 3 shows a hypothetical generating unit with three alternators and one transformer to power the auxiliaries. Power measuring transducers (T1 to T4) are connected across each alternator and load. The outputs are connected to provide individual load indications (I1 to I4) locally. These are repeated remotely (I5 to I8).

Total generated power is displayed by I9 which measures the combined outputs of the three generators. Total export power is displayed by I10 since a reverse current flows from transducer T4. Consequently, ten indications have been achieved using four transducers only, together with three pairs of lightweight cables for the output circuits from the transducers.

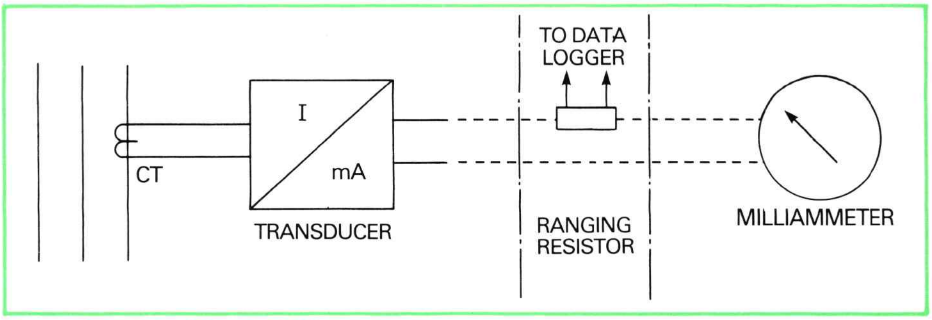


Figure 1 TYPICAL APPLICATION DIAGRAM

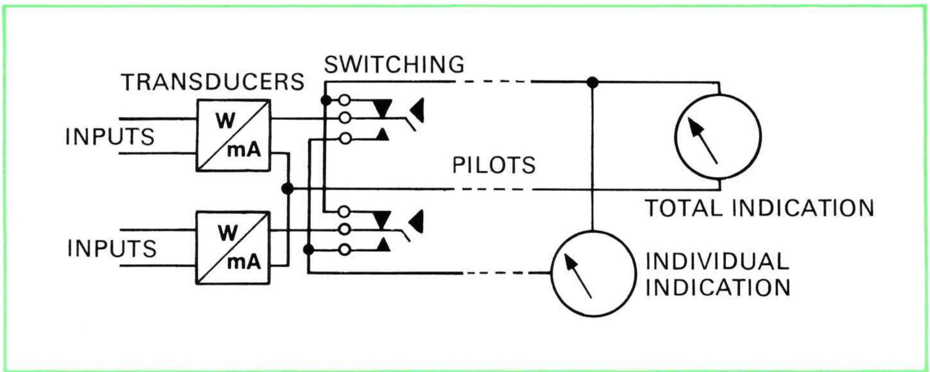


Figure 2 SWITCHING CIRCUIT DIAGRAM

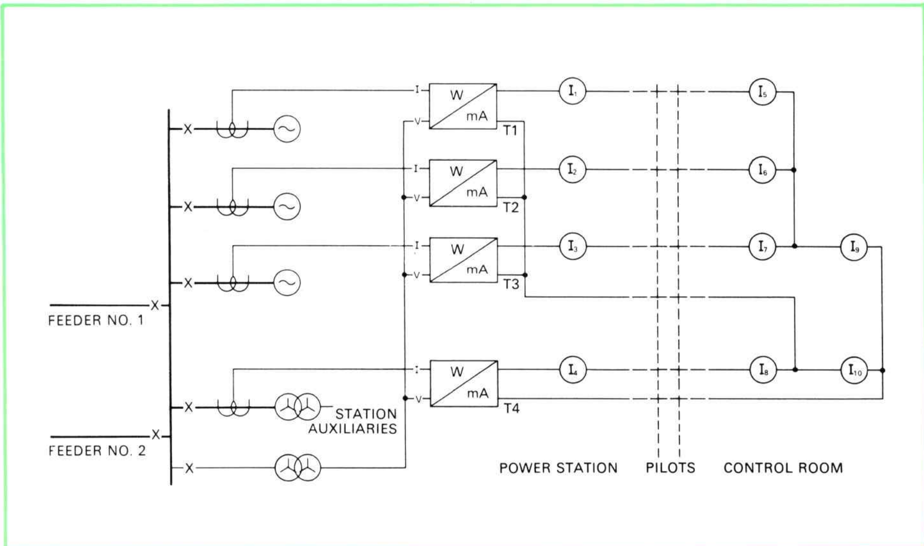


Figure 3 SUMMATION APPLICATION CIRCUIT DIAGRAM

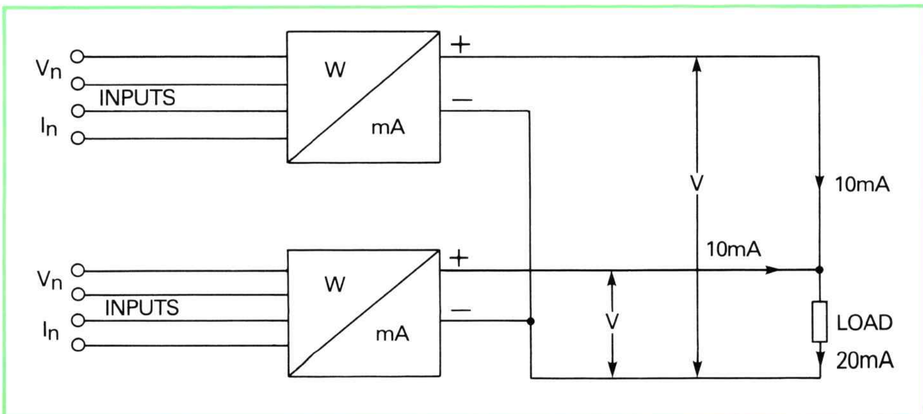


Figure 4 SUMMATED OUTPUTS

When using a number of transducers for summation purposes it should be remembered that these conversion ratios must take into account the individual circuit voltage transformer and current transformer ratios, so that the Watts per mA of output have the same conversion ratio, otherwise the subsequent addition and subtraction will be meaningless. Also that the maximum permissible load across the transducer output terminals (when feeding into a common load) must be reduced by dividing the maximum load resistance by the number of transducers. That is, the compliance voltage remains unchanged for each transducer and the back emf created by the current from the other transducers has to be balanced as shown in Figure 4.
For example:
If the compliance voltage V = 18, the normal maximum load of say 1500 ohms must be reduced to 750 ohms so that the back emf
($750 \times 20 \times 10^{-3} = 15V$) is kept below 18V.

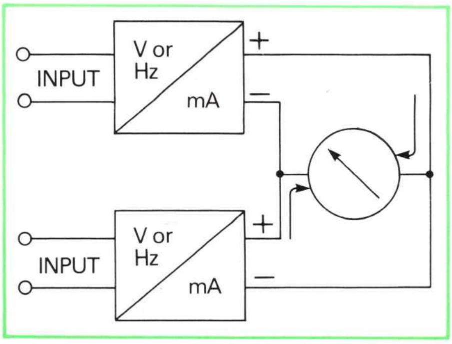


Figure 5 SUMMATED OUTPUTS – VOLTAGE OR FREQUENCY

Differential voltage or frequency

As shown in Figure 5, the difference between two voltage levels or two frequency levels can be obtained by subtraction of the output currents.

Pilot lines

Lightweight Post Office type cables can be used to convey the d.c. analogue output current. The distance between the transducer and receiving equipment is fixed by the operating requirements of the installation and the resistance of the pilots must be included, together with the resistance of the receiving equipment, when calculating the load on each transducer. Figure 6 provides a useful guide to the resistance of cables and shows the transmission distances against loop resistance (forward and return) for various cable sizes.

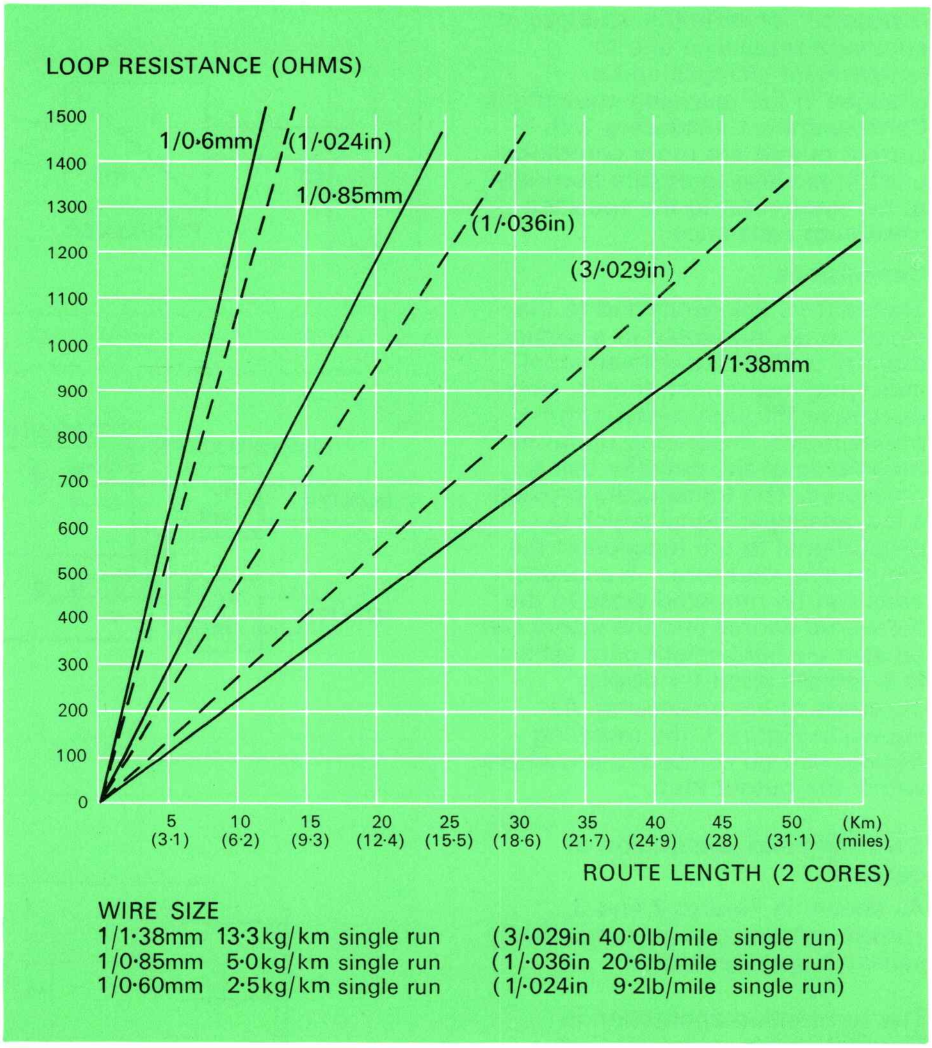


Figure 6 COMPARISON OF STANDARD SIZES – RESISTANCE/TWO CORE ROUTE KILOMETRES

DESCRIPTION

Each transducer provides a high quality d.c. analogue output. The basic measuring elements with outputs 0 . . . 10 mA, (current and voltage), and −1 mA . . . 0 . . . +1 mA, (power), are available together with any one of a range of dedicated amplifiers in the same enclosure. The outputs available from these amplifiers are as follows:

Current outputs

* Bidirectional −1 mA . . . 0 . . . +1 mA to −10 mA . . . 0 . . . +10 mA power and phase angle only
* Unidirectional 0 . . . 1 mA to 0 . . . 20 mA
* Biased: For example 0 . . . 5 mA . . . 10 mA, 4 mA . . . 20 mA

Voltage outputs:

* Bidirectional −1V . . . 0 . . . +1 V to −10V . . . 0 . . . +10 V power and phase angle only
* Unidirectional 0 . . . 1 V to 0 . . . 10 V

Mean sensing current and voltage transducers

These versions are self-powered from the source being measured and since the units require no auxiliary power supply, present an economical way of measuring a.c. current or voltage. The devices are mean sensing, but are calibrated normally in terms of the r.m.s. value of an applied sinewave and provide accurate measurement when presented with good sinusoidal input waveforms.

Mean sensing current transducers

As shown in Figure 7 the input is isolated by a small internal transformer; the output from this is rectified and smoothed. Voltage limitation and protection against transients are provided by zener diodes.

The inputs preferred are 1A or 5A a.c. The circuit provides an output current between 0 . . . 10 mA d.c. at an accuracy of ±0.5% when operating into a load resistance in the range 0 . . . 1000 ohms.

Mean sensing voltage transducers

As shown in Figure 8, the input is isolated by a small internal transformer. The output from this is rectified and smoothed. Because a voltage transformer has a low impedance output, an amplifier is used to provide the transducers with a high impedance current output. Full protection against transients is provided.

A range of preferred input voltages is available from 63.5 V to 415 V. The circuit provides an output in the range 0 . . . 10 mA at an accuracy of ±0.5% of full output into load resistances in the range 0 . . . 1500 ohms.

RMS current and voltage transducers

Within the stated limits of crest factor these transducers provide an accurate d.c. analogue current from the applied input voltage or current. In both current and voltage versions, the input quantity is converted into an a.c. voltage, which is full-wave rectified, and applied to a square law circuit. Although this circuit is non-linear in operation, it provides a d.c. voltage output which is a linear function of the r.m.s. value of the applied input. As shown in Figure 9, the output from the square law circuit is converted to a current signal in the amplifier. This is powered from a separate supply.

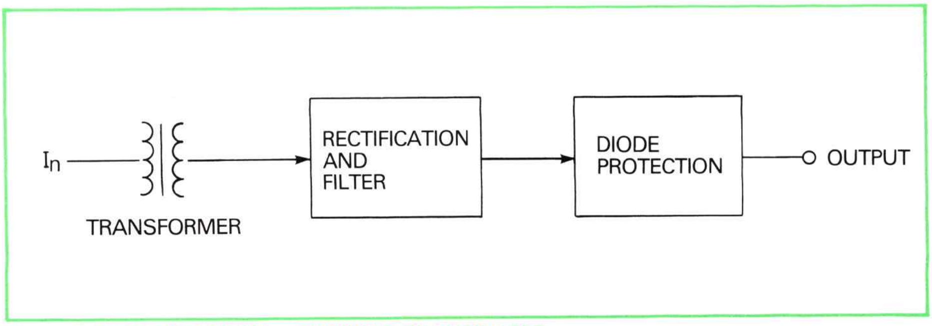


Figure 7 BLOCK DIAGRAM – CURRENT TRANSDUCER

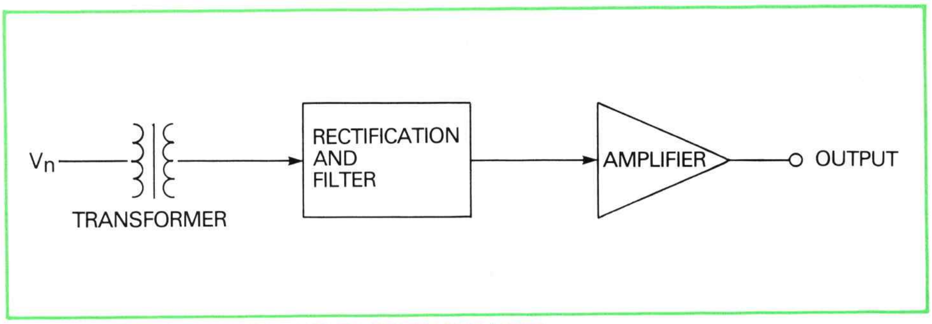


Figure 8 BLOCK DIAGRAM – VOLTAGE TRANSDUCER

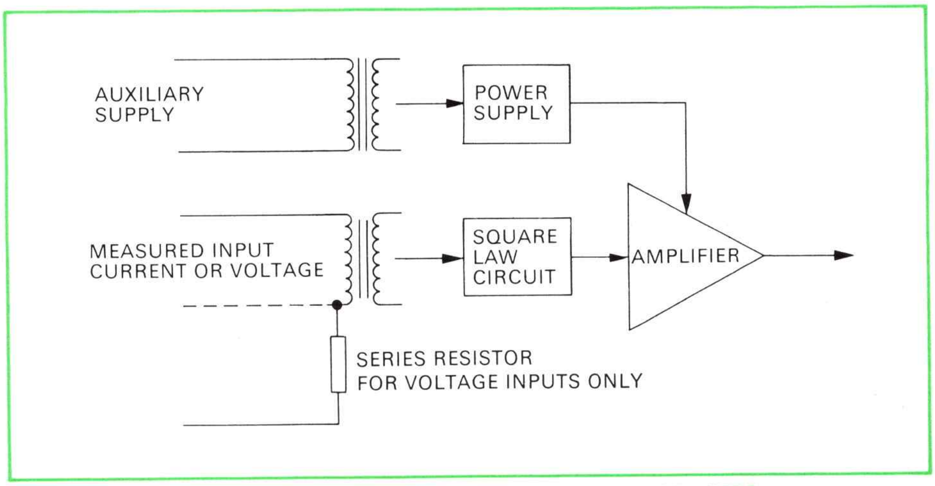


Figure 9 BLOCK DIAGRAM – RMS CURRENT OR VOLTAGE TRANSDUCERS

RMS voltage transducers

These require a separate power supply. Alternatively, power can be taken from the measured voltage source when the rated measurement is within ±20%. Another version is available for connection to a 50 V d.c. (nominal) supply.

RMS current transducers

Two versions are available; each requires a separate power supply:

- for connection to an a.c. auxiliary supply
- for connection to a 50 V d.c. supply (nominal)

Power transducers – Watts and Var

These transducers require an auxiliary power supply, but since the burden is relatively low, this supply can be taken from the measuring voltage transformer if necessary. A single circuit is used for measuring single phase or for balanced load three phase power applications. Two circuits mounted in one housing are used for unbalanced load three phase power applications.
The basic unit provides an output in the range −1...0...+1 mA which can be boosted to −10 mA...0...+10 mA by a dedicated amplifier. The circuit senses true power even when the input waveform is distorted.

As shown in Figure 10 the circuit comprises a power supply, an oscillator, a modulator and an amplifier. The current and voltage components of the input power are used to produce a train of rectangular pulses, each of height proportional to the instantaneous voltage, and width proportional to the instantaneous current. The integral of this signal is proportional to the level of the power being measured. Protection against transient and overload conditions is provided. Links are included for coarse adjustment and potentiometers for fine adjustment of the conversion ratio and calibration to cover a range 70% to 200% of the nominal input. These adjusters are accessible through holes in the top plate and are included specifically for users who have in-house calibration facilities. A wide range of applications is covered by this single device.

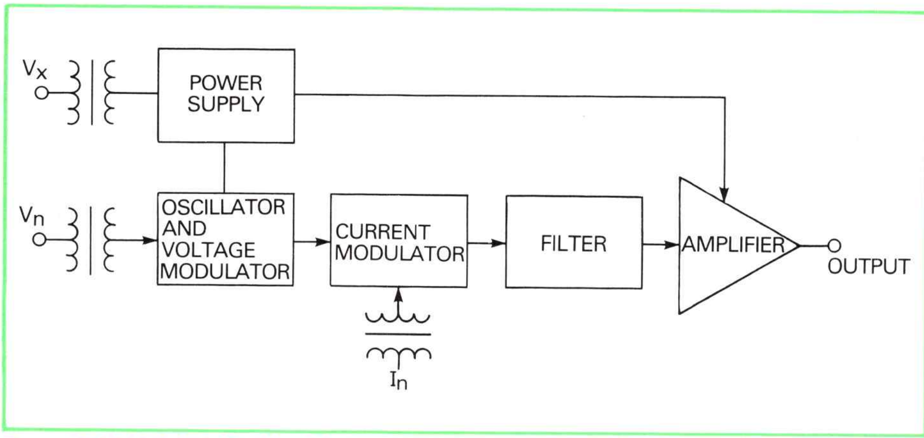


Figure 10 BLOCK DIAGRAM – POWER TRANSDUCER

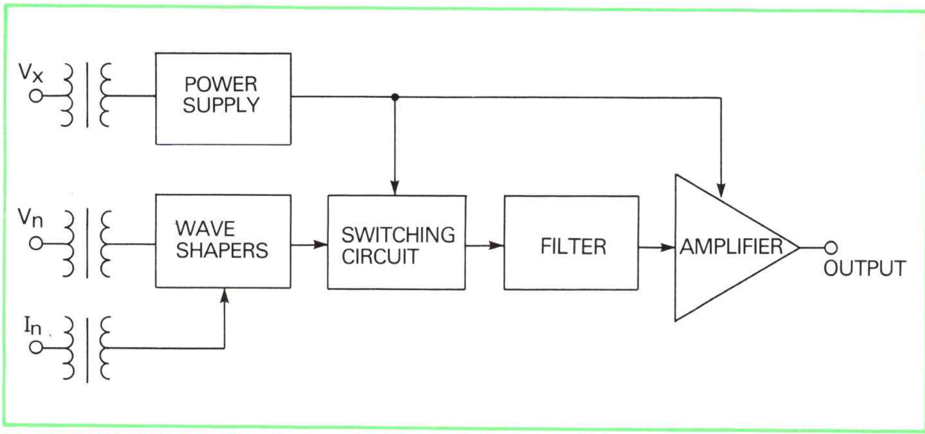


Figure 11 BLOCK DIAGRAM – PHASE ANGLE TRANSDUCER

Phase angle transducers

These transducers require an auxiliary power supply and offer a highly accurate method of measuring the phase angle of the supply. They have a full four quadrant capability. The circuit presents a low burden to the auxiliary supply and low burden for the measured inputs. Although the output is a linear function of the phase angle between the two inputs (which can be current or voltage), the transducers can also be used to display power factor on an appropriately scaled indicator.

The basic circuit provides an output in the range −1 mA...0...+1 mA, but this level can be boosted to an output in the range −10 mA...0...+10 mA by the addition of a dedicated amplifier as shown in Figure 11. This amplifier is mounted within the unit enclosure.

The circuit shown in Figure 11 has internal transformers which feed the current and voltage inputs into a bistable element. Consequently, the output changes state when the inputs pass through zero. The signal from the bistable element is integrated and the resultant d.c. voltage is fed to the output amplifier. Transducers for monitoring phase angles in the range 0...±60° and 0...±180° are available.
To give the stated accuracy, phase angle transducers should be used on waveforms of current and voltage which have identical harmonic content only.

Frequency transducers

These transducers are self-powered in the sense that they measure the frequency of the input to the power supply. A range of input frequencies between 45Hz and 65 Hz can be monitored.
Electrical suppression is provided so that zero output represents the lower end of the input frequency range. The circuit provides an output in the range 0...1 mA to 0...10 mA.

A block diagram of the unit shown in Figure 12 is based on a precision monostable circuit triggered by zero crossings of the input supply voltage. This is followed by an integrator circuit and a current feedback amplifier.

Suppressed zero voltage transducers

As shown in the block diagram Figure 13, these transducers provide a suppressed zero output which permits accurate monitoring over a critical portion of the maximum voltage input on an appropriately scaled indicator.
Used with a negatively biased amplifier, the transducers give a range of suppression rates, and a powerful high impedance output. The accuracy is expressed as a percentage of the output span.

After rectification and smoothing the measured voltage input is held in a negative state by the bias stage until it reaches a value equal to the bias level. Further increases of measured input result in a positive input to the amplifier. Consequently this provides a true current output which is proportional to the measured input voltage.
The output curves shown in Figure 14 correspond to the upper and lower limits of input voltage measurement. Transducers with a linear current output can be supplied for any requirement within the range ±33% and ±10% of rated input voltage.

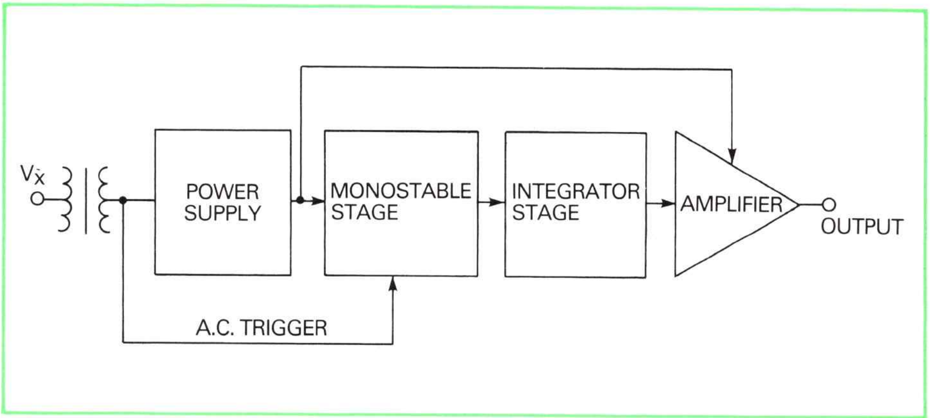


Figure 12 BLOCK DIAGRAM – FREQUENCY TRANSDUCER

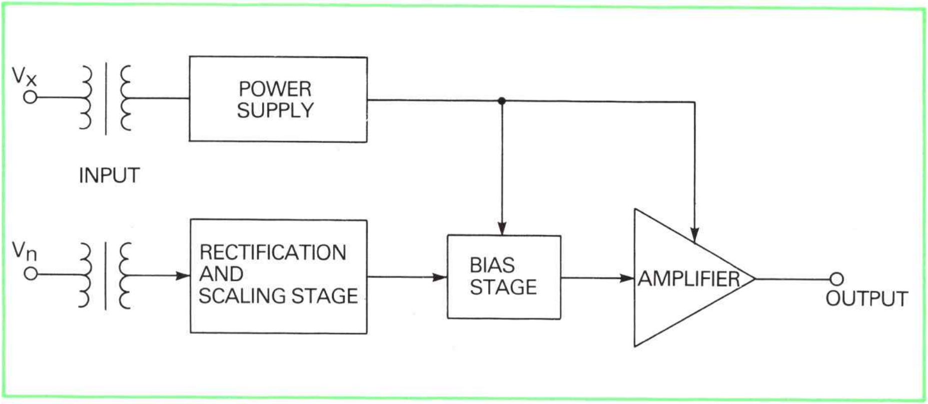


Figure 13 BLOCK DIAGRAM – SUPPRESSED ZERO TRANSDUCER

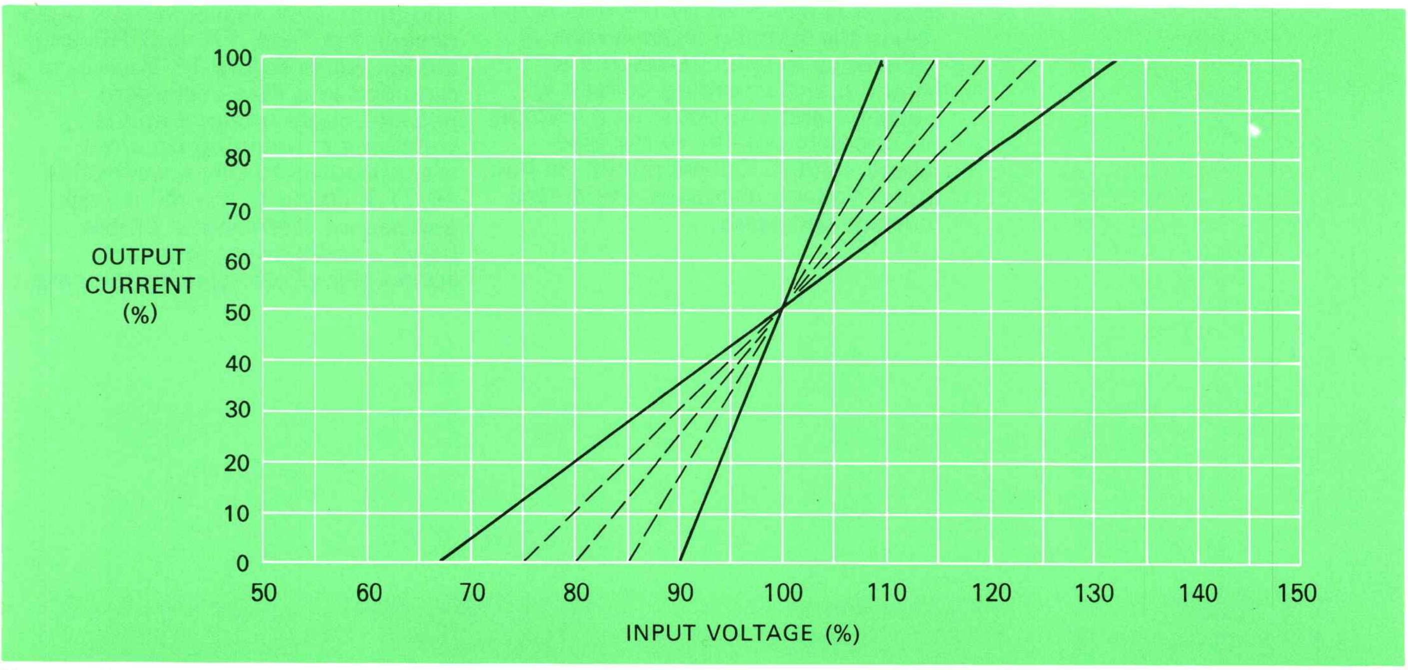


Figure 14 SUPPRESSION CAPABILITY

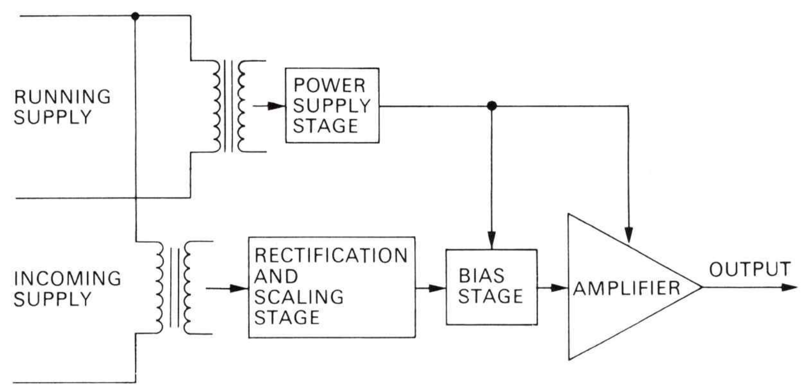


Figure 15 BLOCK DIAGRAM – LINEAR INVERSE VOLTAGE TRANSDUCER

Linear inverse voltage transducers

These special transducers provide maximum output at zero input and zero output at full scale input. These are used where the frequency and voltage of a generator output must be synchronised with the supply levels already in operation before final connection is made. The transducer provides 100% output only when the running and incoming voltages are equal both in magnitude and in phase. The inverse output is a safety feature which prevents wrong synchronisation if a fault develops in the measuring equipment.

As shown in Figure 15 a power supply stage fed from the running input energises the bias stage and the output amplifier. Full scale output is achieved by the bias stage when the running input is zero. A difference in level between the running and incoming voltage is rectified and presented as a voltage of opposite polarity to the bias stage voltage. Consequently, as the input voltage increases, the output current decreases.

CONSTRUCTION

The method employed is based on a series of measuring circuit boards each of a specific measured quantity. These boards can be accommodated alongside a dedicated amplifier on a separate circuit board. The user is thereby offered an extended range of options which is flexible in meeting individual requirements.

For high density applications where large numbers of transducers are to be assembled in one location, considerable space saving can be achieved by housing more than one measuring circuit board in one enclosure.

CASES

The three sizes available have been designated T150, T75 and T55 and are shown in Figure 16. Each case is moulded in a flame retardant polycarbonate material and is suitable for mounting on a rail manufactured to DIN specification 46277.3. Fixing to the rail is easy and secure. Removal is simple using a screwdriver to lever a spring clip which releases the case.

TECHNICAL SPECIFICATION

Output

Parameter	Unit	TRANSDUCERS Voltage	Supressed zero voltage	Linear inverse voltage	Current	Power	Power plus amplifier	RMS voltage	RMS current	Phase angle	Frequency
Accuracy	±%	0.5	1.0†	1.0	0.5	0.5	0.5	0.5	0.5	2.0**	0.5
Accuracy range	%	40...120	0...100	0...120	0...120	0...120	0...120	0...120	0...120	0...100	0...100
Impedance	M ohms	1.5	1.0	1.0	1.0	10	1.0	1.0	1.0	10	1.0
Voltage (O/C)	V	25	25	25	20	25	25	25	25	25	25
Current ⊕	mA	0...10	0...10	0...10	0...10	0...1	0...10	0...10	0...10	0...1	0...10
Output load	k ohms	0...1.5	0...1.5	0...1.5	0...1	0...10	0...1.5	0...1.5	0...1.5	0...10	0...1
Open circuit		All transducers. No damage.									

Auxiliary supply

Voltage Vx	V	–	63.5 to 415	63.5 to 415	–	63.5 to 415	63.5 to 415	63.5 to 415	63.5 to 415	63.6 to 415	–
Voltage range	±%	–	20	20	–	20	20	20	20	20	–
Frequency range	Hz	–	45...65	45...65	–	45...65	45...65	45...65	45...65	45...65	–
Burden: 1 element	VA	–	1.5	2.0	–	1.5	3.0	2.0	2.0	1.5	–
2 elements	VA	–	–	–	–	2.0	3.5	–	–	–	–

Input

Voltage Vn	V	63.5 to 415	63.5 to 415	63.5 to 415	–	63.5 to 415	63.5 to 415	63.5 to 415	–	63.5 to 415	63.5 to 415
Voltage range	%	0...120	±10...±33	0...120	–	0...120	0...120	20...120	–	60...120	60...120
Current In	A	–	–	–	1 or 5	1 or 5	1 or 5	–	1 or 5	1 or 5	–
Current range	%	–	–	–	0...120	0...120	0...120	–	20 to 120	20 to 120	–
Burden: Voltage circuit	VA	1.0	1.0	0.3	–	0.15	0.15	0.6	–	0.15	1.5
Current circuit	VA	–	–	–	1.5	0.2	0.2	–	0.6	0.2	–
Phase angle range	Degrees	–	–	–	–	360	360	–	–	0–180°	–
Frequency range	Hz	40...440	40...440	40...440	40...440	45...65	45...65	45...65	45...65	45...65	45...55 55...65 and 360...440

Temperature

Reference range	°C	0...50	0...40	0...50	0...50	0...50	0...50	0...50	0...50	0...50	0...50
Nominal range of use	°C	−10...60	−10...50	−10...60	−10...60	−10...60	−10...60	−10...60	−10...60	−10...60	−10...60

Miscellaneous data

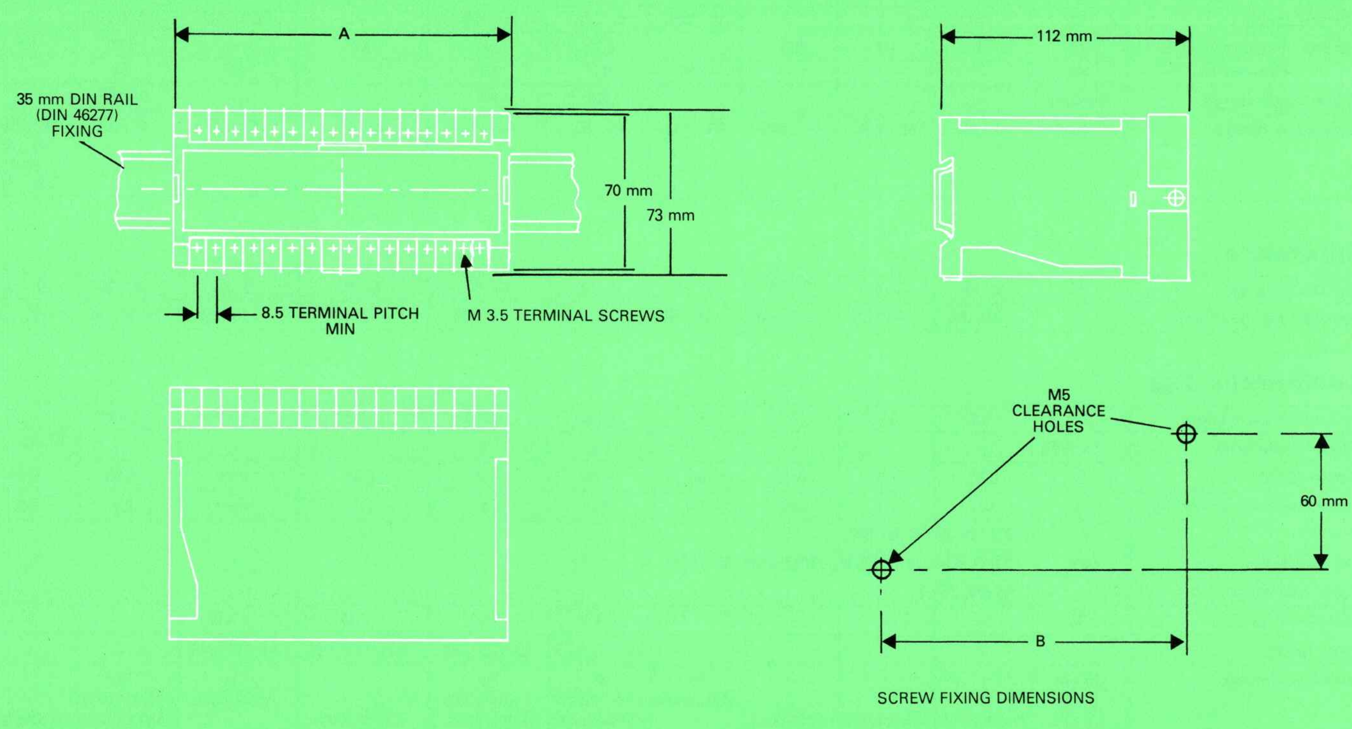
Frequency coefficient	% per Hz	±0.05	±0.05†	±0.05	±0.01	±0.05	±0.05	±0.05	±0.05	±0.05	–
Phase angle error	±% (90°)	–	–	–	–	0.5	0.5	–	–	–	–
Ripple (rms)‡	%	0.35	1.0	0.35	0.5	0.35	0.35	0.35	0.35	0.35	0.35
Response time (0–99%)	s	0.5	0.5	0.5	1.0	0.5	0.5	0.5	0.5	0.5	2.0
Isolation	kV	2.0 rms 50 Hz for 60s									
Impulse test	kV	5.0 (1.2/50μs) to BS923 (1972) and IEC 255-4									
Surge withstand		to IEC 255-4									
Waveform error	%	–	–	–	–	±1.0	±1.0	±1.0	±1.0	–	–
Crest factor		–	–	–	–	1.2<CF<1.8	1.2<CF<1.8	1.2<CF<1.8	1.2<CF<1.8	–	–
Overload ratings	20×In	–	–	–	3s	3s	3s	–	3s	3s	–
	2×In	–	–	–	continuous	continuous	continuous	–	continuous	–	–
	1.2×Vn	continuous	continuous	continuous	–	continuous	continuous	continuous	–	continuous	continuous
	1.5×Vn	10s	10s	10s	–	10s	10s	10s	–	10s	10s

*See text
†The SZV transducer is available with any range from ±10% to ±33% of nominal voltage. The accuracy class and other parameters depend on the range chosen.
‡0.35% rms is equivalent to 1% peak-to-peak (assuming a sinewave).
**Accuracy is stated in degrees.
⊕See text for other options available.

INFORMATION REQUIRED WITH ORDER

Details of:	Current	Voltage	Linear inverse voltage	Suppressed zero voltage	Watts and vars	RMS voltage	RMS current	Phase angle	Frequency
Auxiliary supply voltage (Vx) and frequency	†	†	*	*	*	*	*	*	*
Bi-directional					*			*	
Uni-directional or biased output		*	*	*	*	*	*	*	*
Current transformer ratios	*				*		*	*	
Voltage transformer ratios		*	*	*	*	*		*	
Output conversion ratio. Measured quantity to mA (or V)	*	*	*	*	*	*	*	*	*
Adverse site conditions	*	*	*	*	*	*	*	*	*
System (for example: 3 phase 3 wire balanced)					*			*	
Load resistance	*	*	*	*	*	*	*	*	*
Values of Vn and/or In	*	*	*	*	*	*	*	*	
Values of output voltage or current (Vo or Io)	*	*	*	*	*	*	*	*	*

†Vx is necessary if the output is other than 10 mA



NOTES

1. Type T55 cases do not have fixing holes. A short length of rail or an adaptor plate can be used.
2. Terminal screws are M3.5.
   Unused terminal positions are blanked-off.
3. Washers on terminal screws are captive.

Cases Type	A mm	B mm	Weight kg
T150	150	135	0.59
T75	75	60	0.30
T55	55	—	0.25

Figure 16 CASE OUTLINE AND FIXING DETAILS

PRECISION D.C. MILLIAMP SOURCE

Output

Current (mA)	1	5	10	20
Load resistance (k ohms)	0...10	0...2	0...1	0...0.5

Application

The precision milliamp source simulates the preferred outputs from all transducers offered, and has been designed as a test and maintenance aid for the complete range.
It also has many uses in laboratories and in industry. It is particularly useful for tests on the expanding range of modern equipment which employ static component circuitry.
The unit is one of the very few devices available which offers a true current output. This can be used for accurate calibration of an indication instrument or for equipment in a complete control loop operated by an input from a current source such as a transducer.
A self-contained device, the precision milliamp source obviates the need to locate and connect a separate electrical supply for tests, and because the settings are both accurate and stable, it reduces the maintenance labour requirements by allowing the operator to work unaided. Since the output current is established in 1 ms, the device is extremely useful for response time measurements. Output current levels are provided with an intermediate 'off' position, so that each output level can be switched on or off without the need to traverse other positions.

Operation

A precision reference diode provides a stable voltage which is fed to the amplifier via a 10 turn setting potentiometer, as shown in Figures 17 and 18. This has a clear digital dial with a setting lock, and is adjusted to read the required percentage of the range switch setting value.
The four range output selector can be set to introduce one of four matched resistors. This provides a calibrated feedback to the amplifier.
Powered by three internally mounted batteries in series, the power supply operates at 27V with new batteries until an expiry level of approximately 19V is reached. A light emitting diode (LED) acts both as an operation indicator, and as a battery state indicator. Full brilliance is apparent with new batteries, and this diminishes as the available voltage decreases.

The device is accurate until the light is completely extinguished.

Performance details

Adjustment range: 0–100%
Resolution: 0.1%
Accuracy: ±0.3% of full output
Temperature range: 0°C to 40°C
Temperature co-efficient: ±0.03% per °C
Output rise time: 1.0 ms
Supply: 3×PP7 batteries
Battery life: 40 hours at 2 hours per day

Dimensions

120×170×85 mm

Weight

1.25 kg

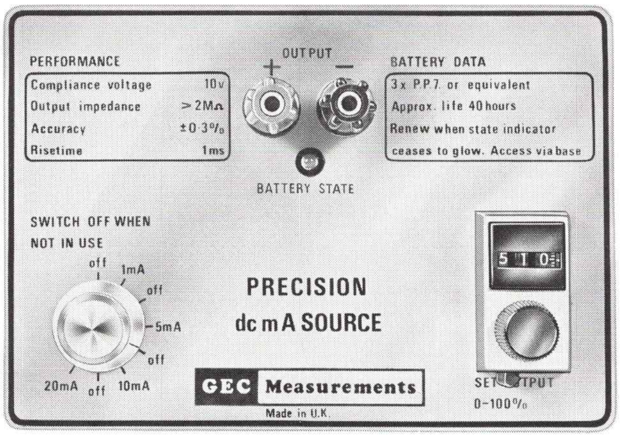


Figure 17 PRECISION D.C. MILLIAMP SOURCE

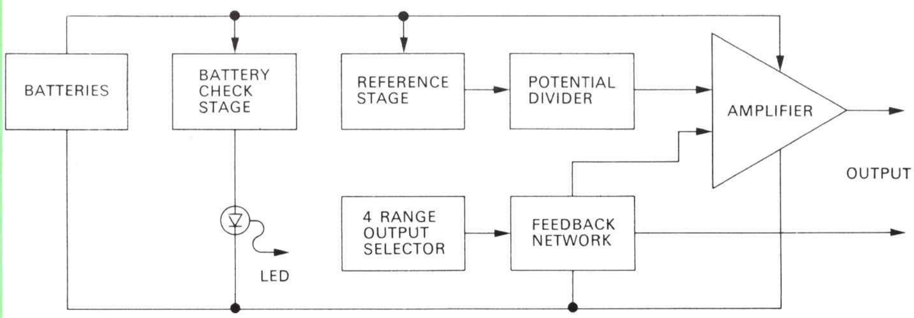


Figure 18 BLOCK DIAGRAM – PRECISION D.C. MILLIAMP SOURCE

GEC Measurements The General Electric Company Limited of England

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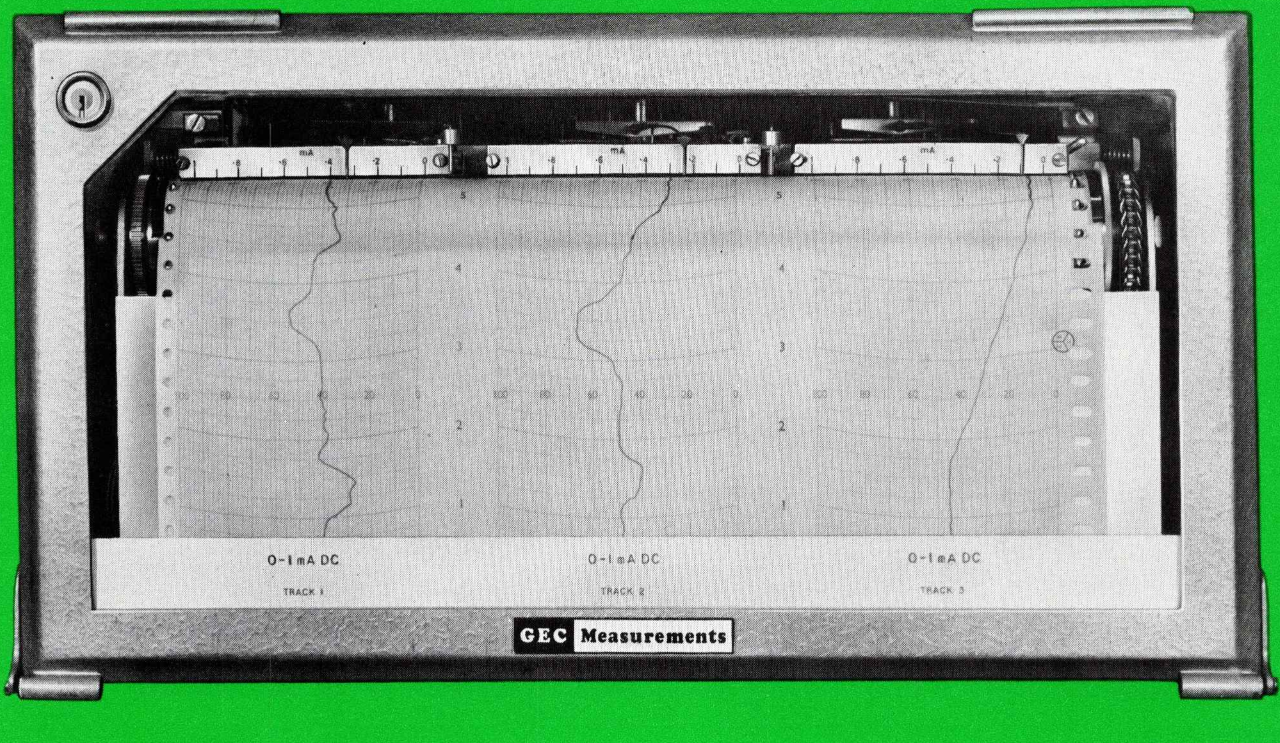
GEC Measurements

Moving Coil Recorders

Single and Multi Channel Models 400, 600, 900, 1200 Series A & B



Models 400, 600, 900, 1200, Series A&B

FEATURES

* Continuous line recording
* Rugged, high torque movement
* Multi-channel recording on one chart
* Range of accessories available

A simple but robust design has provided a moving coil recorder without complicated operating linkages.
The basic equipment has been proved over many years of trouble free service to require negligible maintenance often limited to chart and ink replacement only.

In many instances, the low burden permits direct connection of the recorder, but where an application requires measurement of electrical quantities such as power, current, voltage, or frequency, an associated range of transducers and amplifiers are available. These cover a wide range of inputs compatible with many process transmitters, and are eminently suitable for recording non-electrical quantities such as pressure, temperature, load or flow rate.

For alarm purposes, dual vigilarm units are available from the GEC Measurements 'Istat' range. Full details are available in publication I4-G21.

CASE

Mounting

* All models are available in flush switchboard mounting cases.
* Model 400 (single channel) is available as a portable laboratory instrument.
* Feet can be provided for two to four channel recorders to make these free standing.
* A frame can be supplied for wall mounting (model 400 only).

Bezel finish:

Standard: Silver grey hammertone with high corrosion resistance.
Non-standard: Colours to BS.381C and BS.2660.

* A gasket is provided between case and door which results in an effective dust seal.
* A lock is provided as standard.

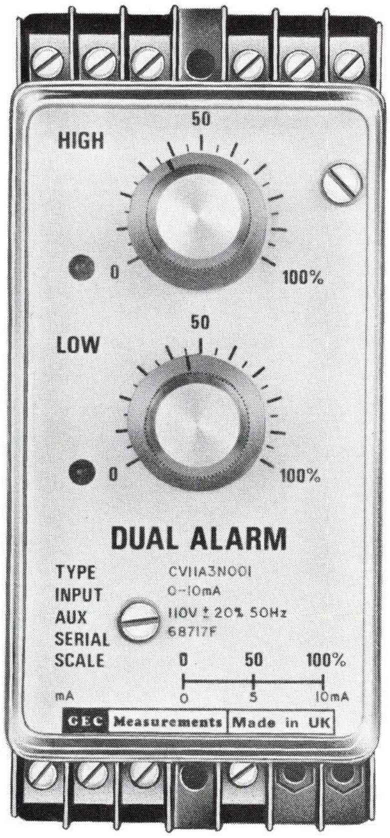


Figure 1 DUAL VIGILARM UNIT

Speed group	1	2	3	4	5	6	Change wheel data		
Motor r.p.m.	1	2	4	60	4	10			
Motor drawings number	ZB9033 –016	ZB9033 –017	ZB9033 –018	ZB9033 –020	ZB9033 –018	ZB9033 –019			
Chart speed	mm/hour			mm/minute			Number of teeth	'A' gear driver	'B' gear driven
Preferred speed group is detailed in column 2 (green). Preferred speed is outlined in column 2. Dual speeds can be selected by reference horizontally across columns 1 to 4, or alternatively by reference horizontally across columns 5 and 6.	9.65	19.05	38.1	9.65	25.4	63.5	16 64	TR5002 001	TR5002 009
	12.7	25.4	50.8	12.7	33.78	84.58	24 72	TR5002 003	TR5002 013
	19.05	38.1	76.2	19.05	50.8	127	32 64	TR5002 010	TR5002 012
	25.4	50.8	101.6	25.4	67.81	169.4	32 48	TR5002 006	TR5002 007
	38.1	76.2	152.4	38.1	101.6	254	48 48	TR5002 011	TR5002 011
	57.15	114.3	228.6	57.15	152.4	381	48 32	TR5002 007	TR5002 006
	63.5	127	254	63.5	169.41	423.4	50 30	TR5002 008	TR5002 005
	76.2	152.4	304.8	76.2	203.2	508	64 32	TR5002 012	TR5002 010
	114.3	225.6	457.2	114.3	304.8	762	72 24	TR5002 013	TR5002 003
	127	254	508	127	342.9	846.6	50 15	TR5002 004	TR5002 002
	152.4	304.8	609.6	152.4	406.4	1,016	64 16	TR5002 009	TR5002 001

Table 1 CHART AND MOTOR SPEEDS

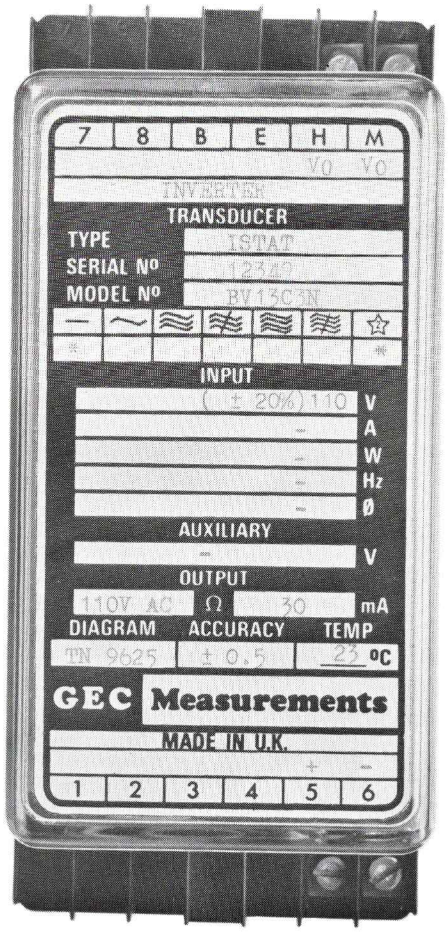


Figure 2 DC/AC INVERTER TYPE BV13C

AUXILIARY POWER SUPPLY

A d.c./a.c. inverter, type BV13C, has been specially designed to facilitate an alternative power source from auxiliary batteries for the chart drive motor within a moving coil recorder. When a mains power supply failure occurs, the inverter is brought into operation automatically by an auxiliary supply supervision relay. Recorders are often required to have some ancillary form of chart drive which can be brought into operation for emergencies. For example, in some instances a separate low voltage d.c. motor has been employed. Whichever system is used, the ancillary drive must be capable of maintaining the operational accuracy over an extended period, so that the recorded information is up to date, and the recorder shows the correct time when the mains supply is resumed.
The importance of sustained accuracy is most appreciated in terms of the time spent in resetting a large number of recorders after a power failure, especially if the recorders are dispersed over a wide working area.

