



INTERNATIONAL SEMINAR ON POLICIES, INCENTIVES, TECHNOLOGY AND REGULATION OF SMART GRIDS

CHANGING OUR VIEW OF THE WORLD

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“Introduction of smart grid concepts and technologies in all contexts — generation, transmission, distribution, and commercialization — will definitely change the business model of the present electrical sector.”

<http://cigrebrasilrio2017.net/>

WHAT *IS* YOUR VIEW OF THE WORLD?



US Dept of State Geographer
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Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth

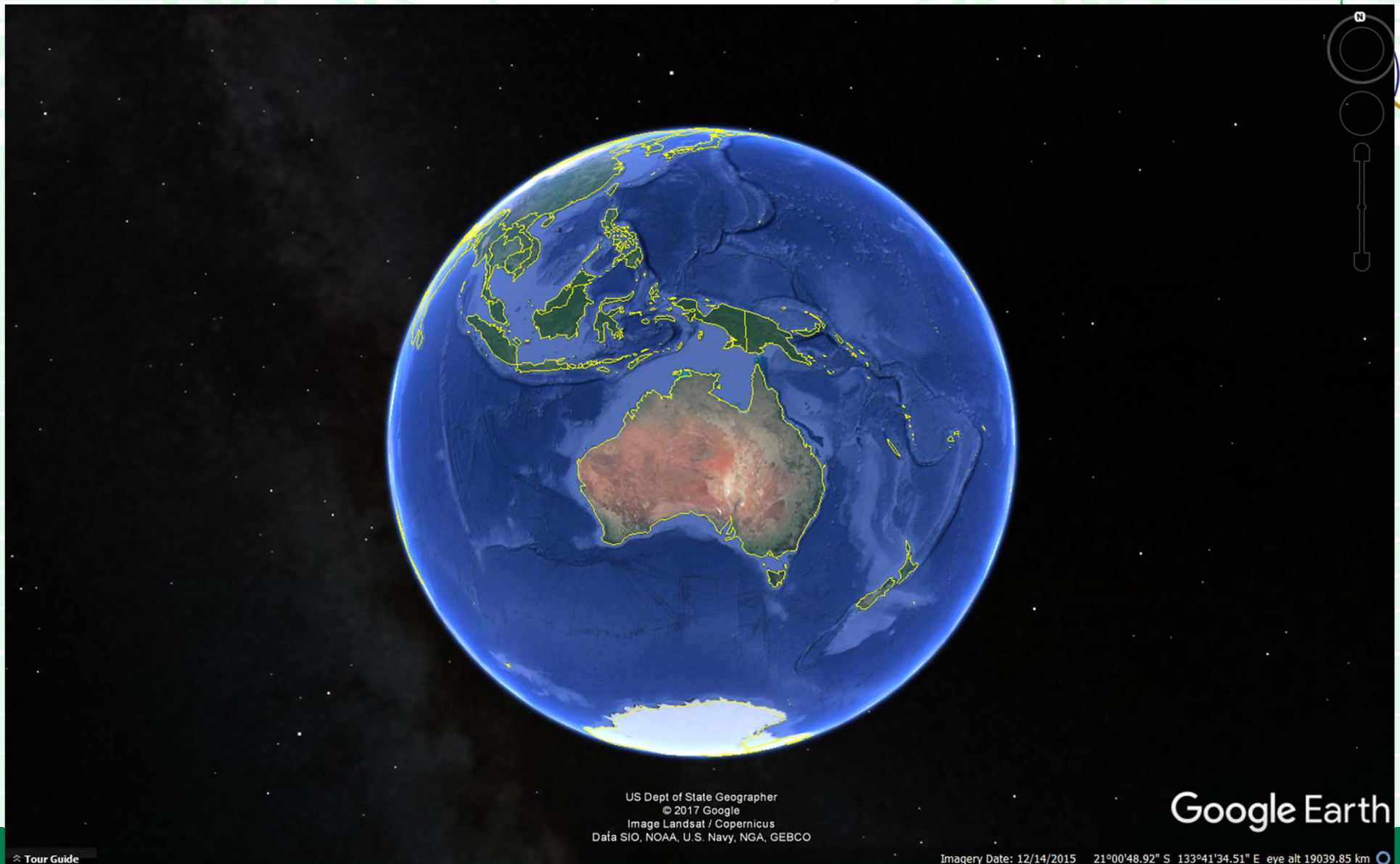


US Dept of State Geographer
© 2017 Google
© 2009 GeoBasis-DE/BKG
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth

Tour Guide

eye alt 19039.85 km

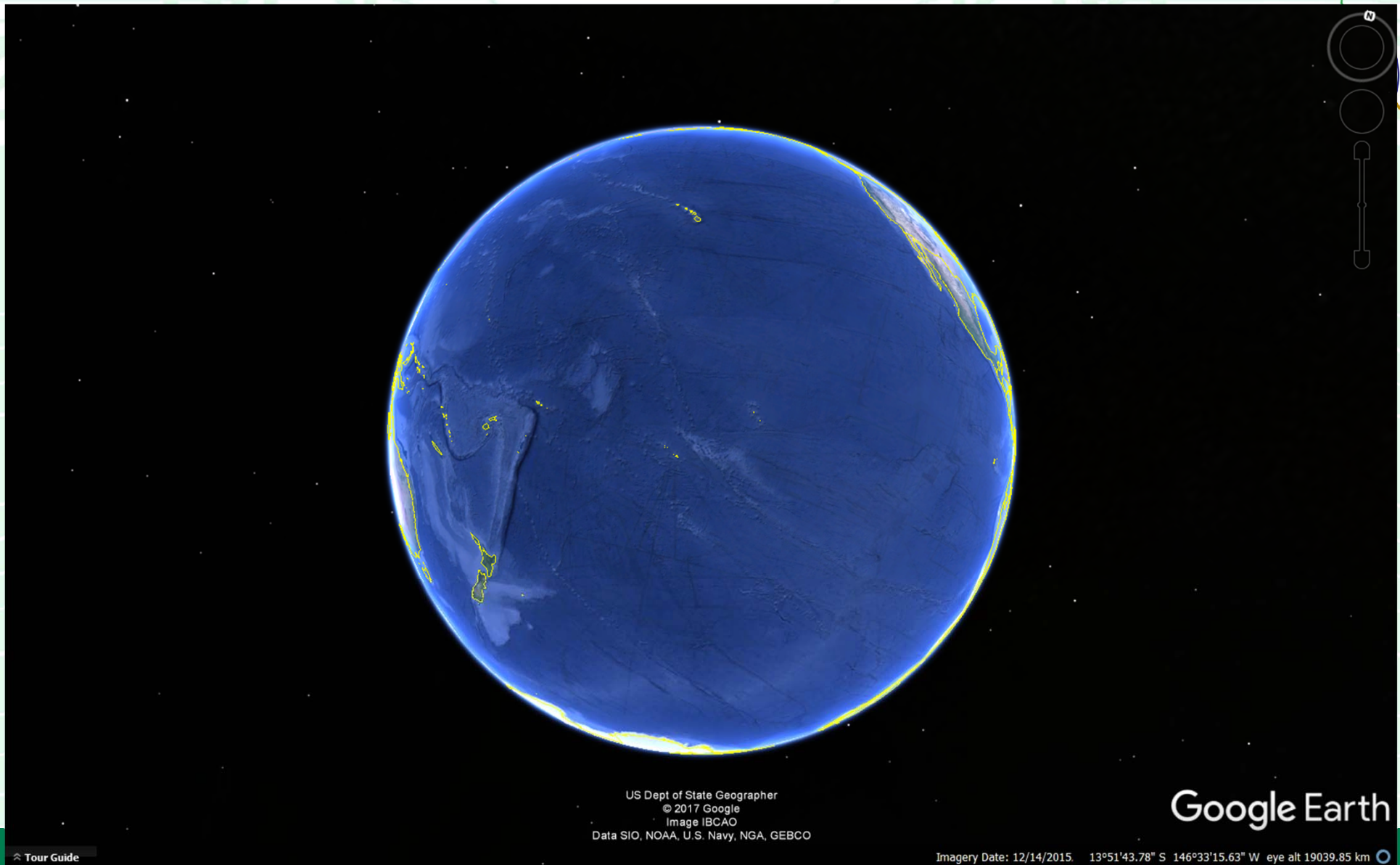


US Dept of State Geographer
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth

Tour Guide

Imagery Date: 12/14/2015 21°00'48.92" S 133°41'34.51" E eye alt 19039.85 km



US Dept of State Geographer
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Image IBCAO
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth

[Tour Guide](#)

Imagery Date: 12/14/2015 13°51'43.78" S 146°33'15.63" W eye alt 19039.85 km

Your challenge here...

- What do I **NEED** to do differently?
- What **CAN** I do differently?
- What **ELSE** do I need to be able to do it differently?

Existing Risks We Live With

- CT explosions and consequential damage/injury



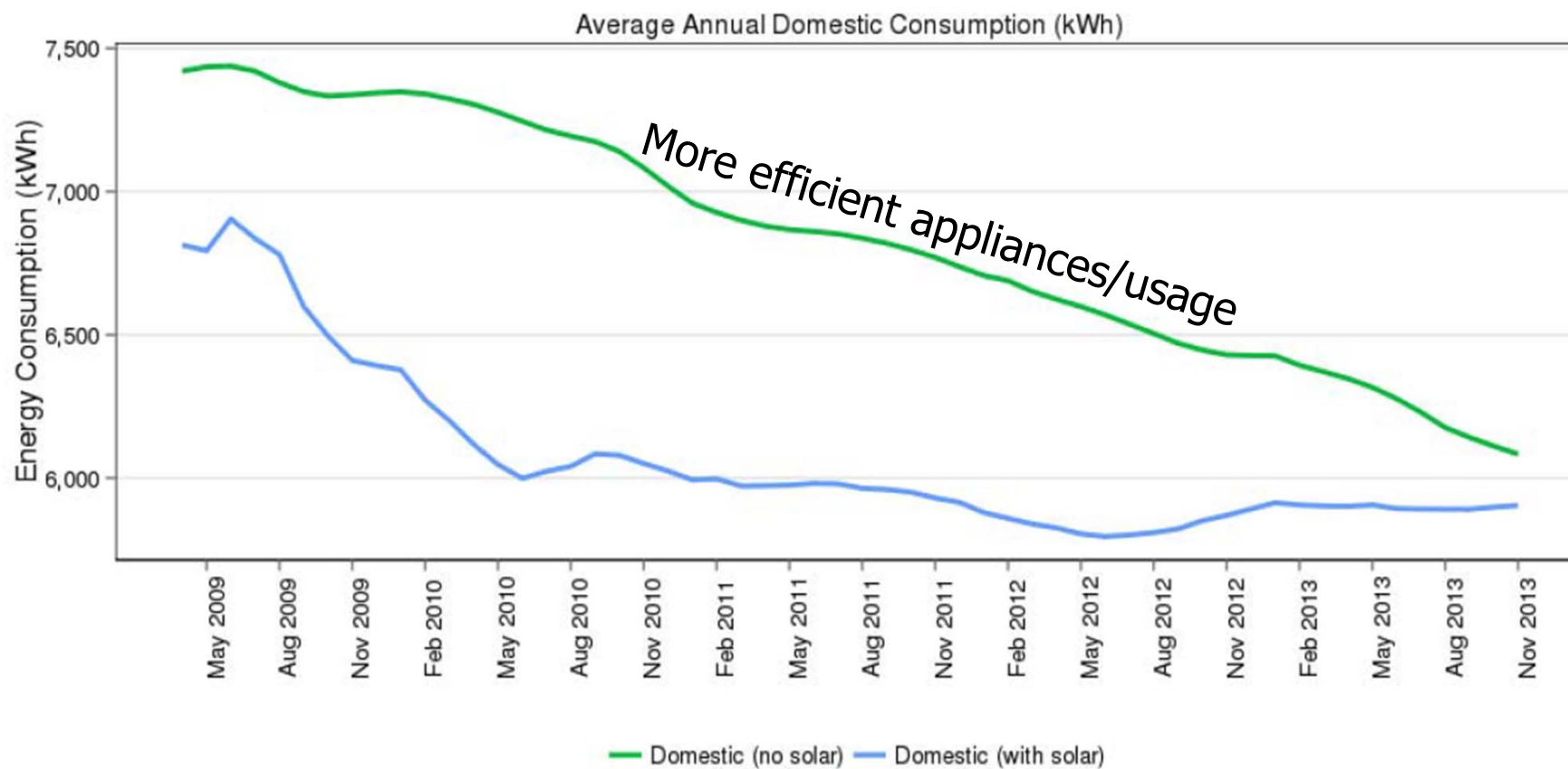
Existing Risks We Live With

- CT explosions and consequential damage/injury
- Not able to test full system
 - Performance assumptions – work when needed, won't operate when it shouldn't
- Documentation errors
 - testing mistakes, blackouts, loss of life
- Wiring errors
 - possible loss of life, blackouts, consequential damage due to uncleared faults
 - Extensive wiring testing by humans to identify human errors
- Multiple communication systems
 - Interfaces to interfaces, \$\$\$\$, Performance constrained by oldest/least technology
- and many more

Is this how you would want
to build a grid from nothing?

WHAT ABOUT THE CONSUMER?

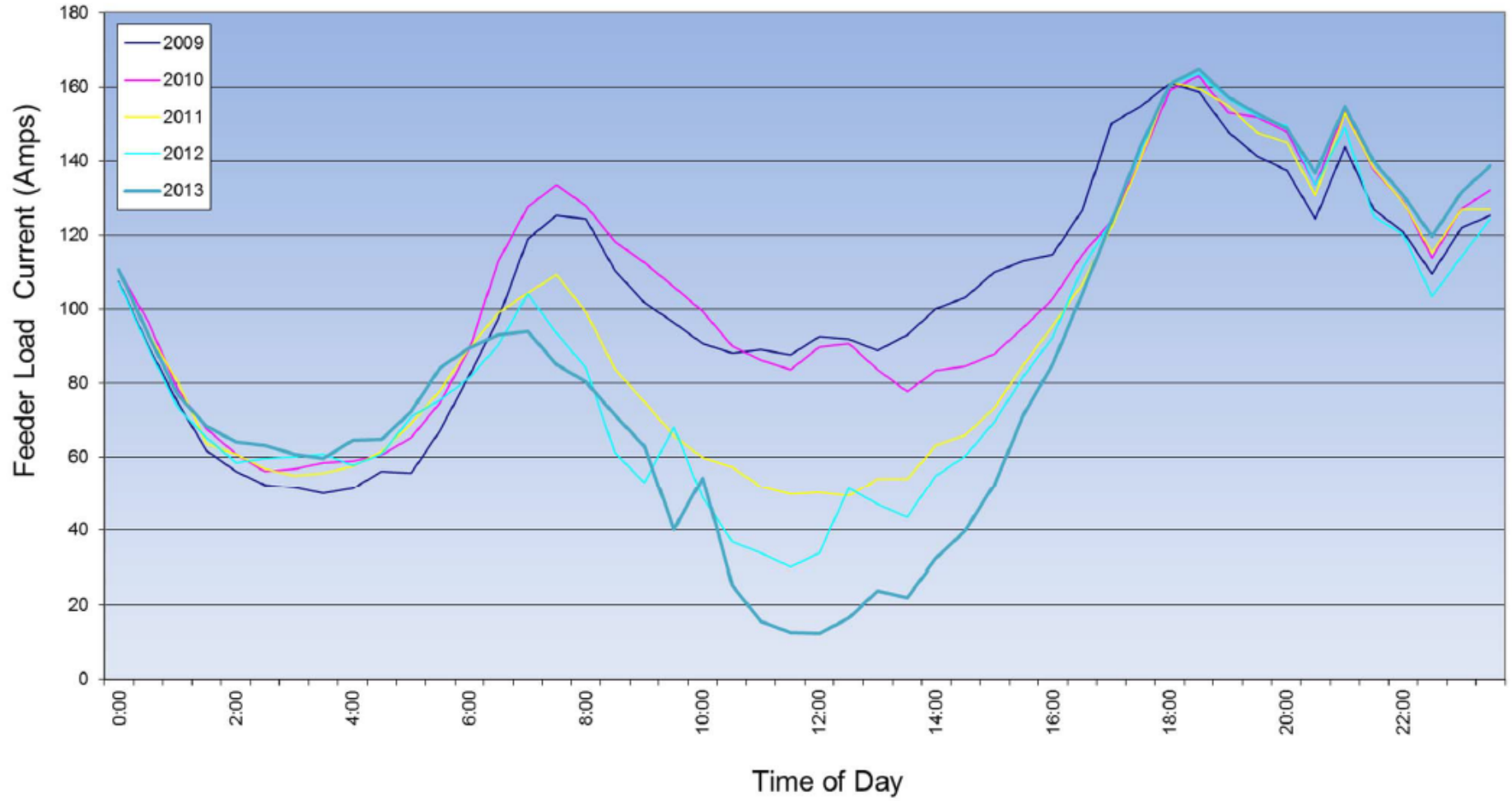
Reduction in consumption





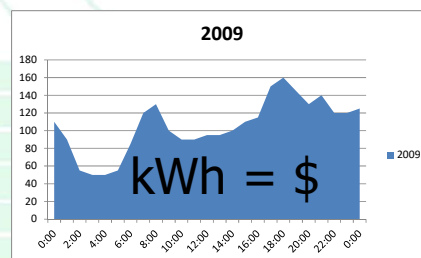
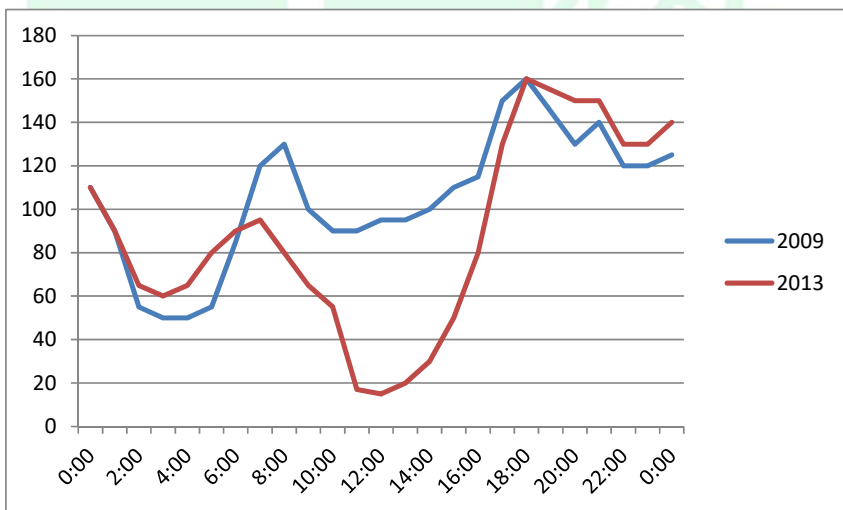
Feeder 'Currimundi 3A' Impacts of Solar PV

Daily feeder demand on the 2nd Tuesday of October for the last six years

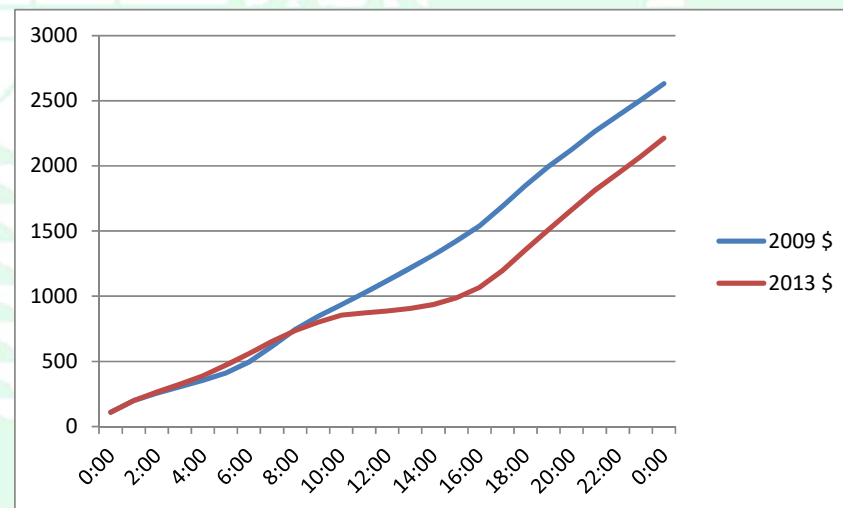


Energex load

MW Demand



Earned revenue



Global Financial Crisis

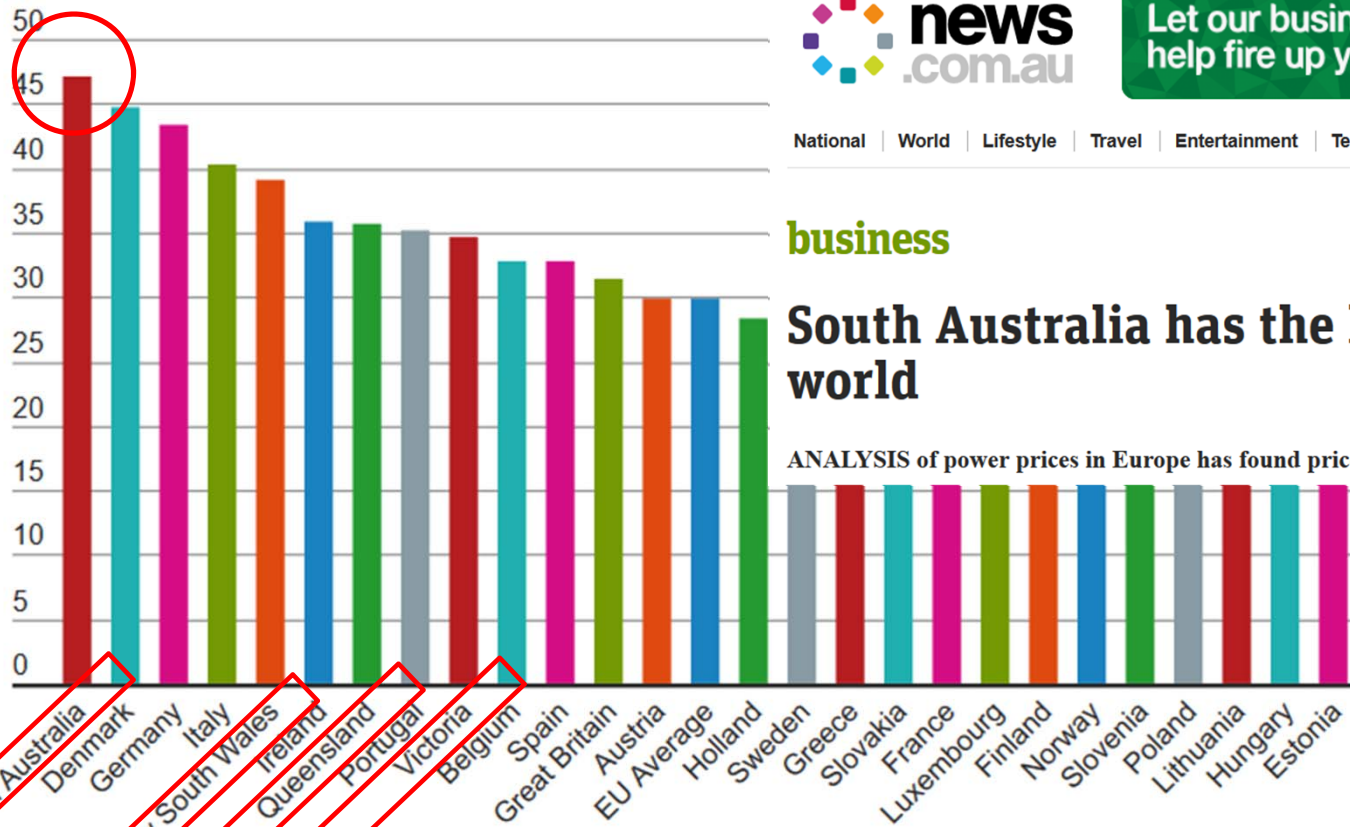
- = more cost conscious customers
- = energy efficient light bulbs, appliances ...

Domestic generation Solar Photovoltaic

Internet and Social media allowing greater cost comparison choices!!

15% reduction in revenue!
Same Peak Demand
Same size TF, poles and wires

South Australia is world leader



Let our business bankers help fire up your business

Find out more



National | World | Lifestyle | Travel | Entertainment | Technology | Finance | Sport

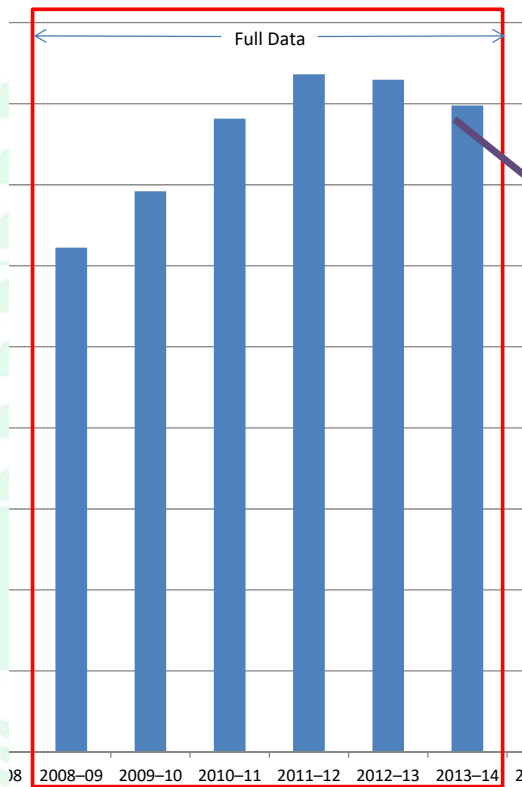
business

South Australia has the highest power prices in the world

ANALYSIS of power prices in Europe has found prices in one Australian state are the highest in the world.

<http://www.news.com.au/finance/business/south-australia-has-the-highest-power-prices-in-the-world/news-story/178987d30a8e6f273cd8949f34a64c83>

Gold plated networks!!!