The inverter is used in conjunction with a separate type VAA relay which initiates an instantaneous switchover when the mains supply fails.
Once started, the chart drive motor will operate at an accuracy within 0.5% for an extended period, until the auxiliary battery voltage falls to 60% of the rated voltage. This feature is most significant during a long power failure, when sustained demands reduce the battery operating potential to a level which is capable of continuous supply for low loads only.

CASE

The inverter is housed in a modern two-part moulded plastic case made from high impact, flame retardant polycarbonate material. The base and terminal covers are opaque black, and the main cover is transparent.

MOUNTING

The unit may be mounted in any position, in any dry location which is within the ambient temperature range stated.

TECHNICAL INFORMATION

Ambient temperature range:	−10°C to +55°C
Input burden at 110V d.c. (with motor at 5VA connected to output):	7VA
Input voltage range:	110V d.c. nominal ±20%
Minimum starting voltage:	85V d.c.
Minimum running voltage:	65V d.c.
Output frequency:	50Hz ± 0.5%
Chart drive accuracy (above 60% rated battery voltage):	± 0.5%

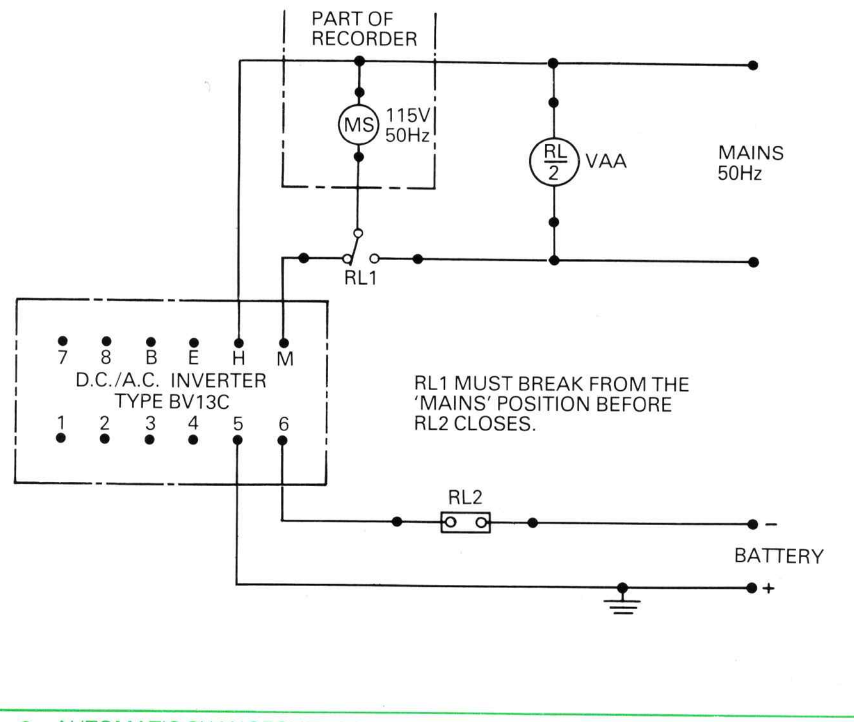


Figure 3 AUTOMATIC CHANGEOVER SCHEME

OVERALL DIMENSIONS

Model	Channels	A	B	C*	D	Weight (max)	
		mm	mm	mm	mm	lb	kg
400	1	192.0	216	303.2	400.0	40.0	18.2
600	2	294.4	216	277.8	400.0	65.0	29.5
900	3	396.0	216	277.8	400.0	95.0	43.1
1200	4	497.6	216	277.8	400.0	125.0	56.7

*Standard case length (Series B recorders). In some instances, case length D may be required (Series A recorders).

The type A recorder comprises a complete type B equipment plus an extension unit fitted to the rear of the recorder. This is utilised to accommodate extra components when additional facilities are required.

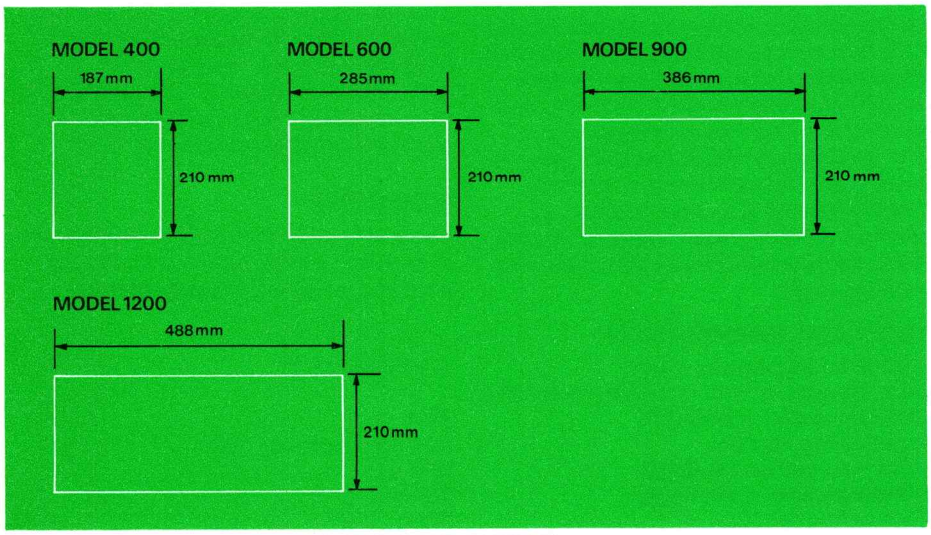


Figure 4 PANEL CUT-OUT – FLUSH MOUNTED PATTERN

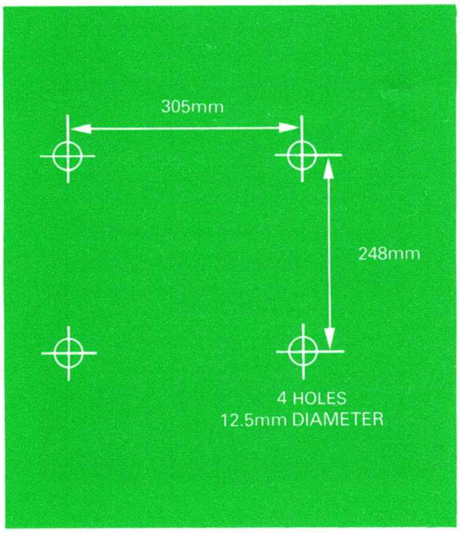


Figure 5 HOLE FIXING CENTRES – PROJECTION MOUNTED PATTERN

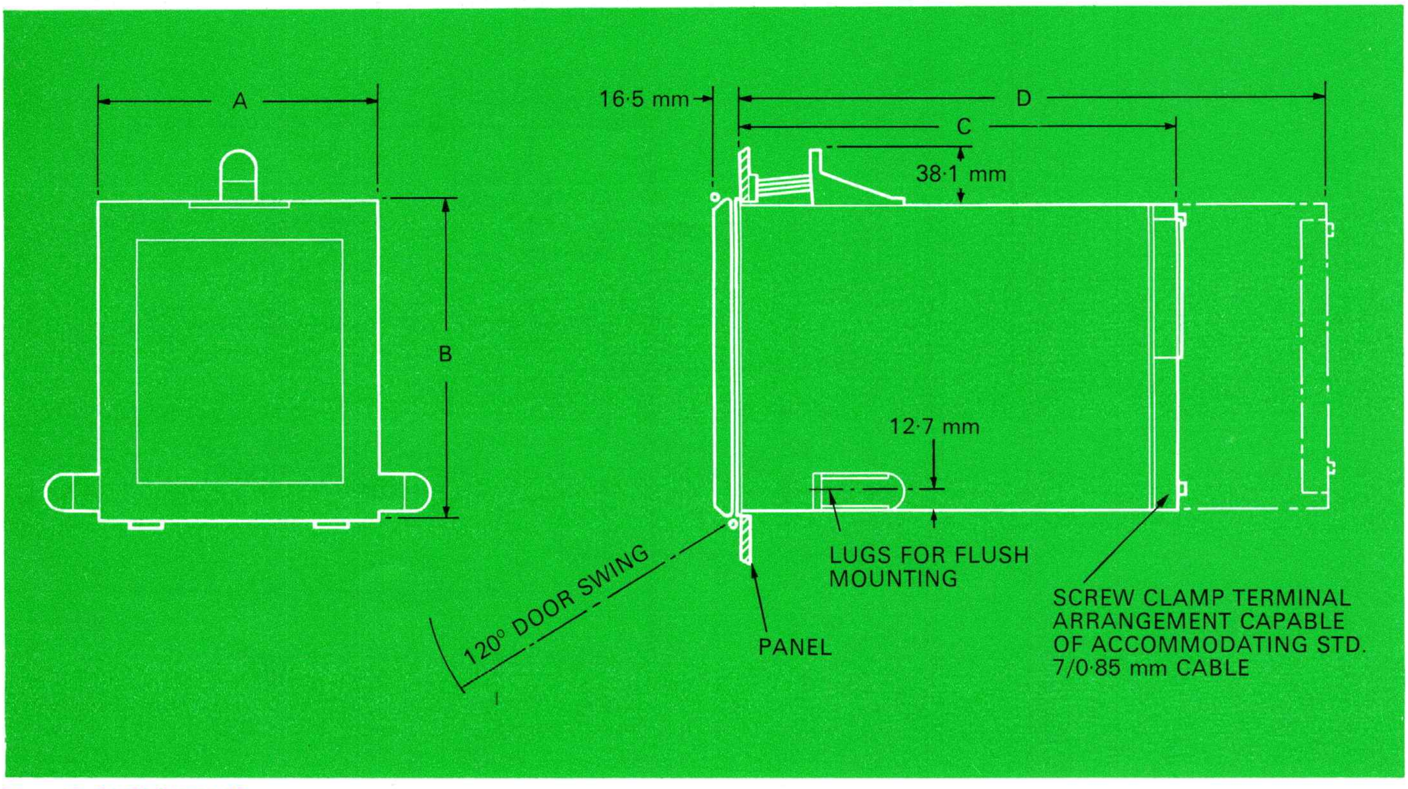


Figure 6 CASE OUTLINE

TECHNICAL INFORMATION

A large self-shielding permanent magnet is employed in the moving coil movement. The method effectively overcomes the pen to paper friction without the use of amplifiers or the consequent increase in burden. A typical input resistance level is 880 ohms at a sensitivity of 1 mA d.c.

D.C. Ranges	A.C. Ranges
0.3 mA to 20A	1A to 50A
75 mV to 750V	10V to 750V

Accuracy – Class index 2.5

Within the limits laid down in BS.90 for current or voltage a.c. or d.c.

When the recorder is used in association with shunts, transformers or transducers, the overall accuracy will be the sum of the combined accuracies.

Standard response time (excluding transducers)

0.5 sec approximately from zero to 98% of full scale when fed from a high impedance signal source. A faster response time of approximately 0.25 seconds is available on request.

Insulation test

2kV rms between case and terminals.

Chart drives

Synchronous Motor
Preferred voltages 110V or 240V a.c. (other voltages via external V.T. on request)
Frequency 50 Hz or 60 Hz.
Dual voltage range 110V or 240V a.c.
Dual frequency range 50 Hz or 60 Hz.

Double speed chart drives

As an alternative version, the recorder is available with two synchronous motors. These provide two chart speeds which can be controlled by a remotely mounted switch. The speed options are shown in Table 1 columns 1-4 or 5 and 6.

Standard chart speed

The preferred standard chart speed for a steady load current, voltage or frequency is 25.4mm/hour. In selecting chart speeds, consideration should be given to the nature of the quantity to be measured. Where rapid fluctuations are encountered, these will be more easily distinguished on a chart driven at higher speeds.

Speed changing

Both the motor gearing and the chart drive gearing can be changed to give a wide range of speeds. Table 1 gives details of change wheels for a wide range of chart speeds.

Charts

Standard number of lines per channel: 40, 50, 60 and 75.
Chart length: 19.8m
Operational chart width
Model 400, 101.6mm
All other models: 76.2mm.
Because of the high cost of producing special charts, scaling and sensitivity requirements will be rounded up to enable the next highest standard scale to be used.
Thus: 0-5V d.c. scaled 8500kg, will be supplied 0-5.88 volts scaled 0-10.000kg (8500kg – 5 volts).
Further details on charts supplied on request.

Pen and inking system

The pen employs a reliable capillary tube assembly. This is a simple arrangement and ensures a high quality trace under most climatic conditions. Capillary action alone feeds the ink to the writing point, which is always above the ink level. There is thus no risk of flooding even when the chart is stationary.

Grade C – Recommended standard ink for general applications.
A – Easy flow – for special slow speed applications.
B – Tropical – for ambient temperatures 30°C - 35°C.
Q – Quick drying – for high speed applications.

Event pens

Available for use on 10V a.c., 50 and 60 Hz supplies (external transformer for 240V or 110V applications). The pens are situated such that they produce a continuous trace between the charts (or to the right hand side in the case of the model 400). The event produces a 1mm step in the trace.

Model 400 – 1 pen
600 – Maximum of 2 pens
900 – Maximum of 4 pens
1200 – Maximum of 6 pens

Internal fluorescent strip lighting

Preferred voltages 110V or 240V a.c.
Frequency 50Hz or 60Hz.
On models 400 and 600 (dual speed) recorders, the choke and starter switch are mounted externally.

Electronic suppression

Preferred voltages	Preferred recorder span
110V a.c.	90-130V
240V a.c.	210-270V
415V a.c.	380-460V

Other a.c. and d.c. voltage ranges on request.

Mechanical suppression

Up to 30% mechanical suppression can be provided on a.c. or d.c. voltages or currents.
Ranges 4-20mA d.c. or 10-50mA d.c.

Overriding electronic alarms

Dual Vigilarm units from the 'ISTAT' range are available with two pre-set points for alarm purposes. Details are available in publication I6-001.

INFORMATION REQUIRED WITH ORDER

1. Model number and pattern.
2. Case finish.
3. Number of channels and signals to be recorded.
4. Chart speed.
5. Clock voltage and frequency (standard 240V 50Hz).
6. Other extras, i.e. event pens, alarms, lighting.

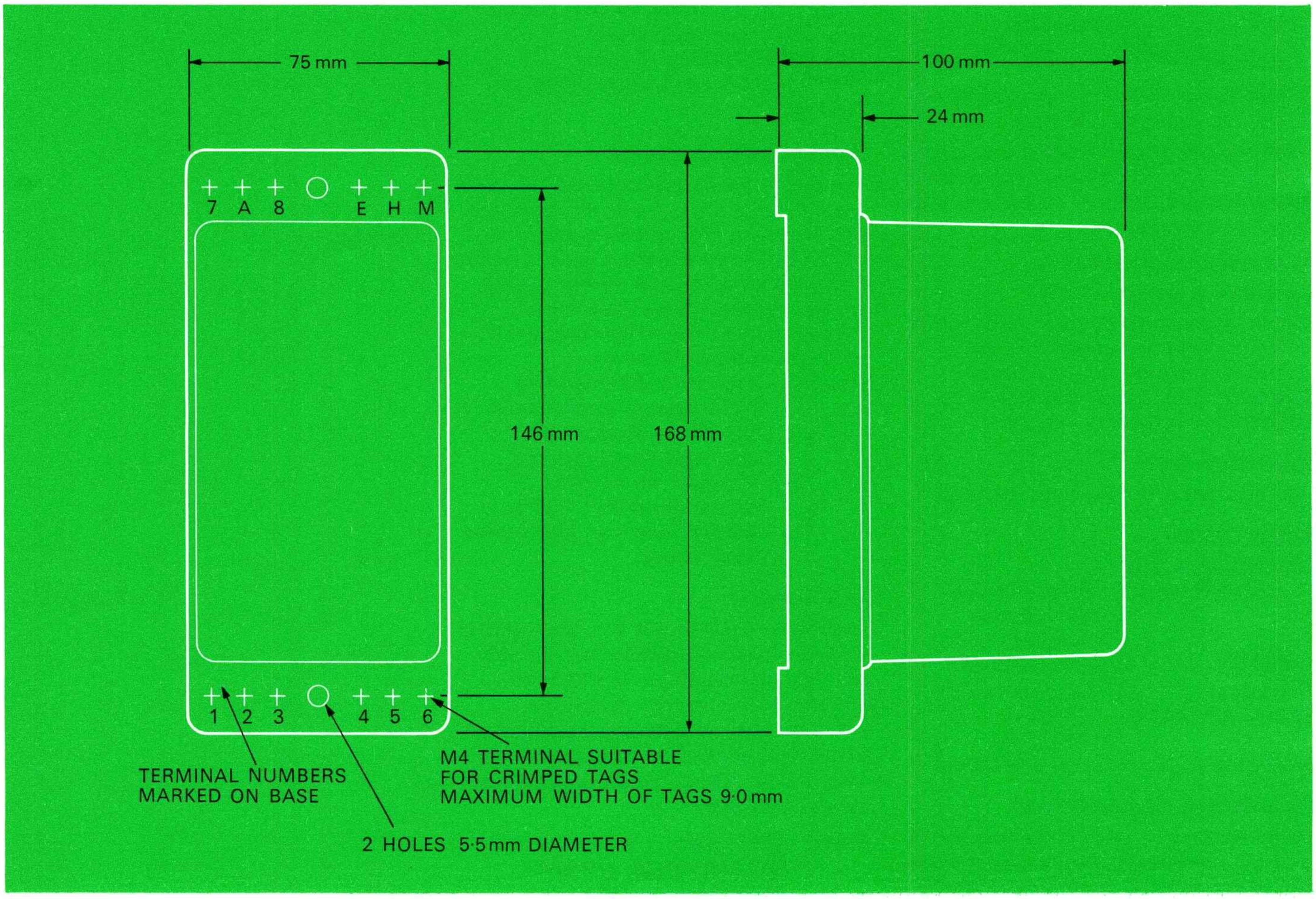


Figure 7 COMMON OUTLINE – INVERTER AND DUAL ALARM

Our policy is one of continuous product development and the right is reserved to supply equipment which may vary slightly from that described.

GEC Measurements The General Electric Company Ltd

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Publication I5-001D

037830 GSP *Printed in England*

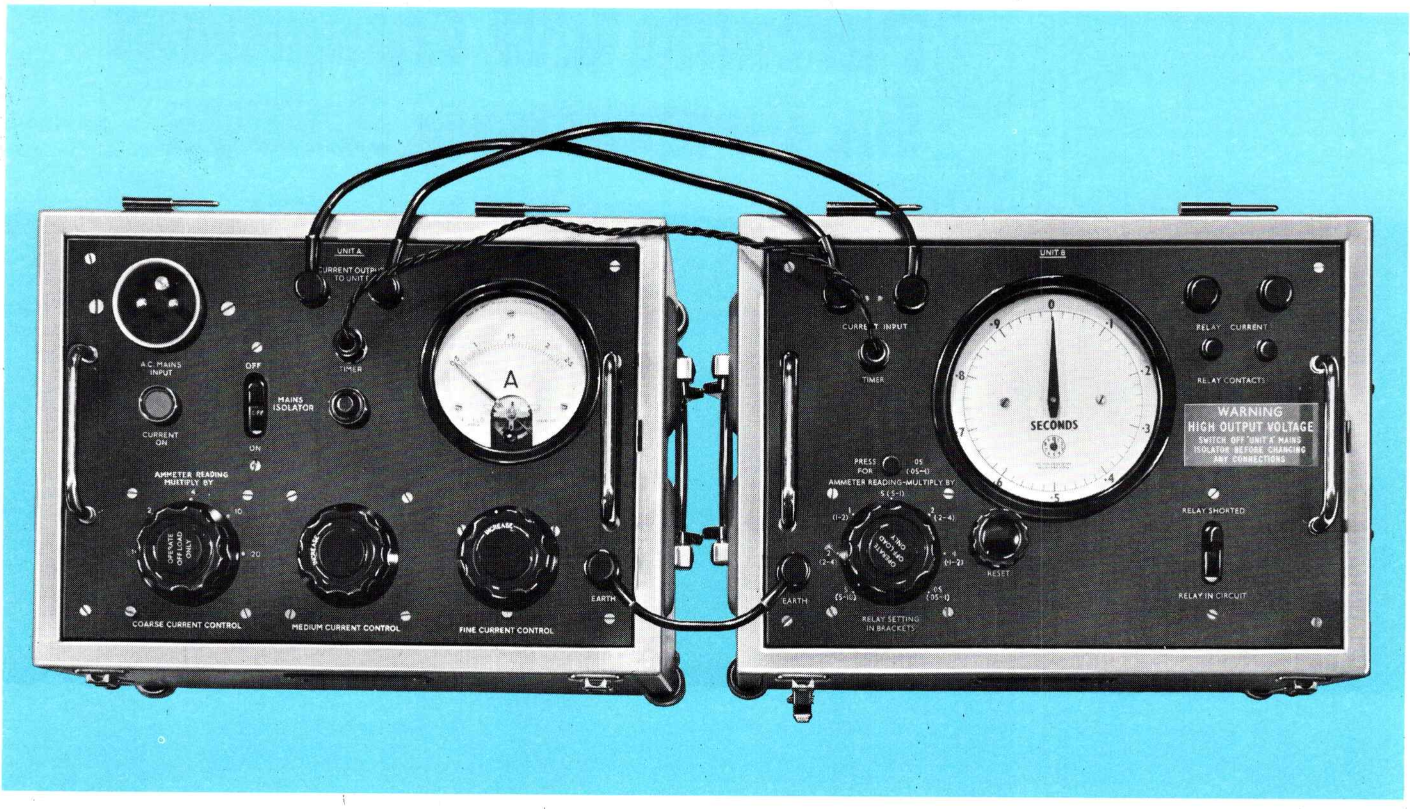
13. Testing and Repairs of Relays Type CFB Test Set

GEC Measurements

Type CFB

Portable Test Equipment for Overcurrent Relays

Type CFB



FEATURES

* Undistorted output waveform
* Easily portable
* Robust construction
* Continuously adjustable – 0·05A to 200A

APPLICATION

The type CFB test equipment has been designed primarily for the testing of inverse time overcurrent relays, at 50 Hz, particularly on site where portability and a steady current output are essential requirements. The units can be used for testing other equipment where a controlled alternating current of good waveform is required.

The coil impedance of many relays is non-linear. In the case of inverse time current relays with definite minimum time, the operating characteristic is obtained by magnetic saturation. Such relays form a non-linear impedance which causes the test current to be distorted to a peaked waveform if the test voltage is applied directly to the relay coil or through a variable transformer. This would result in unreliable test data from relays whose torque is affected by the presence of harmonics.

Normal practice in the past was to suppress this distortion by connecting a control resistor in series with the relay coil of at least seven times as much resistance as that of the relay coil. This necessitated about 50kW if tests were to be made up to 20 times setting and also it required a bigger power supply than was usually available.

The current in the CFB test equipment is controlled by series reactance. In order to suppress the harmonics, tapped non-saturating air gap reactors are utilised. In this way, because the resistance component is relatively small, a good waveform can be obtained with minimum power dissipation. This in turn means that the whole equipment can be made much smaller and lighter for ease of transport.

The test equipment contains a primary supply circuit to which the relay is connected by a current injection transformer. The primary circuit current is variable from 1A–40A and is adjusted by means of coarse, medium and fine controls. This current is matched to the relay setting by the current injection transformer. In other words, the relay appears to the primary circuit as having the same impedance, no matter what its setting may be. This simplifies the testing procedure as explained in the section entitled 'OPERATION'.

NOTE: When using the current transformer the output circuit must not be disconnected when the test equipment is energized, otherwise the output voltage will rise to an abnormally high level.

DESCRIPTION

The test equipment comprises two units, the power supply unit (A) and the injection transformer unit (B). Circuit diagrams showing the connections within these two units are given in Figures 1 and 2. Connections between the units for the control circuits are by means of a multicore cable which is plugged in. The main current connections and earth connection are made by clamping the connecting leads under post-type terminals. A schematic diagram of the complete equipment and its inter-connections is shown in Figure 3.

POWER SUPPLY UNIT (UNIT A)

The power supply unit is used for the control of the test current, the setting being achieved in three stages – coarse, medium and fine adjustments. The coarse control has five settings which are taken from taps on an iron-cored reactor. The medium control has eight settings covering a range equivalent to one coarse setting step; these are made by a selection of taps on an auto-transformer and on an iron-cored reactor. The fine control is a variable transformer energising a bucking transformer in series with the supply and is continuously variable over a range equivalent to one medium step.

NOTE: The coarse control K2, and the current range switch K1, must not be operated under any circumstances while the green button is depressed.

Current indication is given by a built-in 4 inch diameter 0–2·5A ammeter which is connected into the circuit by a multi-range current transformer, the transformer secondary being tapped and the appropriate range selected automatically when the coarse control switch is operated. The actual value of current supplied by the power supply unit may be determined by multiplying the ammeter reading by the constant given on the coarse control selector; see Table 1.

The mains supply to unit (A) is controlled by means of the mains isolator switch and a contactor operated by the pushbutton marked CURRENT ON. The push button must be held down manually. If it is released the contact is broken, cutting off the supply to unit (B) and so to the relay under test. This is a safety feature to ensure that the relay cannot be energized without a deliberate action on the part of the operator.

INJECTION TRANSFORMER UNIT (UNIT B)

The injection transformer unit is, in effect, an impedance matching unit which couples the relay under test to the power supply unit and limits the range of control required in the power supply for the widely divergent currents that can be supplied by the complete equipment. The transformer secondary winding is tapped and the desired ratio is obtained by a selector switch, each position of which is marked with a current range of relay setting current.

A relay short-circuiting switch is also provided that enables the preliminary current settings to be obtained without over-heating the relay or causing its operation before it is required.

The timing equipment, which comprises the clock, a fast-acting clutch and an auxiliary relay type VAA, is also incorporated in the injection transformer unit. The clock is a 6 inch diameter instrument with an open and easily read dial having a 0–1 second sweep-hand and a register indicating up to 10 seconds. Operation of the relay under test stops the timer and opens the supply contactor.

A voltage limiting circuit, including a type VAG relay and provided on the output of the test set, automatically switches off the test supply when the output voltage exceeds 660V. This does not in any way affect the normal testing procedure and operates only if the output terminals are accidentally left open circuit or an unusually high burden is connected across them.

NOTE: This voltage limit will restrict the testing of the higher burden (low current setting) relay. For instance, on the lowest tap of a 0·05–0·2 Amp IDMT relay, the maximum current available will be approximately 10× setting current on the most sensitive setting of 0·05 amps.

RANGE SWITCHING CONSTANTS

These are given in the tables on page 5 for the complete adjustment range of the test equipment. The values given in Table 1 allow the magnitude of mains supply current to be determined.

This value, multiplied by the constant given in Table 2, gives the actual output current in the relay circuit.

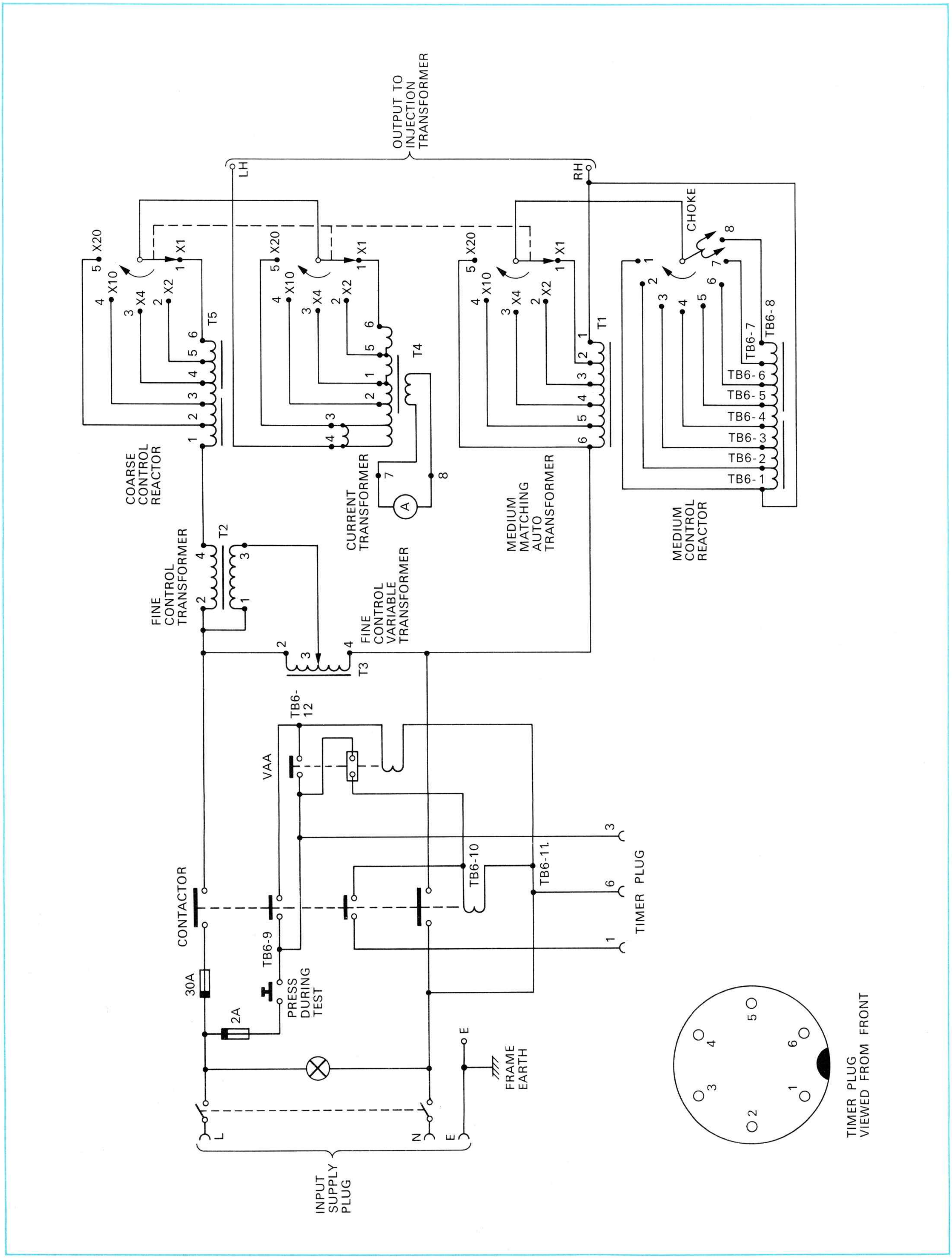


Figure 1 CIRCUIT DIAGRAM OF POWER SUPPLY UNIT (UNIT A)

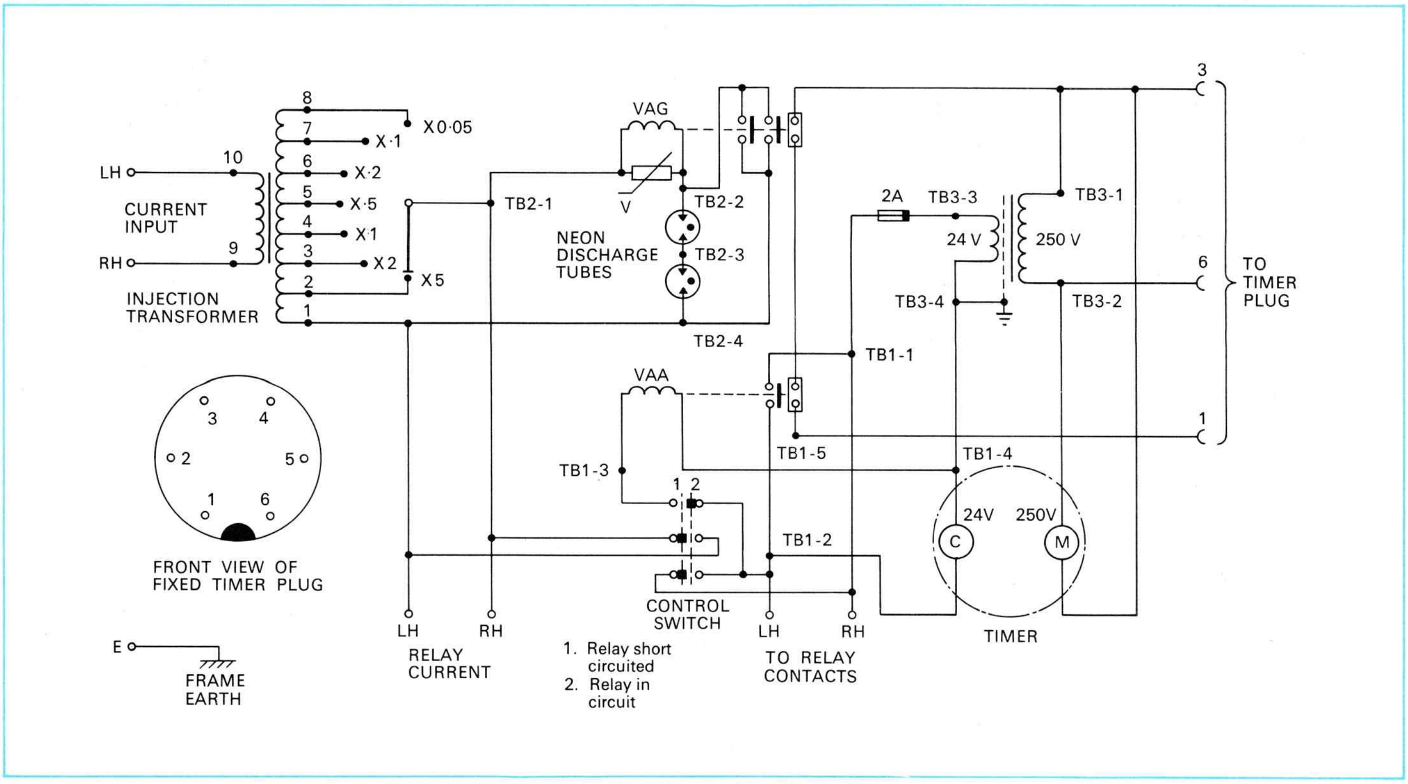


Figure 2 CIRCUIT DIAGRAM OF INJECTION TRANSFORMER UNIT (UNIT B)

For the complete equipment Table 3 gives the appropriate combined multiplier constant for the various settings of the selector switches shown in Tables 1 and 2.

The value of current in the relay circuit (I_R) is given by the product of the current test multiplier shown in Table 3 and the reading of the ammeter I_M. The current test multiplier is merely the product of the constants given in Tables 1 and 2 for the various settings possible:

$I_R = \text{C.T.M.} \times I_M$

OPERATION

NOTE: The coarse control K2 and the current range switch K1 must not be operated under any circumstances while the green button is depressed.

The test equipment is short time rated for intermittent operation only. Table 4 gives the limits of duration on any one setting:

If the equipment supplies current for the times approaching those given it is essential that ample time is allowed for the equipment to cool before being operated again.

For the routine testing of standard I.D.M.T. relays the rating of the equipment is adequate.

TEST CURRENT SETTING FACTORS

Table 1

Multiply ammeter reading by the coarse control multiplier (K2)
1
2
4
10
20

Table 2

Relay setting current ranges	Multiply power supply current by injection transformer setting (K1)
0·05 – 0·1	0·05
0·1 – 0·2	0·1
0·2 – 0·4	0·2
0·5 – 1·0	0·5
1·0 – 2·0	1·0
2·0 – 4·0	2·0
5·0 – 10·0	5·0

CURRENT TEST MULTIPLIERS (C.T.M.)

Table 3

Coarse control multiplier (K2)	Setting of injection transformer (K1)						
	0·05	0·1	0·2	0·5	1	2	5
1	0·05	0·1	0·2	0·5	1	2	5
2	0·1	0·2	0·4	1·0	2	4	10
4	0·2	0·4	0·8	2·0	4	8	20
10	0·5	1·0	2·0	5·0	10	20	50
20	1·0	2·0	4·0	10·0	20	40	100

TEST CURRENT DURATION

Table 4

Coarse control multiplier (K2)	Time (seconds)
1	300
2	200
4	150
10	120
20	90

CONNECTIONS

The CFB test set comprises two units, each housed in separate transportable boxes. These are:
Unit A – Power Supply Unit
Unit B – Injection Transformer Unit
Before using the test set the following electrical connections have to be made:

NOTE: Before commencing to make the connections ensure that the mains isolator switch on the supply unit is in the OFF position.

1. Connect the terminals marked CURRENT OUTPUT TO UNIT B on the power supply unit A to terminals marked CURRENT INPUT on the injection transformer unit B, by means of two of the leads terminated with spade terminals provided with the test set.
2. Connect together the sockets marked TIMER on each unit, using the special lead terminated with multi-pin plugs.
3. Connect the earth terminals on both unit A and unit B together, with the lead provided with the test set.
4. Connect the current coil of the relay under test to the output terminals marked RELAY CURRENT on unit B.
5. Connect the contacts of the relay under test to terminals marked RELAY CONTACTS on unit B.
6. Insert the a.c. mains input plug into the socket marked A.C. MAINS INPUT on unit A and connect to a suitable 200/250V, 50 Hz supply.

For maximum output the demand on the supply is 40A.

It is necessary to connect the body of the plug to a suitable earth point via the supply cable.

OPERATING PROCEDURE

Settings

1. Set the relay under test at the desired current setting.
2. If a time delayed relay is under test set the relay to the required time setting.
3. Set the injection transformer tap selector switch (K1) on unit B so that the range position includes the chosen current tap.
4. Set the COARSE CURRENT CONTROL knob (K2) on unit A to the required multiple of the relay current setting (either 1, 2, 4, 10 or 20 times the relay current setting). This can be determined easily from the expression:
   Coarse current control setting (K2) =

$$\left[\frac{\text{Relay current required } (I_R)}{\text{Tap selector switch setting (K1)}}\right] \times \tfrac{1}{2}$$

   If the required multiple is between two setting positions, select the higher one.
5. Turn the knobs marked MEDIUM CURRENT CONTROL and FINE CURRENT on unit A anti-clockwise to their end stops.
6. Ensure that the relay short-circuiting switch on unit B is in the position marked RELAY SHORTED.

Electrical test procedure

1. After ensuring that the relay short-circuiting switch on unit B is in the RELAY SHORTED position and the mains isolator switch on unit A in the OFF position, switch on the mains supply to unit A.
2. Switch on the power supply to unit A by putting the mains isolator switch in the ON position.
3. Press the green pushbutton on unit A marked CURRENT ON. NOTE: This pushbutton must be kept pressed in order to obtain the relay test supply.
4. Set the current, as indicated on the ammeter in unit A, to approximately 10% above that required for the test, by means of the knobs on unit A marked MEDIUM CURRENT CONTROL and FINE CURRENT CONTROL.

   Ammeter reading (I_M) =

$$\frac{\text{Relay Current } (I_R)}{\text{Current Test Multiplier (C.T.M.)}}$$

   The value of C.T.M. is given in Table 3 for the particular settings of the coarse control multiplier and the relay setting multiplier chosen.
5. Move the relay shorting switch on unit B to the position marked RELAY IN CIRCUIT.
   Adjust the current to the exact value required by means of the knob marked FINE CURRENT CONTROL then release the green push button.

   NOTE: When testing relays with short operating times it may be necessary to disconnect the relay contacts temporarily from the terminals marked RELAY CONTACTS on unit B during current adjustment.

   Be sure that these contacts are reconnected when the current adjustment is completed.
6. Reset the timer on unit B with the knob marked RESET.
7. Put the relay shorting switch on unit B to the position marked RELAY SHORTED.
8. Press the green pushbutton marked CURRENT ON on unit A. Move the relay shorting switch to position marked RELAY IN CIRCUIT and allow the relay to operate. While doing this, check that the current, as indicated on the ammeter on unit A, is still at the required value.

   NOTE:
   (a) The timer will register an incorrect time if the green pushbutton is pressed after the relay shorting switch has been moved to the RELAY IN CIRCUIT position.
   (b) Closure of the relay contacts stops the timer and interrupts the flow of current through the relay.
9. Switch off the incoming mains supply to unit A by putting the mains isolator switch in the OFF position.

NOTE: The connections between the units and the relay under test must not be disturbed under any circumstances while the mains isolator in unit A is in the ON position.

EXAMPLE OF CURRENT SETTING

Relay setting range: 2·5A to 10A
Plug setting: 2·5A
Relay current required say 2× setting current = 5A

Test Box settings required:

K1 = 2 (as the relay setting falls within the range 2A–4A)
K2 = 2 (see paragraph 4 under Settings)

Adjust ammeter to a scale reading of 1·25

Relay injected current=
K1 × K2 × ammeter scale reading
= 2 × 2 × 1·25 = 5A

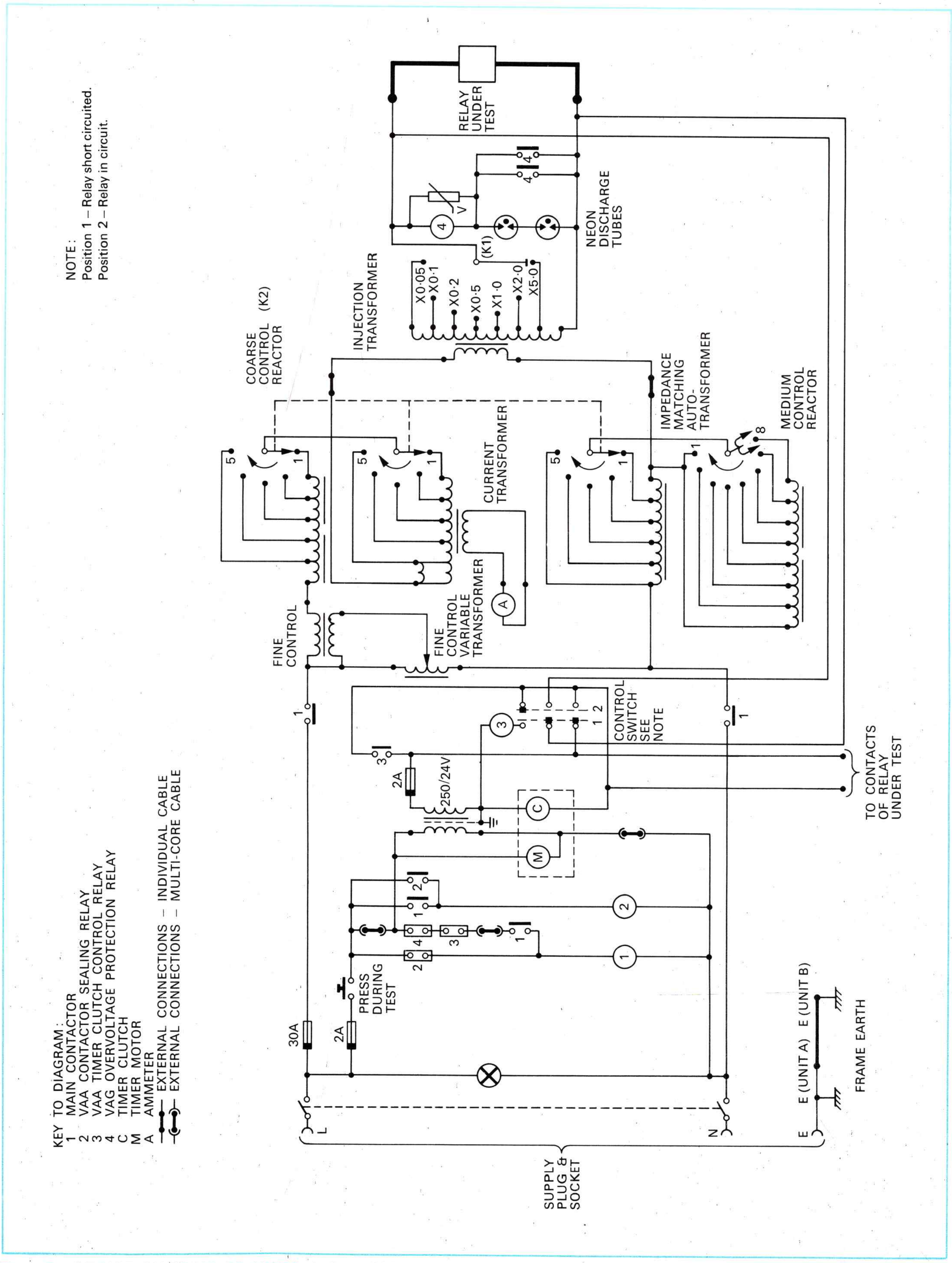


Figure 3 CIRCUIT DIAGRAM OF UNITS A & B COMBINED

TECHNICAL INFORMATION

Input voltage rating	200V–250V 50Hz
Input current range	1A–40A (nominal) depending on setting of coarse control.
Input burden maximum	9kVA at 20 times setting
Output current range	0·05A–200A (full scale deflection)
Output current waveform distortion	2nd harmonic – negligible 3rd harmonic – 1% maximum 5th harmonic – negligible

Timer

Scale	0–1 sec
Cumulative register	0–10 sec
Accuracy	±1% of indication or 20 ms, whichever is the greater

Ammeter

Full scale deflection	1A
Scale	0–2.5A
Accuracy	1.5% of FSD

Indicating Lamp

Make	Klockner-Moeller
Type	GL 130
Rating	130V, 2W

Note: A resistor located within the lamp-holder, is connected in series with the lamp, so that the combination is rated at 220–240V.

Overall case size

Length	457mm (18 inch)
Width	330mm (13 inch)
Height (with castors)	432mm (17 inch)
(without castors)	356mm (14 inch)

Weight

Power supply unit (A)	57kg (126 lb)
Injection transformer unit (B)	52kg (114 lb)

Cases

Each unit is housed in a strong, fabricated steel case having an attractive hammered grey finish. The cases are fitted with robust and conveniently placed handles and detachable castors.

Each unit can be lifted easily out of its case for inspection, maintenance or access to the fuses. The chassis of each unit is connected to its case by an internal flexible earthing strap.

Fuses

In order to replace the fuses in the units, it is first necessary to remove the unit from its case. Two spare fuses are carried in fixtures beneath the circuit fuses.

Types of fuse:

30A rating Type TIA30
2A rating Type TIA2
Available from GEC Fusegear Ltd.

Supply cable

The recommended specification is 3 core, 600V, 6 sq. mm cross section multi-strand flexible cable with heavy duty insulation. A heavy duty plug is supplied to fit the socket in the Power Supply Unit (Unit A).

GEC Measurements **The General Electric Company Limited of England**

St. Leonards Works Stafford ST17 4LX England
Telephone: 0785 3251 Telex: 36240 Cables: Measurements Stafford Telex

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NOTES ON USING A TYPE CFB TEST SET
WITH SEPARATE VOLTAGE SUPPLY
FOR TESTING DIRECTIONAL OR POWER MEASURING DEVICES

As the type CFB test set uses tapped reactors for current control, then the impedance of the set will be such as to produce current having a lagging power factor when compared with the supply voltage. When working at low current level outputs, the impedance must be of the order of

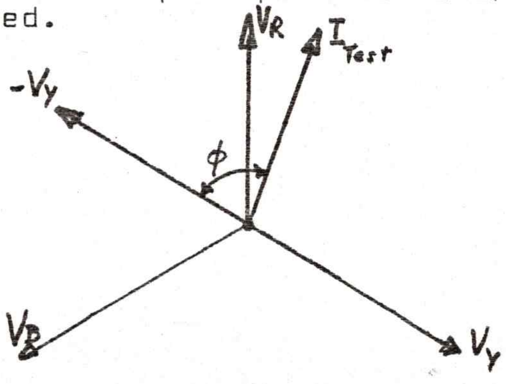
$$\frac{240V}{5A} \simeq 48 \text{ ohms}$$

and the majority of this will be inductive. If the ratio of inductance to resistance of the chokes is approximately 6 to 1, which is not uncommon for a relay coil, then the phase angle produced by this impedance alone and neglecting that of the output load, will be:

$$\text{Artan } \frac{6}{1} = \text{approx } 80^\circ$$

Where it is intended that red phase current is injected into a wattmetric measuring device, such as a power or directional relay, power transducer or power measuring instrument, which has a low input impedance relative to the test set, then it may be more appropriate to apply Y phase volts to the test set which produces a current lagging by an angle of approximately 80°. If -Y phase current is considered, then with an angle of 80° lag it will be seen by the device being tested as a 20° lag on the red-neutral voltage vector. If it is not possible to provide a phase shift to the voltage vector through an appropriate device, then the true watts estimated by the use of voltage and current alone will be reduced by the difference between unity and cos 20° which equals 1 - 0.9369, that is an error of about 6%.

The phase angle error is expected to vary with settings of the test set and impedance of the load. Where it is required to test a sensitive directional device or power relay accurately by secondary injection, it is necessary to use a phase shifter in the voltage supply to obtain the required conditions of test. Where <u>load current</u> is being used at reasonably good power factors, a phase shifter need not be used if simple operation and/or indication checks only are required.



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DRAFT

RELAYS RETURNED FOR REPAIR.

Relays are often returned with a simple comment 'Repair'. Without further history of the nature of the condition to be attended to, unnecessary time must be expended by our technicians to asscertain the nature of the fault and in many cases where it is of a spasmodic or intermittent nature is sometimes impossible to determine.

Relays are often, unfortunately, returned with insufficient packing and are received with broken glass, broken studs and broken stud housings. Relays returned without their case can suffer further damage because delicate components are not sufficiently protected from wrapping materials or impact during transit. Relays sent by carriers outside these works and whether marked 'fragile' or not have often been observed to have been handled roughly at transit points such as airports. Handling packages or boxes like one handles bags of grain can impose severe shocks of a damaging nature. Adequate packing is therefore important.

Also accompanying a relay should be a full description of the circumstances which led to the problem the relay exhibits including any details of overloads e.g. CT ratio, approximate primary current at the time and the approximate time for which the current was on plus details of the application e.g. feeder protection, generator protection etc. A description of the fault in the relay should also be briefly described particularly where an electromagnetic element is sticky, has worn bearings or shows an intermittent fault.

Where a relay is simply sent back for check and overhaul and there has been no suspected fault, this should be clearly stated.

Where a relay has adjustable settings by means of plugs, time dials, potentiometer settings etc a record should be made of the settings that existed <u>prior</u> to removal from their respective circuits. Calibration procedure for most relays usually involves changing the settings for testing purposes and the relay will usually be returned left on the settings as of the final test during recalibration or checking procedures. Before replacing in service the relay should be reset to the settings as recorded by the customer.

Glass surfaces of relay cases should be protected at least by ¼" or 6mm of common hardboard material such as "masonite" or ply wood to give sufficient protection to the glass during transit.

Studs for terminations of the relay should be removed from the case and retained by the customer with the mounting brackets and for replacement in the relay when it is remounted on the switchboard. Studs and mounting brackets should not be forwarded with the relay.

For static or solid state relays exhibiting calibration or intermittent faults the nature of the fault should be clearly described.

In order to trace the origin of the relay and whether warranty provisions exist, and the party who was responsible for supplying the relay as part of a contract, the Customer is requested to quote the circumstances of the purchase e.g. supplied on...11kV switchgear giving the manufacturer's name and if possible the order reference, and the name of the client who purchased the equipment. Where the relay has been purchased as a loose item direct from these works then either the customers order number, customers name or our contract reference number or works order number should be quoted.

<u>QUESTIONAIRE</u>

Customers Name
Customers O/N on which the relay was purchased
Was the relay purchased as a loose item?
Was the relay purchased as part of a switchgear order?
If on a switchboard what is the primary system voltage rating?
e.g. 11kV etc
Was it purchased as part of a separate control relay board?
Project or substation name

Approx. date on which the relay was received by customer.

If known, the warranty period related to the contract for the supply of the relay or gear.

Nature of circumstances in which the relay exhibited a faulty condition (please describe in detail).

Nature of expected fault.

Description of any physical damage prior to packing and shipping for repair (eg broken glass, bent contacts, bent disc, broken PCB, bent brackets, broken moulding, rust, damaged wiring).

Is the relay a spare (yes or no).

It is generally advisable to return relays in their original cases to afford good physical protection to the internal components some of which are very delicate during shipping.

Your attention to the above points would be appreciated in order to assist these works to provide the best repair service at the cheapest cost and at the shortest turn around time. It will be appreciated that not all the queries can be answered but whatever answers you give help us to maintain the good quality of relays we aim to provide and flag up any problems that may occur due to long term effects etc. Quite often blame is attached to a relay mechanism or circuitary failure where as insufficient packing may have been the cause and very rarely, mistakes may be made in interpreting orders or due to production difficulties, and your reporting of such problems always helps in the maintenance of a high quality of equipment and service we aim to provide.