Regulatory Response
Actively slashing approvals 30-50 %

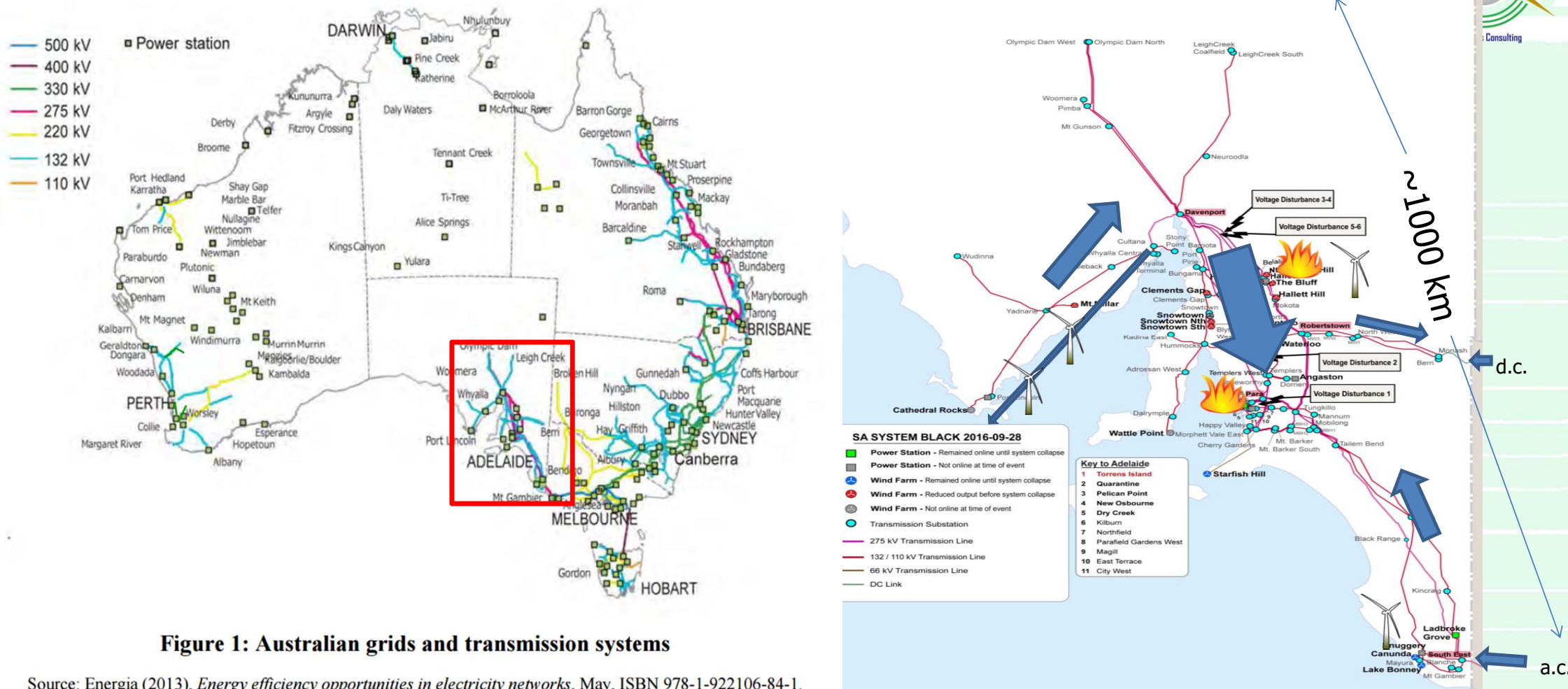
RELIABILITY

24 HOURS/DAY X 7 DAYS/WEEK POWER

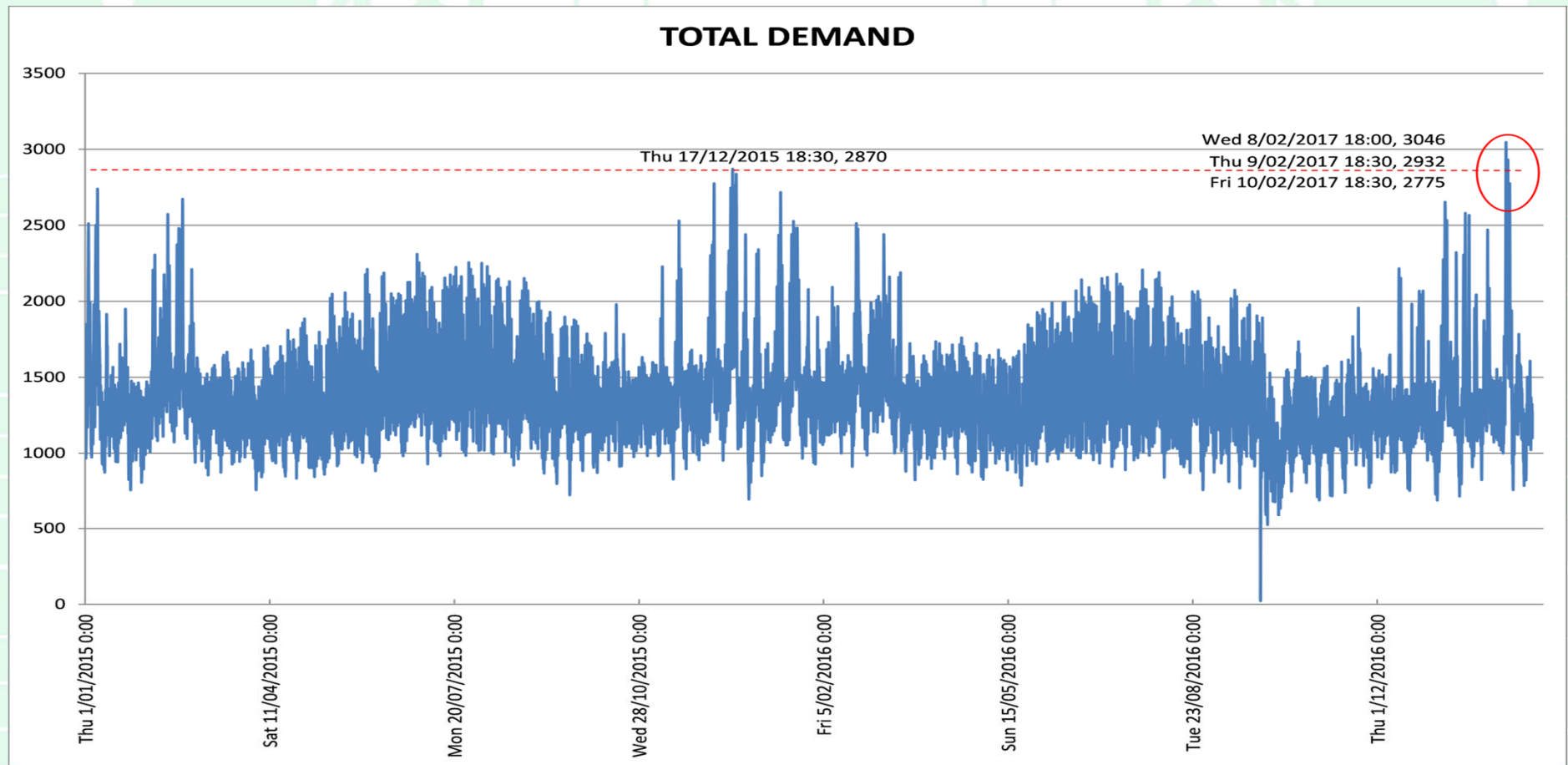


What Did South Australians Use Before Candles?

South Australia Grid

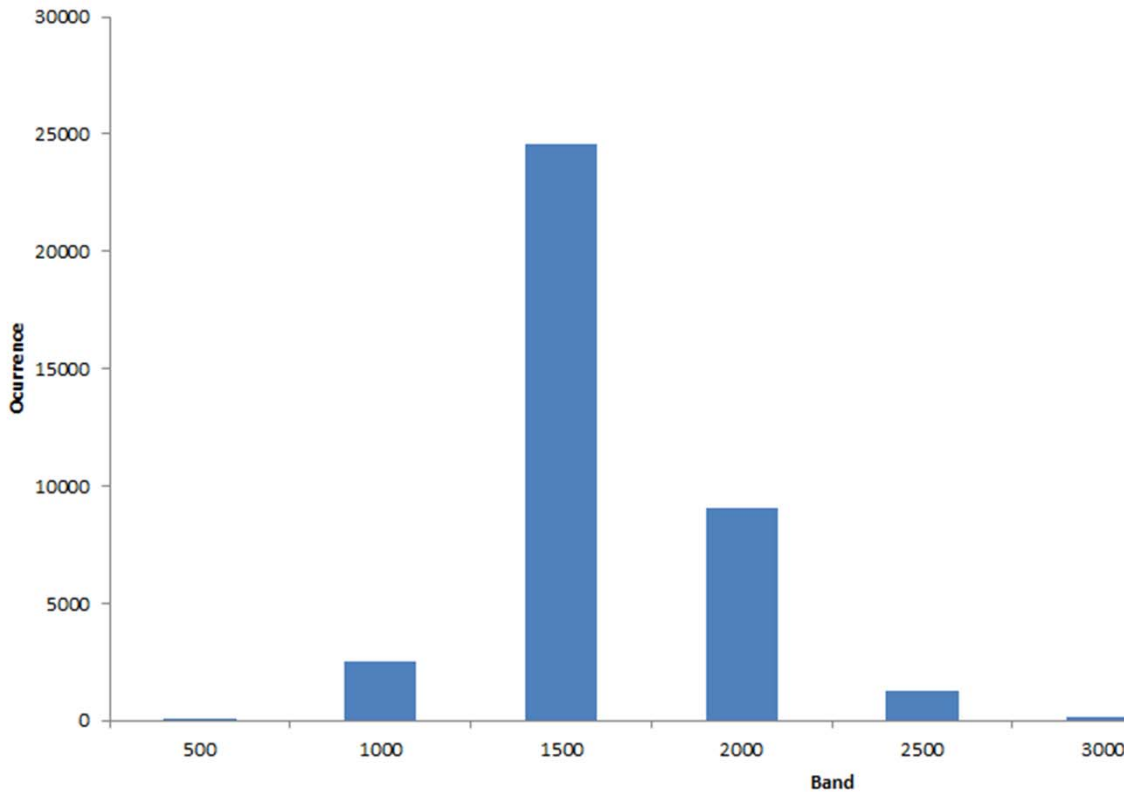


30-minute load profile over 2 years



Design for Peak Demand

Demand Occurrences



37 thousand x 30-minute periods
Average Demand 1372 MW
Peak Demand 3046 MW
Load Factor 2.22

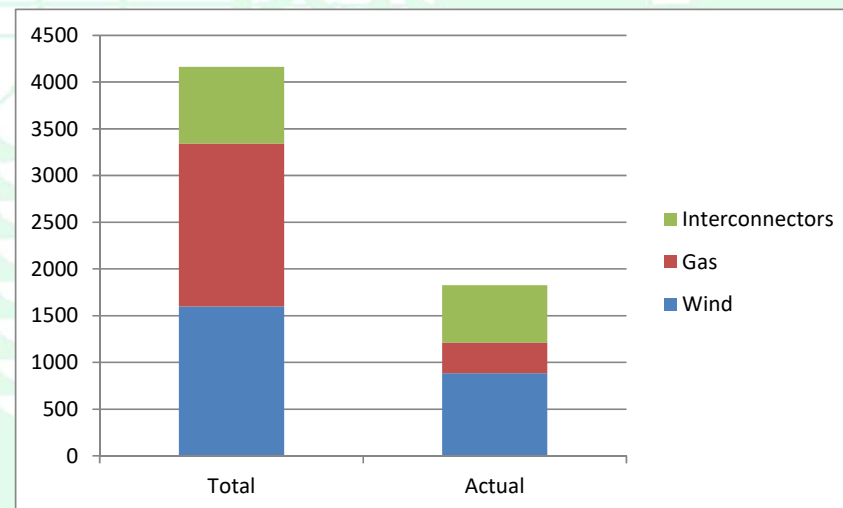
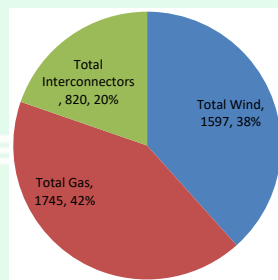
Design for this

Wednesday 28 Sept 2016

- Last in-state coal fired plant closed 12 months earlier

- Generation mix

- | | | |
|------------------|----------|---------|
| ▪ Wind | Capacity | 1597 MW |
| ▪ Gas | | 1745 MW |
| ▪ Interconnector | | 820 MW |
| ▪ Total | | 4162 MW |



* Some Gas stations did not have general gas-supply contracts in place

Wed 28 Sept 2016 4:18 pm



- STATE WIDE BLACKOUT
 - Interconnector segregation
 - Black Start !!!!



Wed 28 Sept 2016 4:18 pm

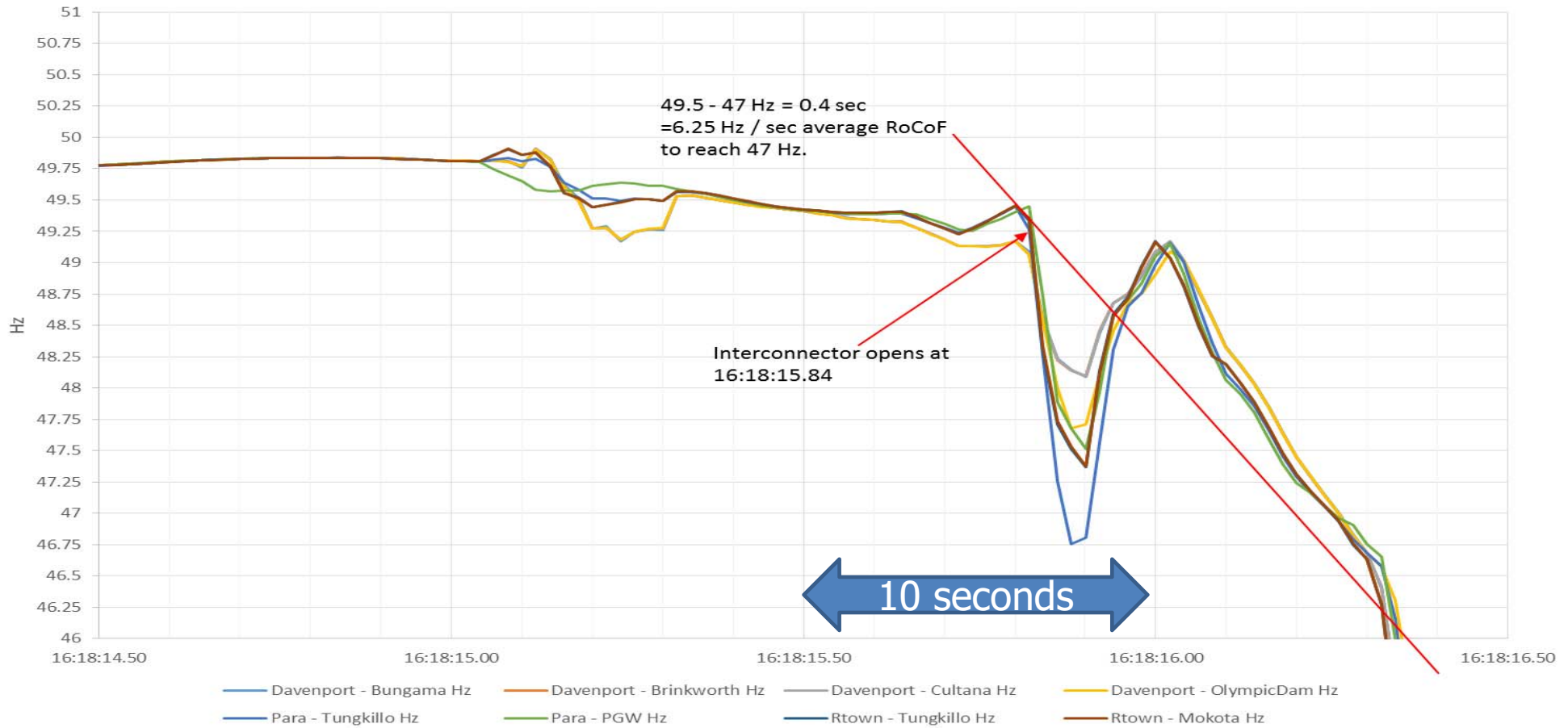
- Wind THE culprit! (... but not the turbines)
 - “we suffered at least seven near simultaneous TORNADOS gusting over **220 km/h** in places!!”
 - Three 275 kV Tx lines cut
 - 27 towers fallen



... but we can't blame God!!

Load Shedding?

SA Frequency - Davenport / Robertstown / Para Disturbance Recorders - 28/9/16 - 16:18



Wed 28 Sept 2016 4:18 pm



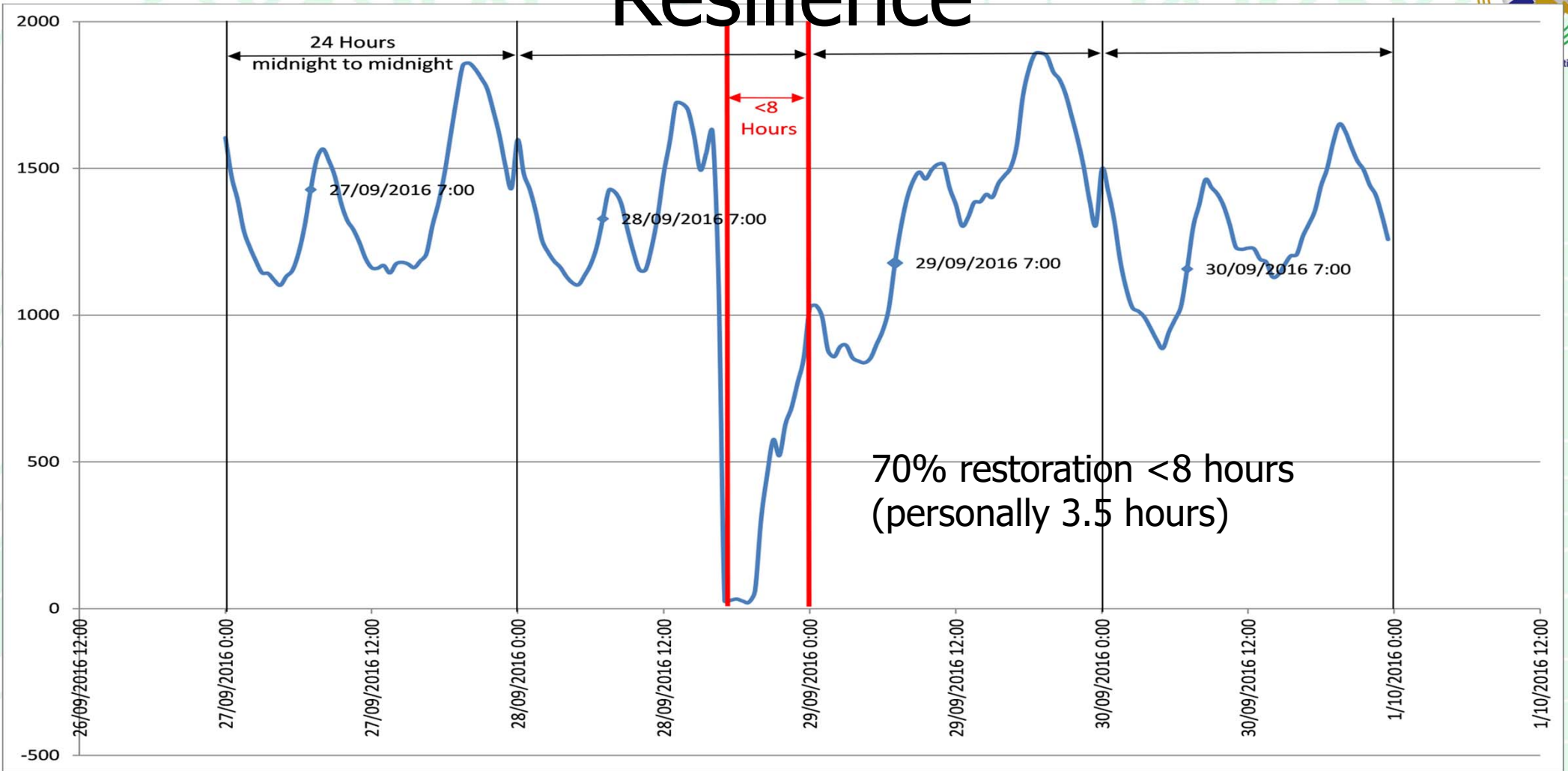
- Wind Turbines the "culprit"
 - Performed better than "expected" - rode through 6-8 seconds of faults
 - "Unknown" wind turbine control setting to trip if 5 or 6 grid faults detected in short time
 - A.C. interconnector overloaded
 - State Black!

- Australian Energy Market Operator Report:
<https://aemo.com.au/Media-Centre/Review-of-the-Black-System-South-Australia-Report-System-event-of-28-September-2016>

- My commentary <https://www.linkedin.com/pulse/sa-blackouts-generation-mix-rodne-y-hughes>



Resilience



General Strategies

- Change turbine setting to “8”!
- Minimum level of synchronous generation online.
 - changes with increase in non-synchronous generation source: system studies
- Reviewing performance of distance protection under low fault levels – assessment of adequacy.
- Improving system strength in the short term
 - by taking actions such as load shedding at specific predetermined conditions - interconnector flows, combination of synchronous generation.
- Assess the use of wind turbines as synchronous condensers to increase system strength,
 - looking at capacity, location/s, performance requirements.

Tasmania DC link



State drought!! Low dams.
21 December 2015
Diesel generators brought in!
Restored 13 June 2016
Cost of outage: \$140 - \$180 million

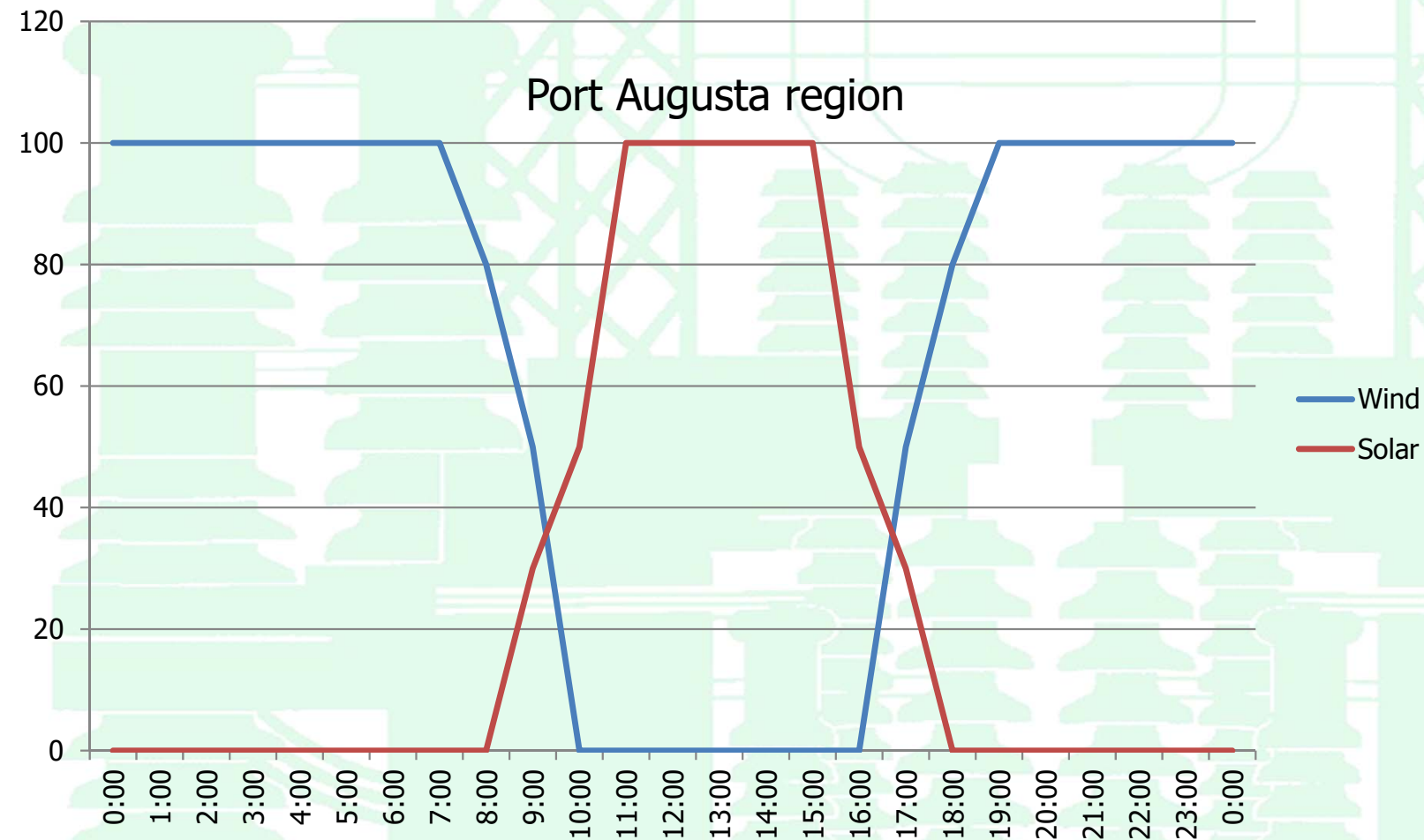
Tasmania is a Hydro state
370 km d.c. link
Bring cheap power to the mainland
Commissioned 2006
Average net benefit >\$40 million per annum

Should we have known?

- Review of Australia's Infrastructure for Climate Change 2010 "The Garnaut Climate Change Review"
 - "Good infrastructure will not always be provided in a timely manner and adequate scale by the market."
 - "Adaptation to climate change and more frequent disruptions of electricity supply will require deeper interconnection capacity."
 - "Climate impacts and pressures on electricity infrastructure are forecast to increase and include changes to demand for electricity, more rapid deterioration of assets, and **increased network failures resulting from severe weather events**"
 - => Government funding of new transmission assets
 - Deregulated market!!
- # new interconnectors since 2010? **ZERO**

Daily Generation

Port Augusta region



Emergence of Renewable Energy Parks

Batteries

Elon Musk makes a bet to fix a state's energy woes in 100 days, or it's free



Elon Musk's remarkable wager proves he's confident in his tech.