14. Pilot Wire Protection and Distance Relays Types SDP Translay S, YTG and PYTs

GEC Measurements

BIASED DIFFERENTIAL 'TRANSLAY' RELAYS

Types HO4 and HOC4

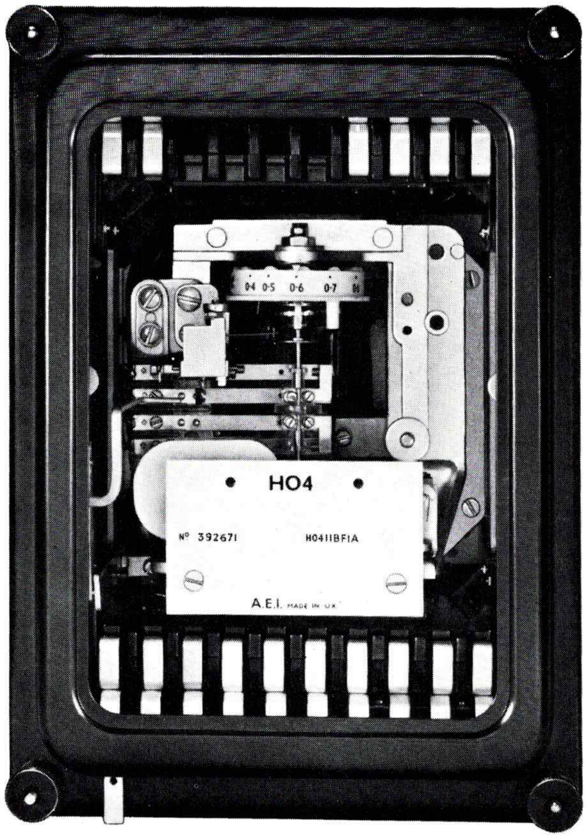
The Translay balanced protection system provides phase and earth fault protection for plain a.c. feeders using a single element type HO4 relay at each end linked by a pair of unscreened private pilot wires. A high degree of stability on through faults and good sensitivity on internal faults is achieved.

The well known principle is used that under healthy conditions the instantaneous currents entering and leaving each end of a feeder are equal in magnitude and phase. However, unlike similar systems where all the relay operating current is passed through the pilot wires, the Translay system operation is produced by two co-operating currents; the operating torque being proportional to their product. One of these quantities is supplied directly by the local current transformers and the other resultant current which passes through the pilot wires is relatively small. The resistance of the pilot wires has therefore little effect on sensitivity and small cross-section conductors can be used without limiting the power available for operating the relay.

Type HO4 relays are for general use on three phase feeders and have a single setting range. A slightly modified version is available for single phase feeders.

Type HOC4 relays, similar to type HO4, are more suited to resistance earthed systems and have taps to give alternative setting ranges.

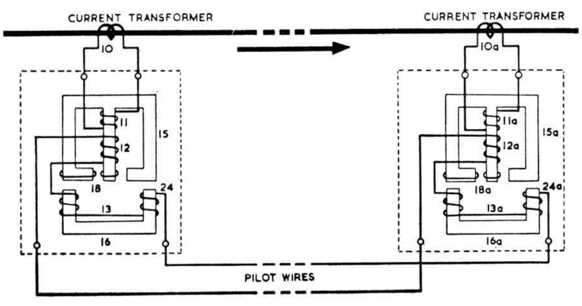
For protection of feeders with plain and fused tees, type HOA4 and type HT4 relays respectively are recommended.



CONSTRUCTION AND OPERATION

The relays are basically robust induction disc units in which rotation of the disc in the contact closing direction is the result of two magnetic fluxes in quadrature.

Referring to the diagram below; the unit has two electromagnets, an upper magnet (15) and a lower magnet (16). The upper magnet has a primary summation winding (11) fed from the line current transformers and a secondary winding (12) connected in series with the lower magnet windings (13). The latter series circuit is connected by the pilot wires to a similar circuit in the remote relay. Copper bias loops (18) produce a small restraint torque when current flows in the primary winding (11).

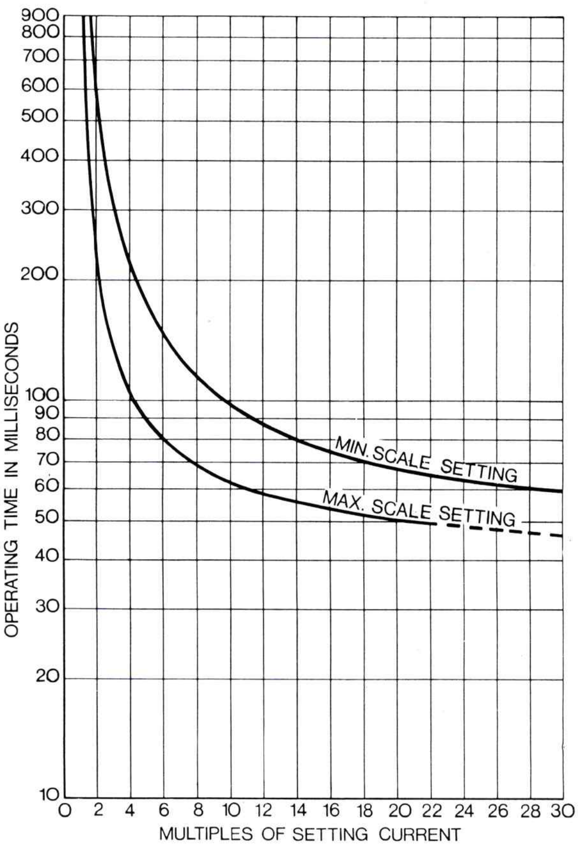


Simplified connections illustrating principles of operation

Whilst the feeder is healthy, the line transformers at each end of the feeder carry equal currents. Equal and opposite voltages are induced in the secondary windings (12 and 12a) and no current circulates in the pilot wire series circuit.

Under heavy through fault conditions there may be a small circulating current due to line current transformer mismatching. A restraint torque is however produced by means of the bias loops (18) which is far greater than the small operating torque produced in these conditions. Another function of the bias loops (18) is to adjust the restraint magnet leakage flux to be in phase or lagging any lower magnet flux due to pilot wire capacitance current. Operation by these currents is thus prevented, even under severe conditions of heavy through faults.

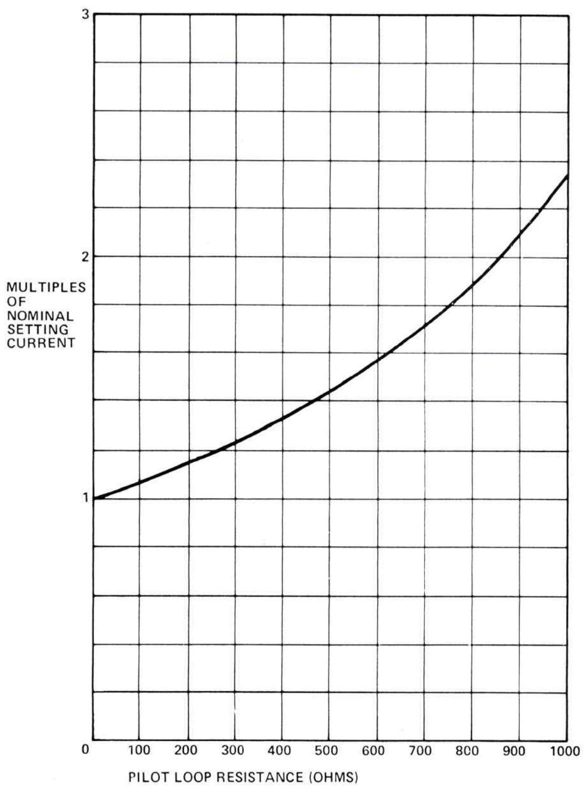
A fault fed from one end of the feeder causes an increase in the current flowing in the primary winding (11) of the relay at that end with a corresponding increase in the voltage induced in the secondary winding (12). The result is an unbalance condition between the induced secondary voltages and current flows in the pilot wire series circuit. An operating torque is produced by the current in winding (13) and at a fault current value in excess of setting current the relay operates.



Typical time/current characteristic

A fault fed from both ends will cause a current reversal in the remote current transformers (10a) and the voltage induced in winding (12a) is therefore additive to that induced in winding (12). The relays at both ends of the feeder will operate.

Since the Translay relays are induction units requiring alternating current conditions they are unaffected by transient line charging currents which are essentially unidirectional.



The effect of pilot wire resistance on current setting

CURRENT RATING

Relays are available for use with current transformers having 1 or 5 amp secondary ratings at 50 or 60 Hz.

CURRENT WITHSTAND LEVELS (for 0·5 sec.)

Multiples of rated current

	Phase Faults	*Earth Faults*
Type HO4	60	30
Type HOC4	60	13

A.C. BURDEN

Type HO4 1·1 VA per phase at setting current
Type HOC4 1·5 VA per phase at setting current

OPERATING TIME

Medium speed class, with operation times down to approximately 30 mS.

FAULT SETTINGS

Due to the use of a summation winding, the basic settings of type HO4 relays differ for the various types of faults, as shown in the table below.

The HOC4 relay has additional tappings on the relay primary windings which provide four alternative groups of basic settings, including:—

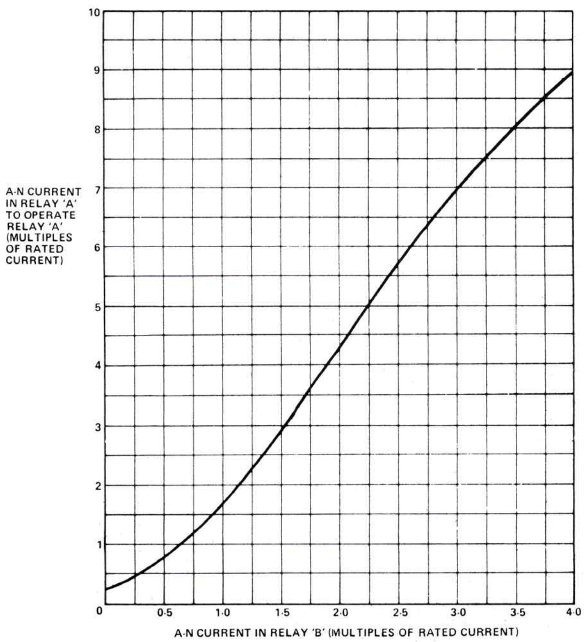
For earth faults: Settings lower than the standard HO4 relay settings, for use where the earth fault current is severely limited.

For phase faults: Settings higher than the standard settings of the HO4 relay, for use when the protection is to remain stable under through load conditions, notwithstanding a pilot fault.

The optimum group of basic settings for a given application is selected by connections to appropriate relay terminals. The HOC4 relays at each line end must have identical current circuit connections.

The basic minimum settings of both HO4 and HOC4 relays can be increased by a factor up to 2·25 by increasing the control spring tension by means of a calibrated knurled disc. On HO4 relays this torsion head adjustment is calibrated in terms of C–N fault setting current (A). On HOC4 relays the calibration is in terms of the multiplying factor.

Pilot wire resistance affects the setting of all relays as shown.



Typical bias characteristic for zero impedance pilots

The actual minimum operation current for either relay type is further affected by the pilot wire resistance as shown typically below.

Type of Fault	Minimum Fault Setting % rated current				
	HO4	HOC4			
A-N	22	22	22	11·5	11·5
B-N	28	28	24	13	12
C-N	40	40	28	15	13
A-B	90	90	180	90	180
B-C	90	90	180	90	180
C-A	45	45	90	45	90
A-B-C	52	52	104	52	104

PILOT WIRE VOLTAGE

The relay electromagnet saturates at high currents, so that the r.m.s. voltage applied to the pilots does not exceed about 250V at maximum fault levels.

However, the voltage output waveform becomes sharply peaked, with voltage spikes at each half cycle of peak value of the order of 1000V at 150 x setting current.

PILOTS

250 volt grade pilot wires are recommended. Anti-capacitance sheaths are unnecessary.

Maximum recommended loop resistance – 1000 ohms
Maximum intercore capacitance – 3 microfarads

CONTACTS

Two pairs of electrically separate self-reset contacts are provided on the induction disc unit rated to make and carry 750 VA with maxima of 6 amps and 250 volts a.c. or d.c.

AUXILIARY UNITS

If required a type VAA auxiliary attracted armature unit can be fitted which provides up to four pairs of hand or self-reset contacts in any combination of normally open or normally closed and rated as follows :—

	Make and carry continuously	Make and carry for 3 seconds	Break
a.c.	1250 VA with maxima of 5 amps and 660 volts	7500 VA with maxima of 30 amps and 660 volts	1250 VA with maxima of 5 amps and 660 volts
d.c.	1250 watts with maxima of 5 amps and 660 volts	7500 watts with maxima of 30 amps and 660 volts	100 watts (resistive) 50 watts (inductive) with maxima of 5 amps and 660 volts

Standard coil ratings are 30, 50, 110, 125, 220 and 250 volts d.c. with a burden of 3 watts.

OPERATION INDICATOR

A hand reset operation indicator is provided as standard on the induction disc unit.

CURRENT TRANSFORMERS REQUIREMENTS

Relay	Minimum secondary knee-point voltage (V)	Secondary magnetising current limit at the stated voltage
HO4	$\frac{I_F.Q}{15}\left(\frac{7}{I^2}+R_{CT}+2R_W\right)$	0·016 I amp at $\frac{10}{I}+I\,(R_{CT}+R_W)$ volts
HOC4	$\frac{I_{FP}.Q}{15}\left(\frac{7}{I^2}+R_{CT}+R_W\right)$ $\frac{I_{FE}.Q}{15}\left(\frac{12}{I^2}+R_{CT}+2R_W\right)$	0·005 I amp at $\frac{10}{I}+I\,(R_{CT}+R_W)$ volts

Where
- V = minimum secondary knee-point voltage
- I = relay 100% current rating
- R_{CT} = resistance of current transformer secondary winding (ohms)
- R_W = resistance per lead from current transformer to relay (ohms)
- I_F = maximum through fault current in secondary of current transformer
- I_{FP} = maximum through phase fault current in secondary of current transformer
- I_{FE} = maximum through earth fault current in secondary of current transformer
- Q = reactance/resistance ratio X/R of the power system, including both the source impedance and the impedance of the feeder to be protected.

Notes:—

(a) A minimum value of 5 must be used for the factor Q for all applications in which the power system X/R ratio is 5 or less Where the X/R ratio of the power system is not known assume Q = 5.

(b) The type HOC4 relays are intended in general for power systems in which earth fault currents are expected to be significantly lower than phase fault currents. The knee point voltage requirements for both phase faults and earth faults should be assessed using the respective secondary fault currents.

(c) The current transformer magnetising current limitations are offered as a guide to ensure that effective primary operating current levels do not exceed nominal setting levels by 15% of setting. Where fault levels are high enough these limitations may be relaxed to suit.

INSULATION

The standard relays will withstand

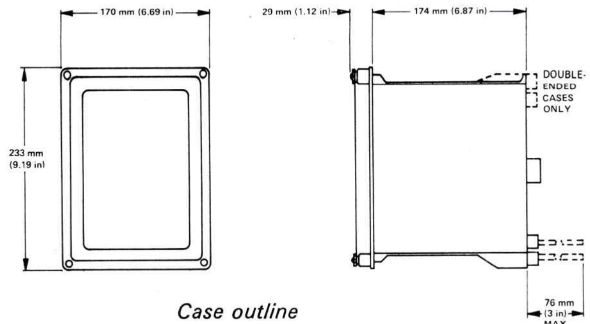
(a) 4 kV 50 Hz for one minute between pilot wire terminals and metal parts of the case

(b) 4 kV 50 Hz for one minute between primary and secondary windings (11 and 12)

(c) 2 kV 50 Hz for one minute between all other circuits and metal parts of the case

(d) 1 kV 50 Hz for one minute between normally open contacts

A separate isolating transformer can be supplied with each relay, for use when the pilot circuits need to be insulated to 15 kV.



Case outline

CASES

The relays are supplied in size 1 drawout cases available for flush or projecting mounting finished phenolic black as standard.

Relays for use in exceptionally severe environments can be finished to BS.2011 : 20/50/56 at extra cost. Standard relays are finished to BS.2011 : 20/40/4 and are satisfactory for normal tropical use.

Fully dimensioned drawings of case outlines, panel cut-outs and mounting details are available on request.

INFORMATION REQUIRED WITH ORDER

Relay type

Current transformer secondary rating

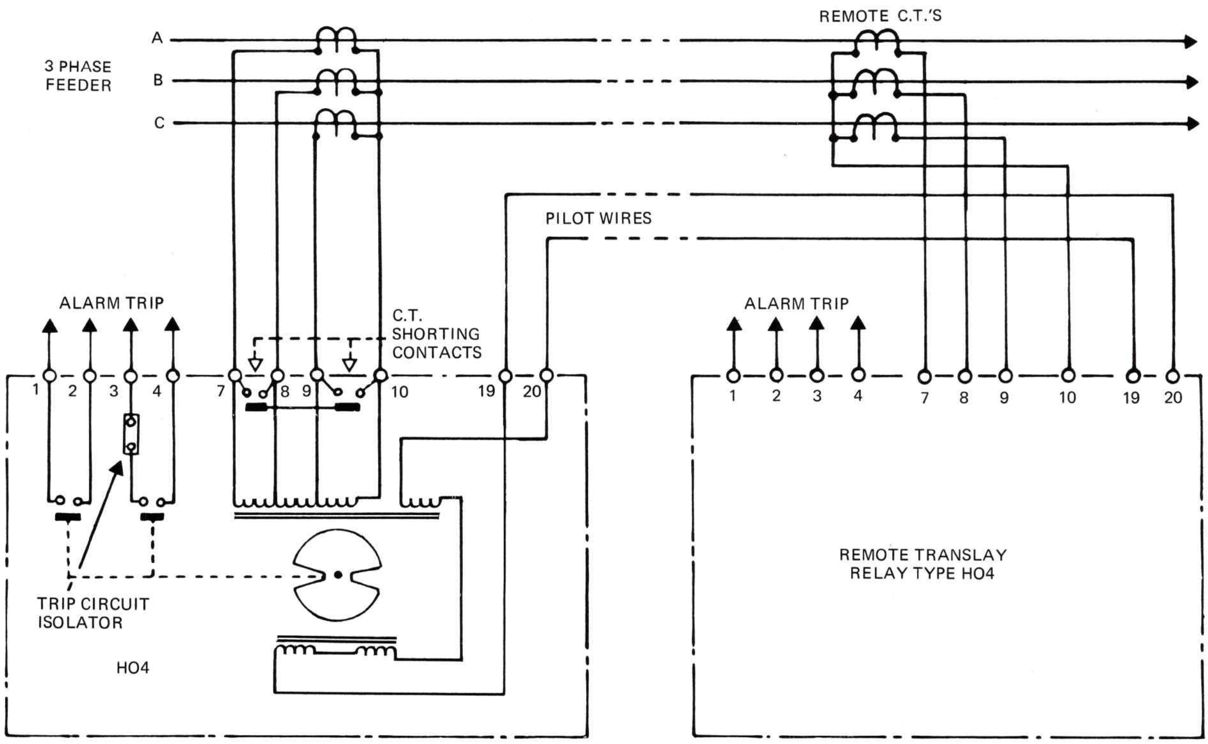
Frequency

Auxiliary unit contact arrangement

Auxiliary unit coil voltage

Pilot wire insulation

Case mounting



Typical diagram of connections

Our policy is one of continuous product development and the right is reserved to supply equipment which may vary slightly from that described.

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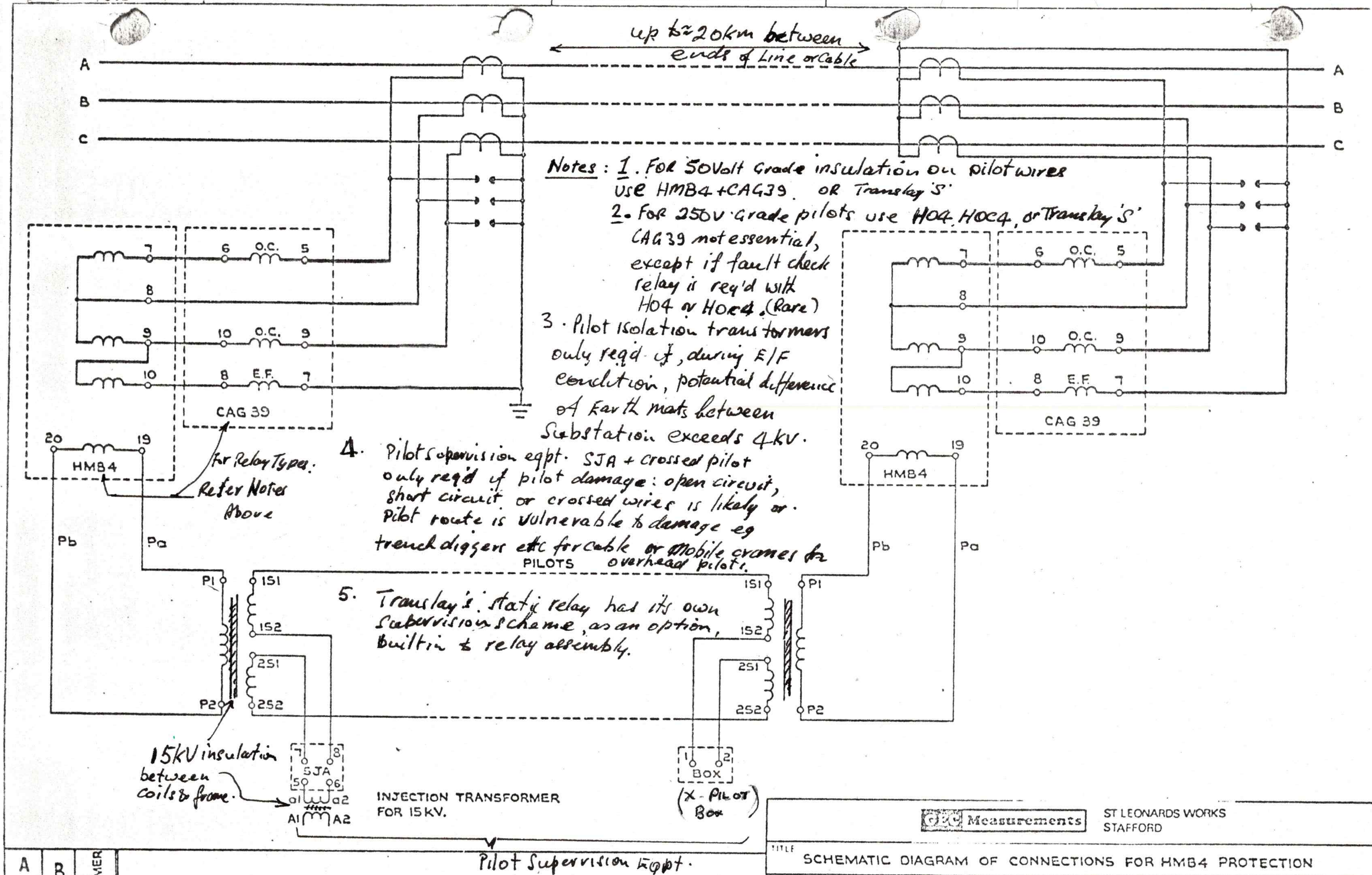

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TITLE SCHEMATIC DIAGRAM OF CONNECTIONS FOR HMB4 PROTECTION

A	ORIGINAL ISSUE	DATE 20.4.72	
B	INJECTION TRANSFORMER ADDED	R.J. 2.5.73	

SCALE | M.R.T. DESIGN | DRAWN R.J. | CHECKED | PASSED | APPROVED

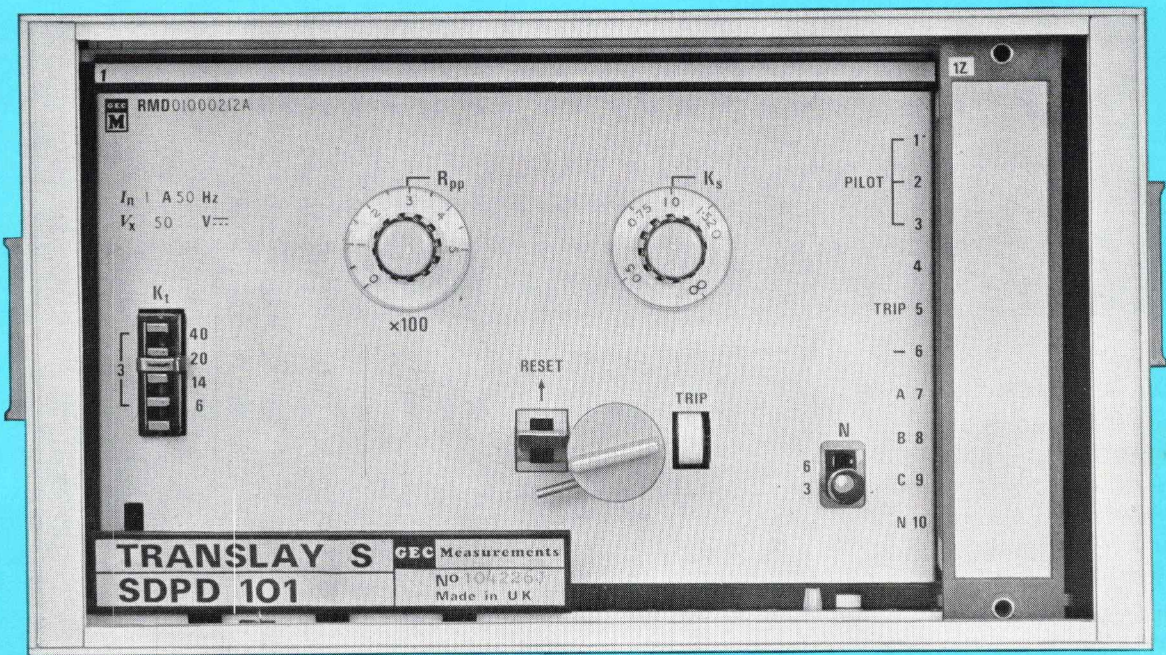
DRG No 595F0154

WHEN QUOTING THE DRAWING NUMBER PLEASE STATE THE LATEST LETTER OF ISSUE

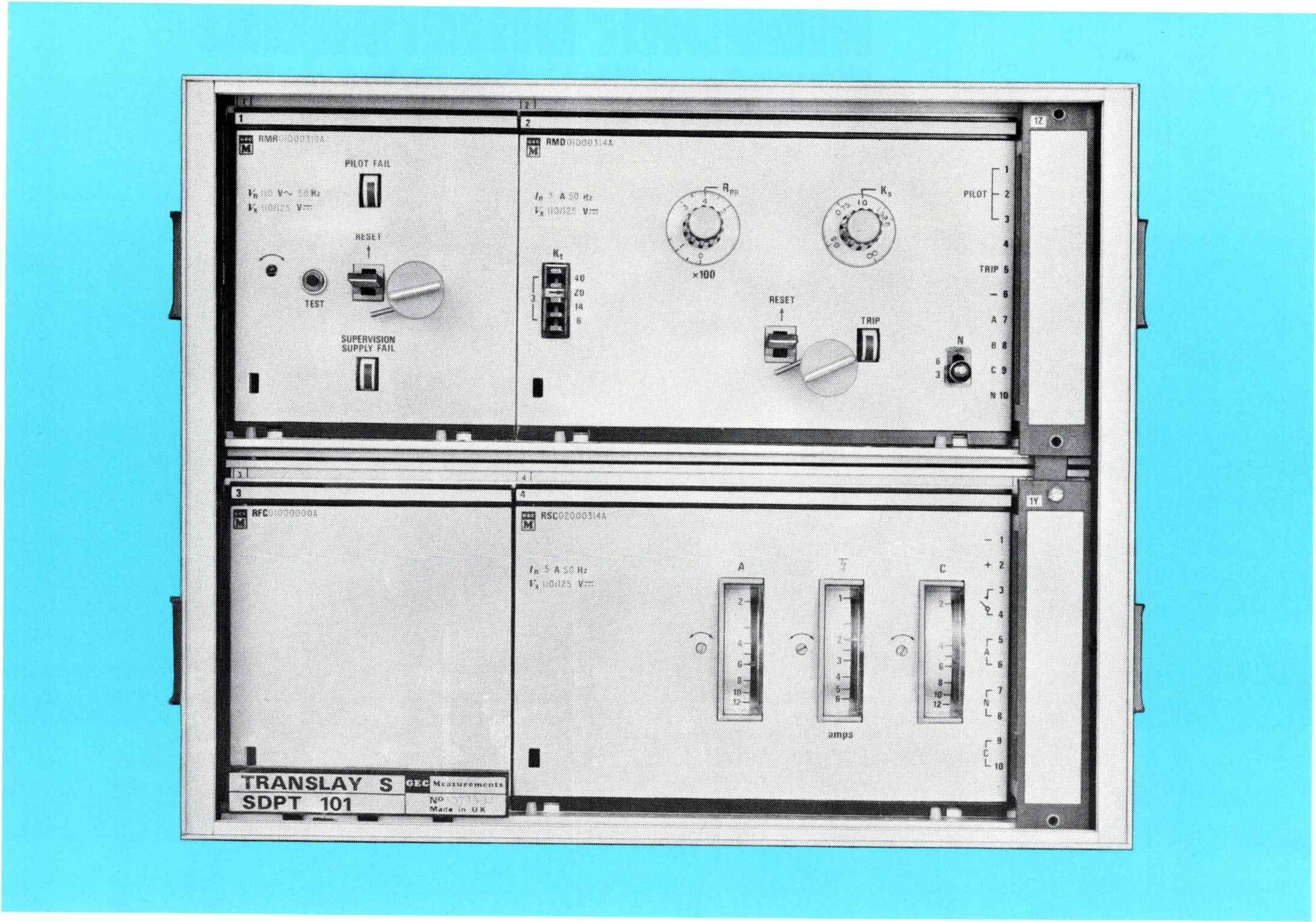
GEC Measurements

Type Translay S

Modular Differential Feeder Protection



Type Translay S



FEATURES

* High stability for through faults
* High speed operation for in-zone faults
* Simultaneous tripping of relays at each line end
* Low current transformer requirements
* Low earth fault settings
* Suitable for both overhead lines and underground feeders
* Suitable for pilots up to 2500 ohms
* Pilot isolation for 5kV or 15kV
* Four electrically separate contacts

APPLICATION

The type Translay S differential schemes have been designed for the unit protection of overhead and underground feeders.

Differential feeder protection requires a comparison of the currents entering and leaving the protected zone. For faults occurring within the protected feeder it is desirable to trip the circuit breakers at each end to isolate the fault. Two relays are therefore required, one for each end of the feeder. A pair of pilot wires is used to transmit information between the two relays so that each may be able to compare the current flowing at their respective end with the current at the other.

The relays at both line ends operate simultaneously, providing rapid fault clearance irrespective of whether the fault current is fed from both line ends or only one line end.

When applying this protection to overhead lines the limiting factor is generally the length of the pilot circuits; for cable feeders the limiting factors are more likely to be the level of line charging current and the method of system earthing.

Intertripping

When the protected line is connected to a busbar system, a fault on the busbars will in general be cleared by the busbar protection by opening some or all of the local circuit breakers. Although such faults will usually appear to the feeder protection as through faults, with resultant stability of the feeder protection, it may be desirable to open the remote line circuit breaker also, to clear the line completely.

The differential feeder protection can be used for intertripping the remote circuit breaker by means of optional items of equipment. A means of destabilising the differential protection can be used when through fault current persists despite operation of busbar protection. If the protected feeder is not carrying current, the differential protection can be operated by means of an additional intertripping unit, from which an a.c. voltage is injected into the pilot circuit.

TYPES OF TRANSLAY S

Several protective schemes are available, some including pilot supervision and overcurrent check features, so that a wide range of applications may be covered. The pilot supervision module provides time delayed flag and contact indication for both pilot failure and supervision supply failure whilst the check feature prevents operation of the differential protection for all but primary system fault conditions.

A tripping output assembly is provided in the rear of the relay case for each of the above types. This assembly comprises any one of the following alternative optional combinations:

* Tripping output element only.

* Tripping output element, plus destabilising element.

* Tripping output element, plus destabilising element, plus intertripping element.

The basic equipment differs at each line end for some schemes. If identical cases are required for both line ends for these schemes, to facilitate standardisation of mounting arrangements, two of the larger cases can be supplied, one having a blank substitution module. Both equipments will then have the basic type reference relating to the larger case.

TYPICAL SCHEME ARRANGEMENTS

SCHEME	PILOT INSULATION LEVEL (kV)	SUPERVISION	O/C STARTERS	ARRANGEMENT OF EQUIPMENT
A	5kV	—	—	SDPD 101 (1) — Pilots — SDPD 101 (1)
B	15kV	—	—	SDPD 101 (1) — SDPD 101 (1)
C	5kV	●	—	SDPS 103 (3) (2) (1) — SDPS 102 (3) (1)
D	15kV	●	—	SDPS 101 (2) (1) — SDPD 101 (1)
E	5kV	—	●	SDPC 101 (4) (1) — SDPC 101 (4) (1)
F	15kV	—	●	SDPC 101 (4) (1) — SDPC 101 (4) (1)
G	5kV	●	●	SDPT 101 (2) (1) (3) (4) — SDPT 101 (2a) (1) (3) (4)
H	15kV	●	●	SDPT 101 (2) (1) (3a) (4) — SDPC 101 (4) (1)

No.	Type of Module
1	Differential
2	Pilot supervision measuring
2a	Pilot supervision substitution
3	Injection filter for use with supervision
3a	Injection filter substitution
4	Overcurrent

15kV Isolating transformer

15kV Isolating transformer with injection filter

Type	Differential Protection	Pilot Supervision	Injection Filter	Overcurrent Checking/ Starting
SDPD 101	●	—	—	—
SDPS 101	●	●	—	—
SDPS 102	●	—	●	—
SDPS 103	●	●	●	—
SDPC 101	●	—	—	●
SDPT 101	●	●	●	●

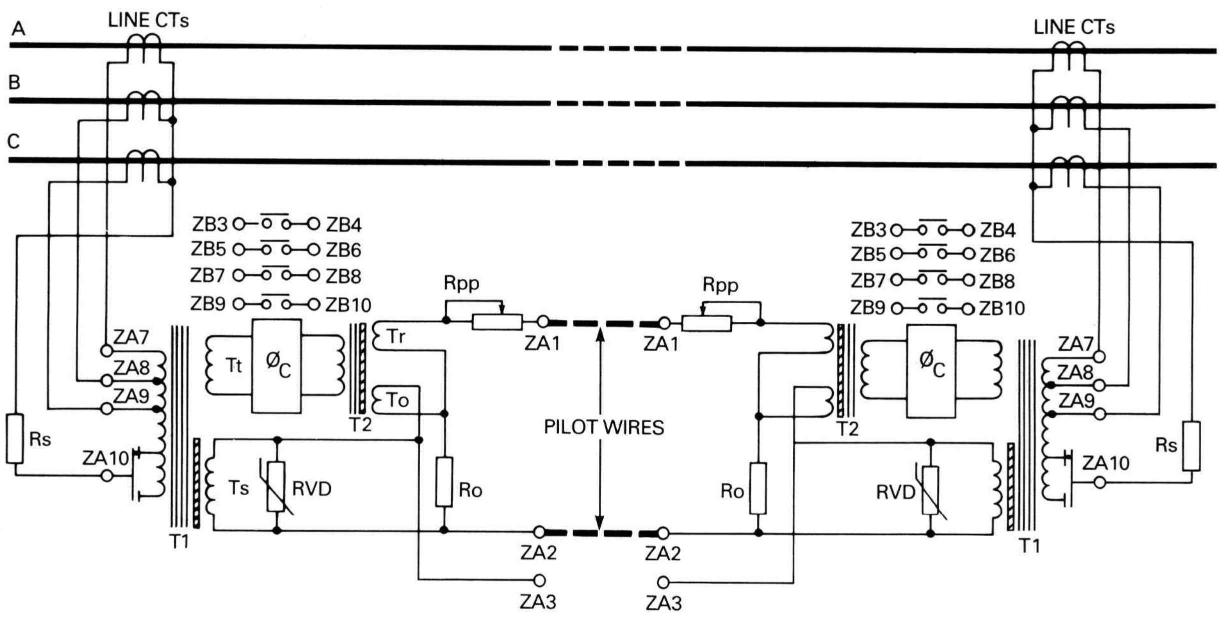


Figure 1. CIRCUIT DIAGRAM FOR TRANSLAY S DIFFERENTIAL FEEDER PROTECTION

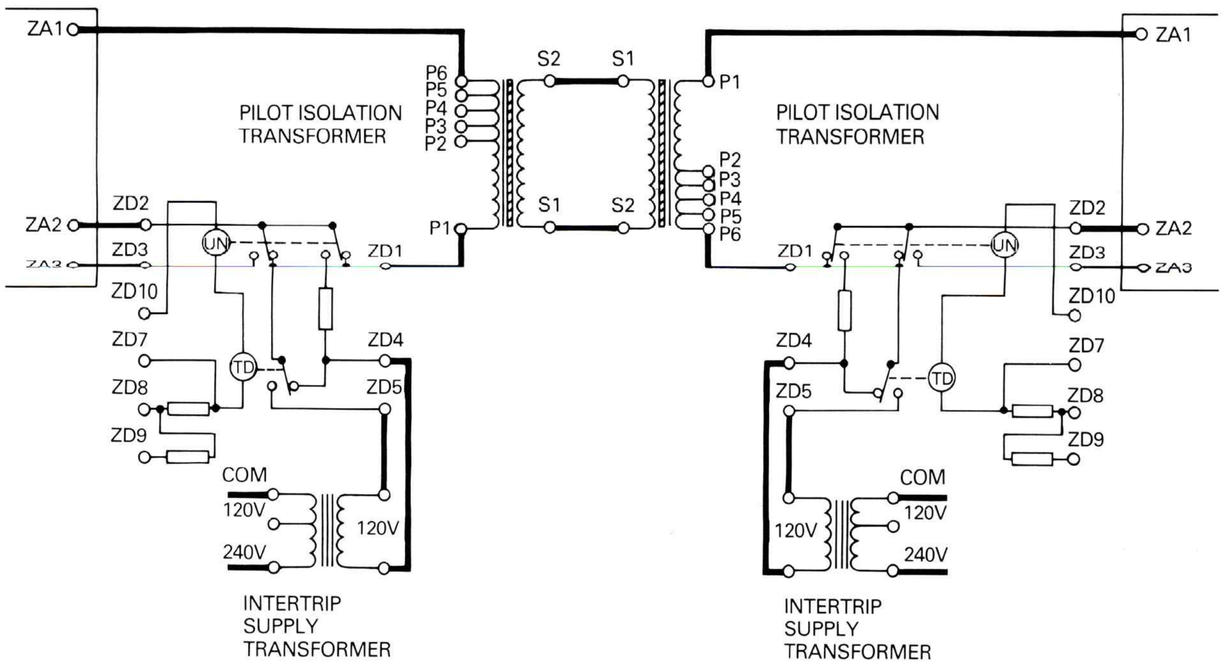


Figure 2. CONNECTIONS FOR INTERTRIP ELEMENT AND PILOT ISOLATION TRANSFORMERS

OPERATION

Differential protection

The differential feeder protection circuit is derived from the well known Merz-Price circulating current system and employs phase comparators as the measuring elements. This novel combination provides high stability performance for external faults, with the minimum of bias (restraint), thereby ensuring that the low earth fault settings are effectively retained even when load current is flowing.

Figure 1 shows the basic circuit arrangement. A summation current transformer T1 at each line end produces a single phase current proportional to the summated three phase currents in the protected line. The neutral section of the summation winding is tapped to provide alternative sensitivities for earth faults.

The secondary winding supplies current to the relay and the pilot circuit in parallel with a non-linear resistor (RVD). The non-linear resistor can be considered to be non-conducting at load current levels. Under heavy fault conditions it conducts an increasing current and thereby limits the maximum secondary voltage. At normal current levels the secondary current flows through the operation winding To on transformer T2 and then divides into two separate paths, one through resistor Ro and the other through the restraint winding Tr of T2, the pilot circuit and resistor Ro of the remote relay.

The resultant of the currents flowing in Tr and To is delivered by the third winding on T2 to the phase comparator and is compared with the voltage across Tt of transformer T1. The emf developed across Tt is in phase with that across the secondary winding Ts which is in turn substantially the voltage across Ro.

Taking into account the relative values of winding ratios and circuit resistance values, it can be shown that the quantities delivered for comparison in phase are:

$(\bar{I}_A+2\bar{I}_B)$ and $(2\bar{I}_A+\bar{I}_B)$

where I_A and I_B are the currents fed into the line at each end (for through faults $I_A=-I_B$). The expressions are of opposite sign for values of I_B which are negative relative to I_A and are between $0{\cdot}5\,I_A$ and $2I_A$ in value. The system is stable with this relative polarity and operates for all values of I_B outside the above limits.

The phase comparator has angular limits of ±90° giving a circular bias characteristic in the complex plane.

If the pilots are open circuited, current input will tend to operate the relay. Conversely, short-circuited pilots will cause the relay to restrain, holding its contacts open.

Transformers T1 and T2 also provide the necessary insulation barriers for static circuitry.

The input circuits of the phase comparator are tuned to the power frequency so that the threshold of operation increases with frequency. This de-sensitises the relay to the transient high frequency charging current that flows into the line when it is energised. A further advantage provided by the tuned input is that the waveform of the derived signal, which may be severely distorted by current transformer saturation, is improved, ensuring

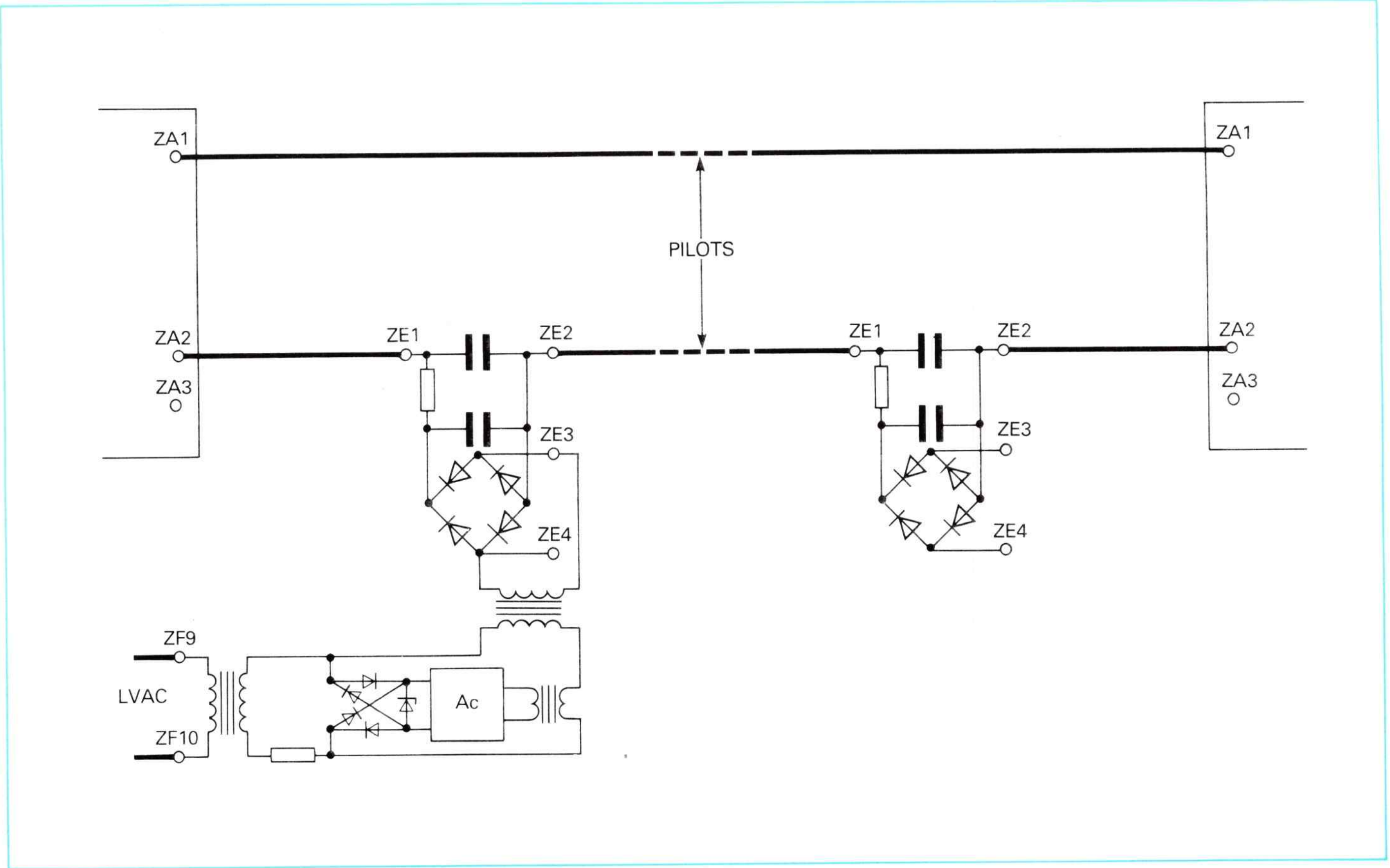


Figure 3. CONNECTIONS FOR PILOT SUPERVISION (5kV INSULATION)

high speed operation under adverse conditions.

In order to maintain the bias characteristic at the designed value it is necessary to pad the pilot loop resistance to 1000 ohms. A padding resistor R_{PP} is provided in the relay for this purpose. However, when pilot isolation transformers are used, the range of primary taps enables pilots of loop resistance up to 2500 ohms to be matched to the relay. The pilot insulation level is also raised to 15kV by these transformers.

Telephone type pilots

When the pilots to be used are of the telephone type, and particularly when they are rented, an alternative limiter based on a zener diode is available to ensure that the maximum voltage which can appear on the pilot system is within prescribed limits. Pilot isolating tranformers are used in this arrangement also, both to provide insulation to 15kV and also indirectly, to enable pilots of relatively high resistance to be used.

Destabilise/intertrip facilities

Figure 2 shows the arrangement for destabilising and intertripping the protection. Operation of the relay (UN) short circuits the local summation transformer secondary winding so that the relay at that end is rendered inoperative. At the same time this action results in the protection becoming unstable, so that the relay at the remote end operates. Destabilising is not satisfactory if overcurrent starters/check relays are used. See section headed Overcurrent/Check Starter.

However, if there is no current flowing in the protected circuit, destabilising the protection will not cause operation. In order to intertrip the remote end it is necessary to inject an a.c. voltage into the pilot circuit. The intertrip relay (TD) operates approximately 120 milliseconds after the destabilising relay to inject the intertrip voltage. The time delay ensures that the injection voltage can never block tripping when the line is carrying current at the time the intertrip is initiated.

When pilot isolation transformers are not used the injection tranformers for the intertrip voltage should be insulated for 5kV. If the destabilising feature only is required, the latter transformers are not required and terminals ZD4 and ZD5 are linked together.

Pilot supervision

Correct interchange of information over the pilot circuit is essential for the proper functioning of any differential feeder protection.

Pilots may be exposed to hazards and some risk of damage and failure always exists. The most common pilot failure is to the open circuit state, caused by the accidental excavation of buried pilots or storm damage to overhead pilots. With the pilots open circuited the differential protection will be unstable and will trip the feeder if sufficient through current is flowing. For this reason the circulating current system is often preferred as such schemes will fail safe and trip so that attention is immediately drawn to the fault.

The addition of pilot supervision will not prevent tripping for pilot faults but will indicate the cause. It will also detect short circuit and cross-connected pilot conditions

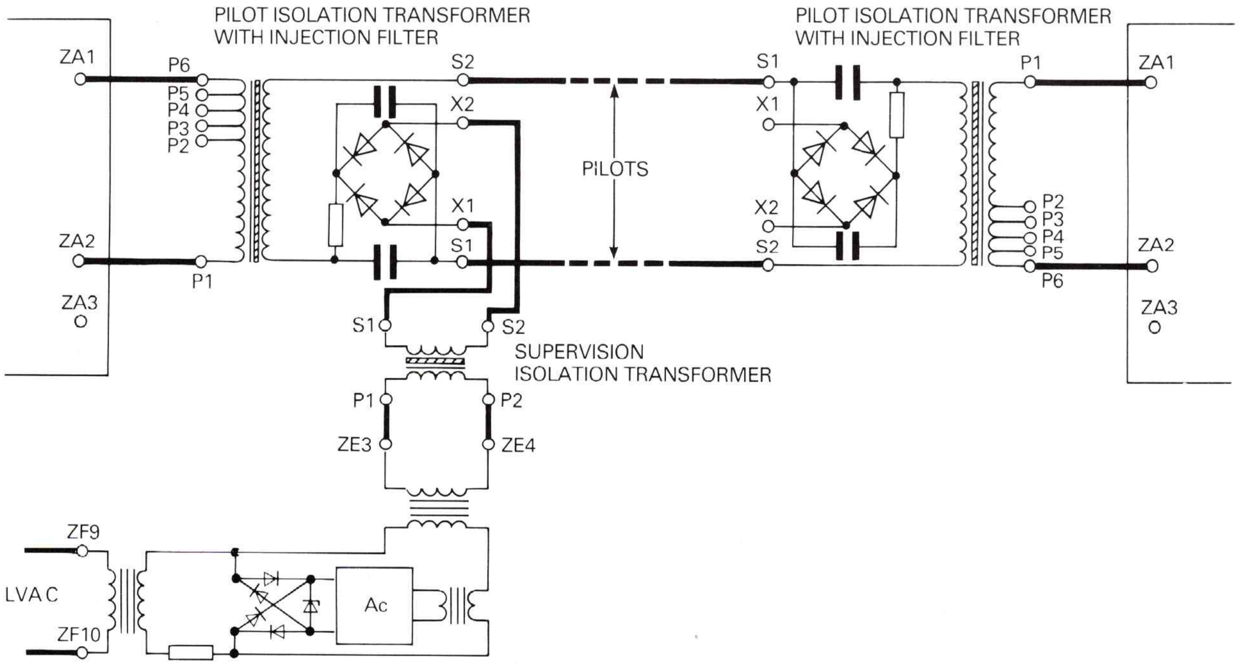


Figure 4. CONNECTIONS FOR PILOT SUPERVISION (15kV INSULATION)

which would not otherwise be detected. Indication is also provided for loss of the supervision supply.

Figure 3 shows the arrangement for pilot supervision in a pilot circuit insulated for 5kV. In this instance the injection filters and the supervision unit are assembled in modules within the relay case.

The supervision circuit requires a low voltage a.c. supply which is connected to terminals ZF9 and ZF10. The input transformer can be provided with a primary winding to suit the available supply. The secondary voltage is converted to a clipped sine wave of constant amplitude by a zener diode connected in a rectifier bridge circuit. The d.c. voltage developed across the zener diode is used to power the measuring circuit (A_C) which in turn measures the current flowing into the injection filter.

The clipped sine wave voltage is rectified in the injection filter and a capacitor is charged to the peak value to produce a constant level d.c. voltage. A capacitor connected in the pilot circuit between terminals ZE1 and ZE2, by-passes the a.c. pilot current and directs a d.c. current from the supervision around the pilot circuit. To enable crossed pilots to be detected and ensure correct indication for pilots which become short circuited at the remote end, it is necessary to include a second injection filter in the pilot circuit as shown for the remote line end. This filter ensures that remote short circuits eliminate sufficient resistance in the pilot loop to cause a detectable current change.

A change in the d.c. supervision current is indicative of a pilot fault and causes a corresponding change in the a.c. current supplied by the supervision unit. The measuring circuit monitors this a.c. current and initiates a PILOT FAILURE alarm after a time delay, if a sufficient change takes place. The a.c. supervision supply is also monitored and in the event of failure a time delayed SUPPLY FAILURE alarm is initiated.

When the intertrip unit is included it should be connected on the relay side of the injection filter so that pilot failure is not indicated when the relay UN is operated. Also the link between terminals ZD4 and ZD5 must not be left open circuited otherwise pilot failure may be indicated. This requirement is not invalidated by

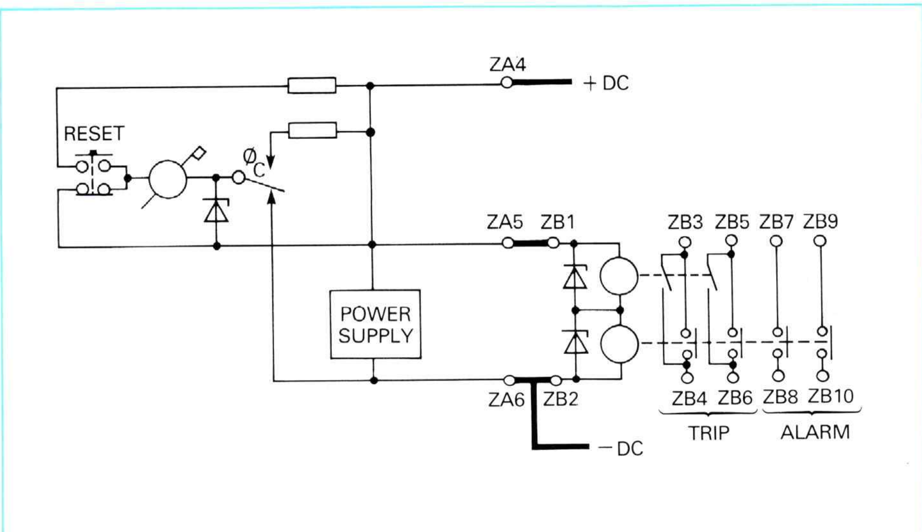


Figure 5. D.C. CONNECTIONS FOR DIFFERENTIAL RELAY

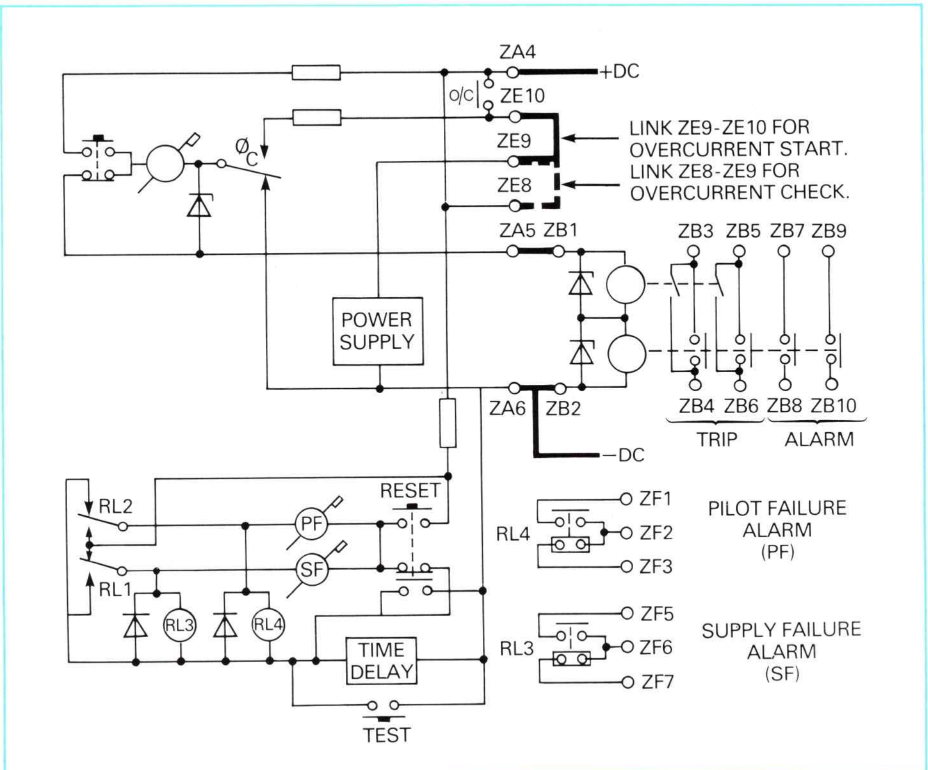


Figure 6. D.C. CONNECTIONS FOR DIFFERENTIAL RELAY WITH PILOT SUPERVISION AND OVERCURRENT CHECK/STARTER

the connection of the transformer across these terminals for the intertripping feature, because the secondary winding of this transformer presents a low d.c. resistance.