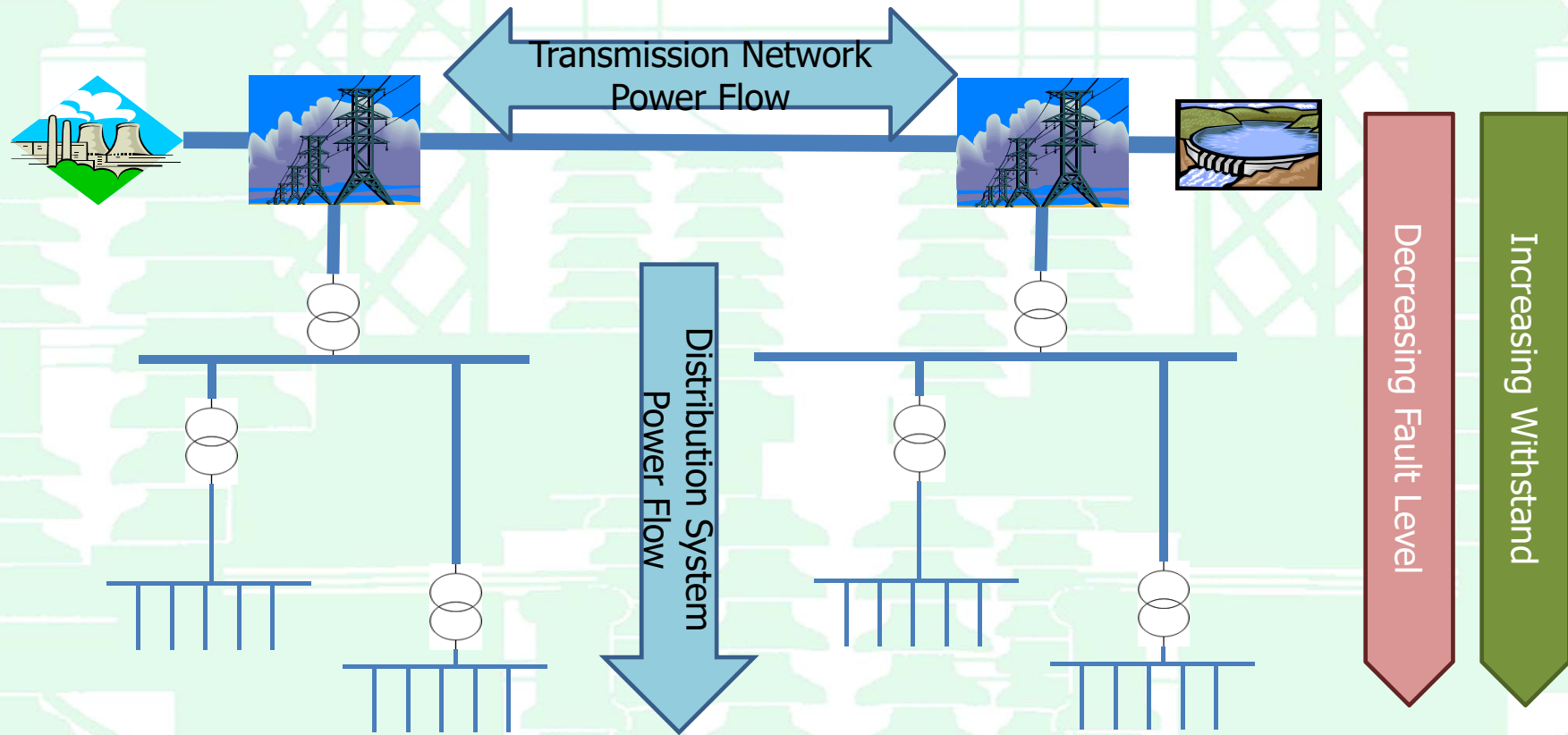
MI5E45V0RKOJAN52ZIN6STTVMI5E5

The world's largest lithium-ion battery
100 MW
129 MWh

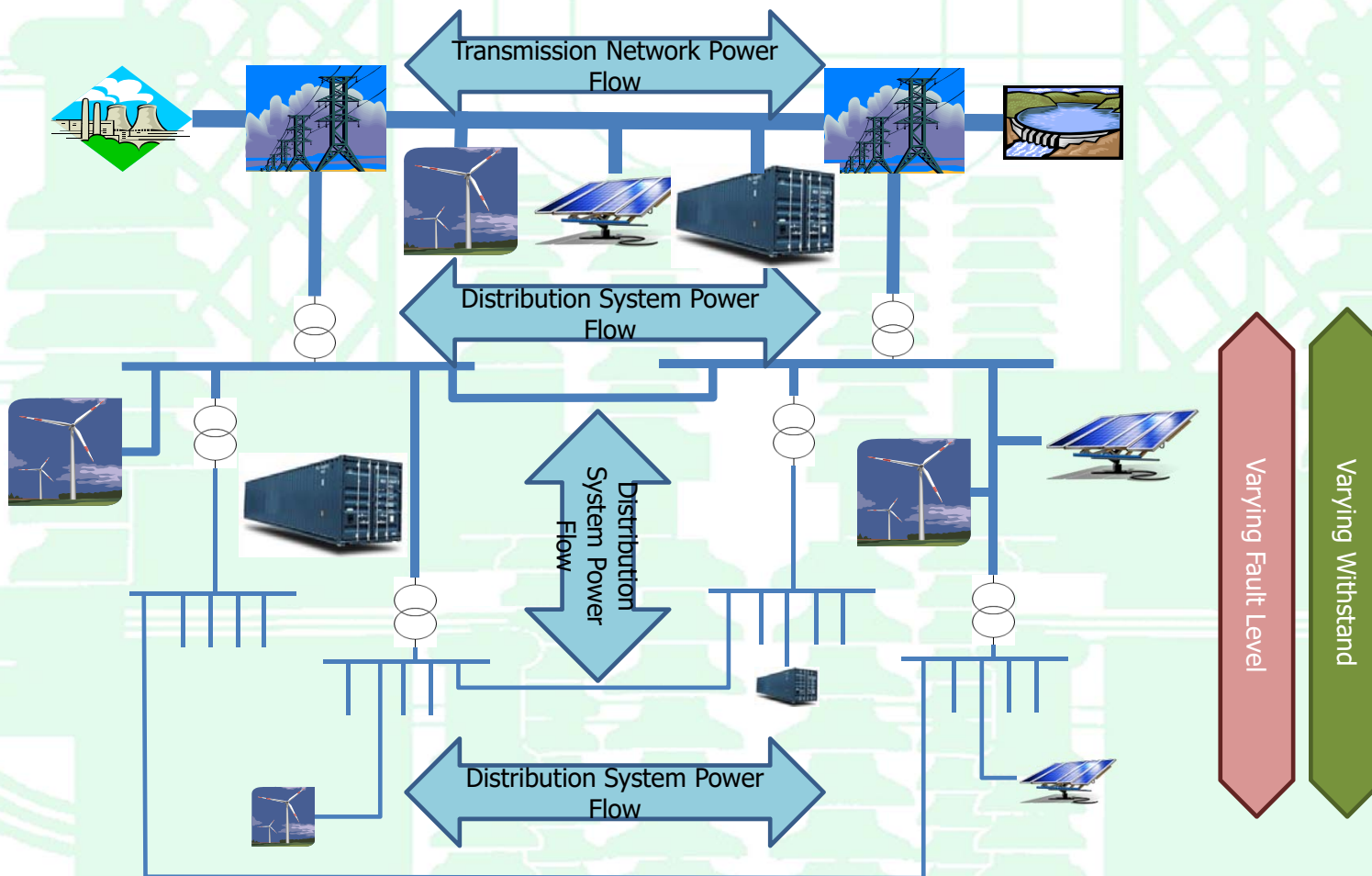
Project planning and contracting actually started ~ 12 months earlier

CHANGE IN POWER FLOWS

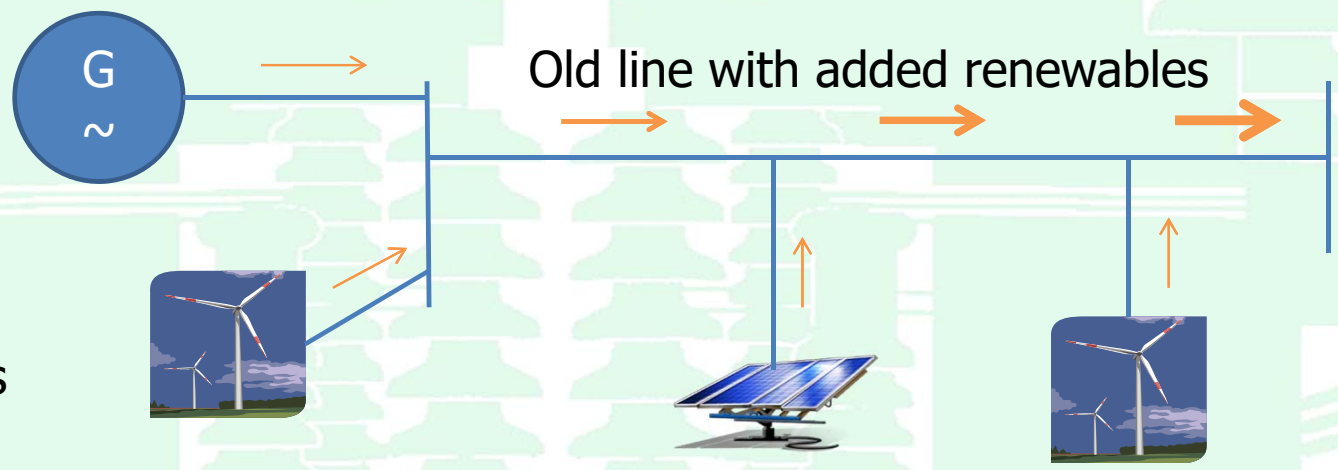
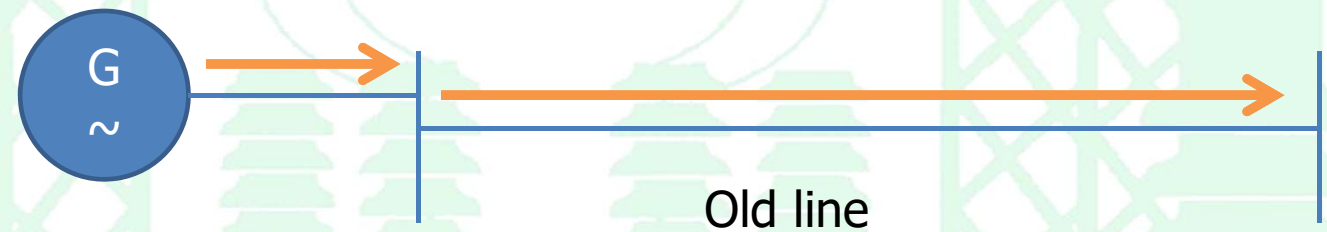
Traditional Grids



New flows



Line ratings



Must constrain original source and intermediary sources

Fault levels



Inverter

$I_{sc} < 1.5 I_r$

"SMART GRID" "BIG DATA" "IoT"

TRANSMITTING INFORMATION ABOUT THE POWER SYSTEM FROM "A" TO "B"

Old systems

Relay wires and SCADA DNP3 ...
"happy as a pig in mud"



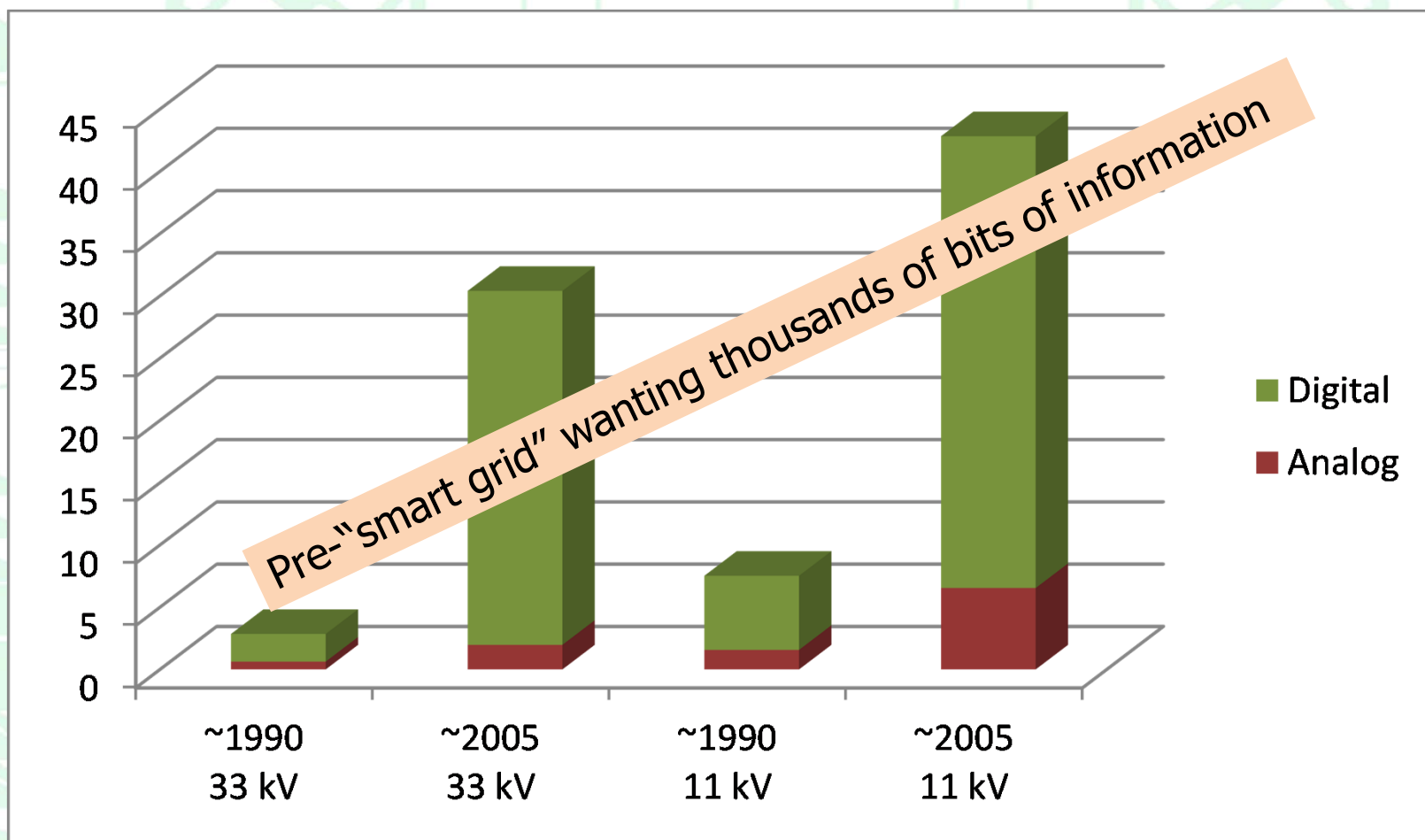
More data, different names by
different vendors

Not a sustainable proposition

We need common semantics!!

...but the mud pit is at the
front door of the abattoir

I/O Count per Bay



Ultimate Objective

Power system engineering is carried out by

- multiple engineers
- in multiple departments
- in multiple organisations
- over multiple phases
- in multiple primary and secondary projects
- coherently deployed over the next "100 years" asset usage
- incorporating hundreds of functions,
- dozens of different IED box types
- from dozens of different vendors
- **to enhance reliability, reduce risks, provide Reusable Engineering and reduce costs.**

CYBER SECURITY

IEC 61850 is not inherently cyber secure

CIGRE Electra Magazine ELT_229_3 Dec 2006



7 Conclusions and Future Developments

The level of security of the older and most current SCADA systems is not enough for the present cyber situation.

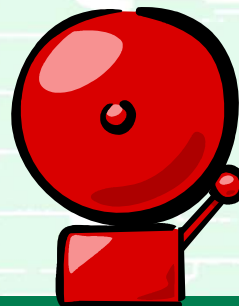
To make things worse the new IEC-61850 standard has no provisions for security yet.

Because of its open network type communication, **it also opens the system for cyber attacks.**

This **new communication standard is really dangerous** if used in a network with a poor security design.

Because the protocol does no longer compartment the communication, **it may loose control over the whole grid.**

All older communication standards do not address security [either].



IEC 61850-3 Ann A

- The SAS should implement security features that counter, within appropriate user and cost constraints, the following threats:
 - Denial of service – this threat attempts to deliberately impede legitimate access.
 - Therefore, appropriate counters should be determined on a system by system basis and **are not subject to standardization within the scope of this standard.**

The Maroochydore Incident

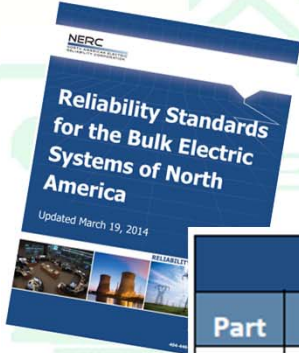


Vitek Boden March and April **2000**
46 attempts to take control of the sewage system
*- caused millions of litres of raw sewage to spill
out into local parks, rivers and even the grounds
of a Hyatt Regency hotel.
Marine life died, the creek water turned black
and the stench was unbearable for residents*

STUXNET 2010

Iranian Nuclear
Power Plant cyber attack

NERC CIP-004-6 Table R5



CIP-004-6 Table R5 – Access Revocation			
Part	Applicable Systems	Requirements	Measures
5.1	<p>High Impact BES Cyber Systems and their associated:</p> <ol style="list-style-type: none"> 1. EACMS; and 2. PACS <p>Medium Impact BES Cyber Systems with External Routable Connectivity and their associated:</p> <ol style="list-style-type: none"> 1. EACMS; and 2. PACS 	<p>A process to initiate removal of an individual's ability for unescorted physical access and Interactive Remote Access upon a termination action, and complete the removals within 24 hours of the termination action (Removal of the ability for access may be different than deletion, disabling, revocation, or removal of all access rights).</p>	<p>An example of evidence may include, but is not limited to, documentation of all of the following:</p> <ol style="list-style-type: none"> 1. Dated workflow or sign-off form verifying access removal associated with the termination action; and 2. Logs or other demonstration showing such persons no longer have access.

1. Know who has access to what.
2. Revocation is critical!

Access for who? For what?

- Engineering personnel
 - Commissioning personnel
 - Maintenance personnel
 - Vendor support personnel
- Geographical region
 - Site specific
 - Device Specific
 - Command Specific
 - Role Specific View – Edit

IED Security

“it is not a problem ...”
 “it is not my problem ...”

Queensland
 Land: 1.8 million km²
 Population: 5 million

Brazil
 Land: 8.5 million km²
 Population 206 million!

SCADA RTUs	Voltage Regulators (MV)
Terminal Server	Distribution Transformers
Protection Relays	Distribution Regulators
Reclosers	Transformers
Fault Indicators (LFI, RMU, Fuse savers)	...
Statistical meters	...
Smart Revenue meters	...
Programmable Logic Controllers (PLC)	...
Substation Battery Charger	...
Backup Generator Controller	...
Main Generator Controller	...
Voltage Regulators (HV)	...

**Explosion of IEDs:
 >850,000
 by 2025**

WHAT DO I NEED TO DO NOW?

Organisation, not Technology

- “Technology is not the barrier to adoption. The fundamental issue is organization and prioritization to focus on those first aspects that provide the greatest customer benefit toward the goal of achieving an interoperable and secure Smart Grid.”

- IEC

- http://www.iec.ch/smartgrid/downloads/sg3_roadmap.pdf

IEC 61850 IS NOT A MERE PROTOCOL

**IT IS A VENDOR-INDEPENDENT
ENGINEERING PROCESS**

TO CONFIGURE IEDs TO COMMUNICATE

ENSTO-E

European Network of Transmission System Operators for Electricity



- 41 Transmission utilities
- Europe - first deployments of IEC 61850
- Largely vendor specific projects initially
 - Laufenburg
 - 8 years experience

ENSTO-E Letter April 2012

<https://tinyurl.com/y7alhyrk>



- **IEC 61850 does NOT work!!**
 - Instantaneous interoperability between suppliers
 - Engineering efforts hard
 - Need mature standardized third-party tool
 - market to clearly move to a top-down approach (i.e. not just vendor tools)
 - TSOs are unable to cope
 - technical knowledge and skills that are required
 - Interoperability over the lifetime



Recipe for success

- Most of the issues are due to
 - incomplete specifications of the users,
 - incomplete implementations in products and
 - lack of knowledge of the key issues of the standard with
 - limited (no) investment in tools

Beware of the “Narbonne Syndrome” *



- 313AD first Basilica
- 441AD fire
37 years to demolish remains
- 445AD new Basilica
- 890AD Cathedral
- **1272AD start new Gothic Cathedral**
 - to be bigger than Notre Damme in Paris

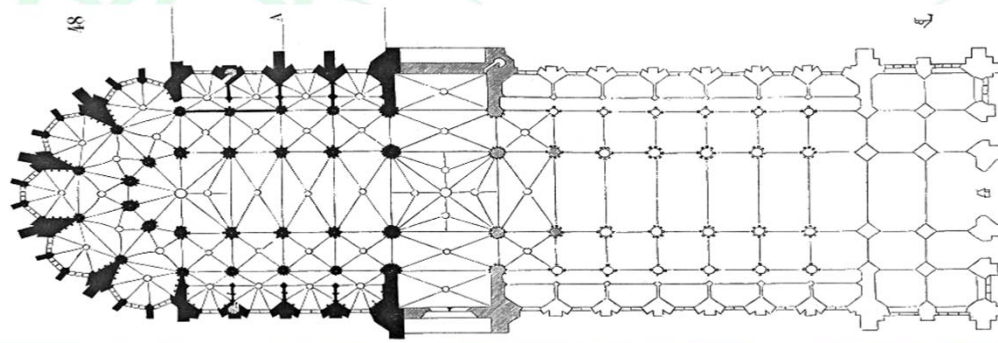


.... And now it looks like:

* not an official syndrome
Term created by Rod Hughes relative
to IEC 61850 implementation planning

Today





- River silted up – port trading economy of city died, no more funding
- Location would have needed destruction of precious fortification walls!
 - medieval times in France hated the Church – hence Rome and Avignon (as home of 9 Popes) are fortified walled cities to protect the Church
- But it is used every week even now ... just less than intended ☹

Working the Plan



leonasafaritours.com



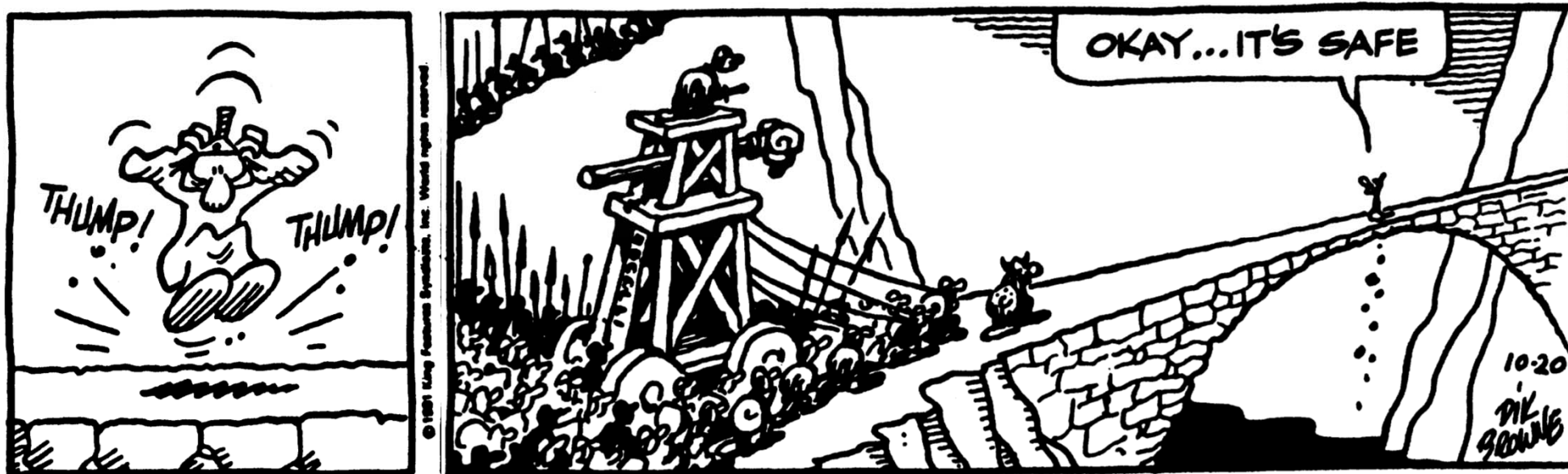
itskeptic.org

- when you're up to your neck in alligators, it's easy to forget that the initial objective was to drain the swamp!
- ✦ Start by stop feeding the alligators – it only encourages them
 - ✦ **Make a strategic significant decision to change significantly**

CIGRE Brazil, Rio De Janeiro, 4-7 December 2017



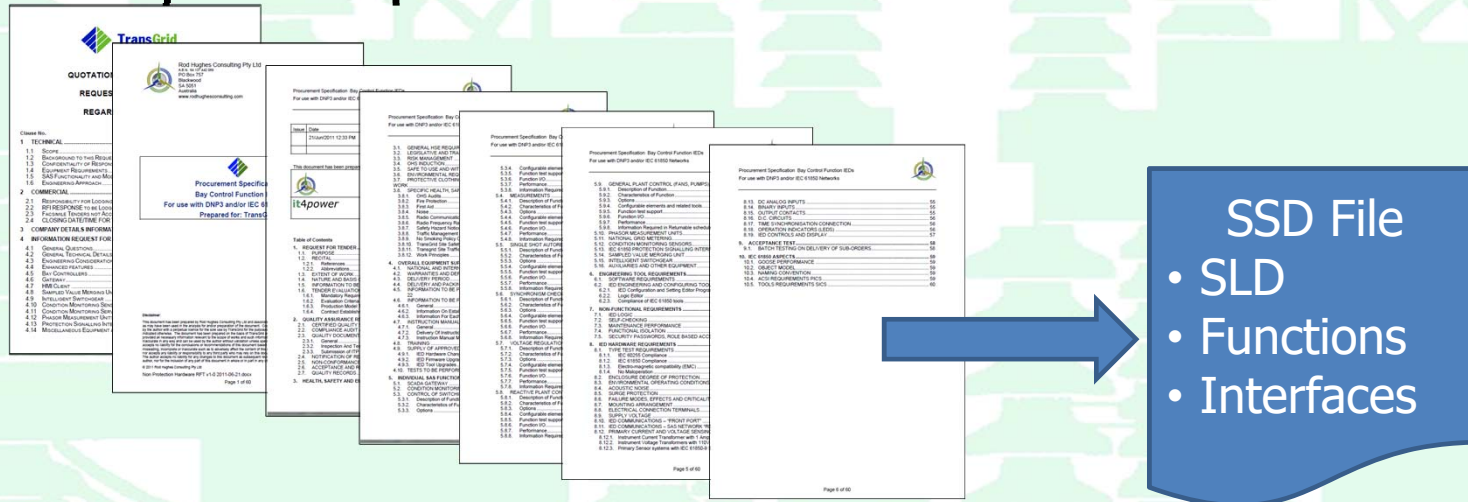
Just Do It



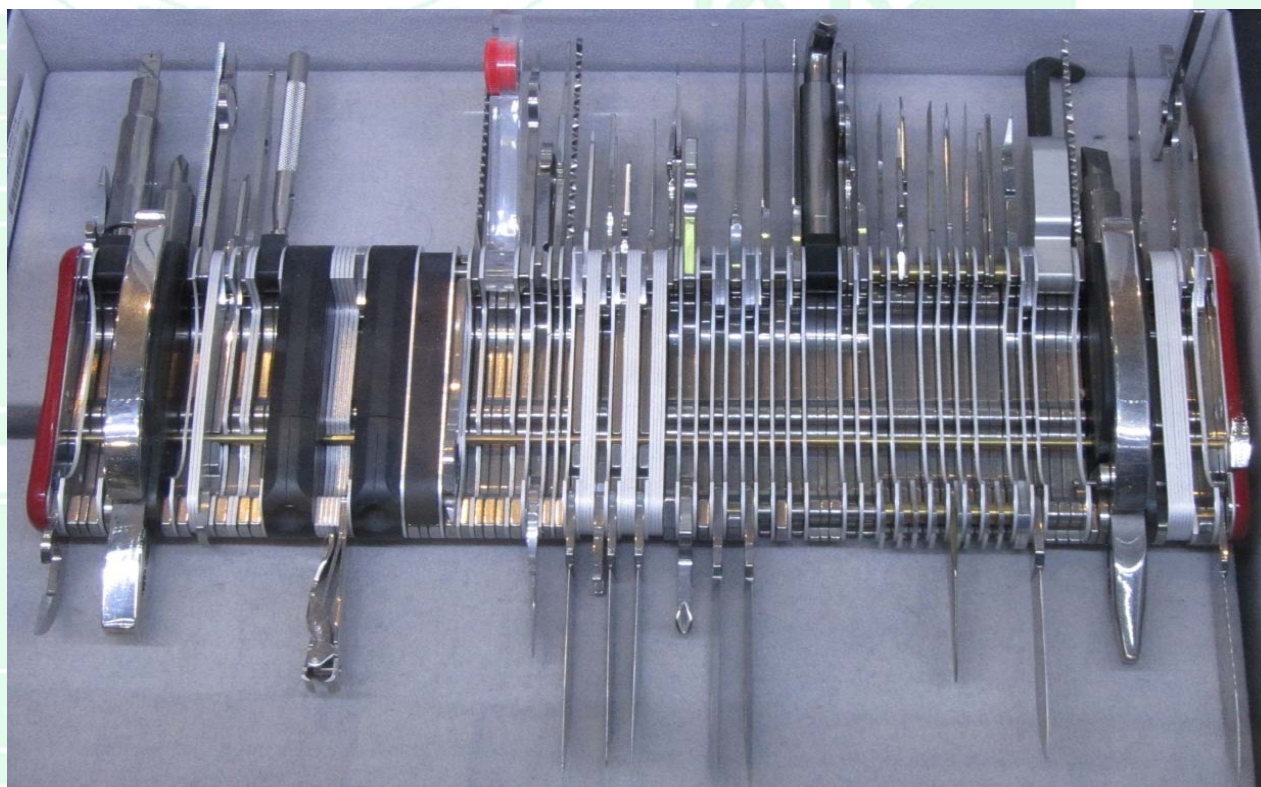
- Introduction of IEC 61850 and its impact on protection and automation within substations CIGRE Technical Brochure 326 Fig 20
 - Leverage experience
 - Seek power engineering context
 - Integrate specialist domain expertise: Protection, SCADA, Primary ... IT

Design Concept Specification

- You have no right to expect to receive the things you want if you do not specify them!
 - Develop the specification in re-usable SCL files