Figure 4 shows the similar arrangement for pilot circuits insulated for 15kV. The injection filters are then assembled as part of the isolation transformers and have to be isolated from the supervision module. The injection tranformer provides the necessary 15kV isolation barrier.

Overcurrent check/starter

Although the supervision scheme provides indication of pilot failure it does not prevent the protection operating if primary current above setting is flowing. Where this hazard is unacceptable it is necessary to add an overcurrent check feature.

A separate module is available, containing three overcurrent elements. Two of these are phase fault elements, with a setting range of 0.4 I_n– 2.4 I_n; the third element, for earth faults, has a setting range of 0.2 I_n– 1.2 I_n.

The differential relay normally draws a current of 15mA from the auxiliary d.c. supply. Where this is undesirable the overcurrent relay may be used as a starter, so that there is no d.c. current drawn unless an overcurrent condition exists. When the starting feature is used the overall operation time of the scheme is increased by the operating time of the starter, as shown in Figure 7. However, there is no increase in the overall operation time when the overcurrent protection performs a check function only.

When overcurrent relays are used the protection cannot be intertripped by a.c. injection into the pilots, and destabilising the protection will result in tripping only if an overcurrent condition exists simultaneously.

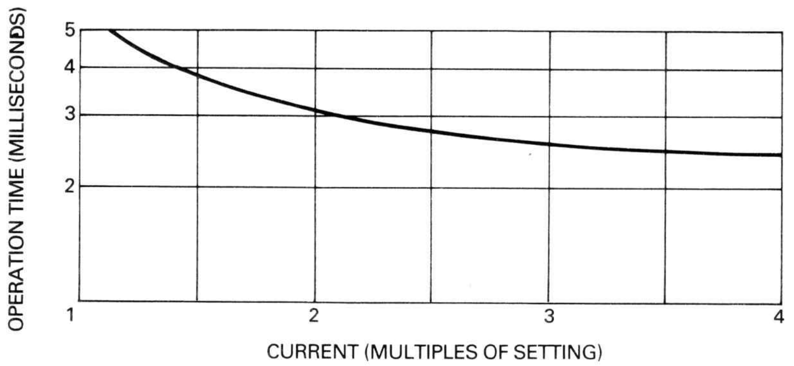


Figure 7. OPERATION TIME OF OVERCURRENT ELEMENT

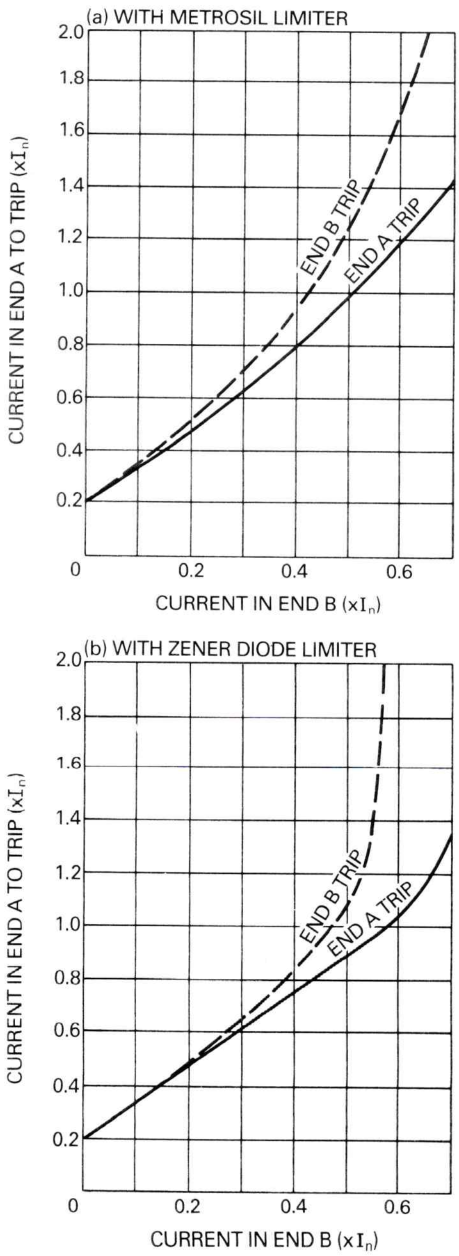


Figure 8. TYPICAL BIAS CHARACTERISTICS FOR A–N FAULTS (Ks=1: N=3)

D.C. CONNECTIONS

The d.c. connections for the basic differential relay are shown in Figure 5. When pilot supervision and overcurrent elements are included the arrangement shown in Figure 6 applies. The necessary external connections are shown in heavier lines in these two figures.

CURRENT TRANSFORMER REQUIREMENTS

High speed operation is obtained with moderately sized transformers.

Where space for current transformers is very limited and the lowest possible operation time is not essential, smaller current transformers may be used. This is made possible by a special adjustment, K_t, by which the operation time of the differential protection can be increased, with a corresponding decrease in the knee-point voltage requirement for the current transformers, whilst ensuring through fault stability is maintained to greater than $50\,I_n$.

Details of the current transformer requirements and operation time characteristics are specified in the Technical Data section.

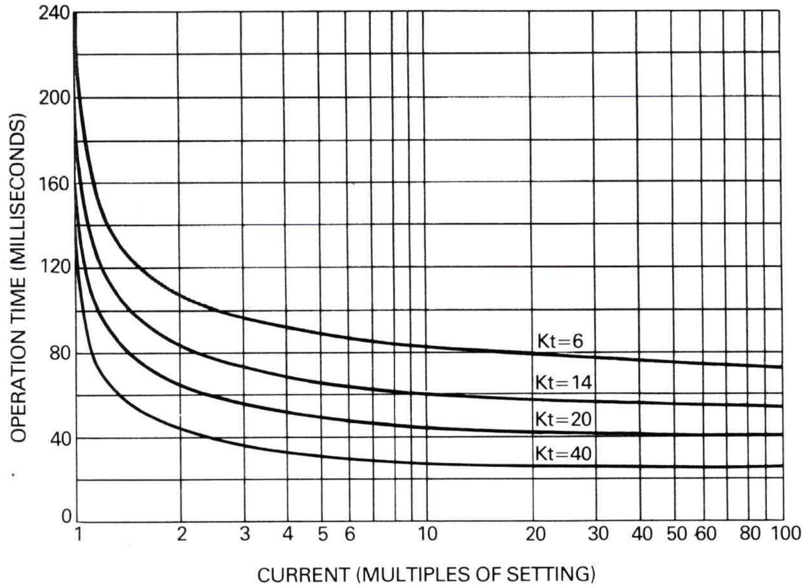


Figure 9. TYPICAL OPERATION TIME CHARACTERISTICS FOR DIFFERENTIAL RELAY

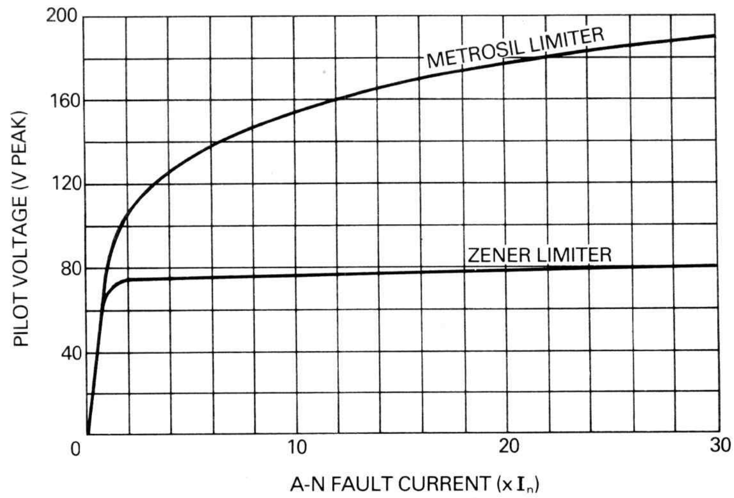


Figure 10. PILOT VOLTAGE CHARACTERISTICS

TECHNICAL DATA

Current rating (In) 1A, 2A or 5A

Frequency rating 50Hz or 60Hz

Current withstand ratings

Fault	Duration (secs)	Differential	Overcurrent
Phase	Continuous	2 In	2 In
Earth	Continuous	2 In	1.2 In
Phase	3 2 1 0.5	45 In 55 In 80 In 100 In	30 In 40 In 55 In 75 In
Earth	3 2 1 0.5	45 In 55 In 80 In 100 In	24 In 30 In 42 In 60 In

Auxiliary supply ratings

D.C. auxiliary supplies: 30, 50, 110/125 or 220/250V (15mA continuous drain)

A.C. supervision supply: 110, 127, 220 or 240V at 50 Hz or 60Hz

Destabilising and intertrip element supply: 50, 110/125 and 220/250V d.c. (continuous rating)

A.C. intertrip supply:

Rated Voltage	Operative Voltage Range
120V	80–140V
240V	160–280V
Frequency	50Hz and 60Hz

Current settings

Differential
(summation ratio=1.25/1/N)

K_s=0.5 – 2.0

Fault	Settings	
	N=3	N=6
A–N B–N C–N	$0.19K_sIn$ $0.25K_sIn$ $0.33K_sIn$	$0.12K_sIn$ $0.14K_sIn$ $0.17K_sIn$
A–B B–C C–A A–B–C	$0.8K_sIn$ $1.0K_sIn$ $0.44K_sIn$ $0.51K_sIn$	

Phase fault check elements: 0.4 In – 2.4 In

Earth fault check elements: 0.2 In – 1.2 In

Reset current levels

Phase and earth fault overcurrent check elements.: Not less than 90% of setting. Typically 95% of setting.

Bias characteristics: As shown in Figure 8.

Stability level: The stability of the protection for through faults is greater than 50 In.

Operation time: The operation time is adjustable, as shown in Figure 9.

Average time at 5 x setting current

(ms)	30	50	65	90
for K_t	40	20	14	6

Maximum line charging current

Solid earthed system	0.9 x (A–N fault setting)
Resistance earthed system	0.32 x (A–N fault setting)

Pilots

Matching ratio K_M	0.8	1.0	1.2	1.5	2.5
Loop resistance (ohm)	800	1000	1200	1500	2500
Capacitance (μF)	6.25	5	4.2	3.3	2
Terminals	P1–P6	P1–P5	P1–P4	P1–P3	P1–P2

Where K_M=(turns ratio)^2 for respective tap of pilot isolation transformers. When pilot isolation transformers are not used K_M=1.

Pilot voltage

The relationship between peak pilot voltage and fault current is shown in Figure 10 for the most severe fault current. When pilot isolation transformers are used the voltage values indicated in Figure 10 should be multiplied by $\sqrt{K_M}$.

Contacts

Differential:

Trip	2 make contacts
Alarm	2 make contacts

Pilot Supervision:

Pilot Failure	1 change-over
Supply Failure	1 change-over

Ratings:

Make and carry 3000VA for 0.2 seconds with maxima of 30A and 250V (Trip output only).
Make and carry 1250VA continuously with maxima of 5A and 250V (Alarm).

Break 100W resistive with maxima of 5A and 250V.

Insulation

The equipment is designed to withstand:

* 2kV r.m.s. for 1 minute between all case terminals connected together and the case.
* 2kV r.m.s. for 1 minute between independent circuits of the scheme, including contact circuits.
* 1kV r.m.s. for 1 minute across the contacts of the normally open outgoing contact pairs.
* 5kV r.m.s. for 1 minute between pilot circuit terminals and all other circuits within the relay and the case.
* 15kV r.m.s. for 1 minute between the secondary winding of the pilot isolation transformer and its primary winding and core.

Impulse withstand

The relay will withstand impulses of 5kV peak and 1/50 microsecond waveform applied both transversely and between relay terminals and earth, in accordance with BEAMA document No. 219, Class 3 and IEC draft recommendations.

High frequency disturbance

The relay meets the draft IEC test recommendation for the High Frequency Disturbance test. The relay accuracy is unaffected by repetitive 1MHz bursts having an initial peak of 1.0kV superimposed across the terminals of each independent circuit, and 2.5kV between independent circuits, and circuits to earth, with a decay time of 3 to 6 microseconds and with a repetition rate of 400 bursts per second. The test is performed with the relay energised.

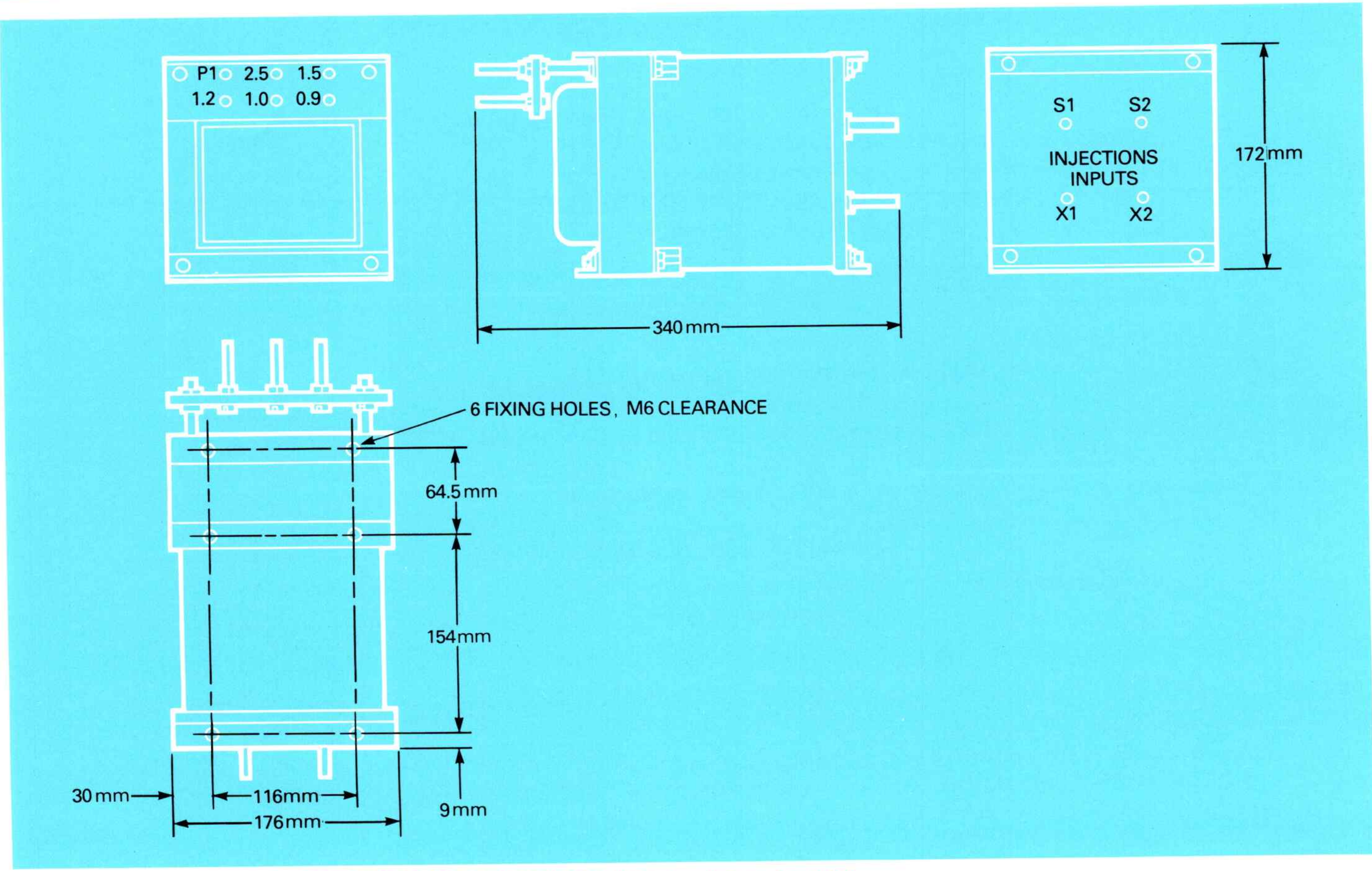


Figure 13 PILOT ISOLATION TRANSFORMER WITH FILTER. With insulation for 15kV

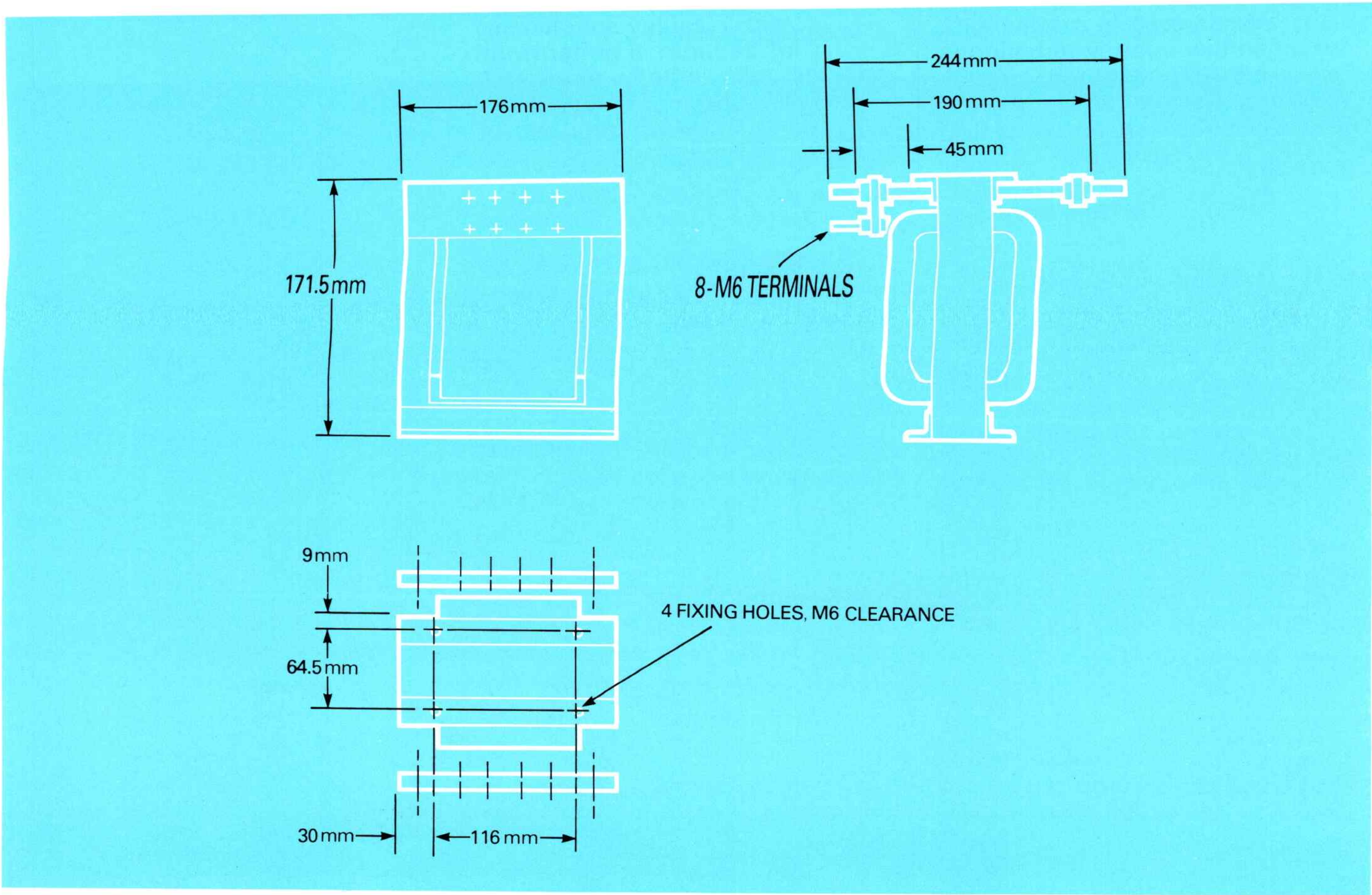


Figure 14 PILOT ISOLATION TRANSFORMER WITHOUT FILTER. With insulation for 15kV

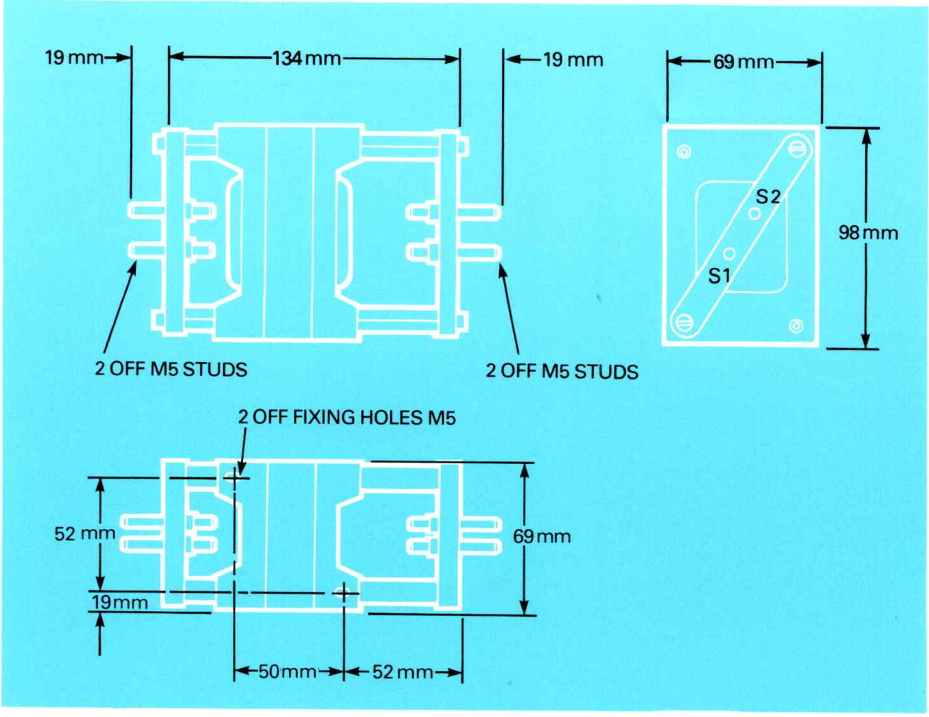


Figure 15 PILOT SUPERVISION ISOLATION TRANSFORMER. With insulation for 15kV

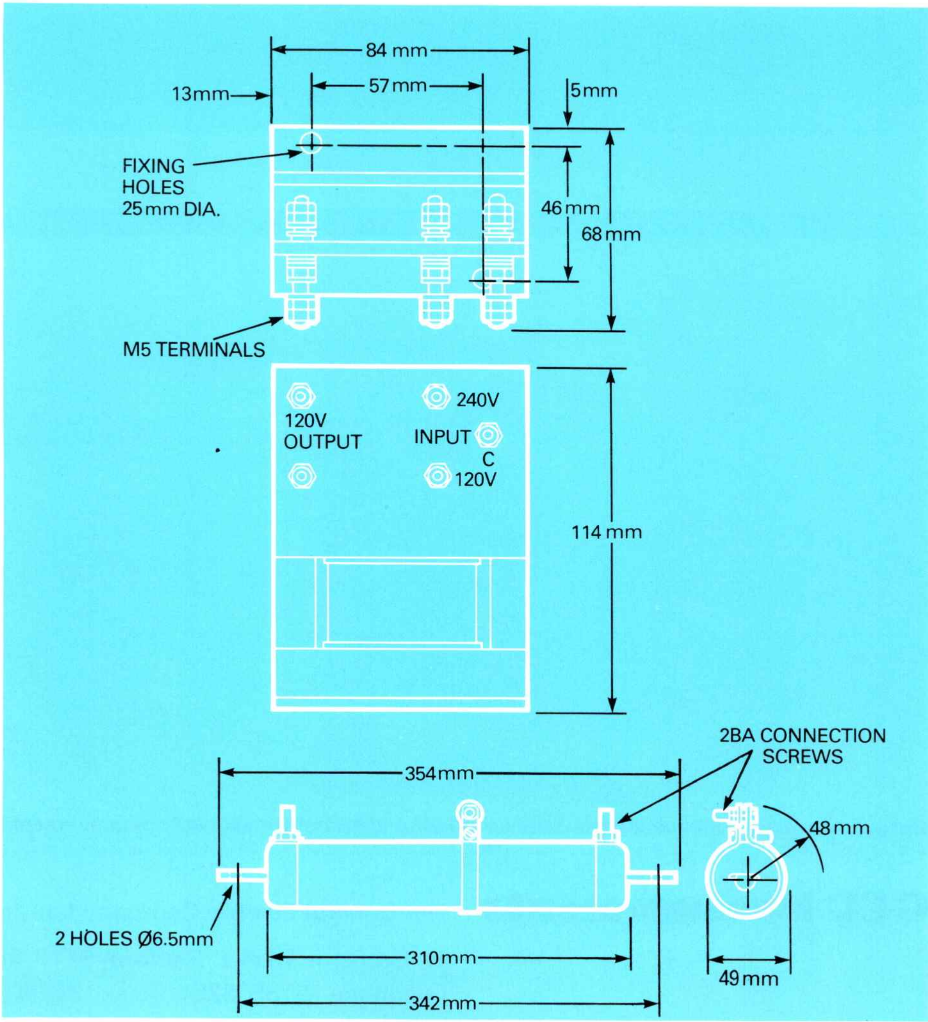


Figure 16 INTERTRIP SUPPLY TRANSFORMER STABILISING RESISTOR

GEC Measurements The General Electric Company Limited of England

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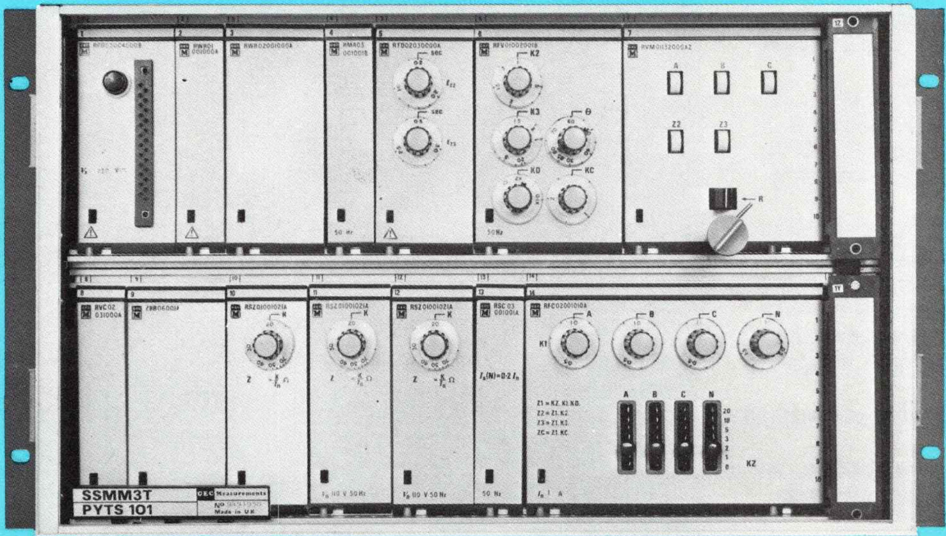
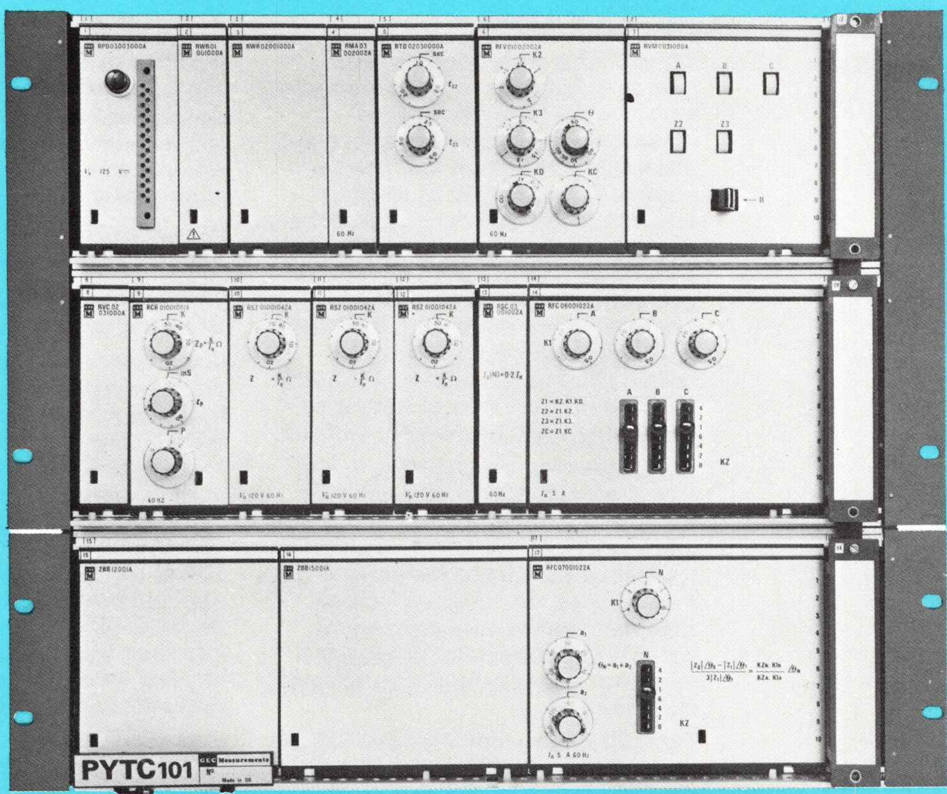
GEC Measurements

Types PYTS & PYTC Switched Distance Relays

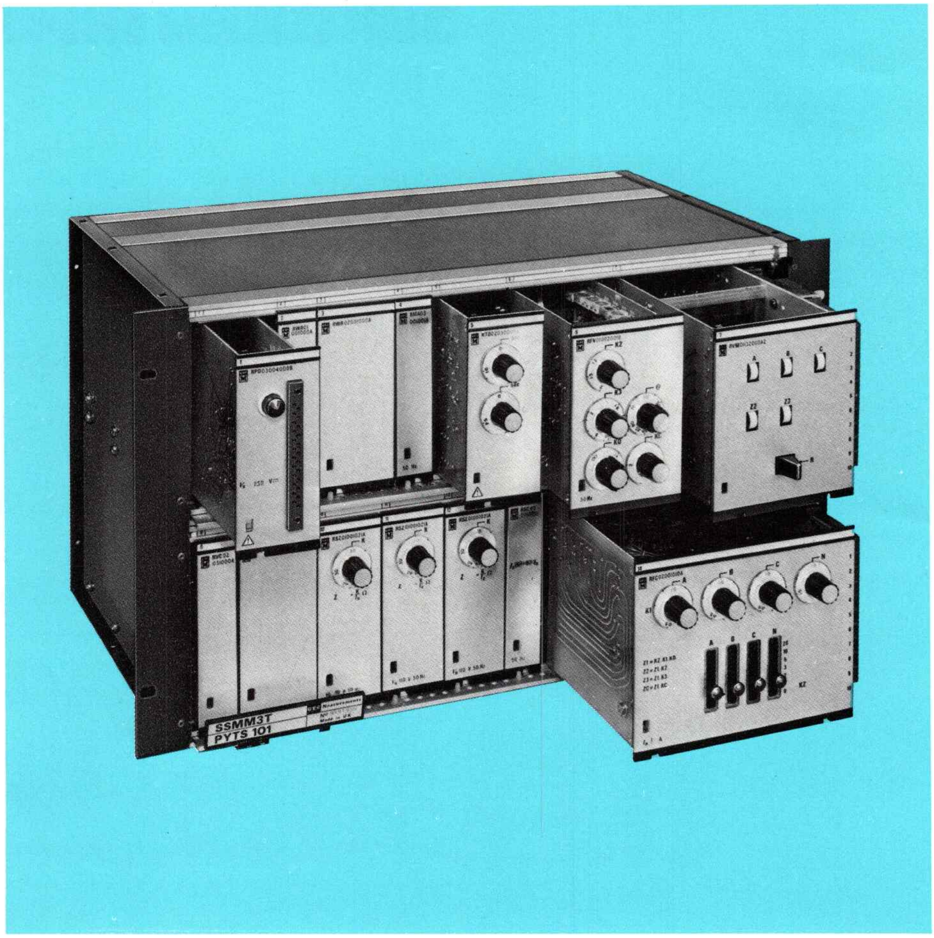




Types PYTS & PYTC

FEATURES

* Minimum operating time 20 milliseconds for Zone 1 faults.
* Mho characteristic with full cross polarisation ensures maximum tolerance of arc resistance on the type PYTS.
* Accurate measurement for source/line impedance ratios up to 100/1 (phase faults) and 60/1 (earth faults).
* Static circuitry throughout imposes low VA burden on current transformers and voltage transformers.
* Mho characteristic with self polarisation and optional cross polarisation on the type PYTC to cover a mixture of overhead and cable systems.
* Angular residual compensation is available on the PYTC for accurate earth fault measurement.
* Versions available to suit systems earthed solidly, by resistance or Petersen coil and to suit insulated systems.
* A relay characteristic angle setting of 30° to 85°.
* Modular plug-in construction, with built-in test points, permits easy maintenance.
* Compact construction saves panel space.
* Trip circuit supervision, high speed trip relays and auxiliary relays for use with protection signalling, available in additional integral sub-rack.



APPLICATION

The PYTS is a fast and accurate switched distance relay scheme which employs the mho principle of measurement. It provides phase and earth fault protection and can be applied economically to short or medium length overhead transmission and distribution lines. The scheme is a practical alternative to directional overcurrent protection in power systems with a multiplicity of infeeds which make grading difficult, a realistic choice for protection where pilot wires cannot be used and as back-up protection on EHV systems.

Complete three phase, three zone distance protection is provided, using a mho characteristic for power systems which are solidly earthed or resistance earthed or are earthed by means of an arc suppression coil. Residual current compensation is included to ensure that the relay measures correctly under earth fault conditions.

The PYTC is a version of the PYTS designed for protection of underground cable systems and combined cable and overhead line applications. It incorporates all the features associated with PYTS, with the addition of a neutral compensation module providing phase angle adjustment as well as amplitude adjustment of the residual compensation factor. This 6″ module is located separately in a third sub-rack.

Two types of starting elements are available for phase selection.

Instantaneous overcurrent starting elements

These can be applied only where the minimum fault current is greater than the maximum load current and where the increase in healthy phase currents for an earth fault is less than the setting of the overcurrent starting elements.

Impedance starting elements

These are recommended for applications where the fault current under minimum plant conditions is less than the maximum load current and are available for solidly or resistance earthed systems only.

A residual overcurrent starting element is a standard feature of the protection.

Features

Standard features among the many facilities available include:

* Provision for single or three phase auto-reclose selection.
* A 'switch-on-to-fault' facility which provides an instantaneous trip if the line is energized on to a three phase fault.
* The protection is suitable for use on systems using either line or busbar voltage transformers and time delay link adjustments are fitted to cater for electromagnetic or capacitor type voltage transformers.

Optional facilities include:

* Instantaneous zone extension. This allows instantaneous tripping for the complete line when used with auto-reclose facilities without the need for a signalling channel. It can also be used in other specialized modes such as in carrier acceleration schemes.
* A directional/non-directional fourth zone which permits time delayed tripping from starting elements.
* Power swing blocking (PSB) used with impedance type starting elements. This module detects power swings on the system and blocks operation of the distance protection. It has the advantage that it can be added when required.
* Override facilities are provided with the PSB element, enabling the distance protection to override it in various zones.
* The relays can be fitted with remote flag control, a feature used in blocking or permissive overreaching schemes.
* Fuse failure detection can be incorporated in the distance protection as an additional module housed in a third sub-rack or provided as a separate relay type PVFS.

Figure 14 shows a diagram of the modular construction together with a key describing the functions of the various modules.

OPERATION

The relays use block-average comparators to produce the well established and proven mho measuring characteristic.
The PYTS relay utilises a fully cross-polarised directional mho measuring element which is switched to the correct phase by starting elements.

The PYTC relay uses self-polarisation with a small amount of cross-polarisation for plain cable feeders. For hybrid combinations of underground cable and overhead line, where high values of arc resistance may be encountered, the relay is provided with 100% cross-polarisation to enable the mho characteristic to expand in the presence of unbalanced faults.

Phase selection is performed by static phase starter elements S1, S2 and S3. Figure 2 shows the block diagram of the complete relay with overcurrent elements; Figure 3 shows the alternative input arrangements for impedance starters.

The neutral overcurrent starter element S4 is fitted to provide remote indication of earth faults and to control the zone extension facility for earth faults only when required. It is also used to override the power swing blocking unit under earth fault conditions when used in conjunction with impedance starter elements.

A voltage V is derived from the faulted phase or phases and a voltage V POL is taken from a combination of faulted and healthy phases depending on the polarising characteristic chosen. A signal (IZ) proportional to the fault current is provided by transactors T5, T6, T7 and T8 which eliminate the effects of d.c. offsets. Transactor T8 provides zero sequence current compensation.

The measuring unit characteristic is produced by a phase comparator circuit which receives the signals V-IZ and V POL. These inputs are selected by a switching network according to the fault detected by the appropriate starting element(s). An output from the phase comparator is fed into an integrator and then to a level detector to initiate a trip circuit.

A 'switch-on-to-fault' circuit controlled by the voltage supplied by interposing voltage transformer (T10) produces an operation signal for the trip circuit if the circuit breaker is closed on to a three phase faulted line.

The d.c. supply for the scheme is taken from the station battery and is regulated and stabilized by a series regulator. An a.c. assisting circuit, fed from an interposing voltage transformer T9, is used to supplement the d.c. regulator, ensuring negligible battery drain under quiescent conditions.

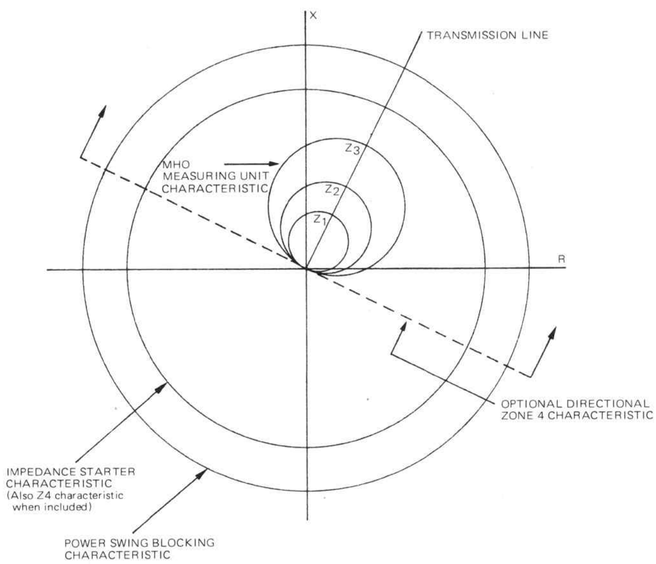


Figure 1. IMPEDANCE CHARACTERISTICS INCLUDING THOSE OF OPTIONAL ZONE 4 AND POWER SWING BLOCKING FEATURE

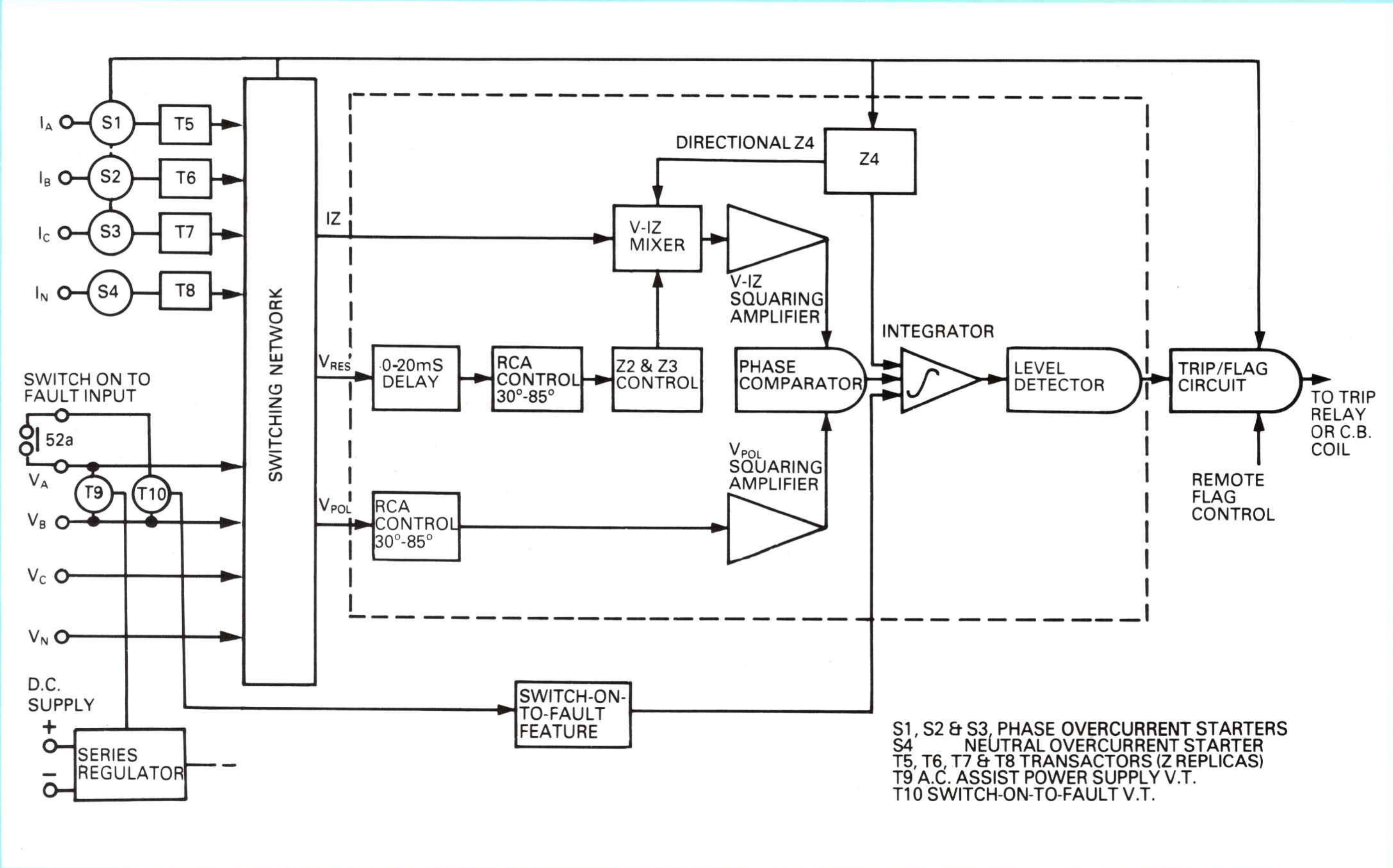


Figure 2. BLOCK DIAGRAM OF COMPLETE RELAY WITH PHASE OVERCURRENT STARTING ELEMENTS

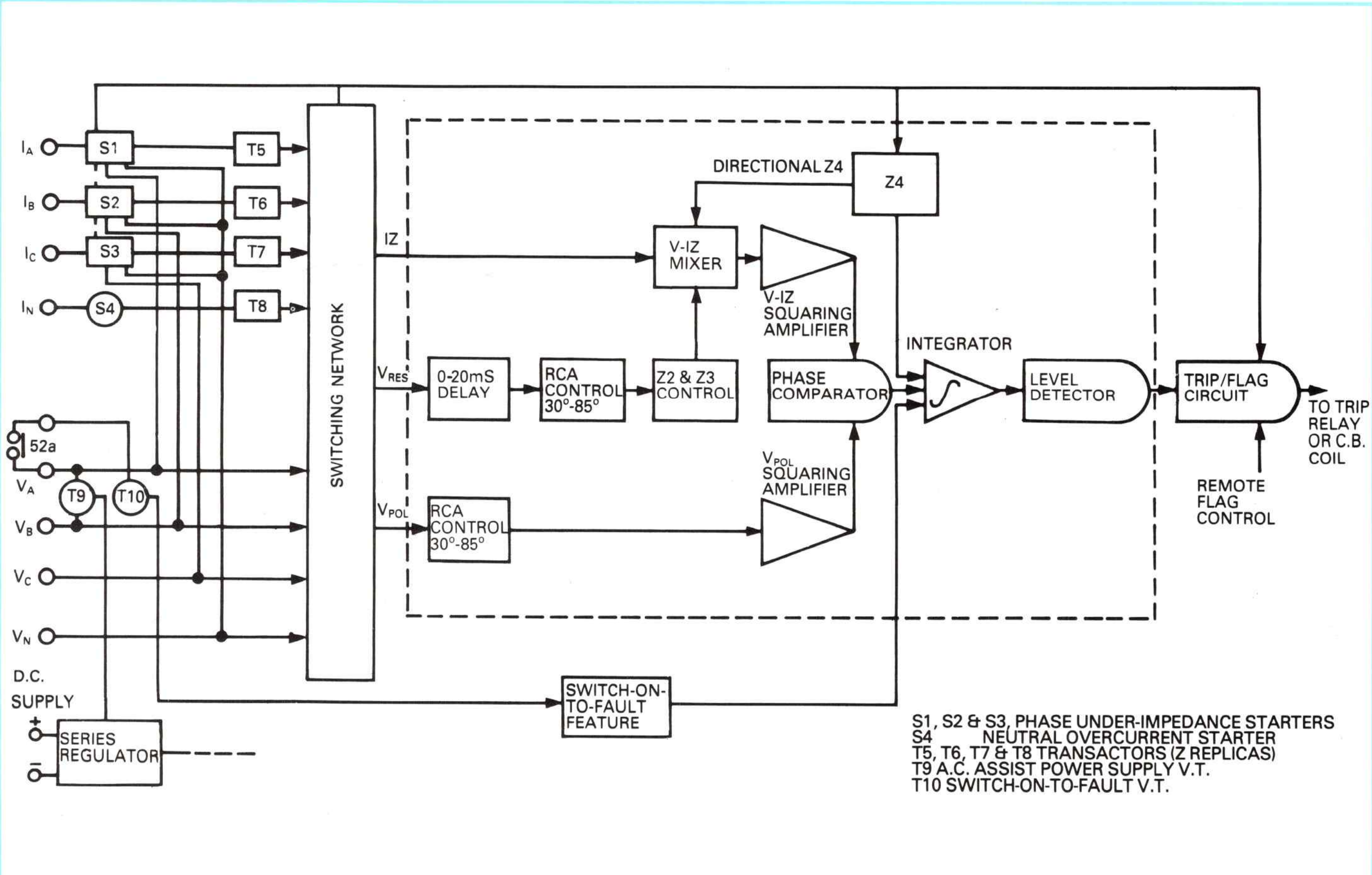


Figure 3. BLOCK DIAGRAM OF COMPLETE RELAY WITH PHASE IMPEDANCE STARTING ELEMENTS

PHASE OVERCURRENT STARTERS

Figure 4(a) shows a block diagram for the overcurrent starter.

A transactor is used which eliminates the effects of d.c. offsets. This ensures that the starter has no measurable transient overreach.

The transactor differentiates the primary current signal to produce a secondary voltage signal which is proportional to the primary signal. This signal is fed into a phase splitting network producing a three phase waveform which is then rectified to produce a d.c. operating voltage signal. This technique enables very short starter operating times to be achieved.

The d.c. operate signal is fed in parallel with a restraint voltage signal derived from the d.c. rails into an operational amplifier having a capacitive feedback loop.

The circuit is arranged so that, at the boundary of operation of the overcurrent starter, the two signals are summed to zero, causing the output of the amplifier to rise. This signal is then fed into a Schmidt-type trigger circuit which, at a predetermined level, operates to produce an output signal.

Adjustment of current setting is carried out using a potentiometer designated K which is mounted on the front plate of the starter module. The range of adjustment is 50% to 300% of rated current.

NEUTRAL OVERCURRENT STARTER

The neutral overcurrent starter circuit is similar to its phase overcurrent counterpart, the only difference being that it has a fixed current setting of 20% of rated current.

IMPEDANCE STARTER

Figure 4(b) shows a block diagram of the impedance starter which monitors phase current and Ph-N voltage and detects both phase and earth faults. The impedance starter does not have a fixed impedance characteristic and is more accurately described as a voltage controlled overcurrent device.

Figure 5 shows the voltage/current characteristic for voltage transformer secondary ratings of 110V a.c. Between 65% and 100% of rated Ph-N voltage the overcurrent characteristic is voltage dependent. Below 65% of rated Ph-N voltage the a.c. voltage signal is cut off and the starter behaves as an overcurrent unit with a fixed setting of 25% of rated current.

The a.c. current and voltage input signals are converted into d.c. operating and restraining signals respectively, using the same design techniques as described for the phase overcurrent starter.

A curve shaping circuit is employed in the a.c. voltage circuit to form the knee of the characteristic and includes the slope adjustment potentiometer designated K which is mounted on the front plate of the starter module.

The operating and restraining voltage signals together with a d.c. bias signal are added together and fed into an operational amplifier having a capacitive feedback loop.

The circuit is arranged so that, at the boundary of operation of the starter, the three signals are summed to zero causing the output of the amplifier to rise. This signal is then fed into a Schmidt type trigger circuit which, at a predetermined level, operates to produce an output signal.

Potentiometer K is calibrated to cover an impedance range of 20 ohms to 70 ohms for 1A relays and 4 ohms to 14 ohms for 5A relays, each at rated Ph-N voltage.

The three impedance starters have no residual compensation. Figures 6, 7 and 8 show the reach characteristic for three types of fault. These are applicable to voltage transformer secondary ratings of 110V a.c.

For a.c. voltage ratings of 100V, 115V and 120V, the voltage/current characteristic and hence the reach characteristics will vary. Details of these can be supplied on request.

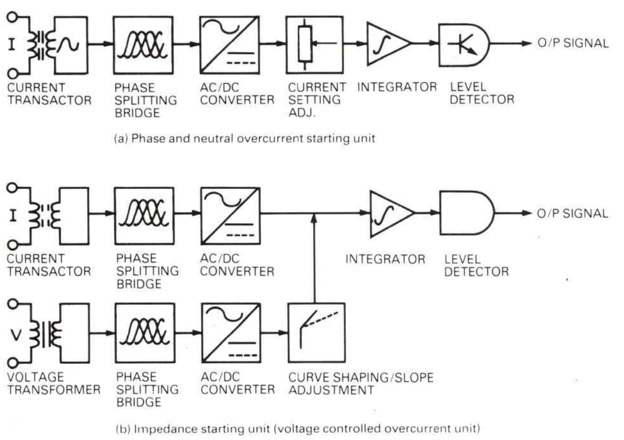


Figure 4. BLOCK DIAGRAM OF STARTING ELEMENTS

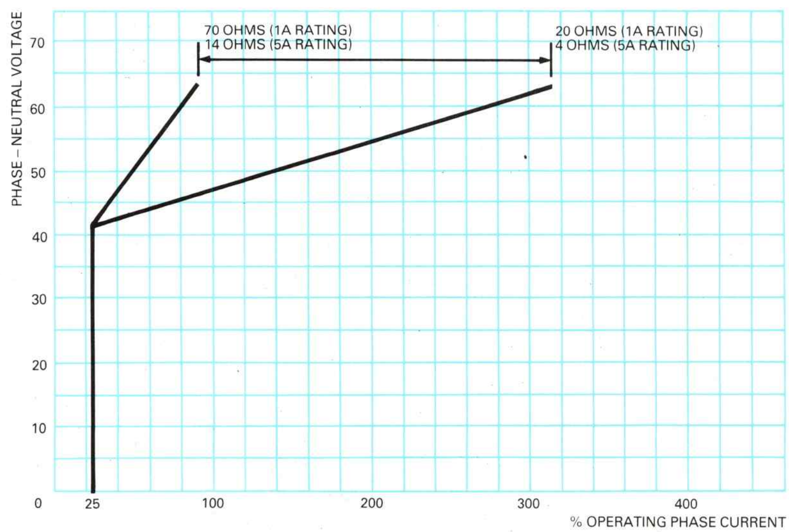


Figure 5. VOLTAGE CURRENT CHARACTERISTIC OF IMPEDANCE STARTER FOR 110V VOLTAGE TRANSFORMER SECONDARY RATINGS

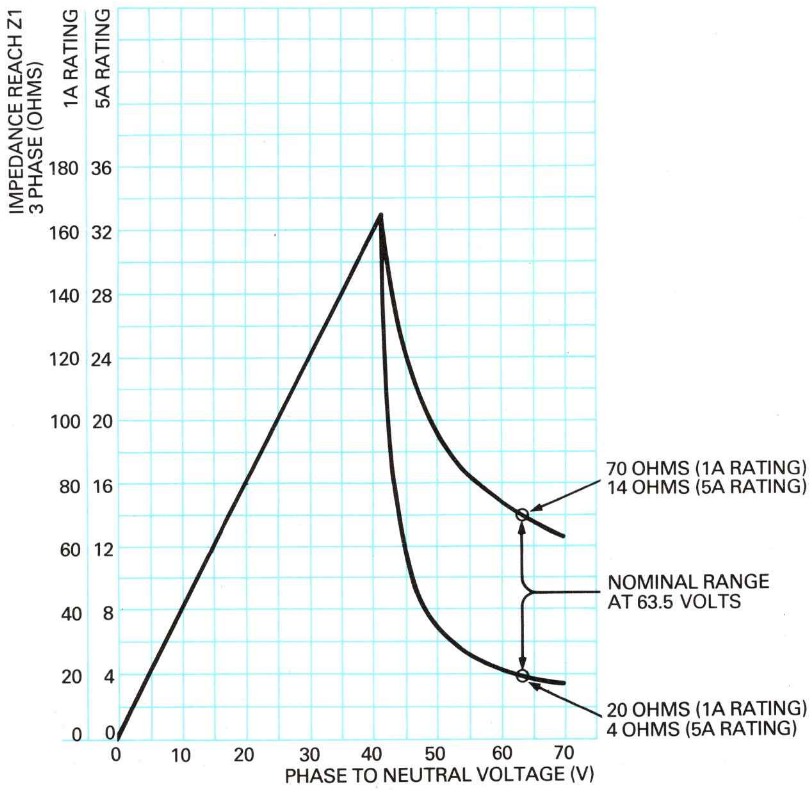
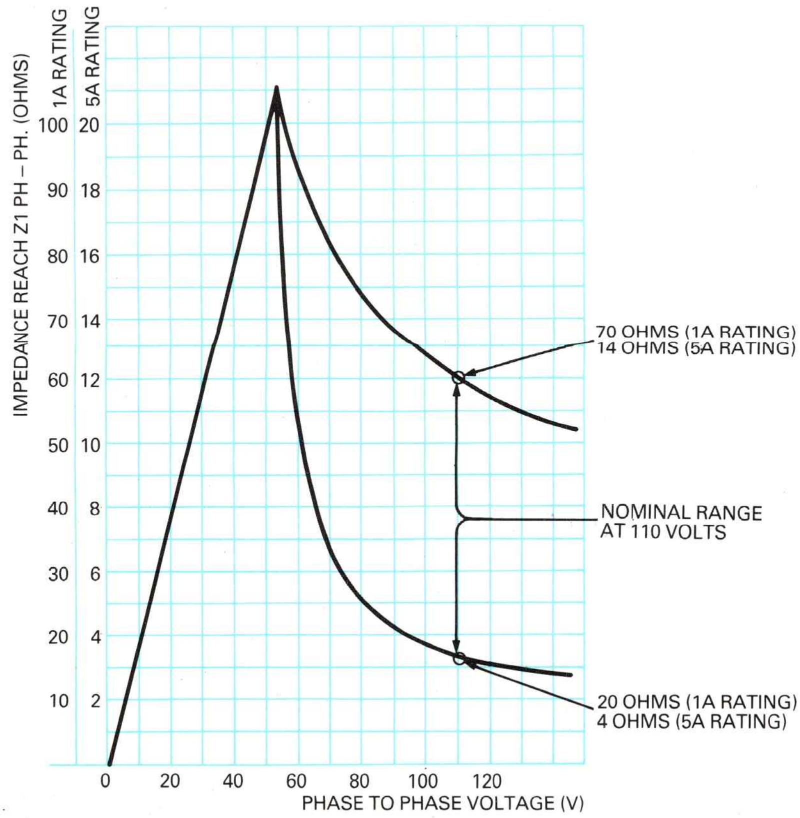


Figure 6. IMPEDANCE STARTER REACH FOR 3 PHASE FAULTS FOR 110V VOLTAGE TRANSFORMER SECONDARY RATINGS



The impedance range limiting values are nominal and refer to the 3 phase fault condition

Figure 7. IMPEDANCE STARTER REACH FOR PHASE-PHASE FAULTS FOR 110V VOLTAGE TRANSFORMER SECONDARY RATINGS

MEASURING UNIT CHARACTERISTICS

Unbalanced faults in the forward direction

When an unbalanced fault occurs in the protected zone, the mho characteristic expands along the resistance axis, the expansion being a function of the source impedance, as shown in Figure 9. This provides an extended fault resistance tolerance.

Unbalanced reverse faults

When an unbalanced reverse fault occurs, the mho characteristic moves away from the origin to an offset position. This provides the scheme with greatly improved directional stability for reverse faults.

Balanced three phase faults

When a balanced three phase fault occurs the phase voltages collapse symmetrically and the measuring unit operates with a normal mho characteristic.

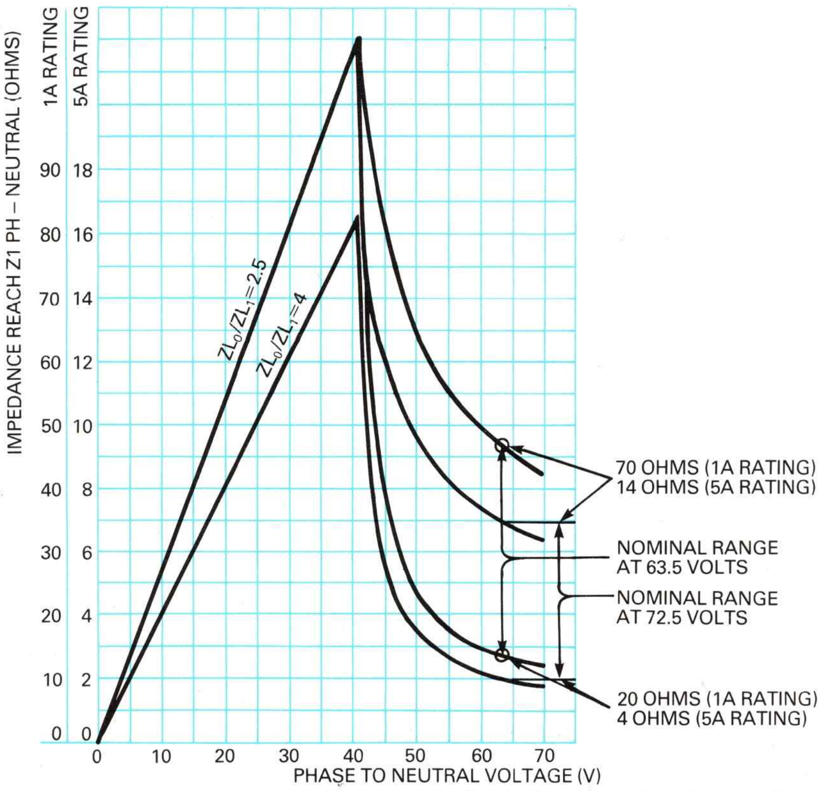
INPUT CIRCUITS

Tapped primary windings are provided on each transactor. These permit a coarse reach adjustment. Zone 1 fine reach adjustment is made in the transactor secondary circuit. The setting range is continuously adjustable from 0·05 ohms to 40 ohms for 1A relays or 0·01 ohms to 8 ohms for 5A relays.

Depending upon the fault condition, an output from the appropriate transactor is selected by the switching network.

Transformers and phase shift networks are the main components of the voltage input circuits. These provide a characteristic angle adjustment from 30° to 85° in steps of 5°. The faulty phase or phases are selected before the switching network can pass voltage signals to the appropriate amplifier.

The V-IZ and the V POL sine wave signals are both 'squared' by integrated circuit operational amplifiers before the phase angle between the two signals is compared.



The impedance range limiting values are nominal and refer to the 3 phase fault condition

Figure 8. IMPEDANCE STARTER REACH FOR PHASE-EARTH FAULTS FOR 110V VOLTAGE TRANSFORMER SECONDARY RATINGS

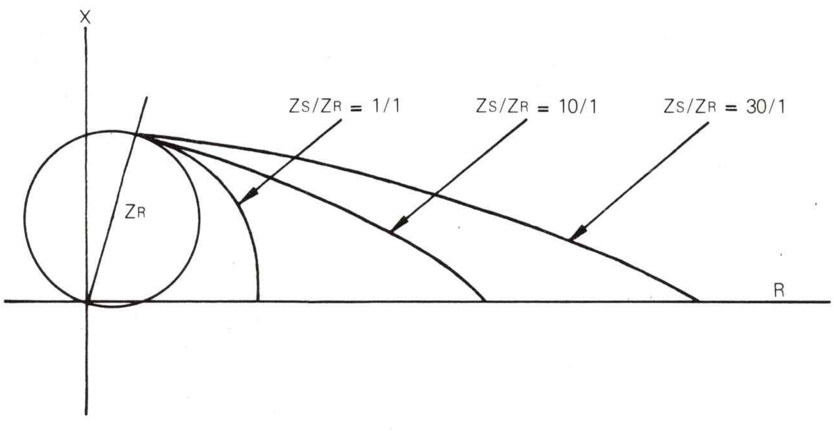


Figure 9. TYPICAL EXPANDING CHARACTERISTIC OF MHO UNIT FOR UNBALANCED FAULT IN THE FORWARD DIRECTION

PHASE COMPARATOR

The comparator is a two input coincidence detector which compares both positive and negative half cycles of the input waveforms. The circuit includes two series connected transistors which conduct when both inputs are of the same polarity.

The output from the comparator is fed to an integrator which employs an operational amplifier with a capacitive feedback loop. The integrator output is measured by a level detector which determines the boundaries of operation.

Figure 10 shows both the comparator and the integrator output waveforms, together with the appropriate trip and reset levels. The integrator waveforms are shown for a boundary condition and also for faults inside and outside the characteristics.

Figures 11, 12 and 13 show typical operating times and measuring accuracy.

INSTANTANEOUS 'SWITCH-ON-TO-FAULT' FEATURE

When a line is energized on to a close-up three phase metallic short circuit, the voltage at the relaying point will be zero. For example, this type of fault may occur when earthing clamps are inadvertently left on the lines. Faults such as these would normally be cleared by the back-up protection.

The design considerations which make the instantaneous 'switch-on-to-fault' facility possible, are based on the assumption of zero voltage on the line before the fault occurs.

When switching the line on to a fault condition resulting from earthing clamps, an instantaneous trip will occur. The voltage applied to the relay is low and this condition occurring simultaneously with the operation of the starters, will give a trip signal.

Faults occurring on an energized line will not be affected by this circuit. It is so arranged that, from a normally energized state, at least 20 seconds must elapse before a trip signal is given. This delay provides time for the operation of auto-reclose facilities and measurement through the time delayed impedance zones.

Where busbar voltage transformers are used, this circuit is energized via an auxiliary contact of the circuit breaker.

Type of fault	Overcurrent or impedance starter operated	Fault measured between
A-E	A & N	A-E
B-E	B & N	B-E
C-E	C & N	C-E
A-B	A & B	A-B
B-C	B & C	B-C
C-A	C & A	C-A
A-B-C	A, B & C	C-A
A-B-E	A, B & N	A-B
B-C-E	B, C & N	B-C
C-A-E	C, A & N	C-A

Table 1 RELAY OPERATING MODE – SOLID OR RESISTANCE EARTHED SYSTEMS

Type of fault	Overcurrent starters operated	Fault measured as
AB	A	A-B
BC	C	B-C
CA	C & A	C-A
AE & BE	A & N A N	A-E A-B —

Type of fault	Overcurrent starters operated	Fault measured as
BE & CE	C & N C N	C-E B-C —
CE & AE	C & N A & N C & A C, A & N	C-E A-E C-A C-E

Table 2 RELAY OPERATING MODE – PETERSEN COIL EARTHED OR INSULATED SYSTEMS (PHASE PREFERENCE: C BEFORE A BEFORE B)

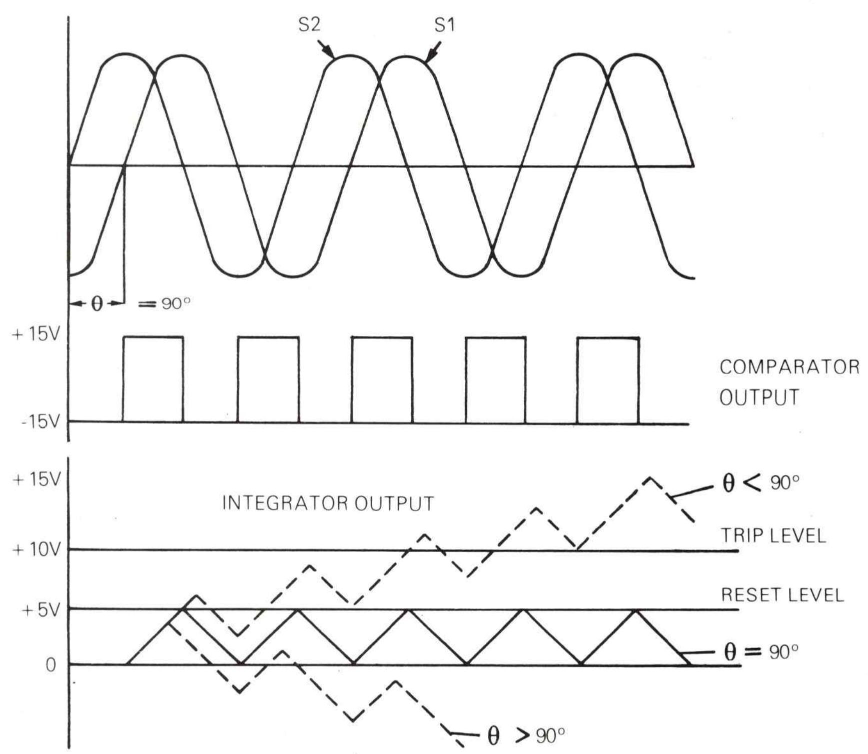


Figure 10. PHASE COMPARATOR AND INTEGRATOR WAVEFORMS

ZONE TIME DELAY ELEMENTS AND SETTINGS

The Zone 2 time delay element extends the reach of Zone 1 by a factor determined by the zone multiplier setting K_2 after a time delay determined by t_{Z2}.

Similarly, the Zone 3 time delay element extends the reach of Zone 1 by a factor determined by the zone multiplier setting K_3 after a time delay determined by t_{Z3}.

When a Zone 4 time delay element is included its time setting range is determined by t_{Z4}.

The Zone 4 reach setting is independent of the mho measuring element and is determined solely by the setting of the starter which is non-directional.

Internal links are provided to enable the Zone 4 characteristic to be directionalized or inhibited as required. This is shown in Figure 1.

INSTANTANEOUS ZONE EXTENSION

A zone extension feature is available which instantaneously extends the reach of Zone 1 by a factor determined by the instantaneous control setting KC.

TRIP CIRCUIT

The trip circuit utilizes a mercury-wetted reed contact which is capable of direct tripping duties.

A second electrically-separate trip contact can be provided when required.

Two auxiliary reed contacts of a lower rating are included as a standard feature, which may be used for alarm purposes.

FAULT INDICATION

Miniature rotary operation indicators are mounted on the relay front panel. These provide flag indication which identifies the phase(s) affected, and the zone in which tripping has occurred.

The indicator comprises a cylindrical permanent magnet which rotates between the poles of an electromagnet when the encapsulated coil is energized.

The magnet rotates through 180° and exposes the flag. This remains exposed when the signal is removed and is reset when an energizing signal of reverse polarity is applied.

The flag indicators of the switched distance relay in its standard form

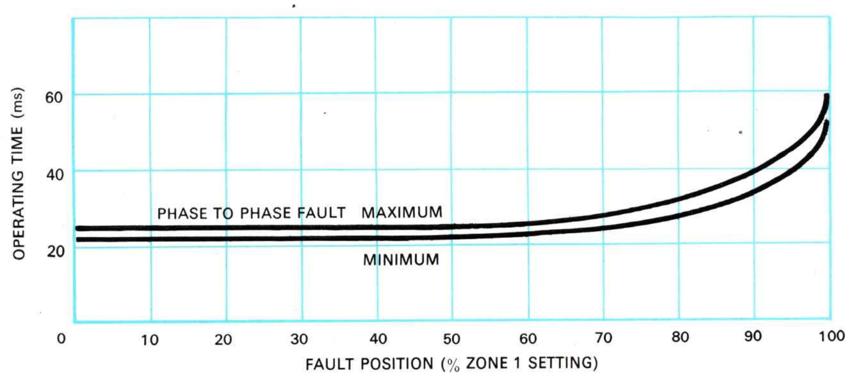


Figure 11. TYPICAL OPERATING TIME CHARACTERISTIC USING OVERCURRENT STARTERS

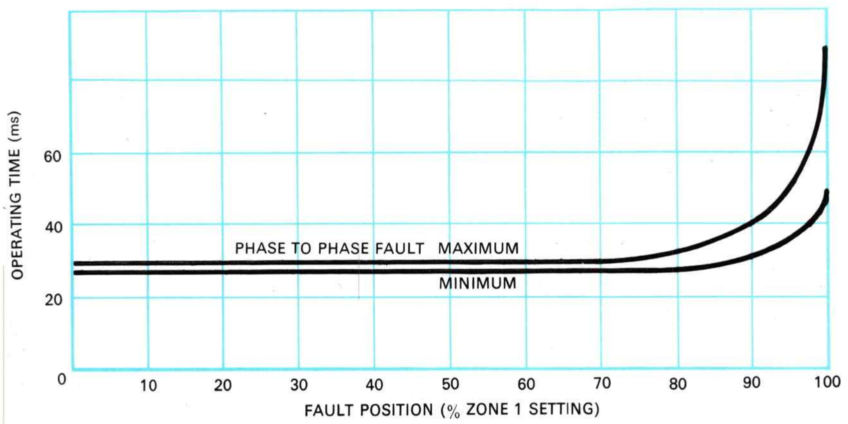


Figure 12. TYPICAL OPERATING TIME CHARACTERISTIC USING UNDER IMPEDANCE STARTERS

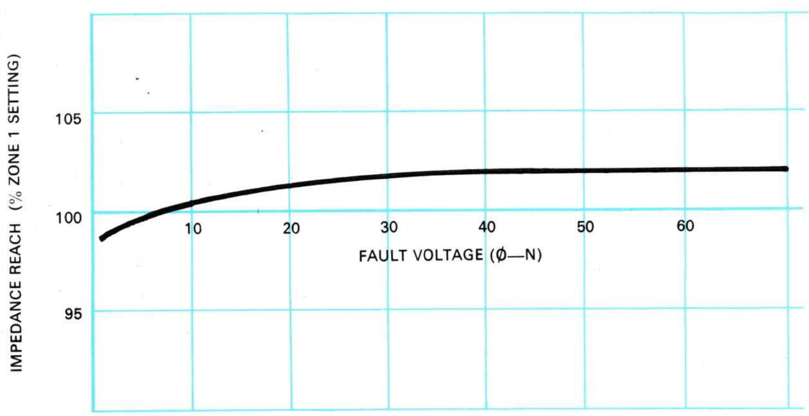


Figure 13. TYPICAL MEASURING ACCURACY CHARACTERISTIC

operate automatically at the instant of tripping.

If the relay is part of the blocking or permissive overreach scheme, a remote flag control feature can be fitted which must be energized externally before indication can take place.

POWER SUPPLY

The power supply arrangement comprises a series regulator supplemented by an a.c. assisting circuit fed from the A-B phases of the line voltage transformer secondary windings, via an isolating voltage transformer mounted in the rear of the modular case. Under quiescent conditions, the load current taken by the starters, the power swing blocking unit, and the residual compensation module in the PYTC, is supplied by the a.c. assisting circuit.

Under fault conditions, the d.c. current demanded by the relay is taken from the station battery supply through the series regulator.

POWER SWING BLOCKING

An impedance starter version of the relay is used when the protection system requires power swing blocking. A fourth impedance element is included in the scheme, set so that its operating characteristic surrounds the impedance starter characteristic.

The difference between a power system fault and a power swing is detected by measurement of the time taken for the impedance locus to pass between the two impedance characteristics. Different rates of power swing are accommodated by an adjustable time setting over the range 40 ms to 80 ms.

The power swing blocking unit is automatically overridden by the residual overcurrent starter under earth fault conditions.

Override facilities are provided to allow the relay to operate in selected zones even though the power swing blocking unit has been energized. The various tripping/blocking modes can be selected by means of a selector switch P mounted on the front plate of the PSB unit.

These modes are as follows:
* Trip in all zones
* PSB in all zones
* Trip in Zone 1, PSB in Zones 2, 3 and 4
* Trip in Zones 1 and 2, PSB in Zones 3 and 4
* Trip in Zones 1, 2 and 3, PSB in Zone 4

BASIC SCHEME OPTIONS

All schemes may be provided with high speed fuse failure protection and schemes with impedance starters may be fitted with power swing blocking.

Two arrangements of each scheme are available:
* 1 phase and 3 phase tripping
* 3 phase tripping

ZONE EXTENSION SCHEME

This provides fast clearance of the end zone faults without the need for signalling equipment. It is used with auto-reclose equipment so that end zone faults are cleared quickly by an overreaching zone of the protection set to reach beyond the remote busbars. The protection reverts to the Zone 1 reach before reclosure takes place. The scheme is particularly useful for fast clearance of transient end zone faults, permanent end zone faults being cleared in Zone 2 time after reclosure.

SCHEMES USING PROTECTION SIGNALLING EQUIPMENT

Protection signalling equipment is used to provide fast clearance of end zone faults which may occur at both ends of the protected line.

The following schemes are available:
* Zone acceleration
* Permissive underreach transfer trip
* Permissive overreach transfer trip
* Blocking

Details of these schemes are available on request.

TECHNICAL DATA

The relay conforms to: British Standard 142: 1966 'Electrical Protective Relays' and International Electrotechnical Commission Standard 255: 'Electrical Relays'

Nominal ratings

Current: 1A or 5A

Voltage: 100V, 110V, 115V or 120V

Frequency (Hz):

Rating	Range
50	47–51
60	57–62

Auxiliary d.c. supply (Vx):

Rated voltage (V d.c.)	Operative range (V d.c.)
48/50	40–60
110/125	66–150
220/250	132–300

Thermal rating

Continuous: Twice rated current and 120% rated voltage on any setting

Short time: 50 × rated current for one second

Settings

Reach settings:

Zone 1 1A relays – 0·05 ohms to 40 ohms continuously adjustable
5A relays – 0·01 ohms to 8 ohms continuously adjustable
Zone 2 1 to 5 times Zone 1 setting
Zone 3 1 to 20 times Zone 1 setting

Zone extension: Zone 1 can be extended by factor of 1 to 2 × setting exclusively for earth faults or alternatively for all types of faults.

A range of 1 to 20 × is also available for special applications.

Overcurrent starters:	50% to 300% rated current, continuously adjustable.
Residual overcurrent starter:	20% rated current (fixed setting)
Impedance starter:	Pick-up current at zero volts at 0·25 × rated current. The impedance reach (Z_R) for 3 phase faults at nominal voltage is 20 ohms to 70 ohms for 1A relay or 4 ohms to 14 ohms for 5A relay. The phase to phase reach of the units is 0·866 Z_R at the rated voltage. The impedance starters are not provided with residual compensation for earth fault measurement. Consequently, the reach is dependent upon the protected line Z_o/Z_1 impedance ratio. The minimum earth fault reach of the units is $\frac{Z_R}{1+K}$ where $K = \frac{Z_o - Z_1}{3Z_1}$ for a system with a single earthing point at the source behind the relay location. For practical systems the reach will be between this value and Z_R.
Power swing blocking:	Pick-up current at zero volts set at 0·15 × rated current. The impedance reach at rated voltage is: 20 ohms to 70 ohms for 1A relays 4 ohms to 14 ohms for 5A relays
Time setting (t_p):	40 ms to 80 ms continuously adjustable.

Resetting characteristics

Impedance starter and power swing blocking element	Less than 105% of setting
Overcurrent starter	Greater than 95% of setting
Transient overreach	Less than 1% of setting

Operating times

Zone 1	Minimum overall operating time 20 ms. Typical overall operating time 30 ms, see Figures 11 and 12. Less than 40 ms, up to 80% reach with source/line impedance ratios up to 100/1 (phase faults) or 60/1 (earth faults).
Zone 2	0·2s to 2·0s continuously adjustable
Zone 3	0·5s to 5·0s continuously adjustable
Zone 4	0·5s to 5·0s continuously adjustable
Impedance starters alone	Not greater than 15 ms at 0·5 × setting
Overcurrent starters alone	Not greater than 12 ms at 2 × setting

Reset time

Less than 50 ms

Characteristic angle

30° to 85° adjustable in steps of 5°.

Residual compensation ranges

PYTS: 50 to 150% of selected neutral impedance setting
PYTC: 0 to 100% of selected neutral impedance setting and angular adjustment of 0–360° in 5° steps.
(0–400% range is available for special applications).
For further information refer to Section entitled RELAY SETTING ADJUSTMENTS.

Characteristic impedance ratios

100 : 1 for phase faults
60 : 1 for earth faults

Ambient temperature range

−5°C to +50°C

Accuracy

Impedance reach of mho measuring element

Zone	Voltage range	Accuracy*
1	Rated voltage to 5V Less than 5V to 1V	±5% ±10%
2	—	±10%
3	—	±15%

*Applies over full setting range.

Starting elements:	Including Zone 4 when fitted Impedance type Overcurrent type	 ±5% ±5%
Zone time delay elements:		±5% of any setting or 25 ms whichever is the greater.
Phase angle:	Relay characteristic angle (R.C.A.) Neutral compensation angle (θ_N) (PYTC Relay only)	±1·2° of indicated angle setting ±1·2° of indicated angle setting
Variation of ambient temperature:	Range – 5°C to +50°C	±5%
Variation of frequency:	Over stated frequency range	±5%

Burdens

A.C. voltage circuits (at rated voltage):	Under normal load conditions Under fault conditions	5·2VA per phase maximum 5·6VA per phase maximum
A.C. current circuits (at rated current):	Under normal load conditions Under fault conditions	1A relay, 1·3VA to 1·8VA 5A relay, 1·8VA to 3·2VA 1A relay, 2·5VA to 3·5VA 5A relay, 3·6VA to 6·6VA
Auxiliary d.c. supply:	Under quiescent conditions Under the most onerous fault conditions	Nominally 5 mA Less than 1A

Contacts

All the contacts tabled below are of the make, or normally open pattern

Function	Number of contacts	Contact Ref.	Contact rating	
			Make and carry	Break
Trip: main	1 or 2*	86X 86Y*	30A maximum at 110V d.c. resistive, for 0·2s	5A maximum at 110V d.c. resistive
Trip: auxiliary	2	86Z	25VA d.c. with maxima of 1A and 250V.	
Starter auxiliary				
– Phase A	2	AS		
– Phase B	2	BS		
– Phase C	2	CS		
– Neutral	2	NS		
– Common repeat	2	DX		
Zone 2 auxiliary	1	AR		
Zone repeat: (remote indication)				
Zone 1	1*	Z1		
Zone 2	1*	Z2		
Zone 3	1*	Z3		
Zone 4	1*	Z4		

*Optional extras

Insulation

The relay will withstand:
2 kV, 50 Hz for 1 minute between all circuits and the case and also between all separate circuits.
1 kV, 50 Hz for 1 minute between normally open reed contacts.

Impulse withstand

The relay will withstand impulses of 5 kV peak and 1·2/50μs waveform applied both transversely and between relay terminals and earth, in accordance with IEC Standard 255–4 Appendix E.

High frequency disturbance

The relay meets the requirements of IEC Standard 255–4 Appendix E for the high frequency disturbance test in which repetitive 1 MHz bursts having an initial peak of 1·0 kV are superimposed across input circuits, and of 2·5kV are superimposed between independent circuits and circuits to earth with a decay time to half amplitude, of 3 to 6 μs. This is carried out with the relay energized.

CURRENT TRANSFORMER REQUIREMENTS

To ensure that the scheme operating times are not seriously affected by CT saturation, due to the transient d.c. component of the fault current, the current transformers should ideally be capable of developing a 'knee point' voltage given by:

$$V_k = I_f \cdot \left[\frac{X}{R} + 1\right] \cdot [R_{CT} + R_L + M]$$

Where V_k = the 'knee point' voltage of the CT which is defined as the point of the magnetizing characteristic at which a 10% increase of voltage produces a 50% increase in magnetizing current (V).

$\frac{X}{R}$ = the primary system reactance/resistance ratio for a fault at the Zone 1 reach point.

I_n = rated current (A)

I_f = the secondary equivalent of the maximum fault current for a fault at the Zone 1 reach point (A).

R_{CT} = resistance of the CT secondary winding (ohms).

R_L = resistance of the secondary leads (lead and return for earth faults, lead only for phase faults) (ohms).

M = impedance of the relay current circuits (ohms/phase).

$= \frac{\text{burden (VA) at rated current}}{I_n^2}$

RELAY SETTING ADJUSTMENTS

The Zone 1 impedance setting range is continuously adjustable from 0·05 ohms to 40 ohms (1A) or 0·01 ohms to 8 ohms (5A). A particular setting is selected by means of a plug tapping K_Z on the primary of the current circuit transactors, a fine adjustment potentiometer K_1 in the transactor secondary circuit and a range multiplier switch K_D in the voltage restraint circuit. The positions of K_D are 0·1X, 1X, 2X and ∞.

The plug tapping K_Z has seven tappings of 0, 1, 2, 3, 5, 10 and 20 ohms (1A) and 0, 0·2, 0·4, 0·6, 1·0, 2·0 and 4·0 (5A).

The fine adjustment potentiometers $K_{1A,B,C}$ give continuous adjustment of 0·5 to 1·0.

A fine adjustment potentiometer K_{1N} is provided on a transactor in the residual circuit to give correct measurement under earth fault conditions.

The range of this potentiometer on the PYTS is 0·5 to 1·5 thus giving a range of 50% to 150% compensation for earth faults. The standard range of this potentiometer on the PYTC is 0–1·0 (or 0–4·0 for special applications).

On the PYTC, a further residual compensation angle adjustment is provided using a phase shift circuit incorporating two switches designated a1 and a2:

a1 covers a range of 0° to 55° in steps of 5°.
a2 covers a range of 0°, −60°, −120°, −180°, +120° and +60°.

The addition of a1 and a2 sets the residual compensation angle, θ_N.

The Zone 2 setting range is 1 to 5 times the Zone 1 setting. This adjustment is by potentiometer K_2 in the voltage restraint circuit.

The Zone 3 setting range is 1 to 20 times the Zone 1 setting. This adjustment is by means of a potentiometer K_3 in the voltage restraint circuit.

Impedance settings

Zone 1 reach setting (Z1) = $K_Z.K_1.K_D$
Zone 2 reach setting (Z2) = $K_2.K_Z.K_1.K_D$
Zone 3 reach setting (Z3) = $K_3.K_Z.K_1.K_D$

Residual compensation settings

Scalar compensation setting, for PYTS and PYTC relays:

$$= \frac{Zo - Z_1}{3Z_1} \times \text{Zone 1 setting} = K_{1N}.K_{ZN}$$

where K_{1N} and K_{2N} are the fine and coarse adjustments on the neutral transactor.

Angular compensation setting, for PYTC relay only:

$$= \frac{|Zo| \angle \theta o \; - \; |Z_1| \angle \theta_1}{3\,|Z_1| \angle \theta_1} = \frac{K_{ZN}.K_{1N}.\angle \theta_N}{K_{ZA}.K_{1A}}$$

where Z_1 = the positive sequence impedance of the protected line in ohms/km

and Zo = the zero sequence impedance of the protected line in ohms/km

INFORMATION REQUIRED WITH ORDER

Nominal current rating – 1A or 5A

Nominal voltage rating – 100V, 110V, 115V or 120V

Frequency – 50 Hz or 60 Hz

Zone 1 impedance setting (secondary ohms)

Voltage of d.c. supply

Type of starter

Method of system earthing

Optional features required

Advice on applications is available when the information requested above is difficult to specify.
Requests for advice should include the following details:

Voltage transformer ratio

Current transformer ratio

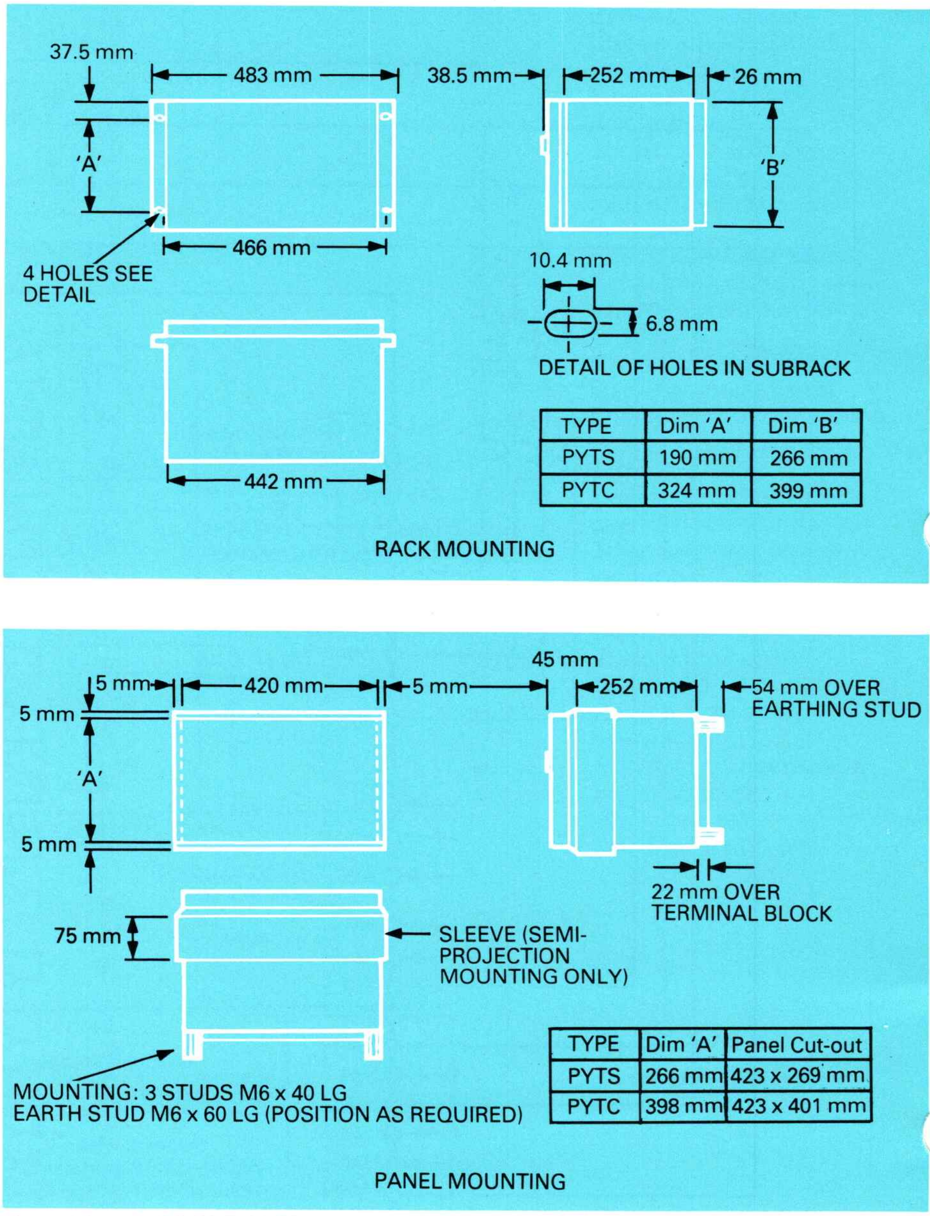
Current transformer knee-point voltage, C.T. winding resistance and lead burden

Positive and zero sequence impedances of the protected feeder or full details of feeder length and construction

Source impedances or fault levels for both minimum and maximum plant conditions.

Method of system earthing:
If multiple and solid earthing, state maximum expected sound phase currents
If resistance earthed, give details of resistors
If Petersen-coil earthed, state if short-circuiting facilities are available

Maximum load current of the feeder



TYPE	Dim 'A'	Dim 'B'
PYTS	190 mm	266 mm
PYTC	324 mm	399 mm

TYPE	Dim 'A'	Panel Cut-out
PYTS	266 mm	423 x 269 mm
PYTC	398 mm	423 x 401 mm

Figure 16. CASE OUTLINES

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GEC Measurements

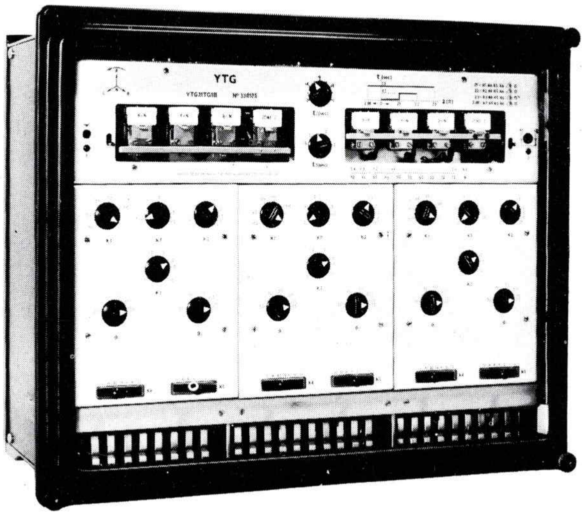
DISTANCE PROTECTION RELAY

Type YTG

The YTG31 relay is a fast, accurate and reliable distance relay, using the mho principle of measurement.
Complete three phase, three zone distance protection for phase and earth faults is given by the MM3T scheme which requires two YTG31 relays and a neutral impedance replica unit. A single YTG31 relay (M3T scheme) gives similar protection for phase faults only, or earth faults only when used with a neutral impedance replica unit.
The use of transistors results in the relay having low burdens and compact dimensions.
Full details are given in Publication MS/5201B.

Description

The YTG31 relay provides consistent high speed clearance for the majority of zone 1 faults with source to line impedance ratios up to 36/1. The operating time is constant for the major portion of the relay reach.
Two measuring relays per phase are used, mho for zones 1 and 2 and offset mho for zone 3 and starting, timing for zones 2 and 3 being by means of separate static timers. Each measuring circuit is similar and utilises a phase comparator, the inputs to which are derived from the line voltage and a voltage proportional to the line current. Replica impedances are used in the relay current circuit to obtain the proportional voltage.
The input to the relay current circuits is through C.T.'s which are tapped on both the primary and secondary windings to give the coarse and medium reach settings for the relay.
Transient overreach has been reduced to less than 1% thus allowing increased zone 1 settings without maloperation on external faults. This is obtained as a result of using replica impedance circuits which give similar transients in both phase comparator inputs when the fault angle corresponds to the relay characteristic angle. These transients cancel out during the measuring process helping to ensure negligible overreach. Each replica impedance circuit consists of a choke and variable resistor in series, variation of the value of this resistor enabling the relay characteristic angle to be changed. The mho and offset mho units are provided with separate replica impedance circuits and therefore their characteristic angles can be varied independently.
The directional mho relays will operate correctly down to zero voltage on phase-phase and phase-earth faults by virtue of a small amount of sound phase compensation. However, with a three phase zero voltage fault this is ineffective. The starting units have offset mho characteristics and will, therefore, operate for three phase zero voltage faults. This type of fault is invariably caused by earthing clamps left connected after line maintenance and is present on line energisation. A circuit is provided in the YTG31 to by-pass the zone 3 timer for a period of up to 10 cycles after line energisation and, provided the V.T.'s are on the line side of the breaker, the zone 3 units will trip instantaneously. Since the instantaneous tripping provided by the YTG31 under these conditions takes place via the starting units, auto-reclosure, if fitted, will be blocked.
In addition to providing instantaneous tripping for faults present on line energisation, the mho zone 1 units of the



YTG31 have been designed to operate for fault voltages of less than 1 volt.
An auxiliary relay is provided in the YTG31 which prevents the distance relay from operating when its coil is energised. This auxiliary may be operated by an out-of-step blocking relay or a loss of voltage relay to prevent tripping under either condition.
D.c. power supplies for all the static circuits are provided by sealed, nickel cadmium cells mounted inside the relay. The batteries, one for the mho units and one for the offset mho units and timers, are equipped with chargers, the a.c. supply being obtained from the C.T. and V.T. secondaries making the relay independent of all station supplies.
Selection of impedance measurement, i.e. phase-phase or phase-earth, is done by means of links at the rear of the relay chassis, and the flag labels are reversible so that correct indication can be maintained.

RATING

Voltage Circuits	110 volts 50 Hz or 115/120 volts 60 Hz, voltage transformer secondary
Current Circuits	1, 2 or 5 amp taps, current transformer secondary

The current circuits will withstand 2 times rated current continuously and 20 times rated current for 3 seconds.
Voltage for auxiliary blocking relay: 20 volts d.c.

SETTINGS

The maximum zone 1 setting is 32, 16 and 8 ohms on 1, 2 and 5 amp line C.T.'s respectively at 75° characteristic angle; minimum setting is 0·25 ohm. The setting is obtained by means of two tapping boards and a potentiometer. The coarse tap (K5) has seven tappings from 0·5 to 32 in 2 : 1 steps. The medium tap (K4) has seven taps from 0·55 to 1·0 in 9% steps. The fine adjusting potentiometer K1 has a continuously variable setting from 0·91 to 1·0.
Zone 2 settings are from 1·0–5·0 times K4 x K5.
Zone 3 forward reach settings are from 1·0–10·0 times K4 x K5.

Zone 3 offset settings are from 0·2–10·0 times K4 x K5. To calculate the relay reach at angles other than 75° a further factor (K6), determined by the relay setting angle, must be used in conjunction with the above. A nomogram is provided on the relay nameplate giving values of K6 for any angular setting of the relay. It should be noted that if the mho and offset mho units are set to different angles, K6 will also differ for the two units.

The relay settings are therefore determined from the following:

Zone 1 = K1 x K4 x K5 x K6
Zone 2 = K2 x K4 x K5 x K6
Zone 3 forward reach = K3 x K4 x K5 x K6
Zone 3 reverse reach = K7 x K4 x K5 x K6

RELAY CHARACTERISTIC ANGLE

The characteristic angle of the YTG31 is infinitely variable between 30° and 75°, the mho and offset mho angle settings being independent.

OPERATING TIME

The zone 1 operating time is 17 to 50 milliseconds for source to line impedance ratios up to 36/1.
Zone 2 : 0·2 to 1·0 second
Zone 3 : 0·5 to 3·0 seconds

ZONE 1 ACCURACY

The accuracy of measurement is ± 10% from 110 volts to 3 volts including transient overreach, with frequency and temperature constant.

With a frequency variation of 47 to 52 Hz the error in impedance reach measurement does not exceed ± 5% and varies almost directly with the frequency.

With ambient temperature variation over the range —20°C to + 50°C the error in impedance reach measurement does not exceed ± 5%.

NEUTRAL IMPEDANCE REPLICA

The neutral impedance replica is housed in an additional case and has the same tappings as the YTG31 phase module. The phase angle adjustment is also provided for both mho and offset mho units.

Neutral impedance setting = K x Zone 1 setting of YTG31 where $K = \frac{Z_0 - Z_1}{3Z_1}$ and Z_0 = Zero sequence impedance of the line, Z_1 = Positive sequence impedance of the line.

A.C. BURDENS

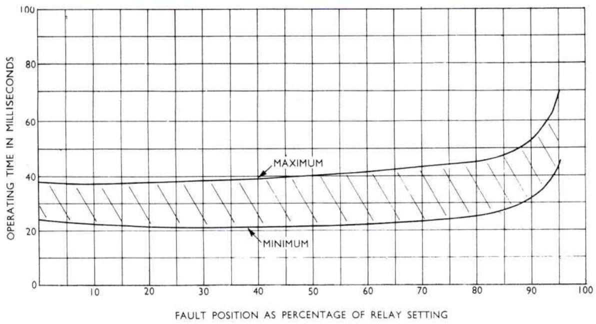
The following burdens are quoted for a complete distance scheme (MM3T) for phase and earth faults, i.e. two YTG31 relays and a neutral impedance replica.

Voltage circuits at 63·5 volts phase-neutral

A-N	B-N	C-N
11·2VA	8·7VA	8·7VA

Current circuits at rated current

Current rating	Ohmic range	A phase	B or C phase
1 amp	0·25–32	0·25–3·8VA	0·04–3·6VA
2 amp	0·25–16	0·62–4·2VA	0·16–3·8VA
5 amp	0·25–8	2·5–8·7VA	1·0–7·4VA



Typical operating time characteristic for phase to earth faults. Z_S/Z_1 = 21/1. Source impedance angle = 88° lag. Line impedance angle = 70° lag. Relay characteristic angle = 70° lag

CASES

The relays are supplied in drawout cases available for flush or projecting mounting, and finished in **phenolic** black or bright black. These cases offer many advantages including ease of maintenance and testing, and are fitted with a contact which short circuits the associated current transformer on withdrawal of the unit. A filter is fitted which equalises the pressure inside and outside the case without admitting dust.

Relay	Case	Maximum Overall Dimensions					
		Height		Width		Depth*	
		ins.	mm	ins.	mm	ins.	mm
YTG31	4½D	14¼	362	17⅞	454	7¾	197
Neutral Impedance Replica	1D	9 3/16	233	6 11/16	170	7¾	197

* Add 3 ins. (76 mm) for maximum length of 2BA terminal studs.

Dimensioned drawings of case outlines, panel cut-outs and mounting details are available on request.

For ease of maintenance, the YTG31 relay has been designed on a modular basis and outstanding accessibility is provided by use of a folding construction for the main sub-assemblies. The modules can be unfolded and the relay replaced in its case so that components can be checked with the relay in service.

INFORMATION REQUIRED WITH ORDER

Type of protection required : Phase-Phase
Phase-Earth
Phase-Phase and Phase-Earth

Voltage transformer secondary rating

Supply frequency

Case finish, and mode of mounting.

NOTE:—The Company's policy is one of continuous development and improvement of its products, and therefore, the right is reserved to supply products which may differ slightly from those described and illustrated in this publication.

GEC Measurements

THE GENERAL ELECTRIC COMPANY LIMITED · ST. LEONARDS WORKS · STAFFORD

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Publication MS/5132 *Printed in England* 017220 GSP

15. Static Overcurrent and Motor Protection Relays Types CTU and CTM/CTMF

NOTES ON THE IMPULSE TESTING OF PROTECTIVE RELAYS.

The standard procedure for insulation testing of the electromagnetic relays is laid down in BS142, Table 12, which calls for a test of 2,000 volts applied for one minute or alternatively 2,500 volts for one second. It is our standard practice to test with 2,500 volts, this being a rather more severe test for a relay than the alternative one minute test. Insulation designed to withstand this test has proved satisfactory over many years for normal applications and there does not appear to be any reason why the test should not be considered still adequate notwithstanding increases in fault power. Where special circumstances exist these are, of course, treated according to their merits; a typical example being those relays which are connected to long pilot circuits which may be subjected to high induced over-voltages. This fact is recognised in BS142 which calls for a higher standard of insulation and establishes two levels of 4,000 and 15,00 volts for test purposes.

With the introduction of semiconductor circuitry into the design of protective relays, it was recognised that these new components were susceptible to transient over-voltages of very short duration. Investigations also showed that relatively high values of high speed transient over-voltage occurred in the auxiliary circuits of power systems. These so-called 'spikes' which have, of course, always been present, have produced no effect on electromagnetic equipment because their duration and total energy was too low to cause relay operation and has not caused damage on account of the natural impulse ratio of the equipment, but they are found to have serious effects in both respects with semiconductor equipment unless suitable precautions are taken in design.

The possible limiting magnitude of such spikes is still a matter of uncertainty. A considerable amount of site investigation work has been done. This work is difficult on account of the very short duration of some of these incidents but it is becoming apparent that although very considerable voltages may be observed in an outdoor substation particularly adjacent to capacitor V.T.'s, these voltages are rapidly attenuated and the values transmitted into the relay room are much more moderate.

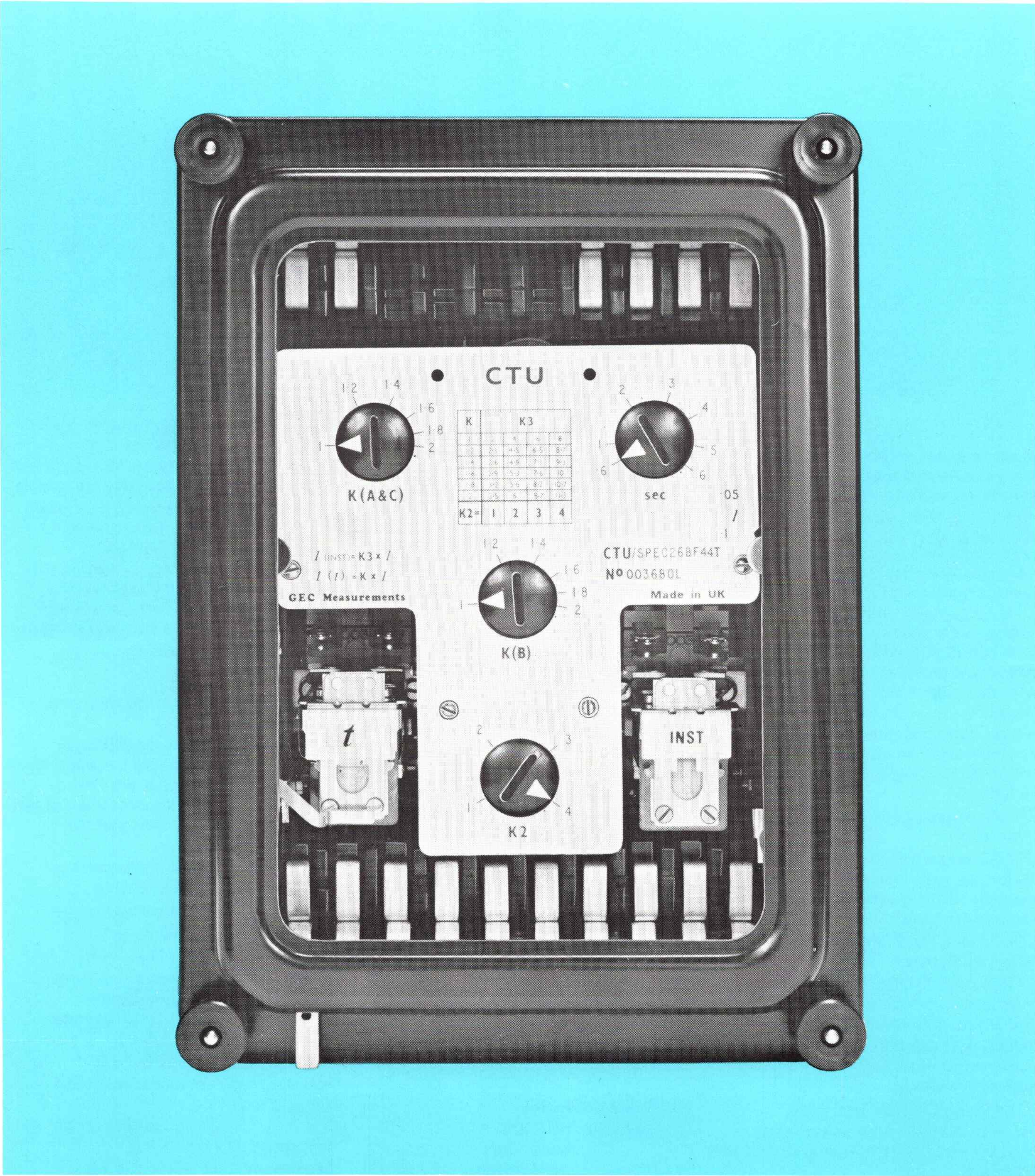
In order to establish a degree of confidence in static designs of relay sufficient to allow such equipment to be applied to the power system, it was necessary to establish a standard of impulse withstand and after some discussion jointly between manufacturers and representatives of the British Power Systems, a standard test has been arrived at for proving all static protective relays. This test comprises a prospective voltage of 5,000 volts having a 1/50 microsecond form and it was recognised by both sides that this test did not represent any known site condition but was established as a standard so that all static protective relays would be comparable in their spike withstand capabilities. The test is therefore on a 'figure of merit' basis and it is probable that the voltage level will ultimately prove to be too high. The test is nevertheless useful for this type of equipment in that it is sufficiently searching to detect any possibility of interference being transmitted by capacitive coupling etc. to various parts fo the static circuit.

It will be seen from the above that the 5kV impulse test is an attempt to cover all possibilities of coupling that may arise with high speed transients and is not really an insulation test in the simple sense. The apparent anomaly of having a separate test for static equipment to that applied to electromagnetic equivalents is not therefore valid.