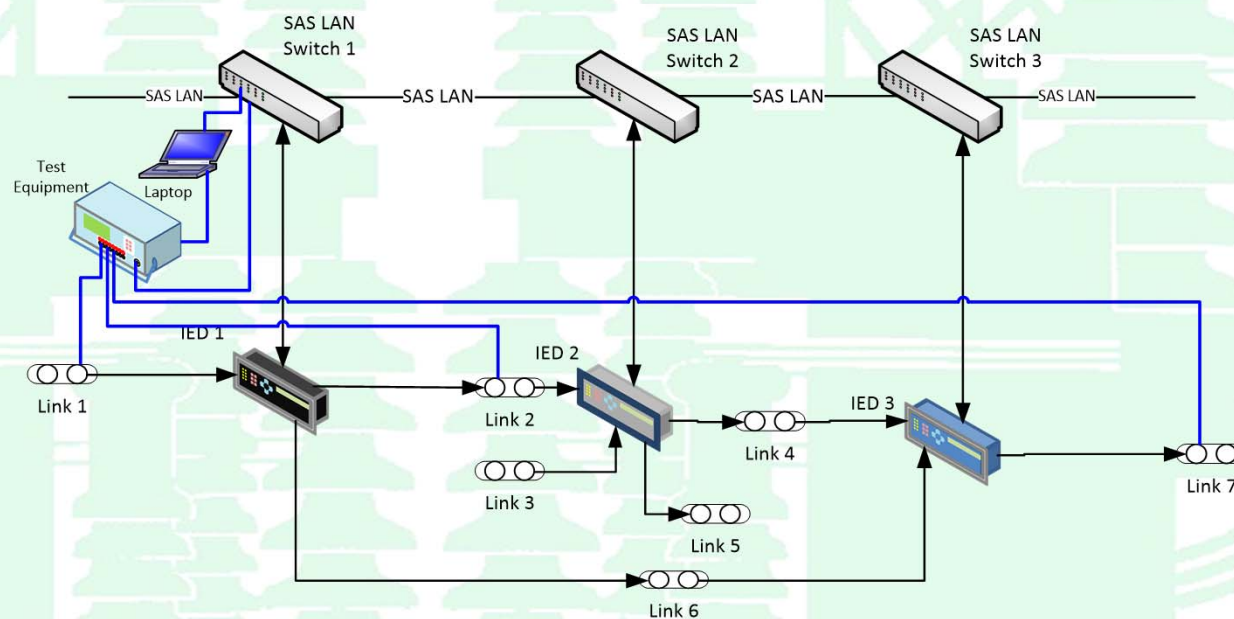


The Single Tool?



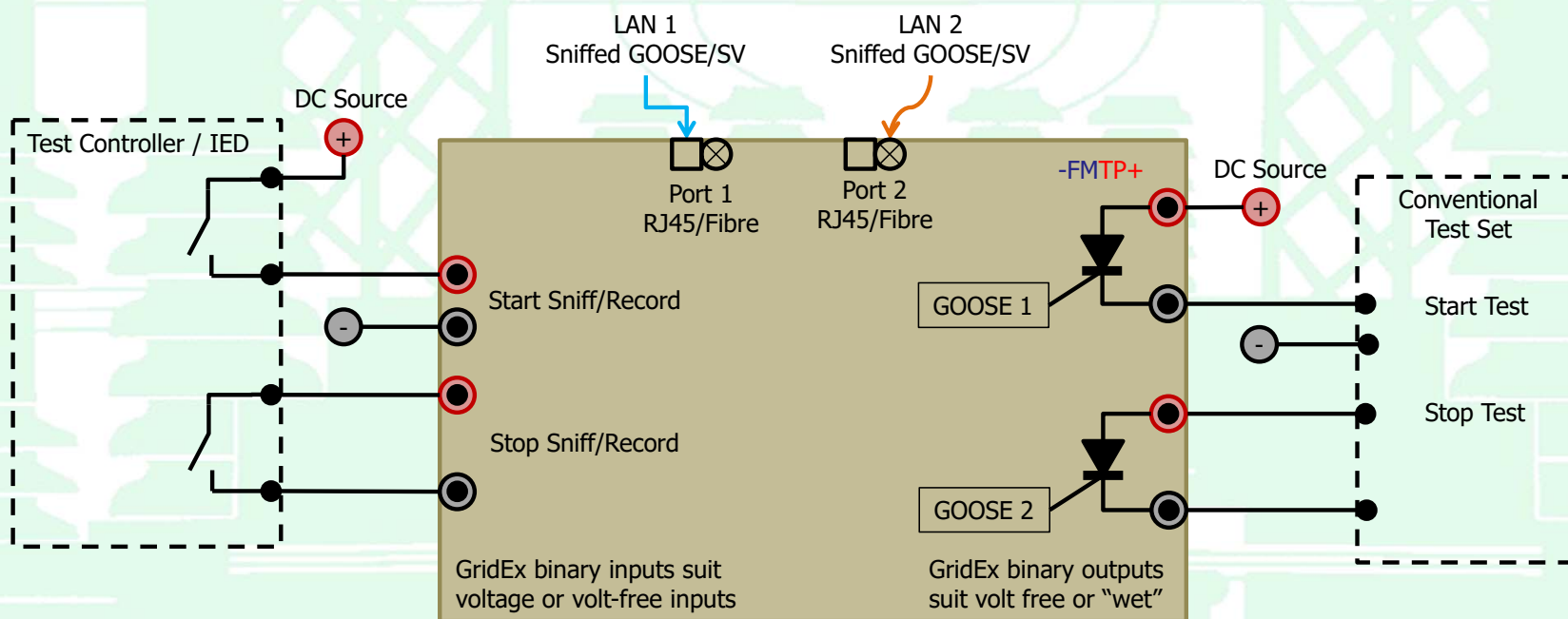
Hybrid Test Environment

- Must consider complete system
 - Wire based signals
 - Virtual signals



Don't throw out old test sets

New IEC 61850 test sets provide extensive IEC 61850 capabilities ... but VERY expensive



Test aid interface units:
 Start/stop sniffing
 GOOSE detection to start/stop test set

Automated Auditing Tools

Main Compare Analysis View A B File Config GridEx®			
Compared in A (29)	Value	Compared in B (34)	Value
S7Sj64PROT : Control_DataSet1	01:0C:CD:01:00:00	S7Sj64PROT : Control_DataSet1	01:0C:CD:01:00:00
S7Sj64CTRL : Control_DataSet2	01:0C:CD:01:00:08	S7Sj64CTRL : Control_DataSet2	01:0C:CD:01:00:08
IED1LD0 : BRC	01:0C:CD:01:01:02	IED1LD0 : BRC	01:0C:CD:01:01:02
IED1LD0 : BRF	01:0C:CD:01:01:03	IED1LD0 : BRF	01:0C:CD:01:01:03
HU_PROLD0 : PROTECTA	01:0C:CD:01:00:00	HU_PROLD0 : PROTECTA	01:0C:CD:01:00:00
HU_PROLD0 : PROTECTA_HS_TRIP	01:0C:CD:01:00:01	HU_PROLD0 : PROTECTA_HS_TRIP	01:0C:CD:01:00:01
A130BL7S8CB1 : Intertrip	01:0C:CD:01:00:01	A130BL7S8CB1 : Intertrip	01:0C:CD:01:00:01
IED1LD0 : PSCH	01:0C:CD:01:01:08	IED1LD0 : PSCH	01:0C:CD:01:01:08
IED2LD0 : PHIOC	01:0C:CD:01:02:05	IED2LD0 : PHIOC	01:0C:CD:01:02:05
IED2LD0 : G_OVERFREQ	01:0C:CD:01:02:02	IED2LD0 : G_OVERFREQ	01:0C:CD:01:02:02
IED1LD0 : DPGGIO	01:0C:CD:01:01:07	IED1LD0 : DPGGIO	01:0C:CD:01:01:07
IED3LD0 : SP16GGIO11TO16	01:0C:CD:01:03:04	IED3LD0 : SP16GGIO11TO16	01:0C:CD:01:03:04
IED1LD0 : MSQI	01:0C:CD:01:01:06	IED1LD0 : MSQI	01:0C:CD:01:01:06
IED3LD0 : PDIS1	01:0C:CD:01:03:05	IED3LD0 : PDIS1	01:0C:CD:01:03:05
IED1LD0 : PLD	01:0C:CD:01:01:04	IED1LD0 : PLD	01:0C:CD:01:01:04
IED1LD0 : MMXU1	01:0C:CD:01:01:05	IED1LD0 : MMXU1	01:0C:CD:01:01:05
		FUTURE2PROT : Control_DataSet1	01:0C:CD:01:1F:00
		FUTURE1LD0 : BRC	01:0C:CD:01:0F:01
		FUTURE1LD0 : BRF	01:0C:CD:01:0F:02
		FUTURE1LD0 : MMXU1	01:0C:CD:01:0F:03
		FUTURE1LD0 : PIOC	01:0C:CD:01:0F:04

Validating contractor's "as built" files are the "as operating" files, and vice versa

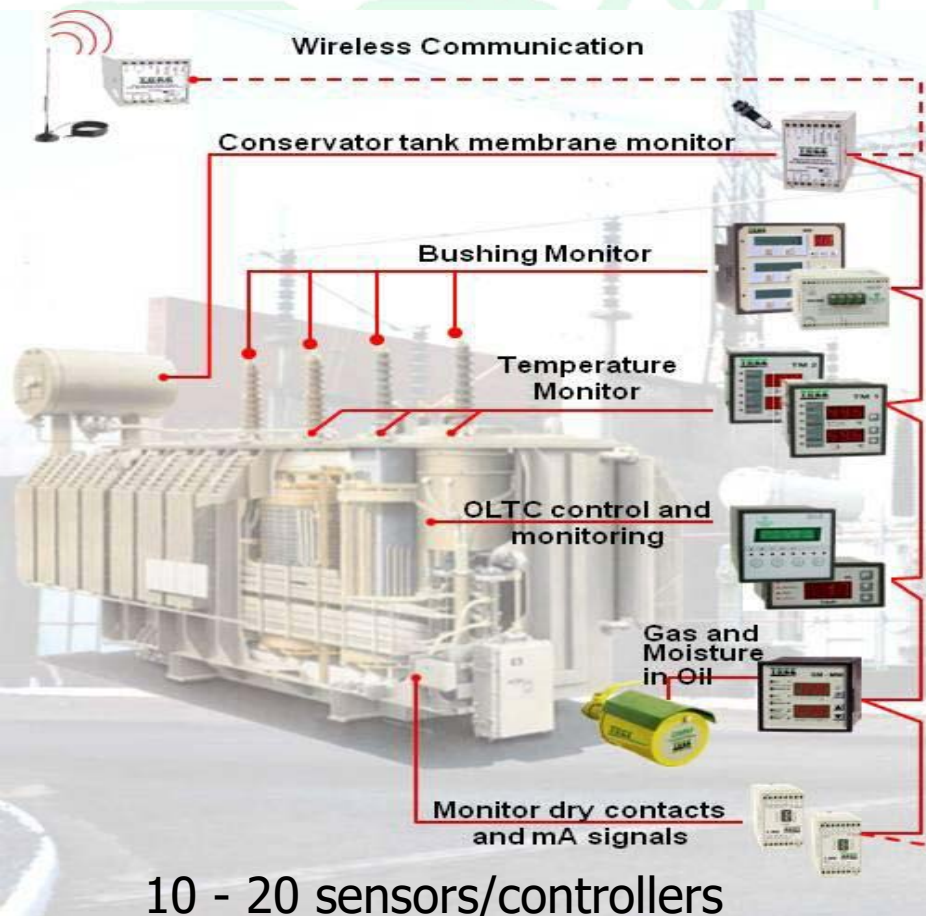
Main Compare Analysis View A B File Config GridEx®			
Compared in A (29)	Value	Compared in B (29)	Value
IED3LD0 : OSCILLATOR	01:0C:CD:01:03:01	IED3LD0 : OSCILLATOR	01:0C:CD:01:03:01
IED2LD0 : gcbTRIP	01:0C:CD:01:02:03	IED2LD0 : gcbTRIP	01:0C:CD:01:02:03
IED3LD0 : SP16GGIO_1TO5	01:0C:CD:01:03:02	IED3LD0 : SP16GGIO_1TO5	01:0C:CD:01:03:02
A130BL7S8CB1 : gcbBFS...	01:0C:CD:01:00:00	A130BL7S8CB1 : gcbBFS...	01:0C:CD:01:00:00
P139System : acb02	01:0C:CD:01:00:03	P139System : acb02	01:0C:CD:01:00:03
S7Sj64CTRL : Control_Dat...	01:0C:CD:01:00:08	S7Sj64CTRL : Control_Dat...	01:0C:CD:01:00:08
S7Sj64CTRL : HA8_Inter	01:0C:CD:01:00:1C	S7Sj64CTRL : HA8_Inter	01:0C:CD:01:00:1C
IED2LD0 : PHIOC	01:0C:CD:01:02:05	IED2LD0 : PHIOC	01:0C:CD:01:02:05
IED1LD0 : MSQI	01:0C:CD:01:01:06	IED1LD0 : MSQI	01:0C:CD:01:01:06
IED3LD0 : PDIS1	01:0C:CD:01:03:05	IED3LD0 : PDIS1	01:0C:CD:01:03:05
IED1LD0 : PLD	01:0C:CD:01:01:04	IED1LD0 : PLD	01:0C:CD:01:01:04
IED1LD0 : PSCH	01:0C:CD:01:01:08	IED1LD0 : PSCH	01:0C:CD:01:01:08
IED1LD0 : MMXU1	01:0C:CD:01:01:05	IED1LD0 : MMXU1	01:0C:CD:01:01:05
AA1735kVLI1A1LD0 : ABB...	01:0C:CD:01:00:00	AA1735kVLI1A1LD0 : ABB...	01:0C:CD:01:00:00
AA1735kVLI1A1LD0 : ABB...	01:0C:CD:01:00:05	AA1735kVLI1A1LD0 : ABB...	01:0C:CD:01:00:05

Verifying nothing has changed from "last year" to now

Not just Protection, SCADA

- IEC 61850 90-3 Condition Monitoring
 - Gas Insulated Switchgear
 - Transformer
 - Tap Changer
 - Underground Cables
 - Transmission Lines
 - Auxiliary Power systems