GEC Measurements

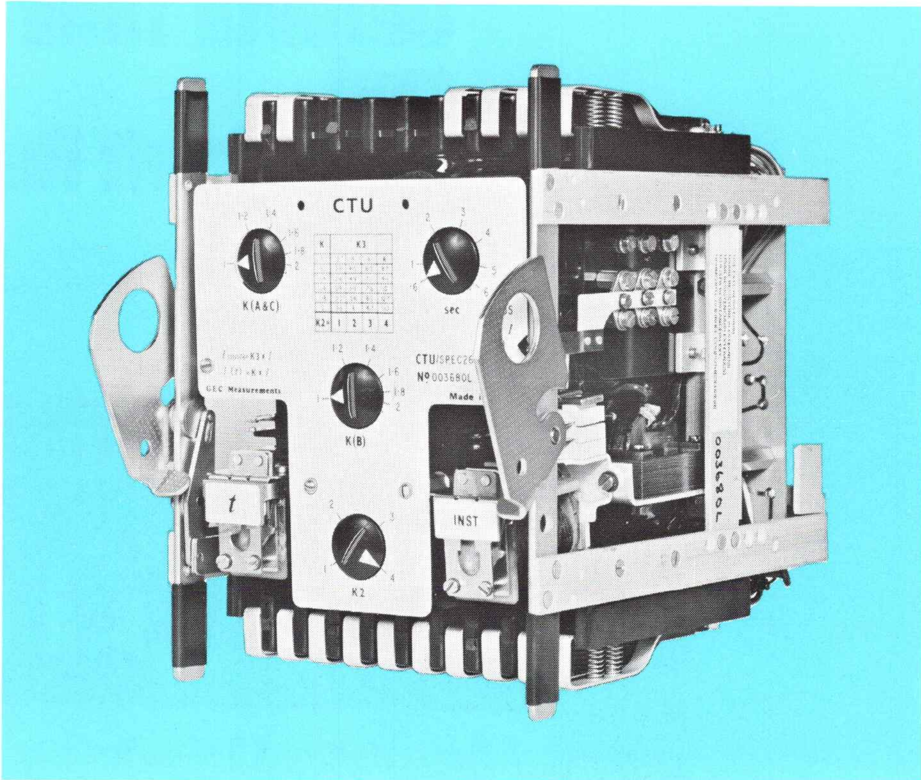
Type CTU

Definite Time Overcurrent and Earth Fault Relay



FEATURES

* Choice of time settings
* High set elements available
* Static circuitry
* Low overshoot
* Low burden
* Fast resetting



APPLICATION

In some cases on power systems where there is a wide variation in source impedance, the use of definite time overcurrent relays offers an advantage over standard inverse time protection, as faults can be cleared in relatively short times irrespective of fault current magnitude. The type CTU relay uses a static circuit to give definite time overcurrent and earth fault protection with low burden, low overshoot and fast reset compared with equivalent electro-mechanical relays.

Single, two and three phase relays are available with or without high set instantaneous units and are identified as follows:

CTU12 single pole overcurrent or earth fault relay.

CTU22 single pole overcurrent or earth fault relay with instantaneous high set element. Both elements operate the same output relay.

CTU23 as CTU22 but with one output relay per element.

CTU31 and CTU32. Three pole overcurrent or two pole overcurrent and single pole earth fault relay.

CTU41 and CTU42. Two pole overcurrent with two instantaneous high set elements.

CTU51 and CTU52. Two pole overcurrent with two instantaneous high set and one single pole earth fault elements.

CTU61 and CTU62. Three pole overcurrent with high set elements.

CTU63 and CTU64. Three pole overcurrent with time delayed high set elements.

Types CTU12, 22, 23, 32, 42, 52, 62, 64 have exceptionally low overshoot. This is obtained with some reduction in accuracy except for relay types CTU12 and CTU23.

OPERATION

The operation is illustrated by the block schematic diagram overleaf.

Multipole relays, that is 2 phase, 3 phase, and 2 phase and earth fault have a detector circuit per pole. The high set element in all relays, except the CTU21 and CTU22, operates a separate output auxiliary relay.

The static circuitry is fully protected against high transient voltages and reversal of the auxiliary supply polarity.

CURRENT SETTINGS

Relays are available for use with current transformers having 0.5, 1 or 5 amp secondaries at 50 Hz or 60Hz.

Definite time unit

Phase faults: 50-200% of C.T. secondary rated current, continuously adjustable.

Earth fault: 5-20%, 10-40%, or 20-80% of C.T. secondary rated current, continuously adjustable.

The setting range is divided into two equal portions and the required portion is selected by a link arrangement. Settings I_t, within the selected portion are obtained by a potentiometer that has continuous adjustment over the selected portion.

Reset: 95% of operating current.

Instantaneous or time delayed high set unit

The instantaneous unit setting is continuously adjustable between limits fixing by the setting of the time delayed unit. The adjustments detailed below cover each portion of the definite time range.

Nominal high set element setting range 1X to 6X, CTU23 only

I_t	High set setting range
Minimum	$1 \times I_t$ to $3.3 \times I_t$
Maximum	$0.95 \times I_t$ to $3.1 \times I_t$

Nominal high set element setting range 2 x to 12X, CTU23 only

I_t	High set setting range
Minimum	$2 \times I_t$ to $6.6 \times I_t$
Maximum	$1.9 \times I_t$ to $6.2 \times I_t$

Nominal high set element setting range 2 x to 11X

I_t	High set setting range
Minimum	$2 \times I_t$ to $8 \times I_t$
Maximum	$1.75 \times I_t$ to $5.5 \times I_t$

Nominal high set element setting range 4 x to 22X

I_t	High set setting range
Minimum	$4 \times I_t$ to $16 \times I_t$
Maximum	$2.9 \times I_t$ to $11 \times I_t$

Reset: 90% of operating current

Transient overreach: Less than 3% on maximum setting and 10% on minimum setting for primary source angles up to 75°.

OPERATING TIMES

The time settings for the time delayed overcurrent and earth fault elements and the time delayed high set elements are continuously adjustable over any one of the following ranges:-

* 0.06 - 0.6 secs.	* 1.0 - 10 secs.
* 0.1 - 1.0 secs.	* 2.5 - 25 secs.
* 0.3 - 3.0 secs.	* 6.0 - 60 secs.
* 0.6 - 6.0 secs.	

For multipole relays, the timing circuit is common, and so the time setting is the same for all poles.

The high set instantaneous element has an operating time of 0.030 seconds at 5 times current setting.

Reset times

Reset time for the time delayed elements is less than 0.25 seconds when the input current falls to 90% current setting.

Reset time for the instantaneous element is less than 0.15 seconds.

OVERSHOOT

CTU41	0.070 secs. maximum
CTU31, 51, 61, and 63	0.090 secs. maximum
CTU12, 22, 23, 32, 42, 52, 62 and 64	0.025 secs. maximum

ACCURACY

The relays are calibrated at 50 or 60Hz. and 20°C.

The following limits are maintained for frequency variation of +2%-6% and at temperatures between −5°C and +40°C.

Current settings

CTU12, 22, 23, 31, 41, 51, 61, 63: less than ±5% of indicated setting.

CTU32, 42, 52, 62, 64: less than +10% −5% of indicated setting.

Instantaneous high set: less than ±10% of indicated setting.

Time setting

±5% or ±0.05 seconds, whichever is greater.

A.C. BURDEN

0.1 VA per phase at lowest current setting; 0.5 VA per phase at highest current setting	0.5 and 1 amp C.T. secondaries
0.15 VA per phase at lowest current setting; 1.0 VA per phase at highest current setting	5 amp C.T. secondary

THERMAL WITHSTAND

The relay will withstand:

twice maximum time delayed (low set) setting continuously.

30 times for 6 seconds

40 times for 3 seconds

70 times for 1 second

AUXILIARY SUPPLY

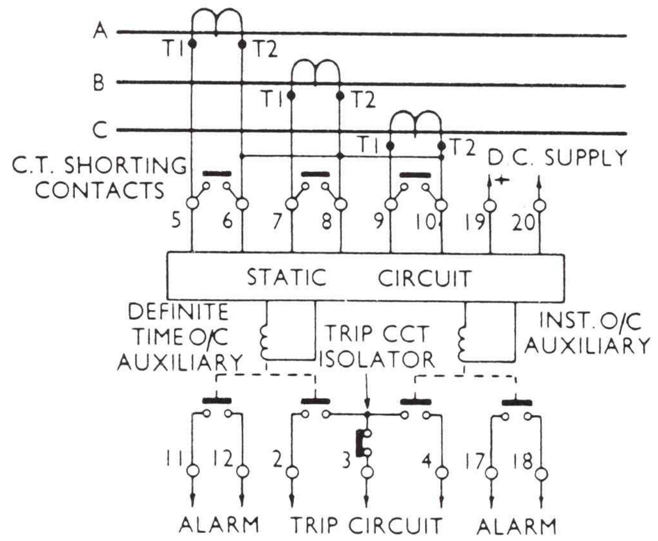
Standard nominal voltages

30, 50, 110/125, 220/250 volts d.c. Relays for use on 50 volts and above are supplied with an externally mounted series resistor.

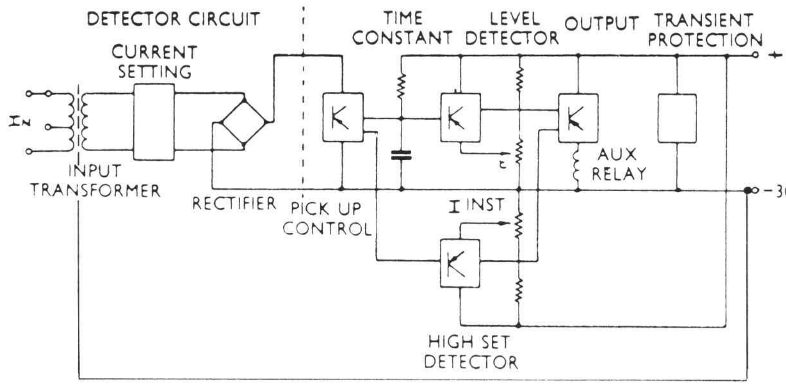
Satisfactory operation is maintained over the range 60-130% of nominal voltage.

Continuous current

CTU22, 41 and 42:	Approximately 30mA
CTU12, 31, 32, 51, 61, 63:	Approximately 40mA
CTU52, 62, 64:	Approximately 50mA
CTU23:	Approximately 60mA



TYPICAL APPLICATION DIAGRAM FOR THREE PHASE OVER CURRENT RELAY TYPE CTU61 OR CTU62.



BLOCK SCHEMATIC DIAGRAM OF RELAY TYPE CTU21.

CONTACTS

Two pairs of normally open, self reset, electrically separate contacts are provided on the attracted armature auxiliary unit, each rated to make and carry for 0.5 second, 7500VA with maxima of 30 amps and 660 volts.

Relays type CTU23, 51, 52, 61 and 62 have separate attracted armature auxiliary units for definite time and instantaneous functions. Two pairs of normally open self reset contacts are provided on each unit with one side of one pair on each unit connected to a common terminal (see diagram). Separate output units are fitted for low set and high set time-delayed elements.

OPERATION INDICATORS

A hand reset mechanical operation indicator is fitted as standard. Relays type CTU23, 51, 52, 61 and 62 have separate operation indicators for definite time and instantaneous functions. Relays type 63 and 64 have separate operation indicators for low set and time delayed elements.

INSULATION

The relay will withstand 2kV, 50Hz. for 1 minute between all circuits and metal parts of the case, and between all electrically separate circuits. It will also withstand 1kV 50Hz. for 1 minute between open contacts. An impulse test is applied at 5kV in accordance with IEC 254-4 Appendix E.

CASES

Relays are supplied in either moulded non-drawout cases (N type) or drawout cases (D type), available for flush or projecting mounting, as given in the following table:

Relay Type	Case Size	Maximum Overall Dimensions		
		Height mm	Width mm	Depth* mm
CTU12	½N	124	153	130
CTU21, 22, 23	½D	154	170	198
CTU31, 32, 41, 42, 51, 52, 61, 62, 63, 64	1D	233	170	197

* Add 36 mm for maximum length of M5 terminals.

Dimensioned drawings of case outlines, panel cut-outs and mounting details are available on request.

Moulded non-drawout cases and drawout cases are finished in phenolic black as standard.

Relays for use in exceptionally severe environments can be finished to B.S.2011:20/50/56 at extra cost: standard relays are finished to B.S.2011:20/40/4 and are satisfactory for normal tropical use.

INFORMATION REQUIRED WITH ORDER

Relay type and settings required.
Current transformer secondary rating
System frequency
Auxiliary supply system
Case type and mode of mounting

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Publication R-5065C

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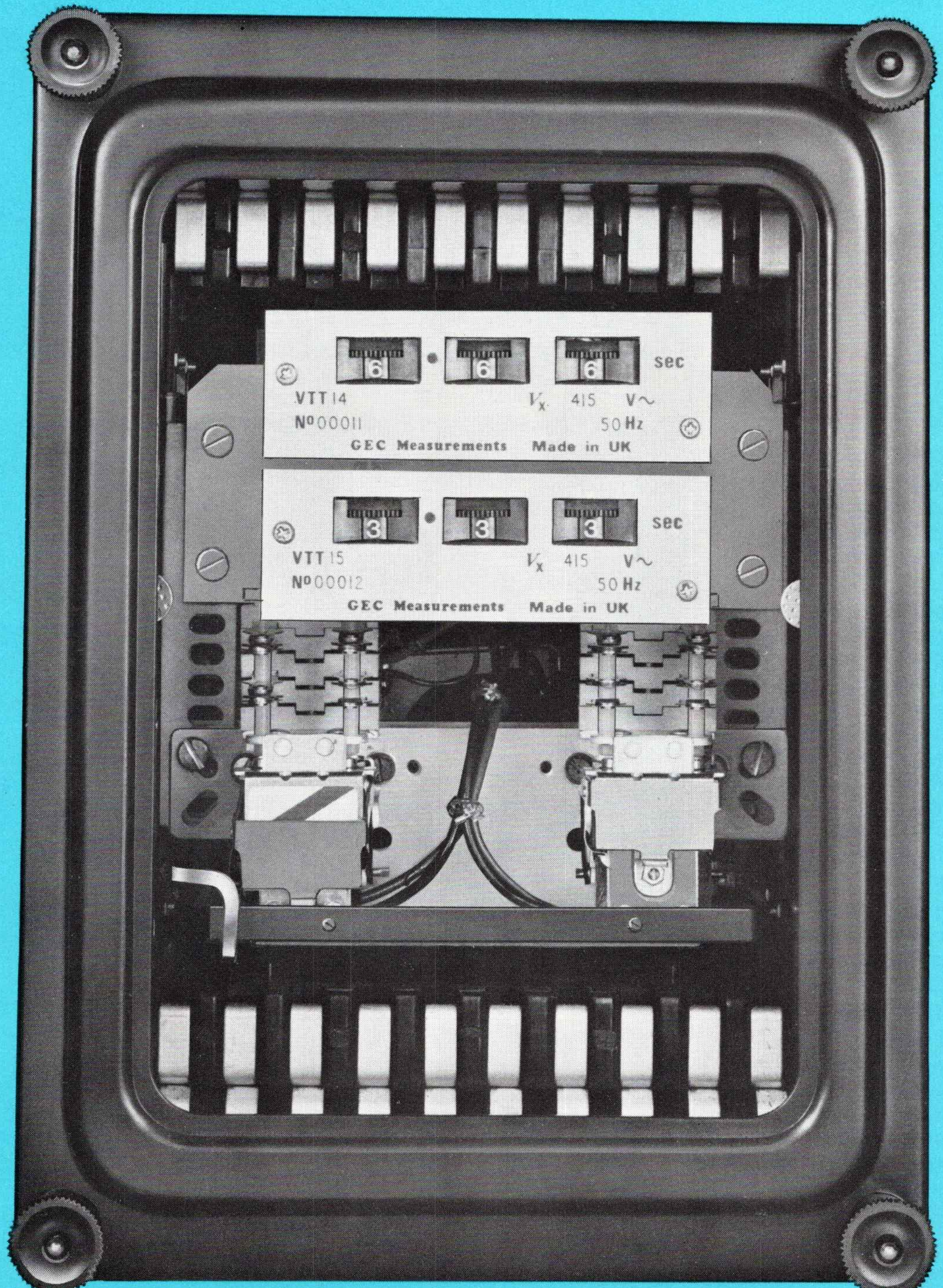
GEC Measurements

Types VTT14, VTT15 and VTT26

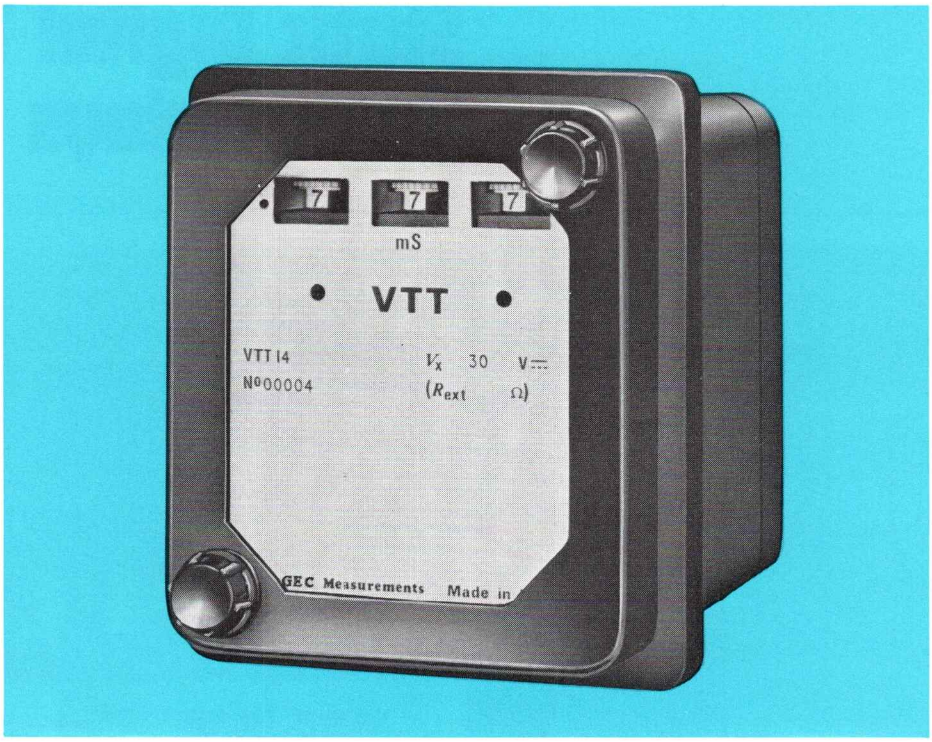
Static Digital Time Delay Relays



Types VTT14, VTT15 and VTT26

FEATURES

* 1000/1 setting range
* Time settings easily selected by means of thumbwheel switches
* Provide time delayed pick-up, drop-off or both functions combined in one relay
* For a.c. or d.c. supplies
* Compact construction



APPLICATION

This range of static time delay relays is particularly suitable for use in protection and control schemes applied to electrical power systems and industrial process plant.

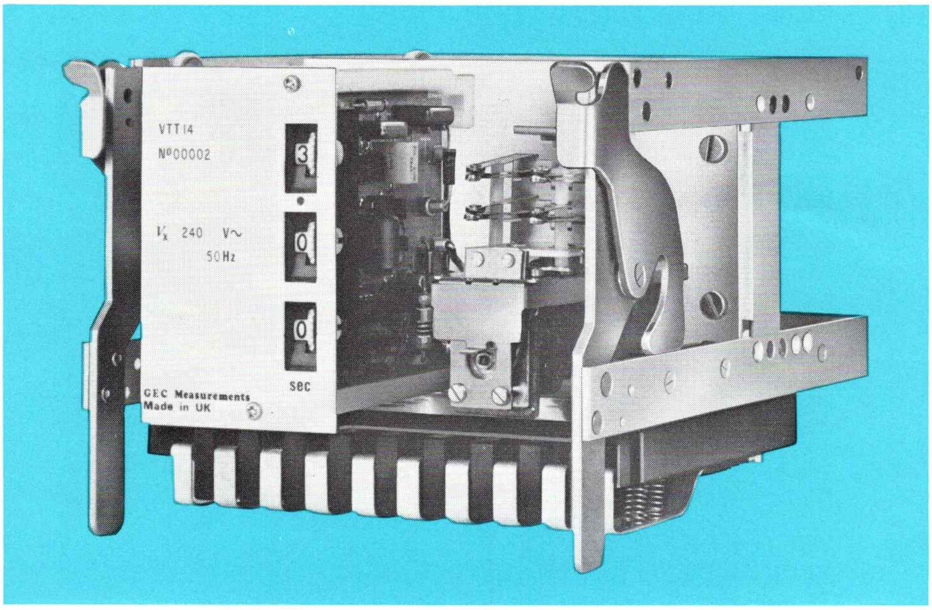
The relays can perform with consistent accuracy over a large number of operations, with little or no maintenance over long periods. Furthermore, the static circuits have been designed to perform with complete reliability in the electrically hostile environments often encountered in electrical power stations and substations, and also over a very wide range of ambient temperature.

The provision of an exceptionally wide time delay setting range, of 1000/1, enables a single design to be used as standard for a very wide range of applications.

The settings are adjusted by means of a group of thumbwheel switches, in an arrangement which provides not only an extensive setting range but also 1000 alternative discrete settings within the range, each closely spaced and exactly repeatable.

Type variations

The relay type variations covering time delayed operation on pick-up or drop-off, or both, are shown in Table 1.



Time delayed operation	Number of elements	Relay type
Pick-up	1 2	VTT14 VTT24
Drop-off	1 2	VTT15 VTT25
Pick-up Drop-off	1 1 } Combined	VTT26

Table 1 KEY TO RELAY TYPES

Single element relays are available as discrete relays supplied in draw-out or non-drawout cases.

Multiple element relays are supplied only in a larger drawout case.

DESCRIPTION AND OPERATION

Type VTT14, with time delayed pick-up

As shown in Figure 1, the VTT14 relay is initiated when the power supply to the relay is switched on, starting a CMOS resistance/capacitance oscillator which generates a square wave output to a binary coded decimal counter.

It is also arranged that when the d.c., or rectified a.c. supply first appears, the counter is set immediately to zero before the count commences.

The required time delay is preset by adjusting a group of three binary coded decimal switches. The time delay setting is selected from within the 1000/1 range by adjusting the thumbwheel protruding from each switch. Although the switch output to the associated circuitry is in binary form, the thumbwheels are calibrated for convenience in decimals, each switch providing a successive decade of 0 to 9.

When the count from the instant of relay initiation reaches the setting of the thumbwheel switches, as detected by a comparator, the latter produces a signal which operates the output element and also stops the oscillator. The relay resets nominally instantaneously when the initiating contact is re-opened.

Typical circuit diagrams for the VTT14 relay are shown in Figure 2. from which it may be noted that the initiating contact closes the rectified d.c. circuit, rather than the input circuit, in the design for use with an a.c. power supply. This is to ensure that the transient time delays normally inherent in the filter circuit to smooth the rectified d.c., do not cause timing errors.

Type VTT15, with time delayed drop-off

As indicated in Figure 3, the VTT15 relay has a similar circuit, but application of the power supply causes the relay to pick-up nominally instantaneously.

The drop-off time delay is initiated by opening an external break contact connected in the inhibit control circuit to the oscillator.

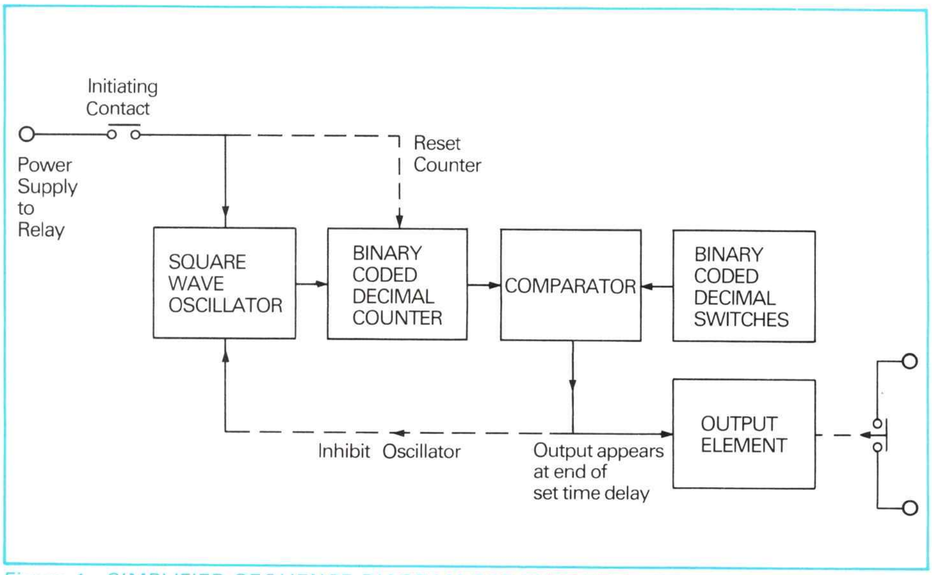


Figure 1 SIMPLIFIED SEQUENCE DIAGRAM FOR TYPE VTT14 RELAY WITH TIME DELAYED PICK-UP.

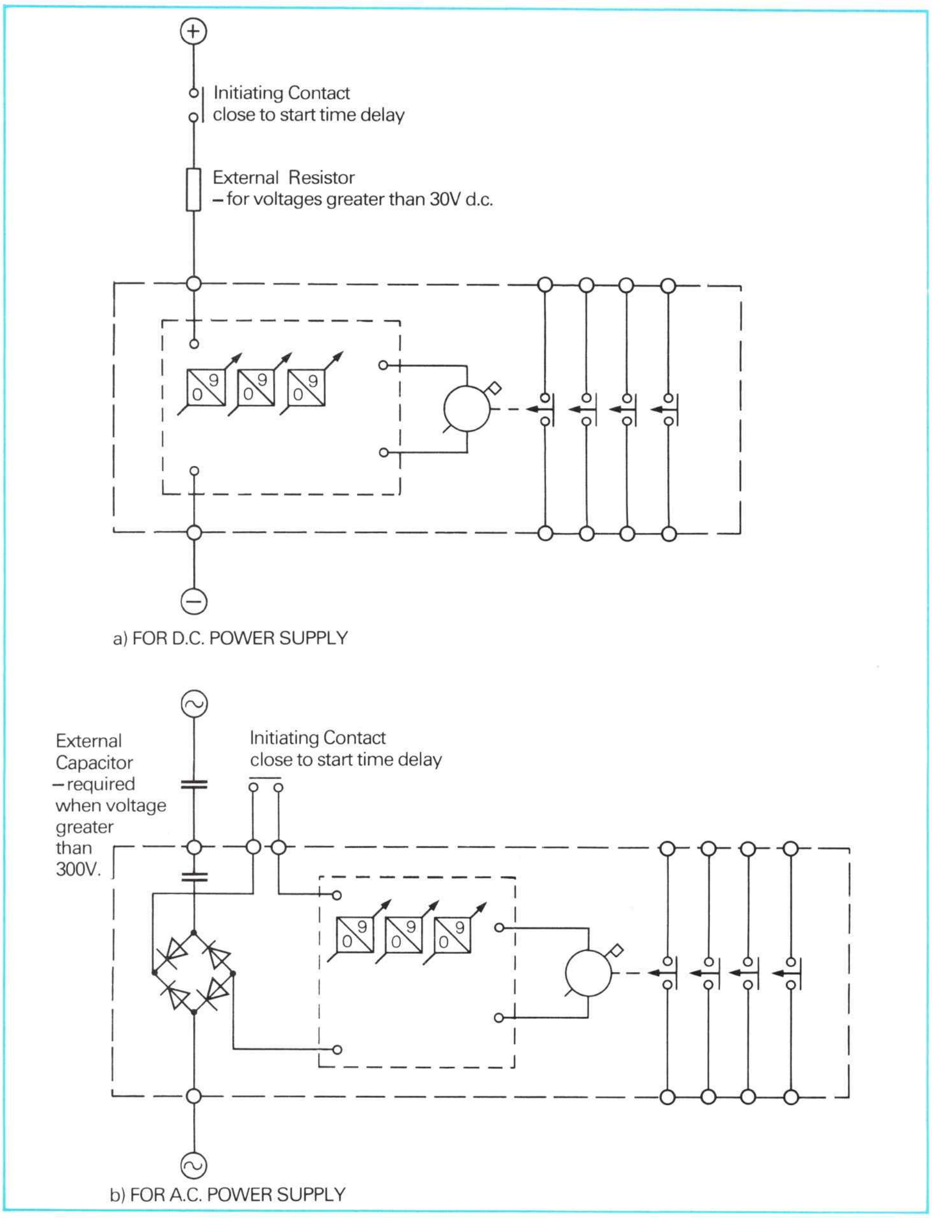


Figure 2 TYPICAL CIRCUIT DIAGRAMS FOR TYPE VTT14 RELAYS

In this relay the output from the comparator disappears at the end of the set time delay. Until then the output element is continuously energised.

Typical circuit diagrams for the VTT15 relay are shown in Figure 4.

Type VTT26

This relay is basically a type VTT14 relay and a type VTT15 relay mounted in the same case. By means of suitable external connections, it is thereby possible to provide a composite relay with time delayed pick-up and drop-off operations.

In the standard design the overall limit of 20 terminals imposes a maximum of three pairs of contacts for each element, for external use.

Output elements

Two alternative types of output element are available. In the more compact arrangement the output element comprises a reed relay, with a limited number of self-resetting contacts.

However, a type VAA attracted armature element may be selected instead, to provide one or more of the following:

* A greater number of contacts
* Heavier duty contacts
* Hand-resetting or self-resetting contacts
* A hand-reset flag indicator. When required in relays having time delayed drop-off, the flag indicator is designed to fall when the element is de-energised.

Power supplies

Relays designed for d.c. power supplies rated higher than 30V d.c. are supplied with an external resistor for connection in series with a power supply terminal.

Relays designed for a.c. power supplies include a bridge rectifier and a series capacitor. For voltage ratings higher than 300V a.c. an additional capacitor is supplied for external connection to the relay.

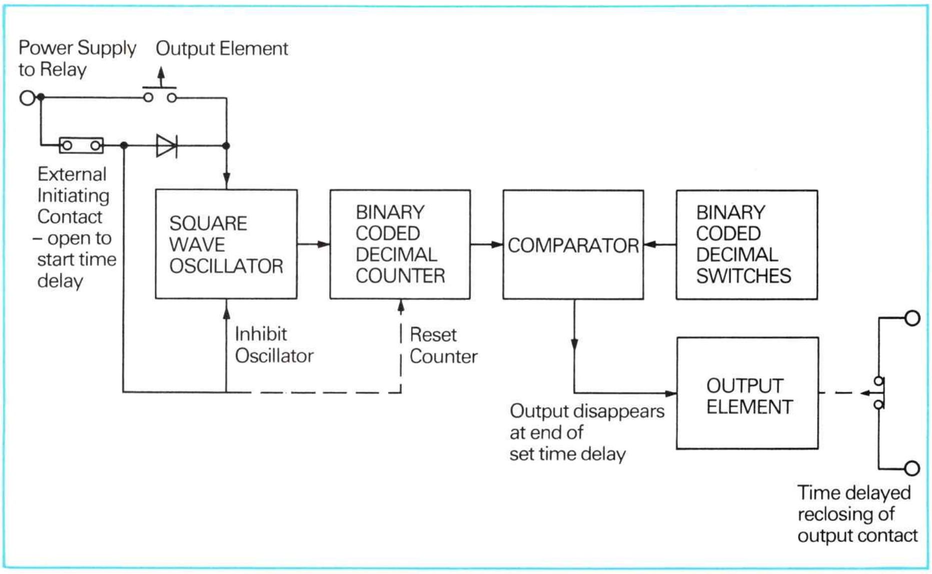


Figure 3 SIMPLIFIED SEQUENCE DIAGRAM FOR TYPE VTT15 RELAY WITH TIME DELAYED DROP-OFF

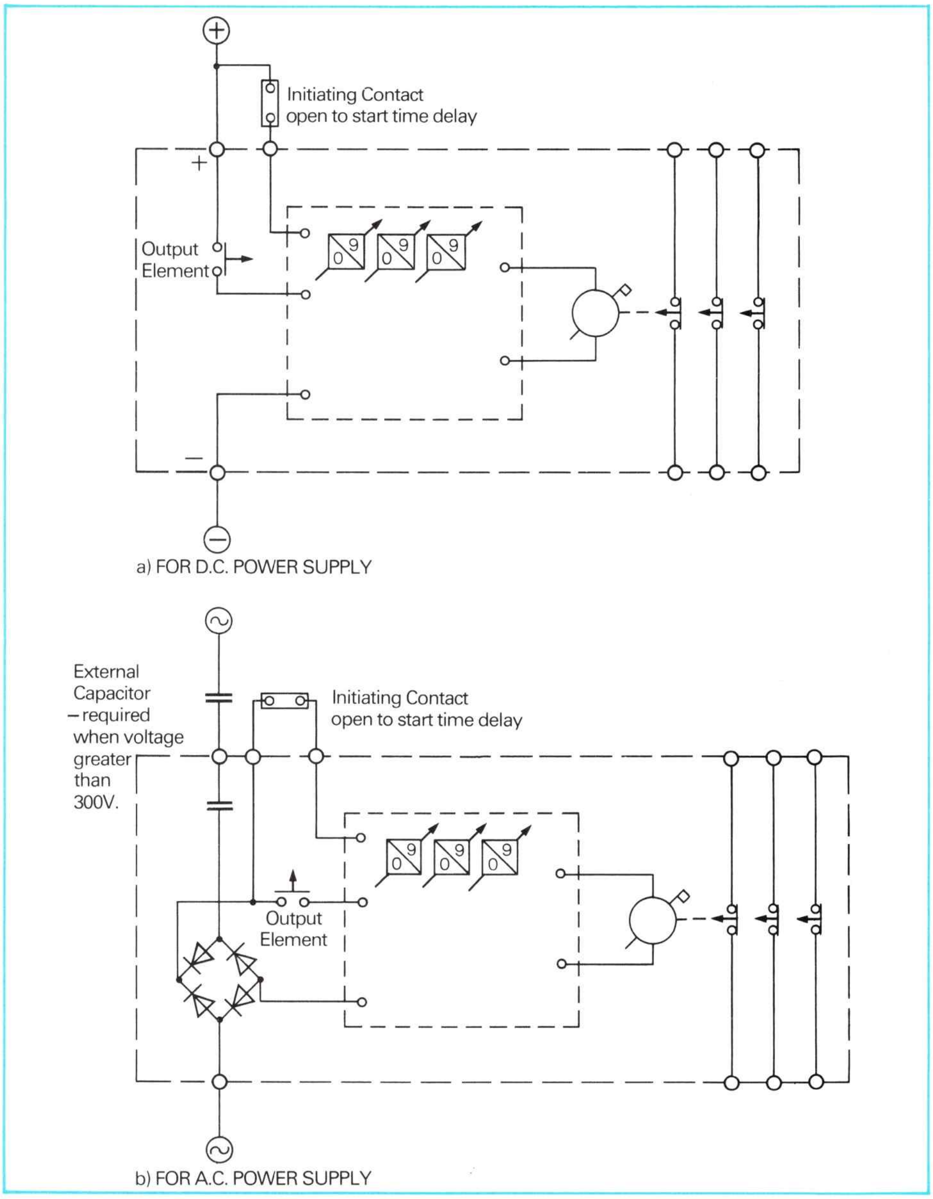


Figure 4 TYPICAL CIRCUIT DIAGRAMS FOR TYPE VTT15 RELAYS

TECHNICAL DATA

Voltage rating
30, 110/125, 220/250V d.c., or
63.5, 110, 240, 415V a.c. at 50 Hz, or
69.3, 120, 266 or 460V at 60 Hz

Operative voltage range
D.C. 80%–125% rated voltage
A.C. 80%–110% rated voltage

Standard setting range
0.01s to 9.99s in steps of 0.01s. Other 1000/1 setting ranges are available, covering from 0.01s minimum to 10,000s maximum. An alternative version providing a setting range of 100/1 is also available.

Operating ambient temperature range
–25 °C to +55 °C

Accuracy
With reed output element: ±2% of setting or +5ms –0ms, whichever is the greater
With attracted armature output element: ±2% of setting or +30ms –0ms, whichever is the greater

Consistency
With reed output element: ±0.5% or ±1ms, whichever is the greater
With attracted armature output element: ±0.5% or ±5ms, whichever is the greater

Disengaging time
With reed output element less than 5ms
With attracted armature output element less than 25ms

Resetting time
With reed output element less than 10ms
With attacted armature output element less than 25ms

Flag indicator
Supplied as standard in relays with attracted armature type of output element

Burden

Relay or element type	Supply	Standing current (mA) when quiescent	Maximum current (mA) during operation
VTT14 (delayed pick-up)	d.c.	10	40
	a.c.	65	65
VTT15 (delayed drop-off)	d.c.	0	45
	a.c.	65	65

Note: for relays having more than one element the current levels are increased pro rata

Contacts

Relay or element type	Output element	Contacts
VTT14 (delayed pick-up)	Reed	2 make, self-resetting
	Attracted armature	4 pairs of make, break, self or hand resetting, in any combination
VTT15 (delayed drop-off)	Reed	1 make, self-resetting
	Attracted armature	3 pairs of make, break, self or hand resetting, in any combination

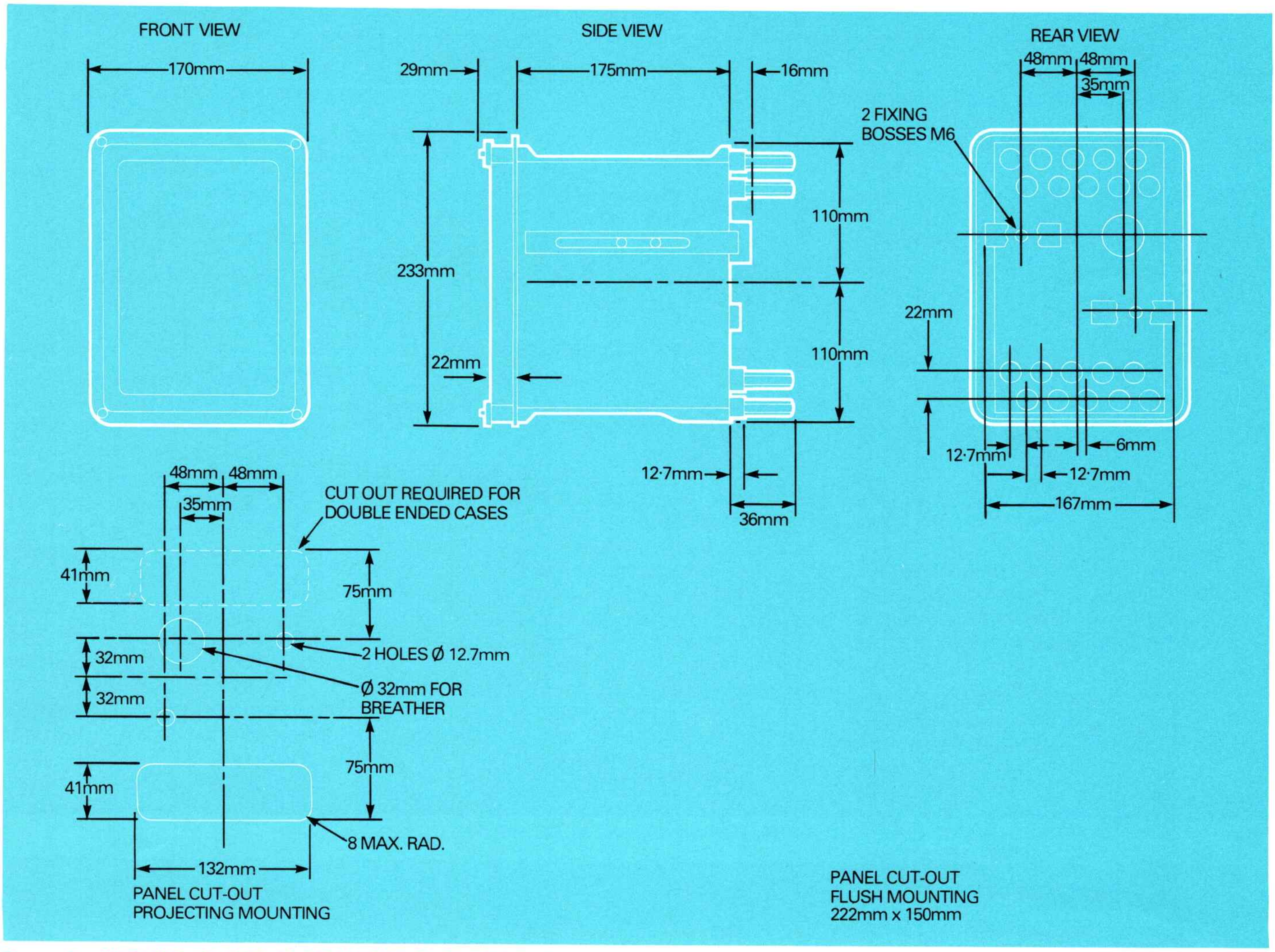


Figure 7 OUTLINE OF SIZE 1D DRAWOUT CASE FOR TWO ELEMENT RELAYS

Our policy is one of continuous product development and the right is reserved to supply equipment which may vary slightly from that described.

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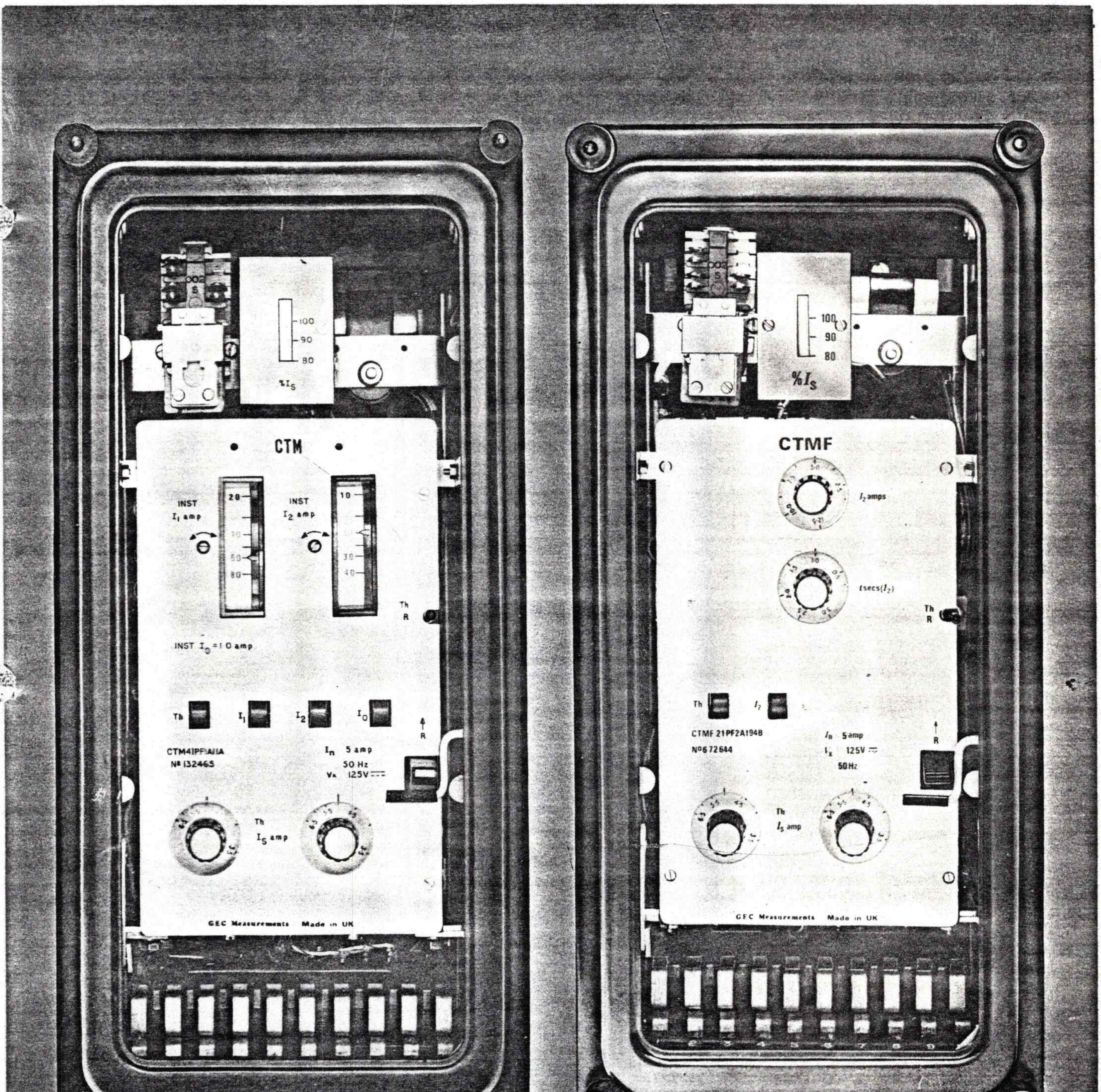
Types CTM & CTMF

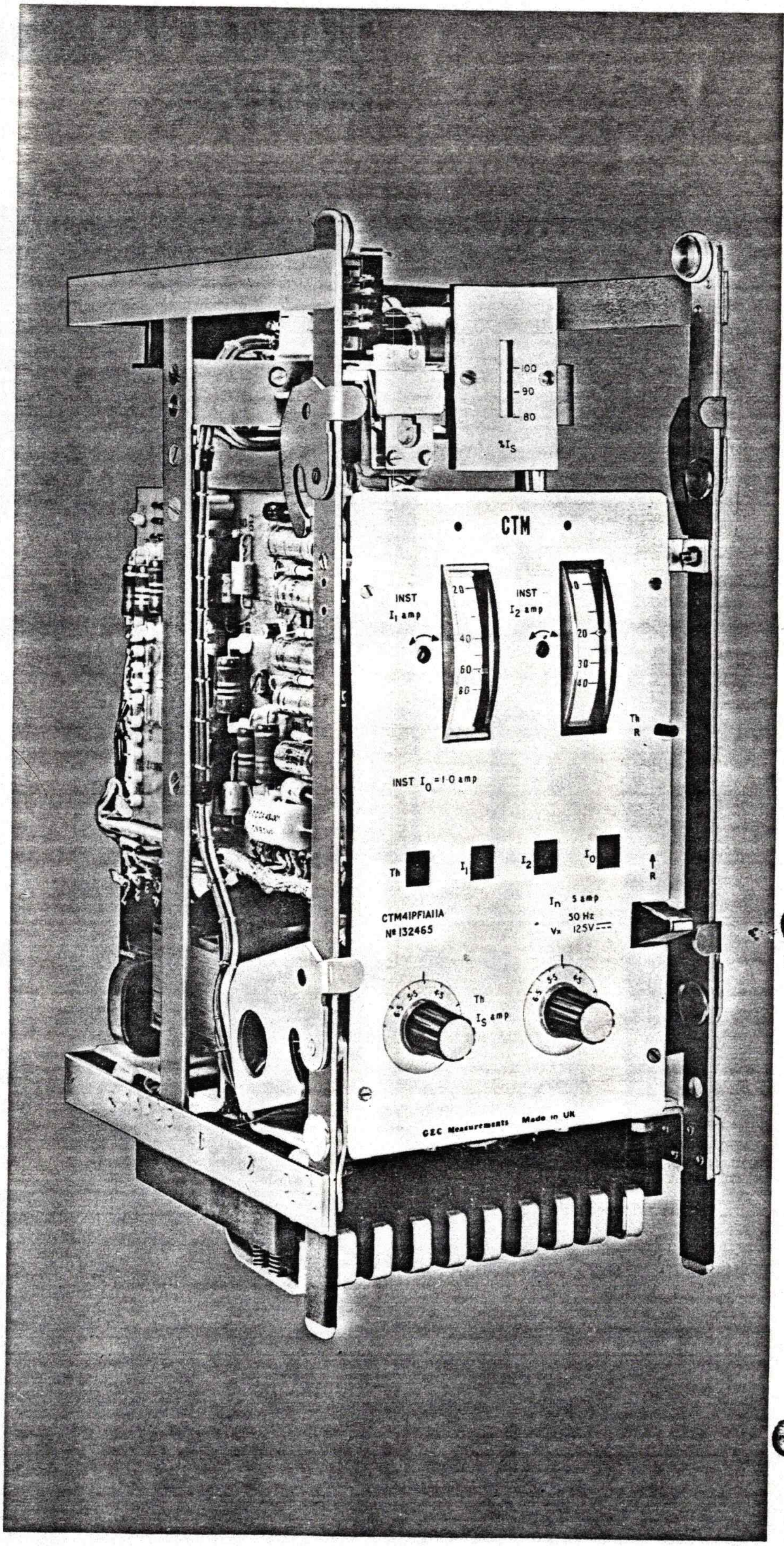
Motor Protection Relays



Types CTM & CTMF

FEATURES

* Current setting range continuously adjustable
* Greater choice of characteristic curves
* Improved unbalance protection
* Low burden—less than 1VA per phase
* Less than 2% thermal overshoot
* Improved accuracy
* Single phase stalling protection
* Optional running load indicators
* Thermal re-set facility (Th_R) to enable hot re-starting



APPLICATION CONSIDERATIONS		TYPICAL CORRELATION OF RELAY AND MOTOR TYPES					
Protection Provided	Motor Controlled by	Submersible Pump Motors	C.M.R. Motors	Standard Industrial Motors		Special Motors For High Inertia Drives	
i) Thermal (Th)	Circuit Breaker	CTM11	CTM12	CTM13	CTM14	CTM15	CTM16
i) Thermal (Th) ii) Instantaneous earth fault (I_0)	Circuit Breaker	CTM21	CTM22	CTM23	CTM24	CTM25	CTM26
i) Thermal (Th) ii) Time delayed, unbalance & single phasing (I_2)	Fused Contactor	CTMF21	CTMF22	CTMF23	CTMF24	CTMF25	CTMF26
i) Thermal (Th) ii) Instantaneous three phase overcurrent (I_1) iii) Instantaneous unbalance & single phasing (I_2)	Circuit Breaker	CTM31	CTM32	CTM33	CTM34	CTM35	CTM36
i) Thermal (Th) ii) Time delayed, unbalance & single phasing (I_2) iii) Time delayed earth fault (I_0)	Fused Contactor	CTMF31	CTMF32	CTMF33	CTMF34	CTMF35	CTMF36
i) Thermal (Th) ii) Instantaneous three phase overcurrent (I_1) iii) Instantaneous unbalance & single phasing (I_2) iv) Instantaneous earth fault (I_0)	Circuit Breaker	CTM41	CTM42	CTM43	CTM44	CTM45	CTM46
Relay Thermal Operation Characteristic — Curve Number	CTM & CTMF	1	2	3	4	5	6
Relay Thermal Operation Characteristic — Nominal Operation Time (s) at 5 x Setting Current ('Cold' curves)		4	8	16	32	64	128

APPLICATION

The protection usually provided for three phase motors, while generally effective against overloads and short circuit conditions, rarely takes into full account the harmful effects of unbalanced line currents. Even a modest unbalance can cause damage to a motor by overheating and in the extreme instance of a motor stalling due to loss of one phase, severe rotor damage can occur within the normal starting time.

The types CTM & CTMF relays measure the load current and the unbalance current independently, and provide accurate protection against thermal damage under all operating conditions. The thermal characteristic of the relay is designed to follow closely the thermal withstand characteristic of typical motors, this ensures that the relay isolates the motors only when the insulation life is threatened.

The relay can also provide instantaneous and time delayed protection against motor circuit faults.

A range of type CTM and CTMF relays, manufactured to suit various applications of motors, controlled either by circuit-breakers or fuse contactors are shown in the table above.

One group in the series, designated CTMF, has been designed for motor control centre applications where fuse contactors are used. These relays include a time delayed single phasing element and an earth fault element which, in the event of the fault level being above the rupturing capacity of the contactor, allows the fuse to blow before the contactor operates.

To cater for a wide range of motor characteristics, a range of alternative operating characteristics is provided on differing thermal units.