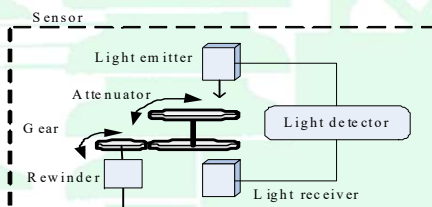
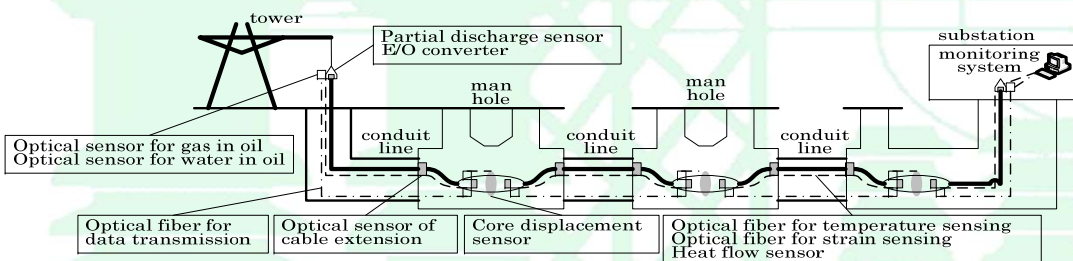
Transformer Condition Monitoring



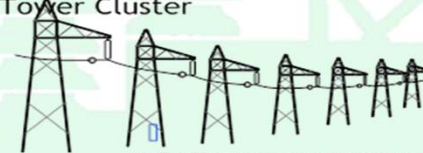
Logical Node	Description	Status	Measured Values	Controls	Settings
SIML	Supervision Insulation medium (liquid)	30	19	1	22
SPDC	Monitoring and diagnostics for partial discharges	2	4	1	2
SPTR	Power Transformer Supervision	6	4	1	
SIMA	Supervision Insulation moisture and aging (solid)	3	11	1	
SBTP	Bubbling temperature supervision	3	11	1	
ZBSH	Bushing	2	6		3
CCGR	Cooling group control	4	10	7	1

155 data objects
and many more data attributes

Under Ground Cable, Over Head Line



Conditioning Info Tower Cluster



LNB : Transmission Local Node Box



- CMD Manager**
- Line and Tower, Insulator Soundness
 - Maintenance Schedule
 - System Configuration History

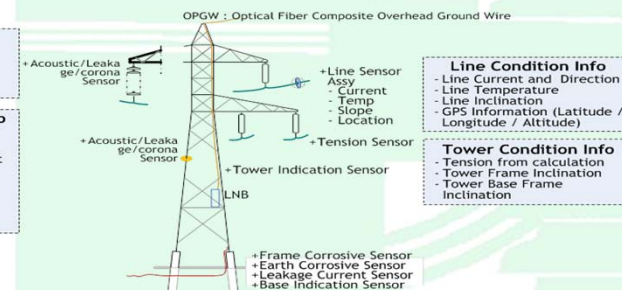


- CMD Gateway & Proxy Server**
- Statistical Processing
 - Analyzing and Diagnostic Processing
 - System Configuration information

Insulator Condition Info

- Corona
- Leak Current
- Acoustic

- Meteorological Info**
- Wind Velocity and Direction
 - Humidity and Ambient Temperature
 - Rain fall
 - Snowfall
 - Sunshine
 - Salt

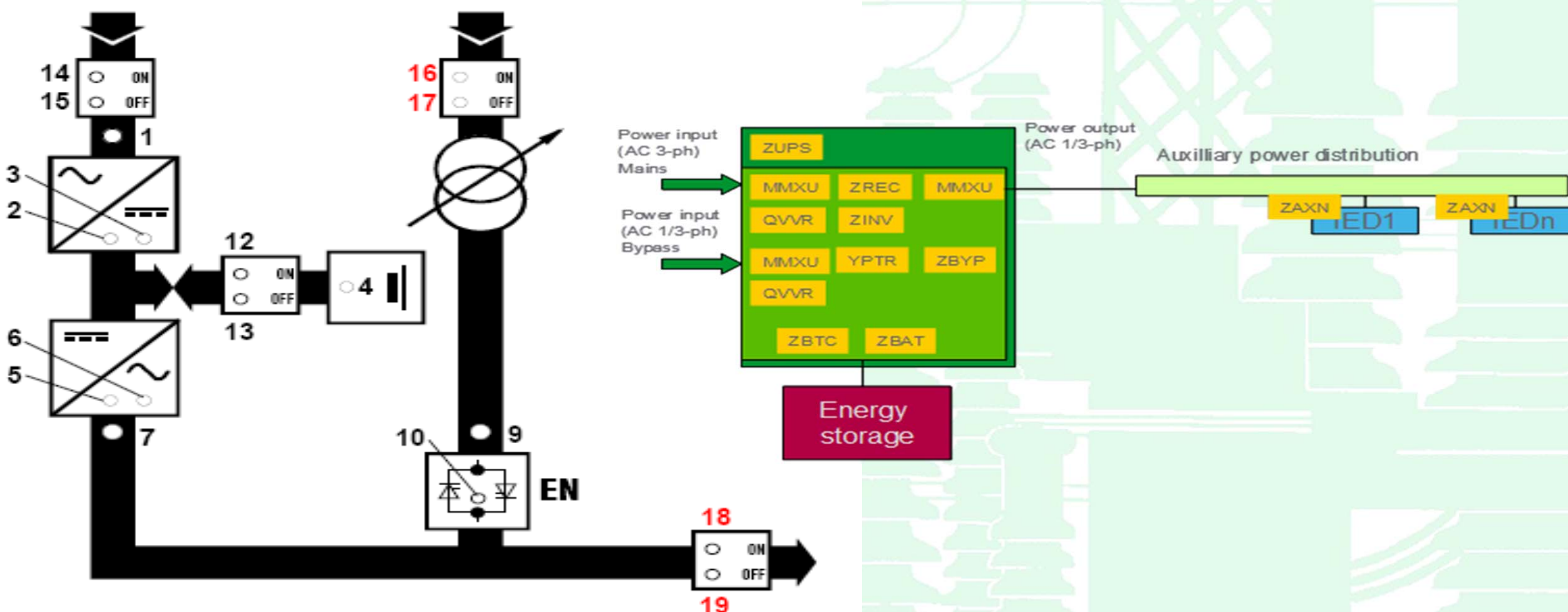


- Line Condition Info**
- Line Current and Direction
 - Line Temperature
 - Line Inclination
 - GPS Information (Latitude / Longitude / Altitude)

- Tower Condition Info**
- Tension from calculation
 - Tower Frame Inclination
 - Tower Base Frame Inclination

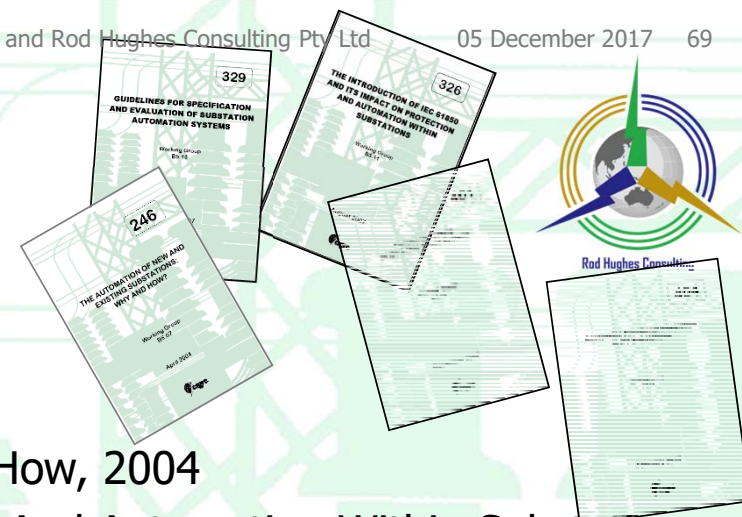
Secured AC system

AC input, AC backup, Inverter supply





Technical Brochures



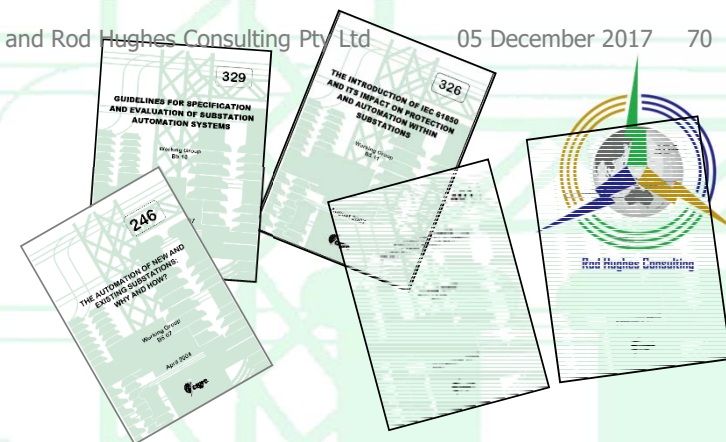
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- 329: Guidelines For Specification And Evaluation Of Substation Automation Systems, 2007
- 401: Functional Testing Of IEC 61850 Based Systems, 2010
- 404: Acceptable Functional Integration in HV Substations, 2010
- 464: Maintenance Strategies for Digital Substation Automation Systems, 2011
- 466: Engineering Guidelines for IEC61850, 2011
- 540: Applications of IEC 61850 Standard to Protection Schemes, 2013
- 628: Documentation Requirements From Design To Operation To Maintenance For Digital Substation Automation Systems, 2015



Technical Brochures



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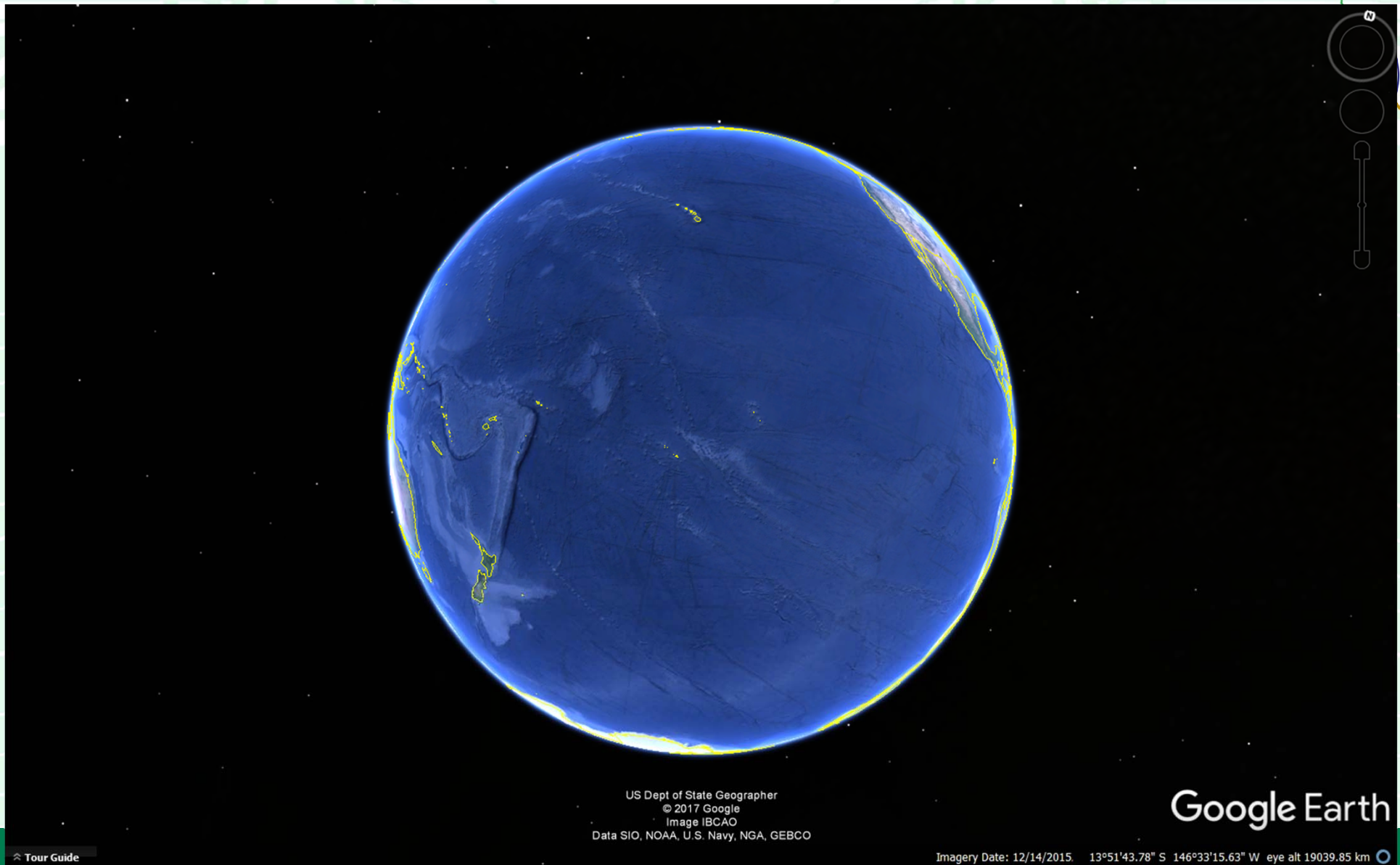
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Specifically on **cyber security** and networks

- 317 (2007) "Security For Information Systems And Intranets In Electric Power Systems"
- 419 (2010): Treatment of Information Security
- 427 (2010): The Impact of Implementing Cyber Security Requirements Using IEC 61850
- 507 (2012): Communication Architecture for IP-based Substation Applications
- 603 (2014): Application and Management of Cybersecurity Measures for Protection and Control
- 615 (2015) Security architecture principles for digital systems in Electric Power Utilities
- New Working Group B5.66

Your challenge here...

- What do I **NEED** to do differently?
- What **CAN** I do differently?
- What **ELSE** do I need to be able to do it differently?



US Dept of State Geographer
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[Tour Guide](#)

Imagery Date: 12/14/2015 13°51'43.78" S 146°33'15.63" W eye alt 19039.85 km



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