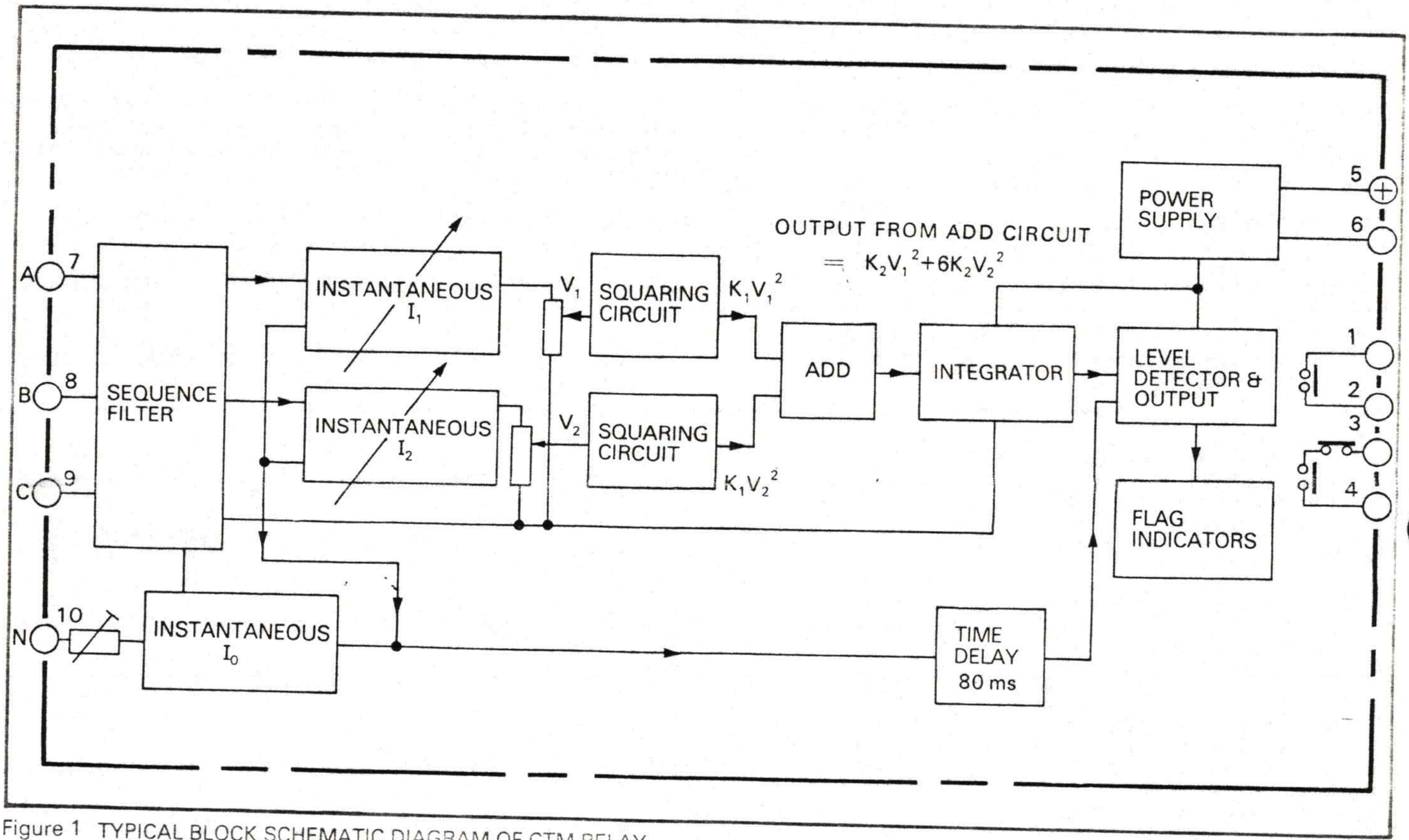


Figure 1 TYPICAL BLOCK SCHEMATIC DIAGRAM OF CTM RELAY
The input connections correspond to those shown in Figure 4

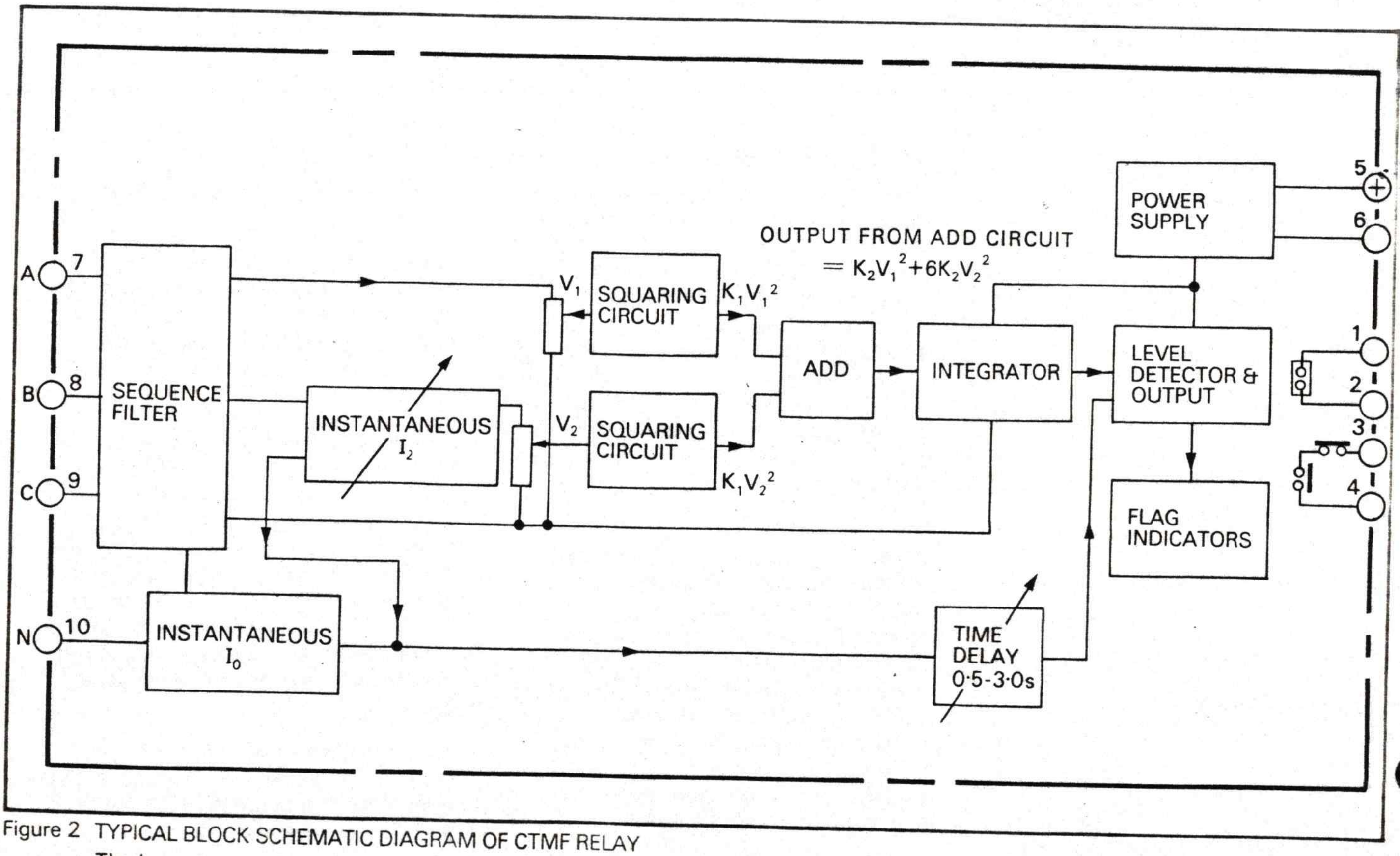


Figure 2 TYPICAL BLOCK SCHEMATIC DIAGRAM OF CTMF RELAY
The input connections correspond to those shown in Figure 4

CIRCUIT DESCRIPTION

Figures 1 and 2 show block schematic diagrams of typical CTM and CTMF relays. In both cases, the inputs from the current transformers, which are connected in each phase of the motor supply, are fed to a sequence filter network which separates the positive and negative sequence components of the input current. These quantities are in turn fed to separate setting potentiometers via instantaneous operating elements, I_1 and I_2. The potentiometers provide two output voltages V_1 and V_2 which are proportional to the positive and negative phase sequence components of the input current. V_1 and V_2 are fed into squaring circuits to give $K_1V_1^2$ and $K_1V_2^2$, these values are then added to give an input voltage to the integrator, $K_2V_1^2 + 6K_2V_2^2$. A feedback circuit across the integrator causes the output voltage from the integrator circuit to rise exponentially from zero up to a voltage which is equivalent to 105% of the relay setting current and linearly above this setting.

The output voltage from the integrator is fed to a level detector which, when the set voltage is reached, energises an electromagnetic output unit. This operates two pairs of electrically separate contacts which are used to trip the circuit-breaker or fuse contactor controlling the supply to the motor.

Instantaneous elements—CTM relay (see Figure 1)

The three instantaneous elements are for overcurrent (I_1), single phasing and unbalance (I_2) and earth fault (I_0).

The I_1 and I_2 elements are connected in the appropriate outputs of the sequence filter and are continuously adjustable over their setting ranges. The I_0 element has a fixed setting and is included in the neutral connection of the C.T. secondary circuits together with a continuously adjustable stabilising resistor. This ensures stability when, under motor starting conditions, unequal saturation of the current transformers might otherwise cause operation of the relay.

The output of each element is fed into a common electromagnetic output unit via a nominal time delay of 80 milliseconds which prevents operation due to the initial starting transient.

Time delayed elements—CTMF relay (see Figure 2)

In this relay there are two such elements, single phasing and unbalance (I_2) and earth fault (I_0). Both are connected in a similar manner to the instantaneous elements of the CTM types. Their outputs are fed via an adjustable definite time delay element (0.5 to 3.0 seconds) to the electromagnetic output unit. This ensures that any high fault currents are cleared by the fuse and not the contactor. A positive sequence element (I_1) is not necessary in this application because of the protection provided by the fuses.

An auxiliary supply, either a.c. or d.c., is used to provide a 30 volt zener stabilised supply to the relay.

OPERATION

Balanced conditions

Under normal conditions the motor draws balanced load currents from the supply and the filter delivers only positive sequence voltage to the relay. If the motor current exceeds the relay setting, tripping will occur as shown in the thermal operation characteristics.

Unbalanced conditions

An unbalance in the supply voltage results in negative sequence currents flowing in the motor stator windings. The degree of unbalance will depend upon the level of the negative sequence component in the supply voltage and the negative sequence impedance of the machine. This latter value is much less than the positive sequence impedance and hence the ratio of negative/positive sequence current is much greater than the ratio of the negative/positive sequence voltage.

The negative sequence stator current will induce a corresponding negative sequence current in the rotor circuit, the effective frequency of which will be approximately twice normal frequency; thus for a 50 Hz supply the effective frequency will be 100 Hz.

The ratio of the rotor a.c. resistance at double the system frequency, to the d.c. resistance, which applies under normal running conditions, is in the range 3 to 6 for the majority of machines. Thus one unit of negative sequence current will have a greater heating effect than one unit of positive sequence current. This unequal heating effect should be taken into account in the design of a relay which protects against unbalanced conditions, so that the motor will not be tripped unnecessarily. The equivalent current for operation of this range of relays is in accordance with the following expression:

$$I_{eq} = \sqrt{I_1^2 + 6I_2^2}$$

where I_{eq} = Equivalent operating current

I_1 = Positive sequence component of the supply current

I_2 = Negative sequence component of the supply current

The I_2 multiplying factor of 6 has been carefully chosen to provide adequate protection to both the stator and rotor windings for all designs of motors without causing nuisance tripping.

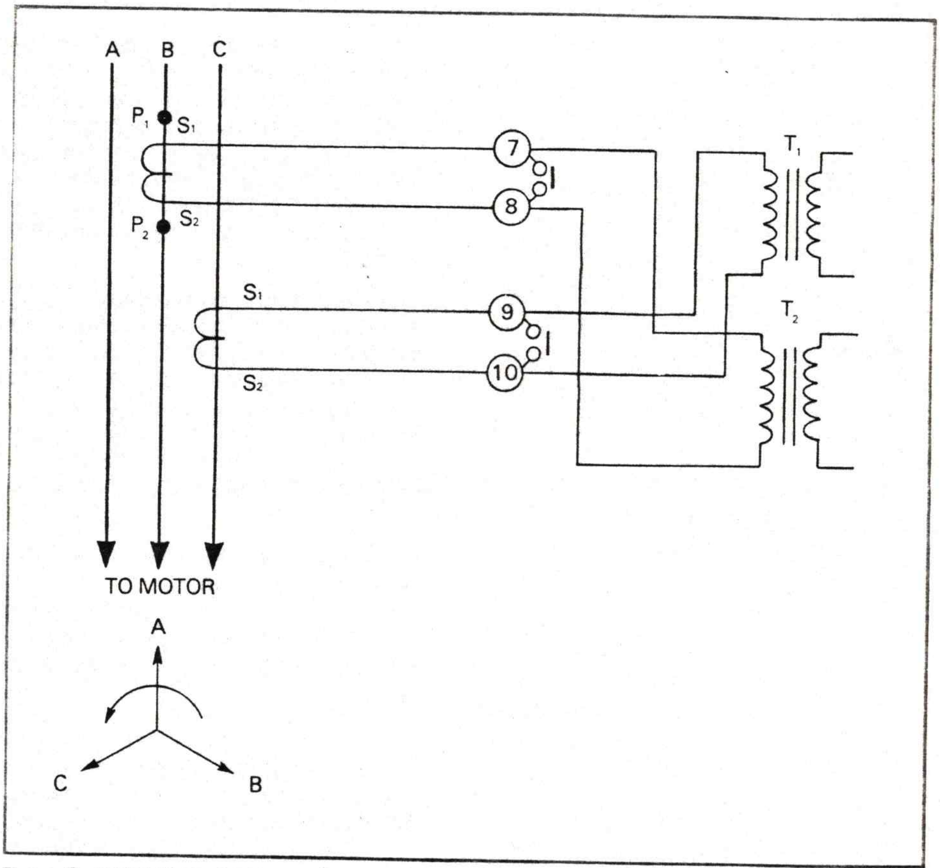


Figure 3 EXTERNAL CONNECTIONS CTM11 TO 16, CTM31 TO 36 AND CTMF21 TO 26

STALLING PROTECTION

Three phase stall

For normal machines started direct-on-line the starting current is virtually constant and equal to the locked rotor current throughout the starting period. One of the features of this relay is the very small thermal overshoot—less than 2%. This means that the relay operating time can be set very close to the motor starting time. Providing the allowable stall time for the motor is greater than the starting time, a separate stalling relay will not generally be required as the CTM relay thermal characteristic can be selected to prevent damage to the machine when stalled.

In the case of motors driving high inertia loads, the allowable stall time may be less than the starting time. In this event, protection against stalling can only be provided by means of a shaft speed monitoring relay in conjunction with a relay measuring motor current.

Single phase stall

The most likely cause of stalling in induction motors is the loss of one phase of the supply, due for example, to the blowing of a back-up fuse by the inrush current when the motor is first energised. In this situation, the motor would be connected to a single phase supply with the motor in a stationary condition. This could result in excessive damage to sections of the rotor winding unless the motor is disconnected quickly, although the stator current, under this condition is only 0.866 of the normal starting current. A relay measuring stator current to detect this condition would therefore have to have a time delay longer than the starting time.

Some variations of the CTM relay can be provided with an instantaneous element which is arranged to operate from the negative sequence component of the stator current. This will not operate under normal starting conditions and can therefore be arranged to trip the motor instantaneously in the event of a single phase stall condition. In the CTMF relay, this element is time delayed as described previously.

OPERATING CURRENT

Current settings are adjusted by two potentiometers on the relay front plate. The setting ranges enable the standard 1A and 5A relays to cover a wide range of motor ratings.

The thermal element begins to operate when the motor current rises to 1.05 times the relay current setting. This may be due to a load increase, or to a combination of normal load current and negative phase sequence current due to unbalanced supply voltages. If this increased current is due entirely to negative phase sequence current, the relay will begin to operate when the negative sequence current is 13.1% of the relay setting current.

For typical motors this is caused by an unbalance of about 2.2% in the supply voltage.

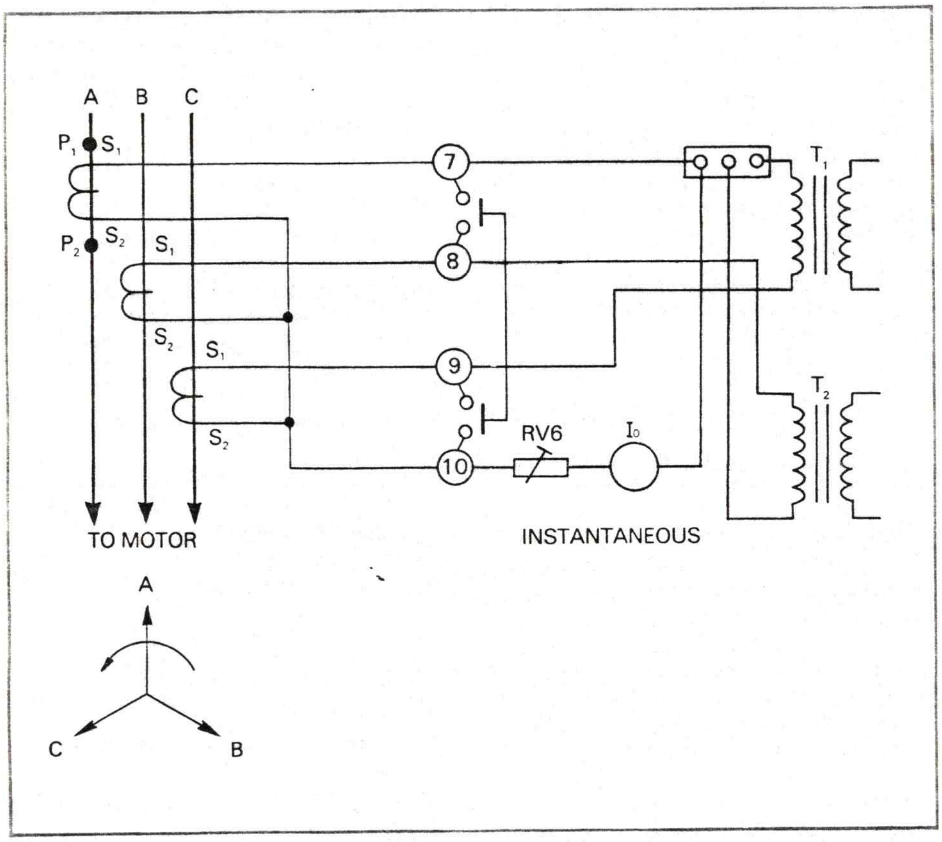


Figure 4 EXTERNAL CONNECTIONS CTM21 TO 26, CTM41 TO 46 AND CTMF31 TO 36
with internal star connection

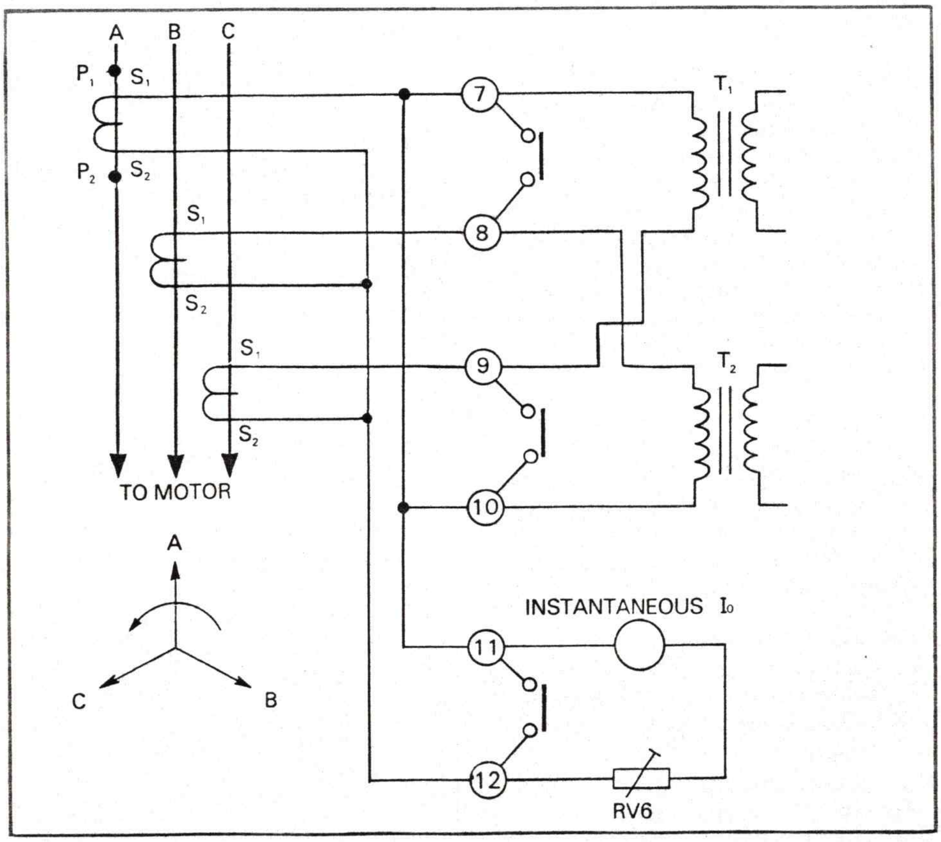


Figure 5 EXTERNAL CONNECTIONS CTM21 TO 26, CTM41 TO 46 AND CTMF31 TO 36
with external star connection

TECHNICAL DATA

Current ratings (I_n)

Suitable for operation from C.T.'s with secondary current ratings of 1A or 5A.

Frequency rating

Separate designs are available for nominal frequencies of 50 Hz and 60 Hz.

Current settings

Settings are expressed as percentages of the relative rated current.

Thermal element (Th)
70%—130% continuously adjustable.

Instantaneous overcurrent element (I_1)
400%—1600% continuously adjustable.

Instantaneous unbalance element, CTM relay (I_2)
200%—800% continuously adjustable.

Delayed unbalance element, CTMF relay (I_2)
50%—250% continuously adjustable.

Instantaneous earth fault element (I_0)
20% fixed. Other fixed settings are available. This element incorporates an adjustable stabilising resistor.
0—27 ohms for 5A
0—240 ohms for 1A

Operating times

CTM
Instantaneous elements I_1, I_2 and I_0
All nominally less than 80 ms at 5 x respective setting current.

CTMF
Elements I_2 and I_0
Common time delay continuously variable from
0·5 secs. to 3·0 secs.

Disengaging and resetting times—thermal elements

Curve reference no.	Disengaging time (seconds)	Time to reset to the cold curve (minutes)
1	40	10
2	42	13
3	50	20
4	66	33
5	120	63
6	400	120

The times quoted above may vary slightly from relay to relay and should therefore be treated as a guide only.
With all versions, it is possible to reset the thermal units instantaneously by means of a push button (Th_R). This feature is provided essentially to facilitate testing. The push button can only be operated when the relay cover is removed, this minimises the chance of misuse during normal service.

Pick-up current

The thermal element begins to operate at 1.05 times the nominal setting current.

Accuracy

Current Settings:
Thermal element. Th.
± 3% of the nominal pick-up current.

Instantaneous elements I_1, I_2 and I_0 (CTM relays) ± 10% of nominal setting.

Time Settings:
Time delayed elements I_2 and I_0 (CTMF relays) ± 10% of nominal setting.

Operating Time:
Thermal element. Th.
± 10% of nominal operation time at 5 x the equivalent current setting for both hot and cold curves.

Frequency variation:

The thermal operating times vary less than 10% over the following frequency ranges:

Nominal Frequency 50 Hz:
47 Hz to 51 Hz.
Nominal Frequency 60 Hz:
57 Hz to 61 Hz.

Temperature limits

Ambient −5°C to +40°C. Variation of thermal element operating time is within ± 10%. The relay will operate satisfactorily over the ambient temperature range of −20°C to +50°C.

Thermal overshoot

The thermal overshoot for all relays is less than 2%.

Current transformer requirements

Relay and C.T. Sec'dary Rating (A)	Nominal Output (VA)	Accuracy Class	Accuracy Limit Current (x rated current)	Limiting Lead Resistance (ohms)
5	10	5P	10	0·31
1	7·5	5P	10	3·0

These requirements comply with BS3938—1973.
Class 5P corresponds to the maximum composite transformation errors of ± 1% at rated current (I_n) and ± 5% at the accuracy limit.
The accuracy limit is a value of current expressed as a multiple of rated current.

Note: The limiting resistance is given for the leads between the C.T.'s and the relay. The respective limiting value should include go and return leads when the relay includes an earth fault element (I_o).

Auxiliary supplies

Separate designs are available for operation from any one of the following rated voltages. Relays suitable for other rated voltages are available upon request.

D.C.: 110V, 125V, 220V
operating range 80% to 115% of rated voltage.

A.C.: 110V, 240V
operating range 80% to 115% of rated voltage.

Note: Auxiliary supplies above 125V require an external resistor.

Contacts

Two pairs of electrically separate contacts are provided on the standard relay. These may be either hand reset or self reset.
All contacts of the electromechanical output element are rated to make and carry 7500 VA for 3 seconds with maxima of 30A or 660V a.c. or d.c.

Impulse withstand level

The relay will withstand impulses of 5 kV peak and 1/50 microsecond wave form applied both transversely and between relay terminals and earth, in accordance with BEAMA document No. 219 and IEC draft recommendation.

High frequency disturbance

The relay meets the draft IEC test recommendation for the High Frequency Disturbance test.
The relay accuracy is unaffected by repetitive 1 MHz bursts having an initial peak of 1.0 kV superimposed across input circuits, and 2.5 kV between independent circuits, and circuits to earth, with a decay time of 3 to 6 microseconds and with the relay energised.

Insulation

The relay will withstand:
2 kV, 50 Hz for 1 minute between all circuits and the case, and also between all separate circuits.
1 kV, 50 Hz for 1 minute between normally open contacts.

Operation indicators

A miniature rotary operation indicator is provided as standard for each of the four tripping elements.

(i) Thermal (Th)
(ii) Instantaneous (I_1)
(iii) Instantaneous (I_2)
(iv) Instantaneous (I_0)

Load Indicator (optional):
Calibrated from 80% to 100% of the thermal element current setting, the load indicator can be provided to give continuous monitoring of the motor load condition.

Overload ratings

The relay will withstand:
(i) The relay setting current continuously.
(ii) 20 times the relay rated current for 9 seconds.
(iii) 100 times the relay rated current for 0·5 seconds.

Selection of optimum current setting

The calculation of the optimum setting for the thermal unit simply requires knowledge of:

Motor full load current (A) : I
C.T. ratio (A) : I_P/I_R
Required minimum operation (equivalent) current (% full load) : I_{eq}

The values usually recommended for I_{eq} are:

for CMR motors : 100% full load
for totally enclosed motors : 110% full load
for open type motors : 125% full load

Optimum current setting

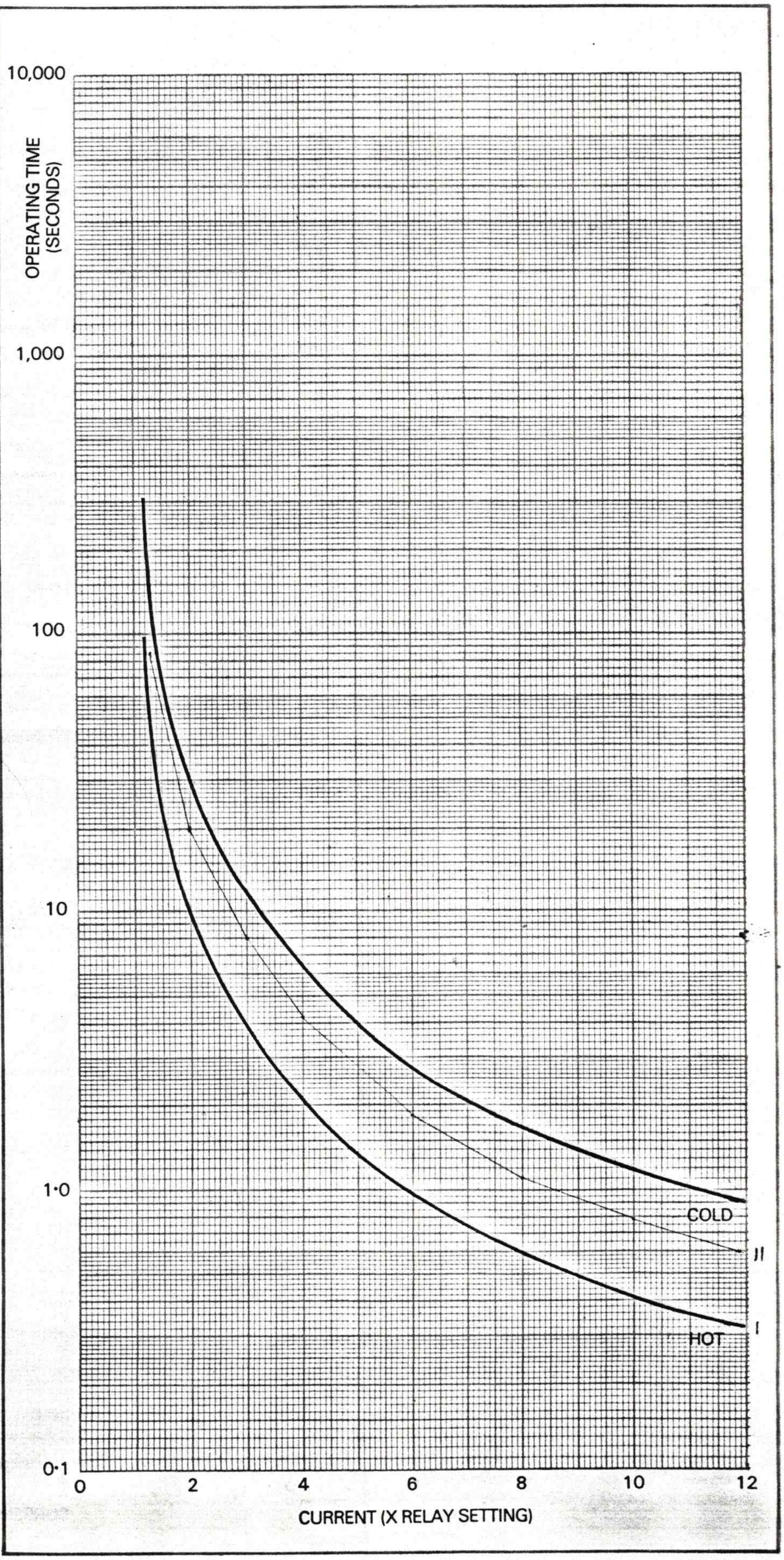
$$\text{Th } I_s \text{ (A)} = \frac{I_{eq} \times I \times I_R}{100 \times 1.05 \times I_P}$$

Burden

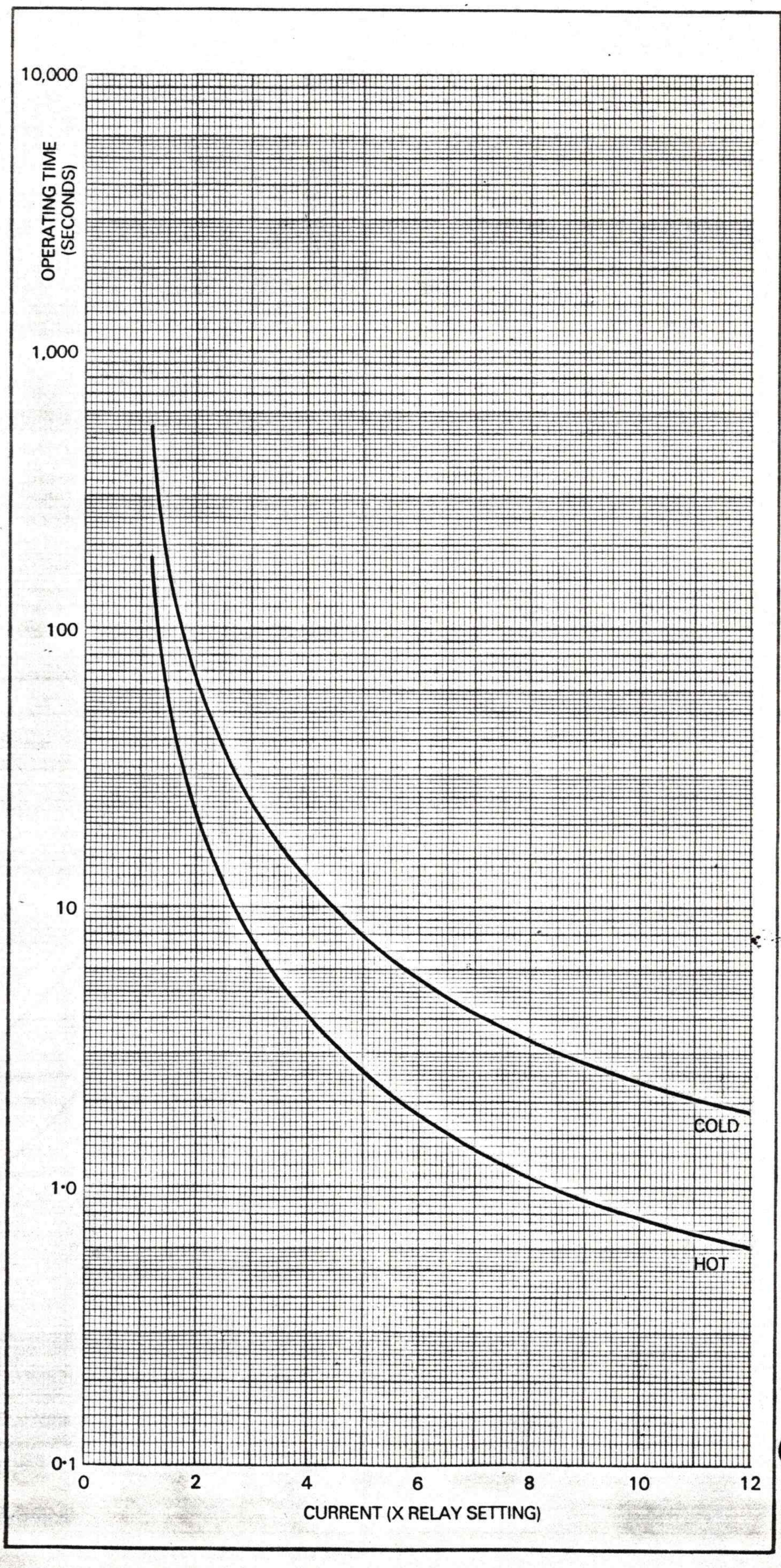
AC burden : less than 1 VA per phase at rated current

Auxiliary burden:
14W at nominal voltage.

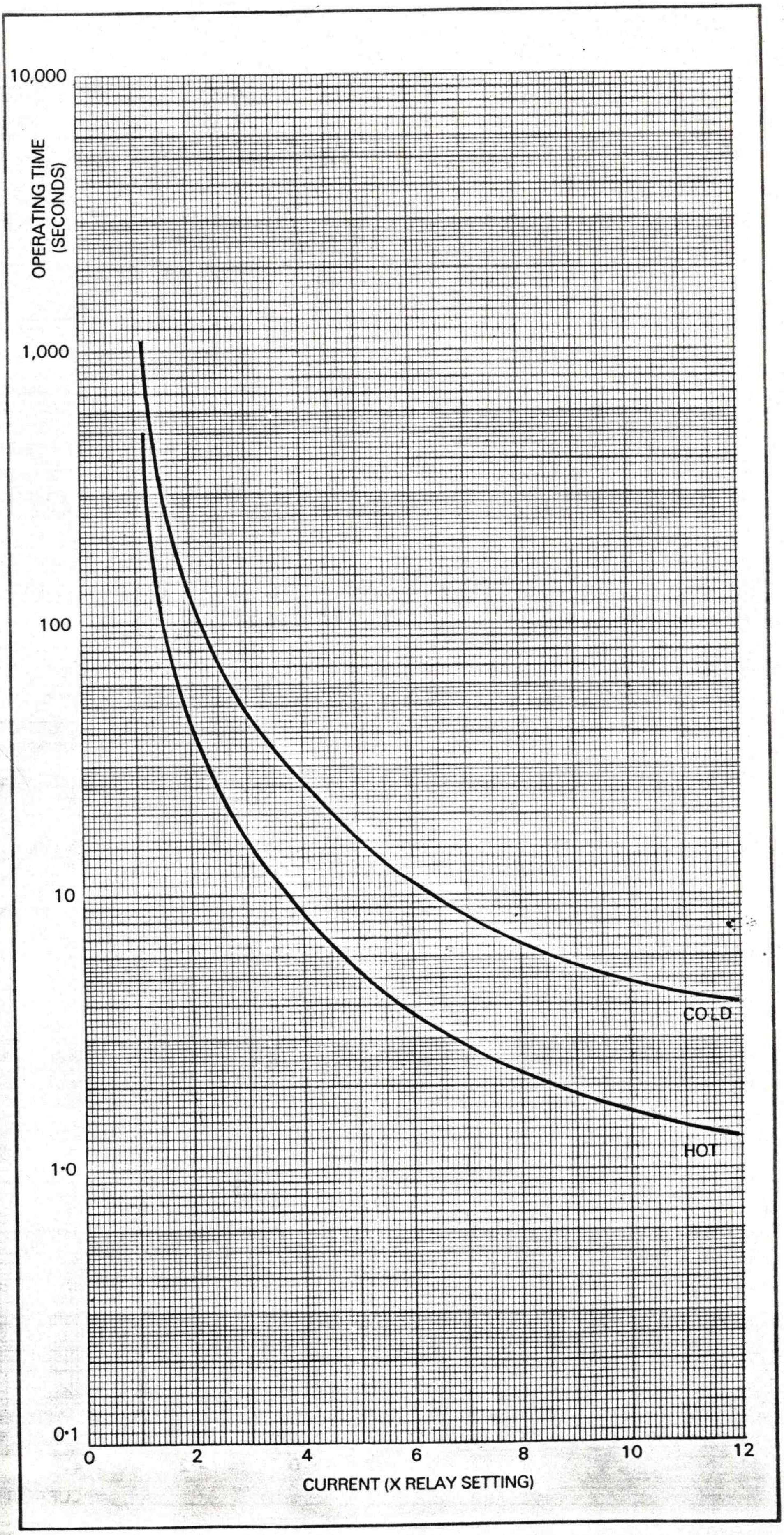
THERMAL CHARACTERISTIC
REFERENCE 1



THERMAL CHARACTERISTIC
REFERENCE 2



THERMAL CHARACTERISTIC
REFERENCE 3



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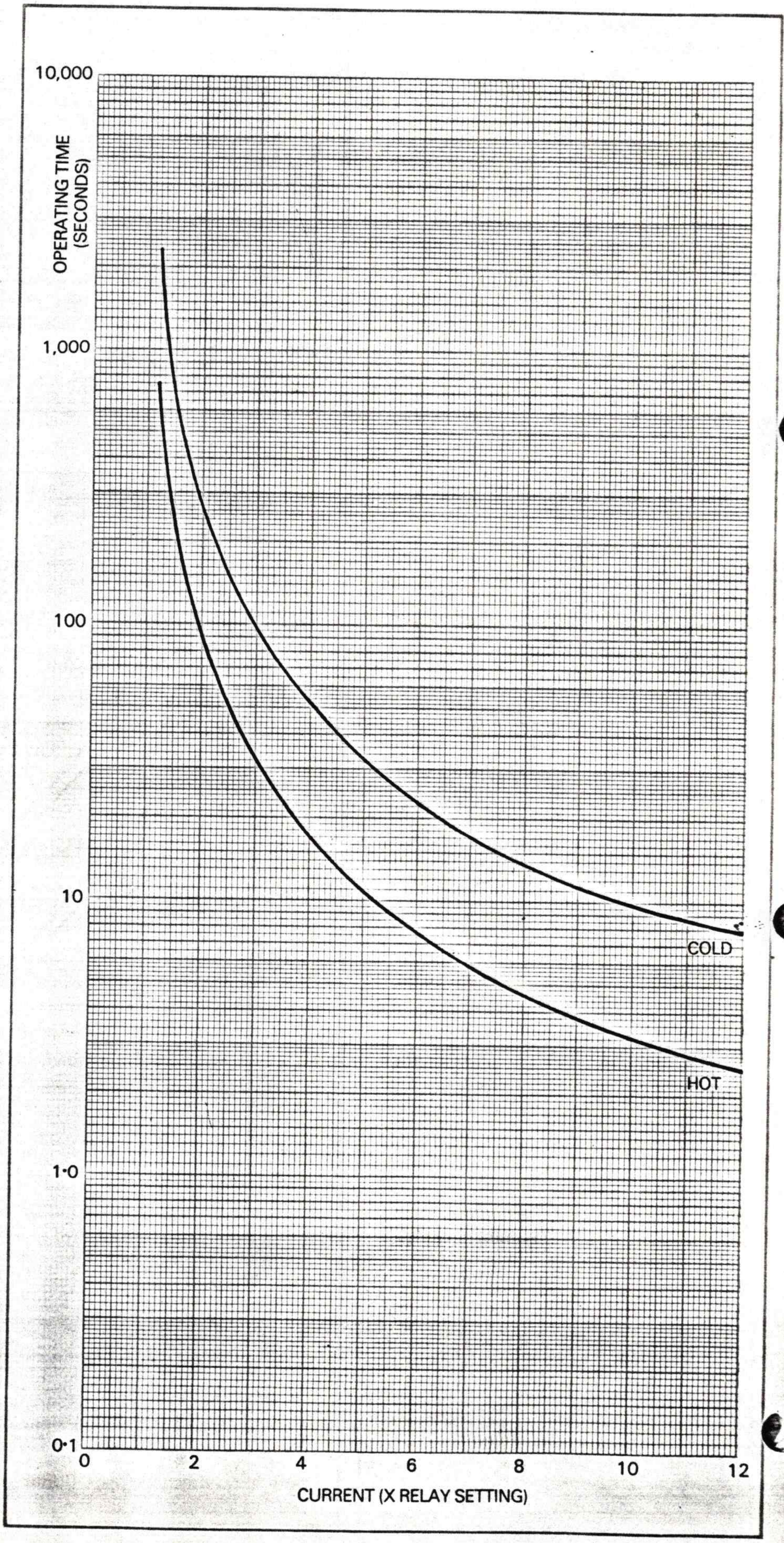
REFERENCE 4



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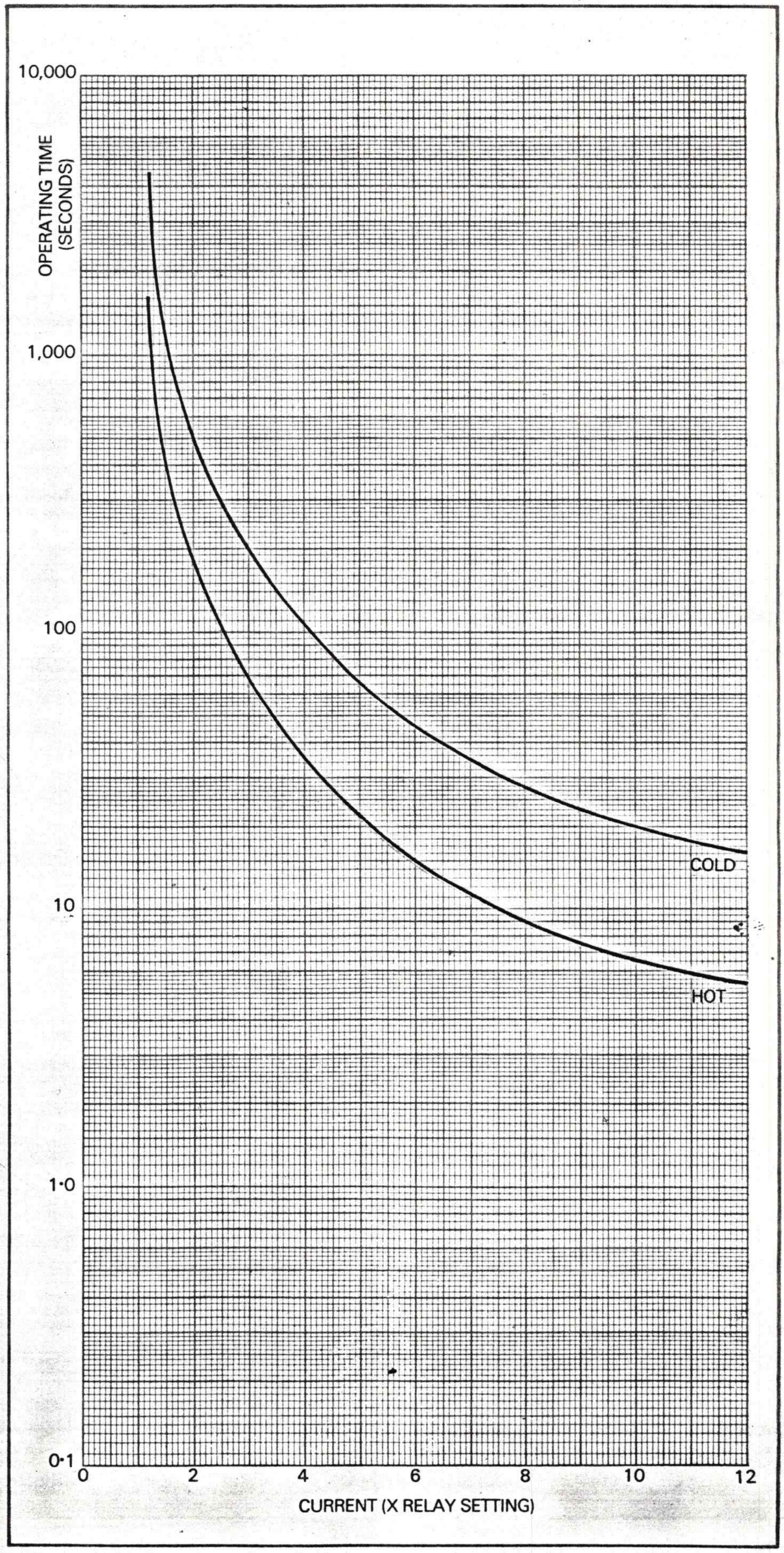
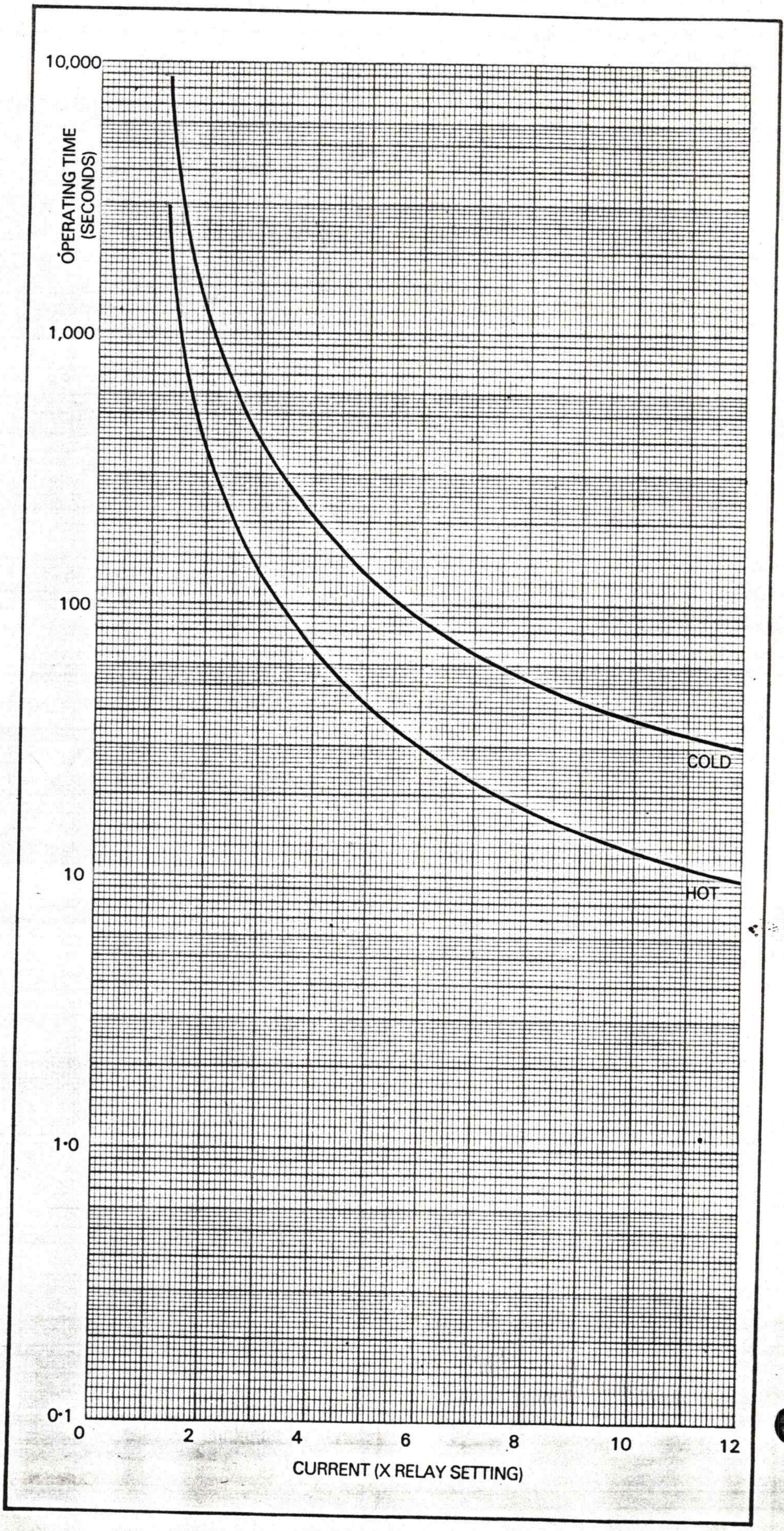
REFERENCE 5



THERMAL CHARACTERISTIC
REFERENCE 6



CASES

Relays in the CTM and CTMF series are accommodated in either a single ended size 1½D case or a double ended size 2D case, depending principally upon the C.T. connections required.

The size 1½D case is used for the basic arrangements, including those with an internal star connection, as shown in Figures 3 and 4. Alternatively, where special contact arrangements and/or an external star connection are required, as shown for example in Figure 5, the double ended size 2D case is used.

Cases of both sizes are available for flush or projection mounting, and finished phenolic black as standard.

Relays for use in exceptionally severe environments can be finished to BS2011 : 20/50/56 at extra cost. Standard relays are finished to BS2011 : 20/40/4 and are satisfactory for normal tropical use.

INFORMATION REQUIRED WITH ORDER

Relay type.
Relay current rating (1A or 5A).
Supply Frequency (50 Hz or 60 Hz).
Contact arrangement—hand or self reset, normally open or normally closed.
Auxiliary supply voltage rating and whether a.c. or d.c.
Case mounting (Flush or projection).
Load indicator—whether or not required.
Whether internal or external star connection is required. The alternative connections and relevant relay types are shown in Figures 3, 4 and 5.

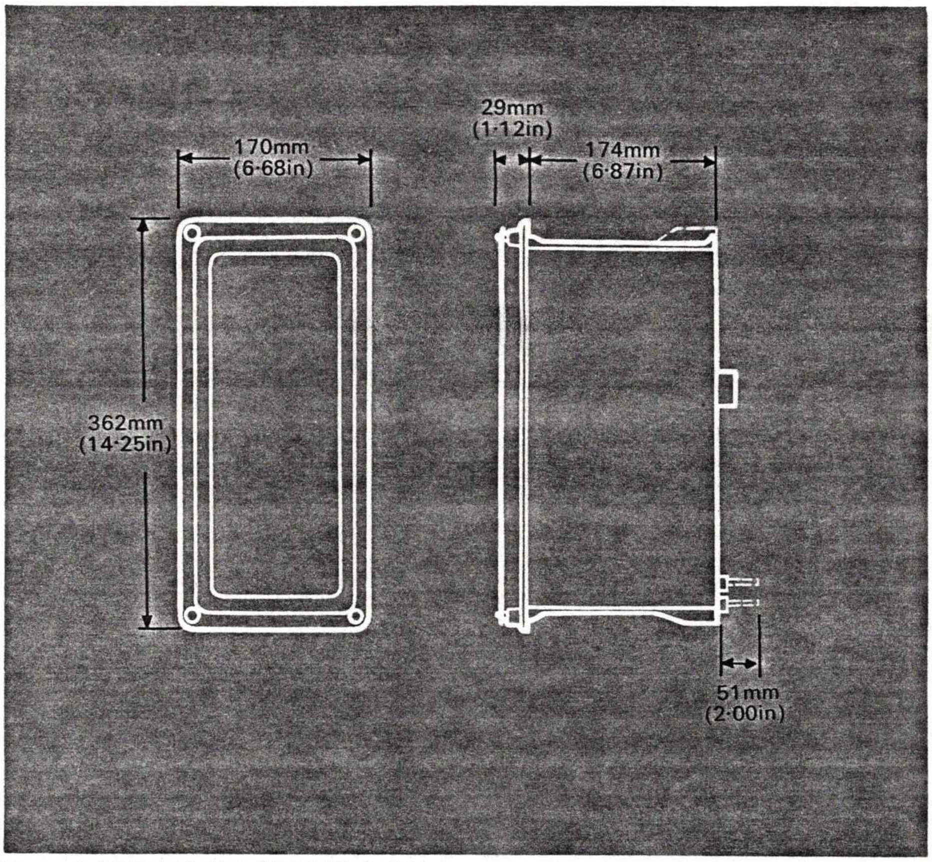


Figure 6 OUTLINE FOR SIZE 1½D CASE

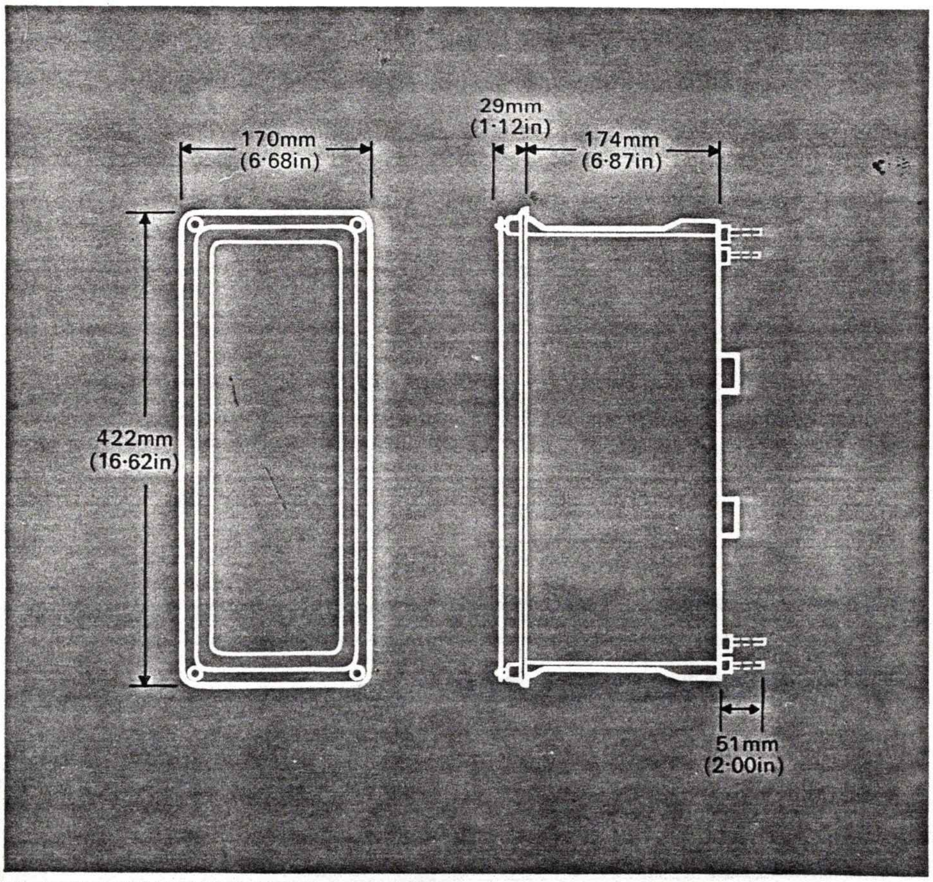


Figure 7 OUTLINE FOR SIZE 2D CASE

Our policy is one of continuous product development and the right is reserved to supply equipment which may vary slightly from that described.

GEC Measurements The General Electric Company Limited of England

St. Leonards Works Stafford ST17 4LX England
Telephone: 0785 3251 Telex: 36240 Cables: Measurements Stafford Telex

Publication R-5171C

MOTOR PROTECTION RELAYS

TYPES CTM, CTMF AND CTMC

Supplementary Notes

To Be Read In Conjunction With Publication R-5171C

Flags

The indication flags for instantaneous faults I_1 and I_2 have been reduced to a single common flag.

Stabilising Resistors

Stabilising resistors are not required or supplied on CTMF relays since the definite time delay element 0.5 - 3 seconds provides sufficient time delay to overcome transient unbalanced conditions. Figures 4 and 5 and the technical data beside figure 4 should have a common note added indicating that stabilising resistor shown as RV6 is not used on CTMF relays.

CTMC Relays

An additional relay type has been added, type CTMC, for use where a single core balanced earth fault CT is used separate from the main CTs. Figure 5 in the publication would be the application diagram for the CTMC, except that no stabilising resistor is supplied. The CTMC is in a size 2D double ended case only.

Current Transformer Requirements

The current transformer requirements table on page 8 may be ammended in respect to the 1A secondary rating relay and reduce the requirements to a nominal output of 2.5VA, combined with a limiting lead resistance of 1 ohm. The requirements for the 5A relay have not been reduced.

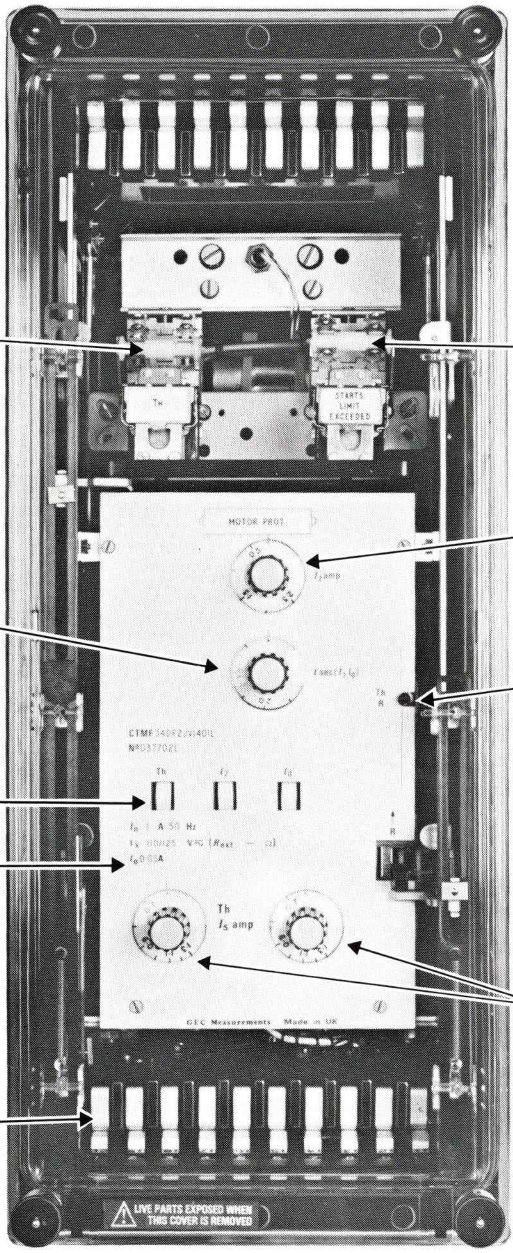
Earth Fault Elements

For CTM relays, and where three CTs are used and the earth fault is operated by the residual circuit, the earth fault element will be of the type CAG11 fixed setting variety, mounted internally and complete with an external, separately mounted stabilising resistance. Where more than two output contacts are required, type CTM relays must be mounted in size 2D double ended case and in these instances, it is important to note with order details that the earth fault detection circuit will be operated by the residual connection of three CTs. The same comments apply to the CTMF used in double ended cases.

For CTMF and CTMC relays, the earth fault relay is of the vibrating reed type and as stated above, no stabilising resistors are supplied.

GEC Measurements

ADVANTAGES OF TYPE CTMF MOTOR PROTECTION RELAY



To meet market demands for improved performance at no cost penalty, manufacturers are producing electric motors with a reduced capacity to withstand fault conditions for much longer than the minimum time necessary for normal usage.
This, added to increasingly high repair costs and the sheer nuisance value of machine outages, is inducing maintenance engineers to re-assess the adequacy of their motor protection equipment.

CTMF relays enable the user to select in advance the types of protection best suited to his needs and the operating characteristics most compatible with those of his motors.

The following notes are intended to give a brief resumé of the advantages offered by the CTMF relay at a surprisingly low cost premium compared with the less comprehensive, traditional types of motor protection.

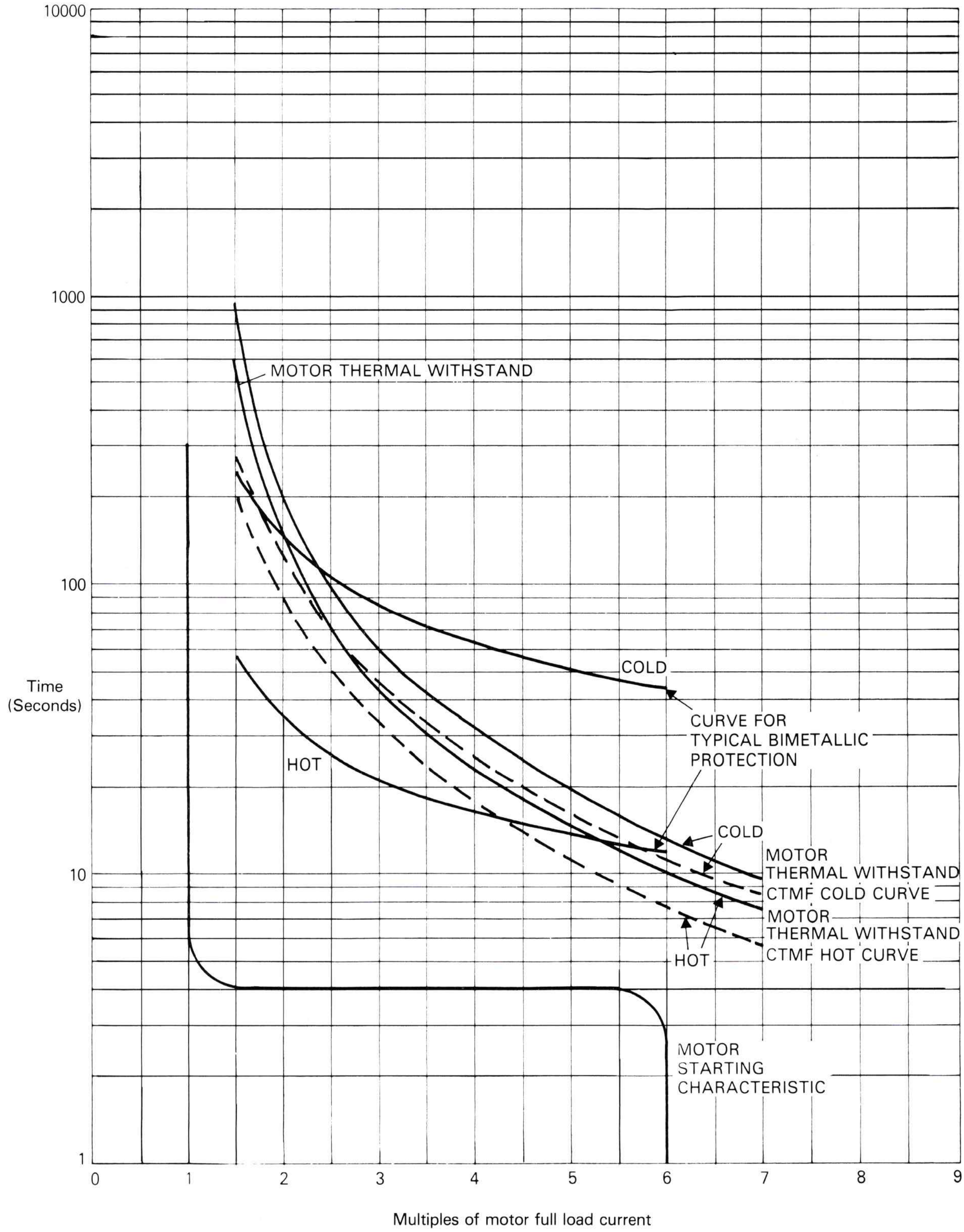


Figure 1. TYPICAL MOTOR THERMAL WITHSTAND CURVES RELATED
TO THOSE FOR CTMF AND BIMETAL PROTECTION.

Twelve thermal characteristics

The wide diversity of motor designs and duties makes it impossible to cover all types of motor with the few characteristics normally offered by motor protection relays. The CTMF has twelve thermal characteristics, giving time constants from 1 to 40 minutes, enabling closer matching of the relay to the motor withstand. Selection of the most suitable characteristic enables better utilization of the full capacity of the machine.

Stall protection

A typical motor is designed to withstand perhaps 6 times normal full load current for the short time necessary for a normal start. A current of the same order may be drawn for a dangerously long time if a motor stalls whilst running or is unable to start due to an excessive load. The protection must therefore distinguish between these conditions on the basis of the time for which this high current flows.
Figure 1 shows a typical motor starting characteristic and illustrates how the CTMF curves can usually match those of the motor more closely than other types of protection, to give a higher safety margin in these conditions. This means that in over 90% of applications, separate stall protection will not be required.

Time delayed element for single phasing and imbalance protection (I_2)

The loss of one phase of a three phase supply during starting is a common cause of induction motor failure. The current taken in these circumstances is 0·866 times the three phase stalling current and is quite sufficient to cause excessive overheating of parts of the rotor winding.
To guard against this condition the CTMF relay has a time delayed negative phase sequence current (I_2) element, adjustable from 0·5 to 2·5 times the relay setting.
Since this element operates solely on the negative phase sequence component of the motor current, it is not energised during normal starting conditions. The choice of setting is thus independent of the starting current.

Sensitive negative phase sequence protection

Negative sequence currents are caused by imbalance in the system voltage or motor current. The impedance of the rotor to negative sequence currents is up to six times the positive equivalent, causing a proportionately greater degree of heating in the rotor. The relay has a sensitivity to negative sequence currents of 13%, equivalent to a supply voltage imbalance of 2.2%. The relay characteristic follows the motor withstand curve under these conditions and provides correct sensitive protection without nuisance tripping.

Negligible thermal overshoot

A thermal overshoot of less than 2% allows the relay to be set closer to the machine characteristic, giving more efficient protection and hence more efficient motor utilization.

Earth leakage protection

The CTMF relay is designed to operate from a core balance current transformer when the earth fault current exceeds 5% of the current transformer secondary rating, as shown in Figure 2.

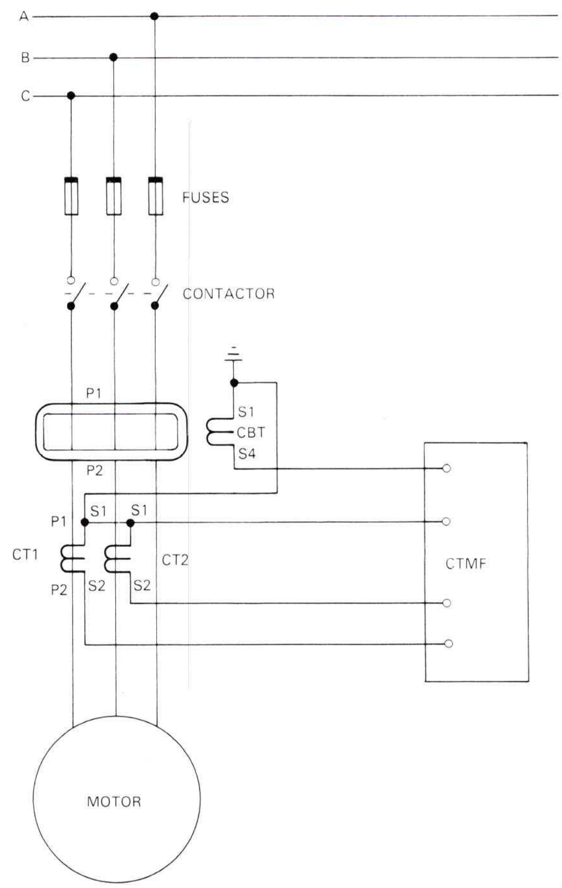


Figure 2. TYPICAL APPLICATION DIAGRAM FOR TYPE CTMF RELAY.

Clear flag indication.

Separate flag indicators are provided for thermal overload, single phasing/phase imbalance conditions and earth faults. Indication is maintained even in the event of a loss of auxiliary supply.

Optional functions

A load indicator, additional alarm contacts or undervoltage protection are options which may be specified at the order stage and are incorporated within the relay case.

Ease of commissioning/testing

Commissioning and test procedures are greatly simplified by front access test terminals. A thermal reset pushbutton eliminates the waiting between tests necessary with other relays which simulate a thermal replica of the motor.

Drawout cases

The relay is housed in a metal drawout case which is sealed against atmospheric pollution and allows instant withdrawal of the relay with automatic isolation from the primary circuits.

Proven design

The CTMF relay has been manufactured since 1970 and many hundreds of units are in service throughout the world. It complies with all relevant British and IEC standard specifications for insulation, impulse and high frequency disturbance tests. Each is assembled and checked to the high standards for which GEC Measurements is internationally famous.
The relay is backed by the Company's technical advice and servicing facilities.

GEC Measurements The General Electric Company Limited of England

St. Leonards Works Stafford ST17 4LX England
Telephone: 0785 3251 Telex: 36240 Cables: Measurements Stafford Telex

Publication R-5439

028120GSP *Printed in England*

16. Grading Exercises

SCOPE OF INFORMATION USUALLY REQUIRED
FOR PROTECTION STUDIES

1. Single line diagram of whole plant including the power source and showing all voltage levels and kVA ratings of major plant.

2. Estimated fault levels at each bus or voltage level or,

3. Source impedances and/or source fault levels together with transformer ratings and their impedance values and generator impedances.

4. Details of any special earthing conditions on either HV or LV side e.g. solid or impedance earthing, current limitations on E/F if any, Statutory Authority limitation on E/F if applicable, e.g. Mining regulations.

5. Operation combinations of source supplies particularly when local generation may run in parallel with Power Authority supplies and details of any special conditions imposed by the Authority on parallel running e.g. reverse power limits.

6. Method of operating double bus plant or duplicated bus system with bus ties, e.g. normally open, normally closed bus ties, open transition, closed transition or momentary parallelling schemes.

7. Typical protection a.c. and d.c. protection schematics for following types of circuits for each voltage level and including the following:

   (a) Incoming circuits.

   (b) Transformer feeders both HV and LV sides.

   (c) Motor protection feeders for each range of motor sizes using different relays.

   (d) Busbar protection.

   (e) Transformer protection including protection auxiliaries.

   (f) Tie feeders between bus locations.

8. Motor sizes KW ratings, I_{FL}, Istart and estimated start times, max stall capability hot and cold, for each class of motor drive and stall current for all synchronous motors.

9. In the case of motor protection using contactor control, max allowable current capability of the contactor, particularly for vacuum contactors.

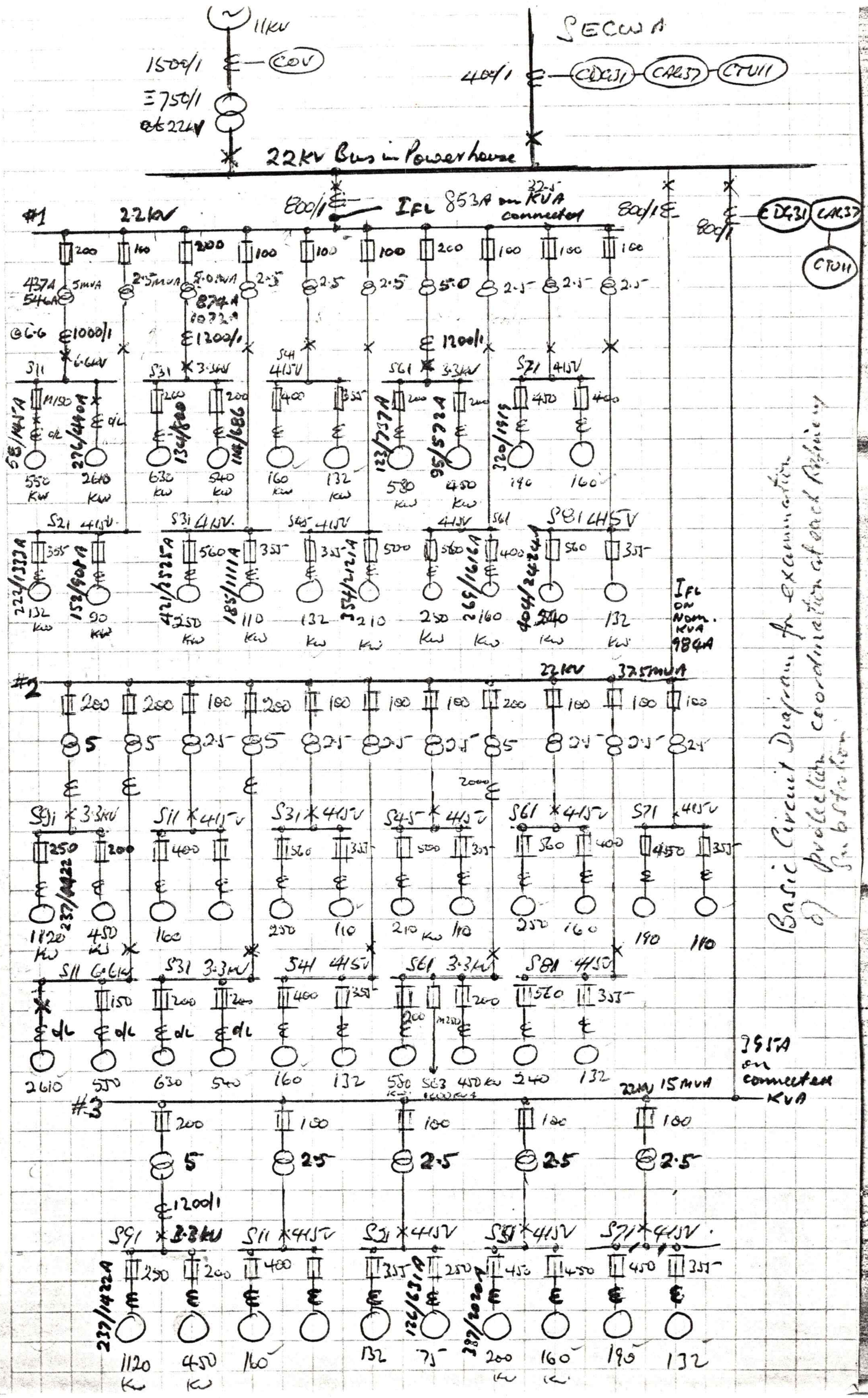
10. List of all protection relays chosen, together with details of their characteristics, setting ranges for both current and time as applicable, series or shunt operated auxiliary elements and their current or voltage ratings. (DC)

11. Details of characteristics and setting ranges of any self contained protection devices fitted directly to circuit breakers.

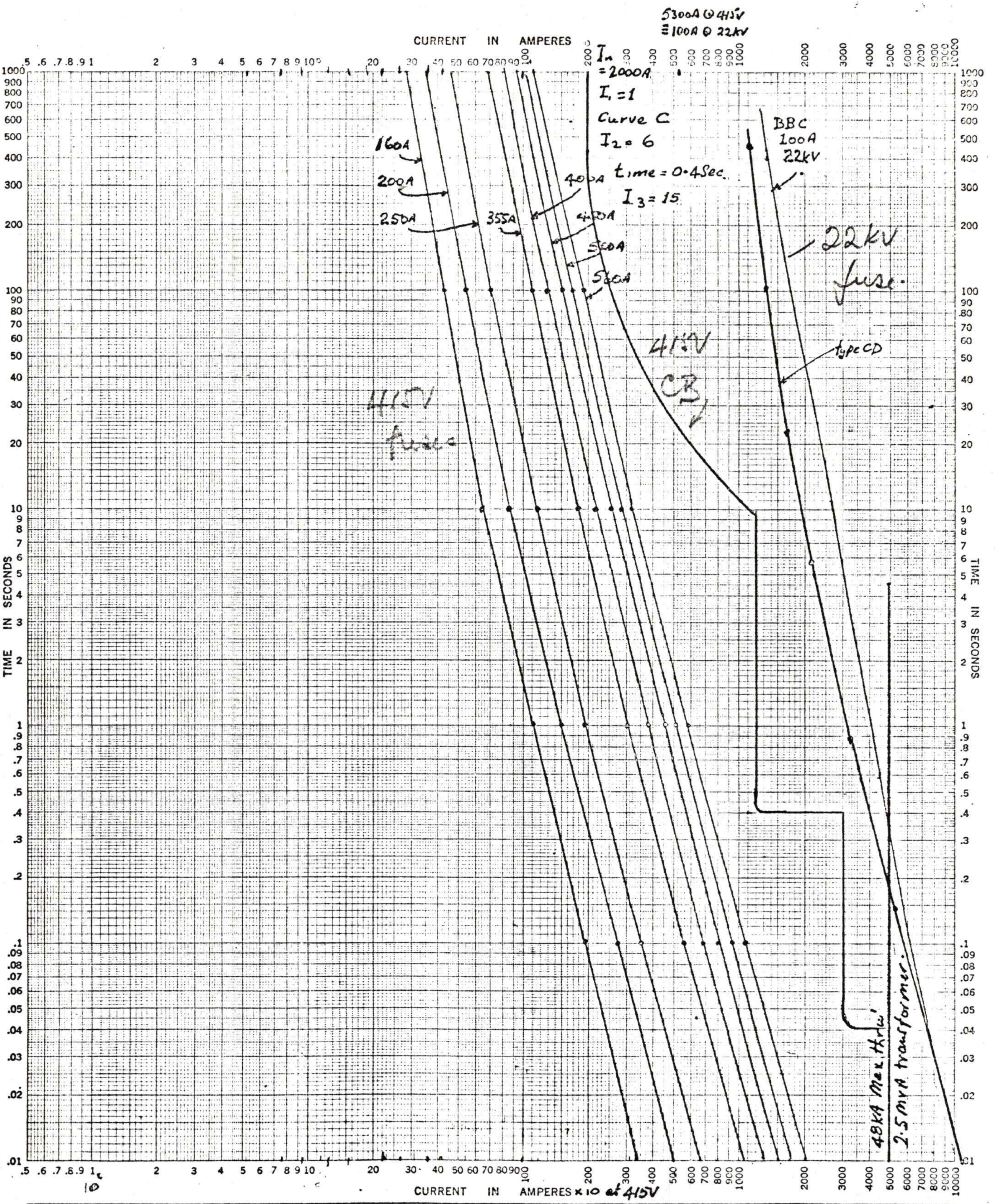
12. Characteristics of all HV fuses and largest fuses on the load side of every busbar.

13. Protection current transformer specification or accuracy classes.

14. Any details related to special operating conditions or special equipment and which may be applicable to the study.



Basic Circuit Diagram for examination of protection coordination at each Refinery Substation



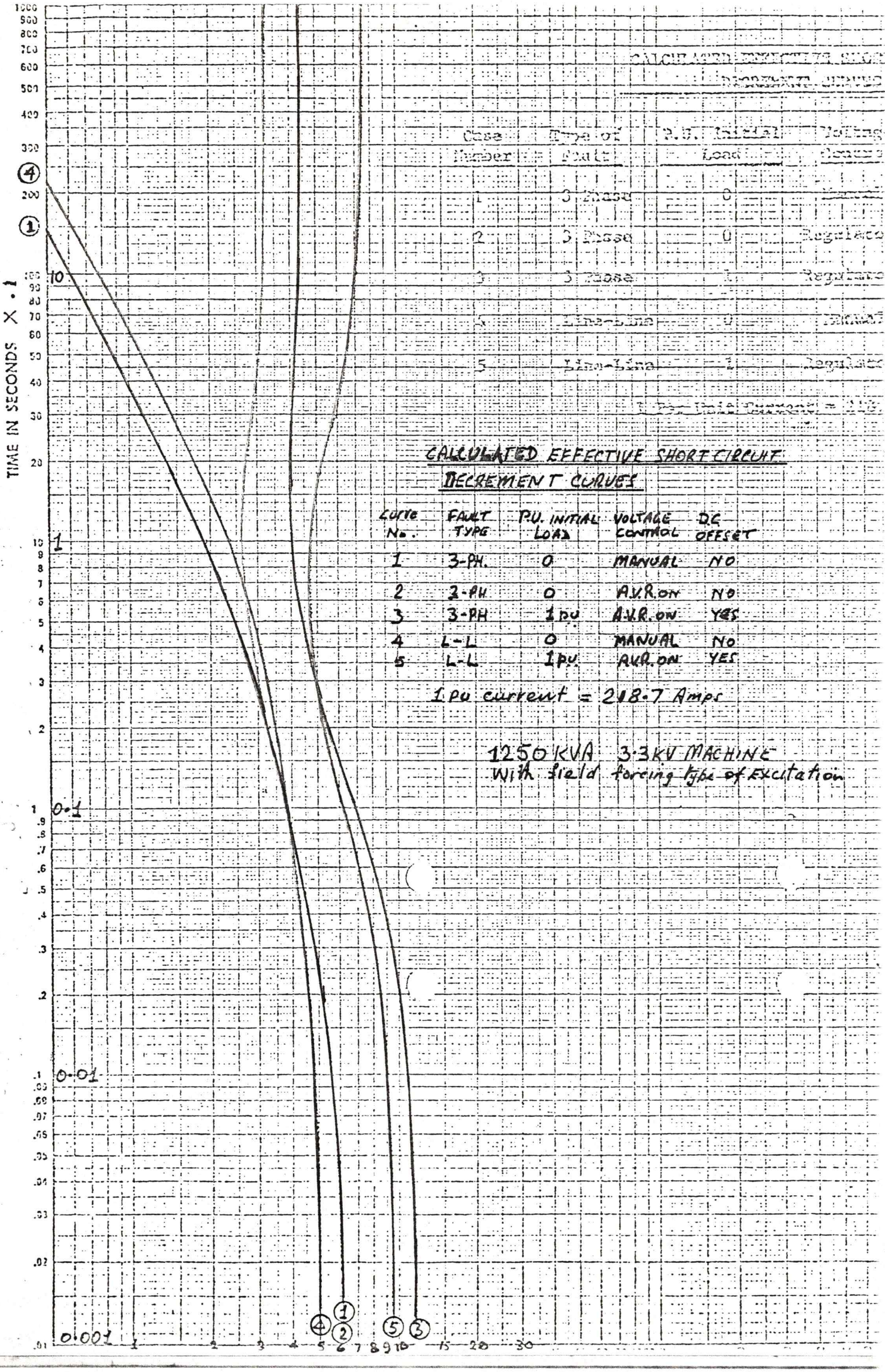
TIME-CURRENT CHARACTERISTIC CURVES

For *GEC General Purpose Fuses with SSi Static o/c* Fuse Links. In ________

~~BASIS FOR DATA Standards~~ *unit & 100A 22KV BBC Fuse* Dated ________

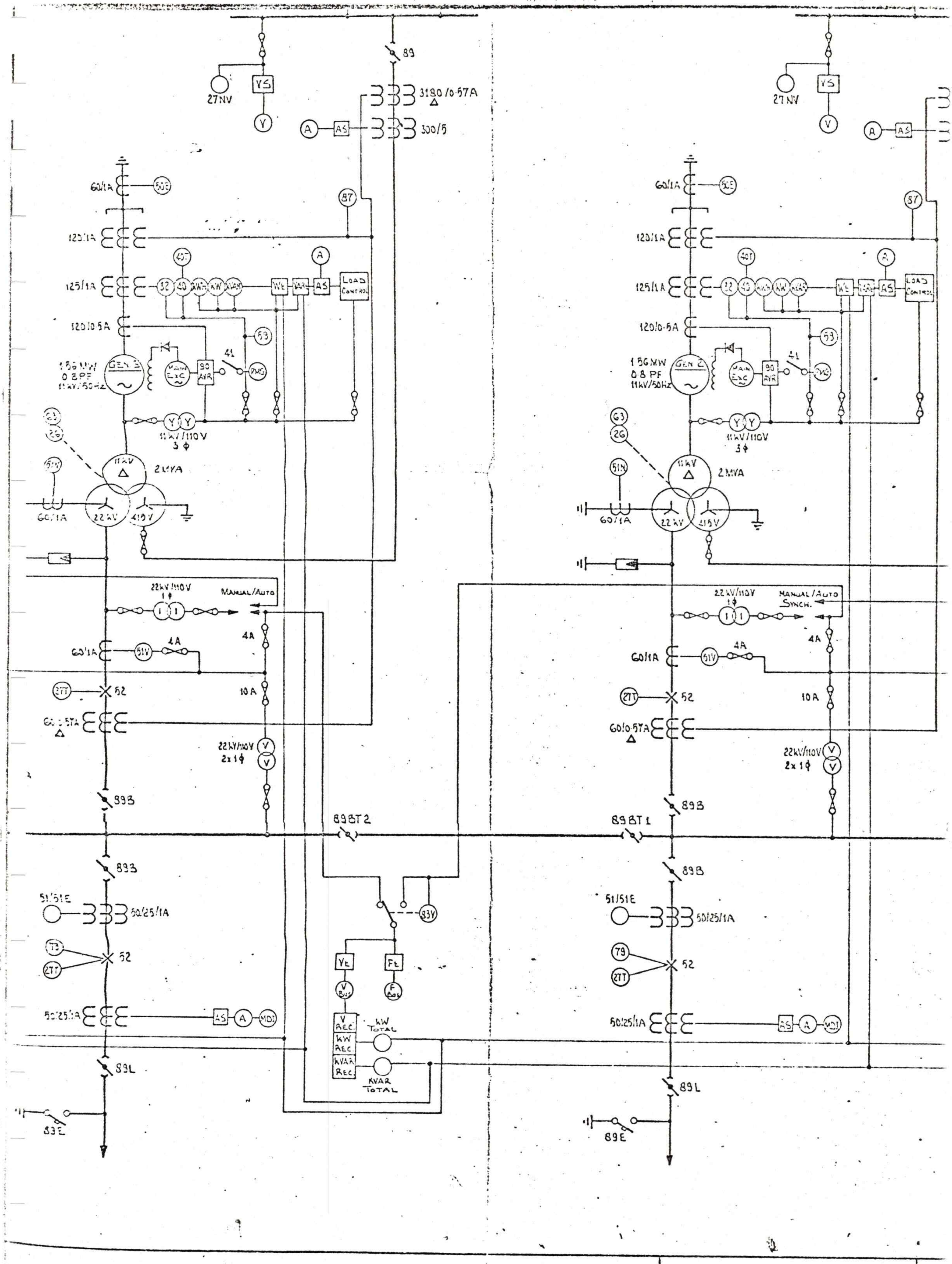
1. Tests made at ________ Volts a-c at ________ p-f., starting at 25C with no initial load ________ No. ________
2. Curves are plotted to ________ Test points so variations should be ________ Date ________

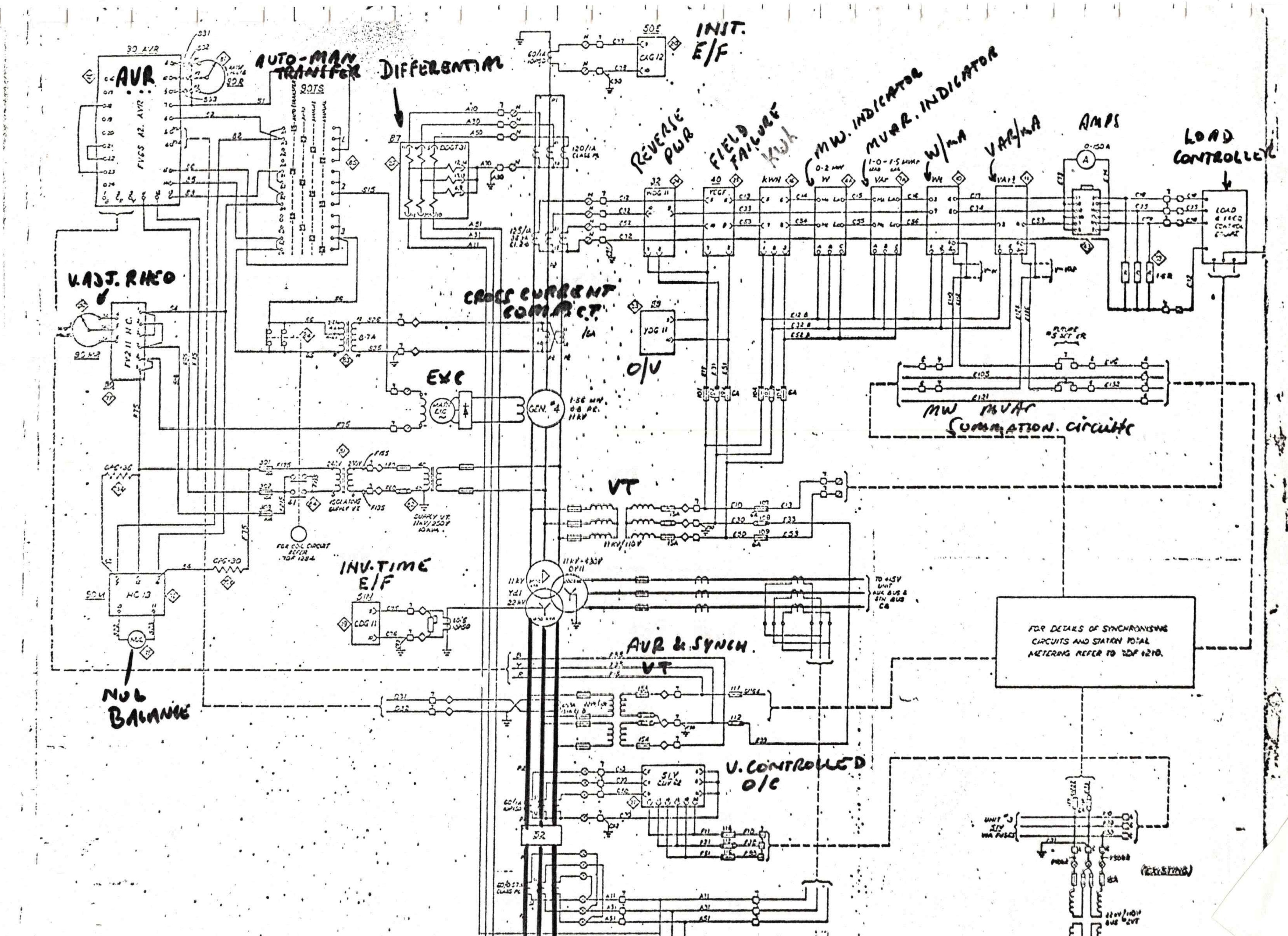
K+E TIME-CURRENT CHARACTERISTIC 48 5258
KEUFFEL & ESSER CO. MADE IN U.S.A.

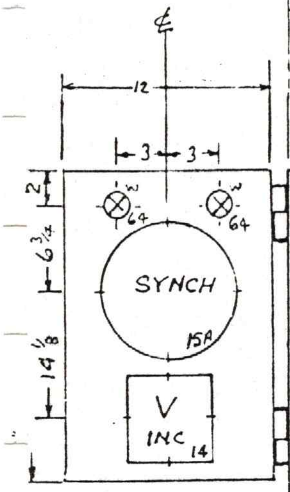


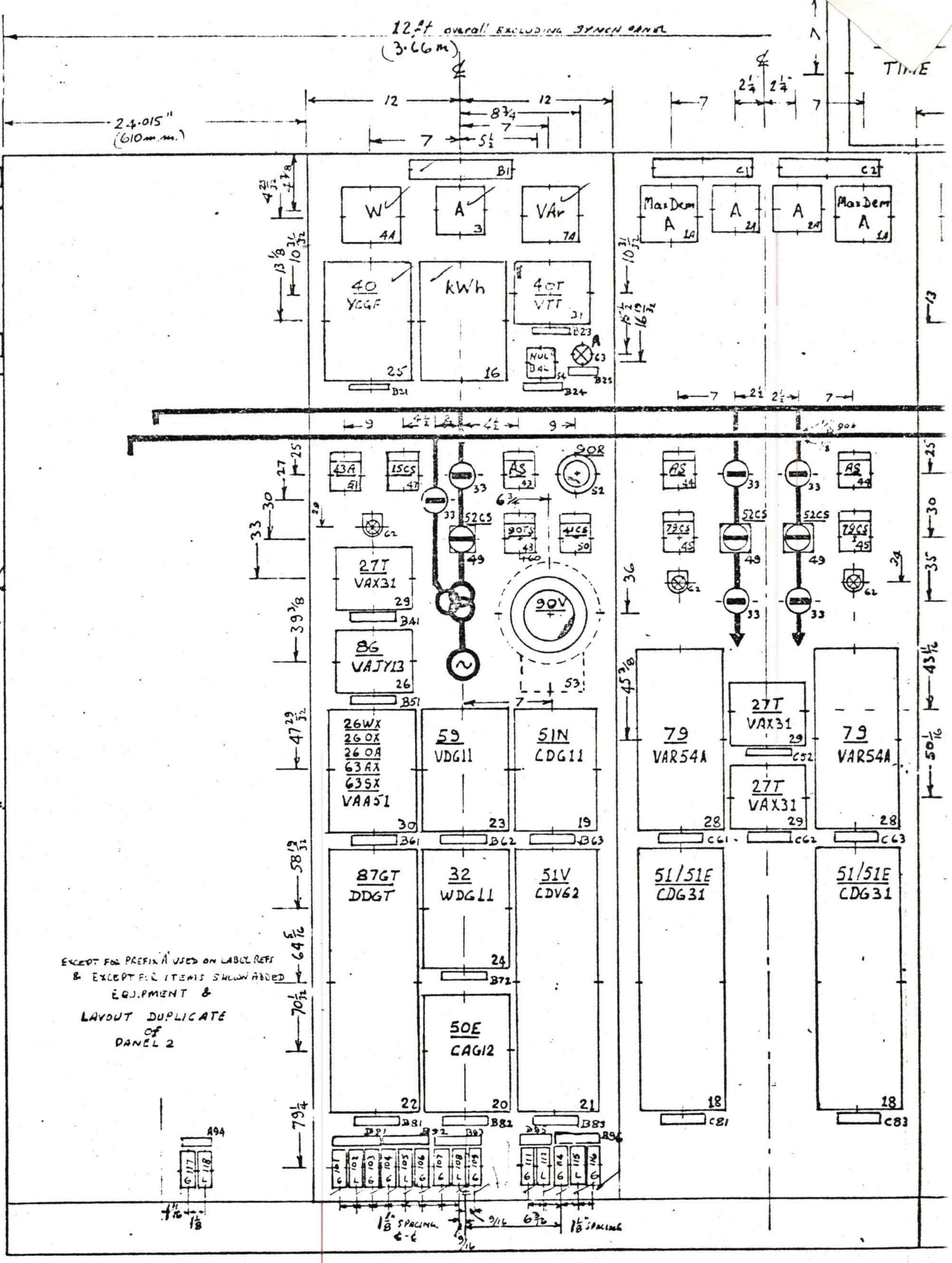
CALCULATED EFFECTIVE SHORT CIRCUIT
DECREMENT CURVES
CURVE No. | FAULT TYPE | P.U. INITIAL LOAD | VOLTAGE CONTROL | DC OFFSET
1 | 3-PH. | 0 | MANUAL | NO
2 | 3-PH | 0 | A.V.R. ON | NO
3 | 3-PH | 1 pu | A.V.R. ON | YES
4 | L-L | 0 | MANUAL | NO
5 | L-L | 1 pu. | AVR. ON | YES
1 pu current = 218·7 Amps
1250 KVA 3·3KV MACHINE
With field forcing type of Excitation
TIME IN SECONDS X ·1
10
1
0·1
0·01
0·001

17. Development of Control and Protection of a Small Power Station


89
VS
27NV
Y
3180/0.57A
300/5
A
AS
60/1A
50E
87
125/1A
40T
125/1A
32
40
KWH
KW
KVAR
Wt
VAR
AS
LOAD CONTROL
120/0.5A
59
1.56 MW
0.8 PF
11kV/50Hz
GEN 3
MAIN EXC
90
AVR
41
DMG
63
26
11kV/110V
3 φ
11kV
2MVA
51N
60/1A
22kV
415V
22kV/110V
1 φ
MANUAL/AUTO
4A
51V
52
27T
10A
60/0.57A
22kV/110V
2x1φ
V
89B
89BT2
89BT1
51/51E
50/25/1A
79
MDI
89L
89E
83Y
Yt
Ft
V Bus
F Bus
V REC
KW REC
KVAR REC
kW TOTAL
KVAR TOTAL
27NV
120/1A
GEN 2
SYNCH.


AVR
90 AVR
FVGS A2. AVR
AUTO-MAN TRANSFER
90TS
DIFFERENTIAL
DDGT31
120/1A CLASS PL
INST. E/F
50E
CAG12
REVERSE PWR
FIELD FAILURE
KWH
MW. INDICATOR
MVAR. INDICATOR
0-2 MW
1-0-1.5 MVAR
W/mA
VAR/mA
AMPS
0-150A
LOAD CONTROLLER
LOAD & FREQ CONTROL CUBICLE
V.ADJ. RHEO
CROSS CURRENT COMP. C.T.
YDG 11
O/V
EXC
GEN. #4
1.56 MW 0.8 PF 11 KV
MW MVAR SUMMATION. CIRCUITS
VT
11KV/110V
SUPPLY VT 11KV/250V
ISOLATING SUPPLY VT
FOR COIL CIRCUIT REFER TDF 1284
INV. TIME E/F
CDG 11
11KV-433V DY11
11KV YD1 22KV
TO 415V UNIT AUX BUS & STN BUS C8
HC 13
NUL BALANCE
AVR & SYNCH VT
FOR DETAILS OF SYNCHRONISING CIRCUITS AND STATION TOTAL METERING REFER TO TDF 1210.
U. CONTROLLED O/C
52
(EXISTING)





NOTES.

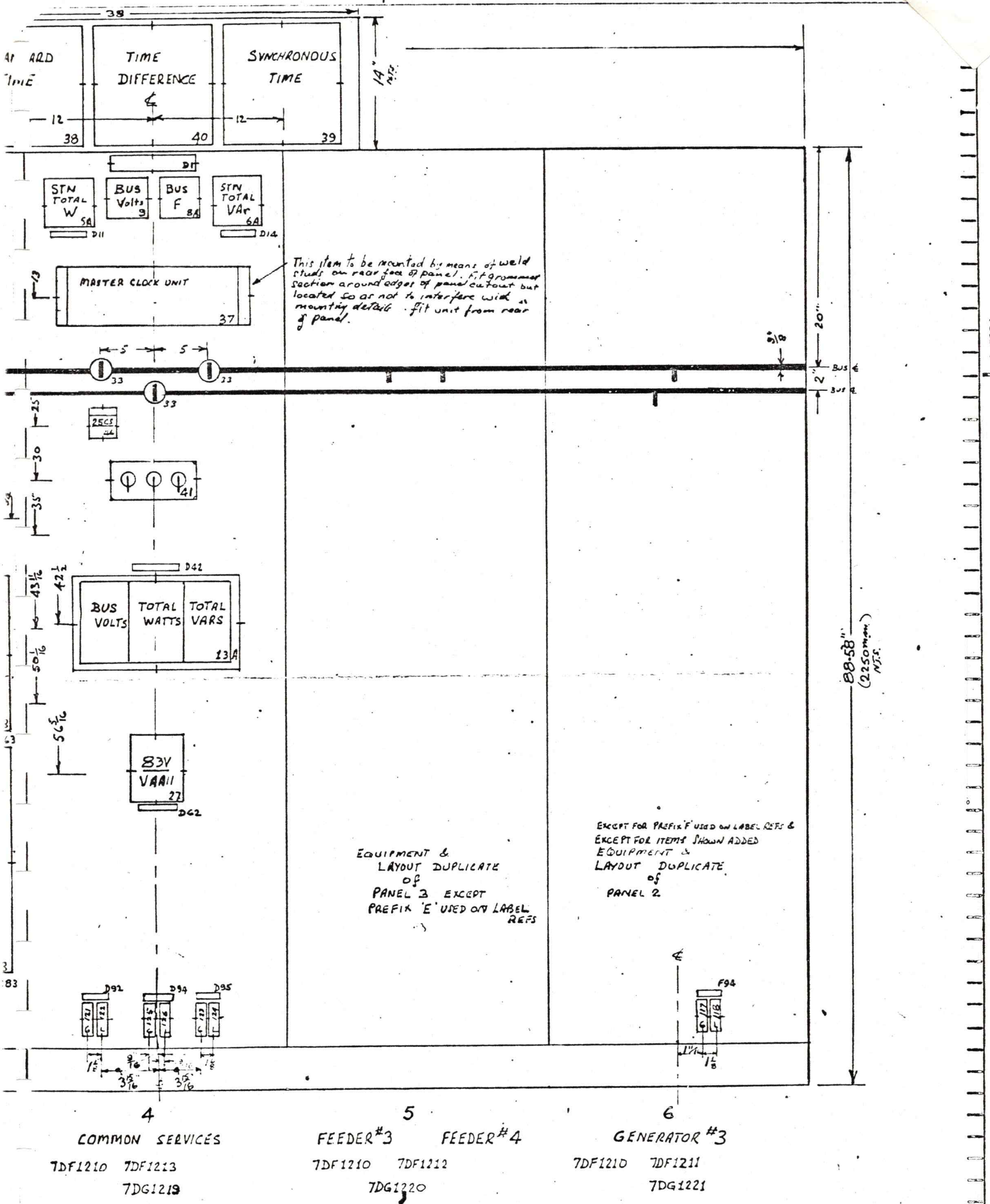
1. For further details of all items refer to Job Material List 7DA1270 & Using item nos shown near bottom right hand corner of each device or assembly. [Fuse nos are schematic diag refs.]
2. Device labels to be placed 1/4 below (or above) respective item or group as indicated.
3. For label engraving details refer dwg... 7DA1273
4. Mimic bus colours as follows:
   - 22kV : Blue
   - 11kV : orange
   - 415V : Brown

   } ESAA colours
5. Mimic bus components are detailed on dwg:.. 7DB1589
6. Centreline positions of all items are located with respect to top of panel or panel ℄ as appropriate.
7. All dimensions in inches with overall equivalents in meters
8. For floor plan & end view refer dwg 7DA1272
9. PANEL PUNCHING NOTE
   - (i) All vertical dimensions are given with respect to top edge of panels.
   - (ii) All horizontal dimensions are given with respect to the panel centrelines (except for fuse layout given as ℄-℄ spacing)
10. [illegible] panel title [illegible] all labels are to be mounted 1/4" below (or above) respective devices (or fuse groups) as indicated. Panel title labels to be located [illegible] location above doors at rear of cubicles

PANEL No.	1	2	3	
TITLE	GENERATOR #1	GENERATOR #2	FEEDER #1	FEEDER #2
SCHEMATIC DIAGRAMS	7DF1210 7DF1211	7DF1210 7DF1211	7DF1210 7DF1212	
WIRING DIAGRAM	7DG1216	7DG1217	7DG1218	

DRAWN	E.D.R. 19-11-73	A Original Issue	B [illegible] ITEM 62 ADDED. [illegible] 7/74	C Note 9 & [illegible] [illegible] Feb 6/74	D Dev. 43A was 25C. Dev. 25C added to Pnl 4. [illegible] 11/74	E [illegible]	F Vertical dimension was 90 inches - panel width was 24in. Auto clock into note revised. [illegible] Apr 30/74
TRACED		DATE 23-11-73					
CHECKED							
APPROVED							

SCALE 1½ = 1ft (1:8)



CUSTOMER REF. SPEC DES72/28 | GEC PROJECTS REF SC7022/6 | R.P. WORKS ORDER 468-D-9973

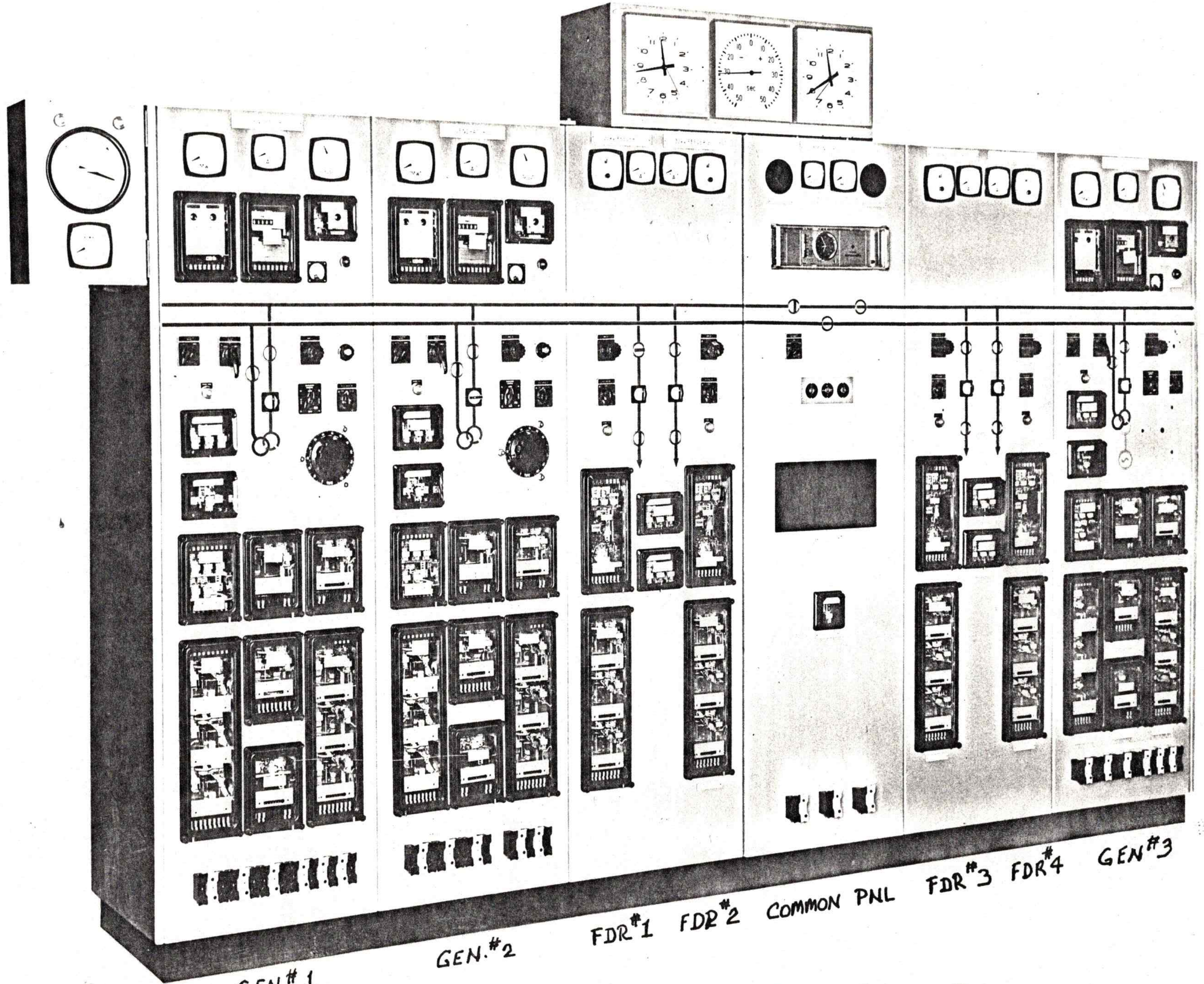
GEC DISTRIBUTION EQUIPMENT DIVISION

TITLE GENERAL ASSEMBLY - H.V. CONTROL & PROTECTION BOARD for GENERATORS & 22kV FEEDERS _ TENNANT CREEK POWER STATION

DWG. No. 7DA1271

(PLEASE QUOTE LATEST LETTER OF ISSUE)

A2 420 x 594 mm



TENNANT CREEK POWER STATION

865.

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FOR FURTHER

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