Transmission 2040
(Grid Development Strategy)

Work Package 6 – Grid Communications, Control and Protection Technology

Consultation Material

November 2008

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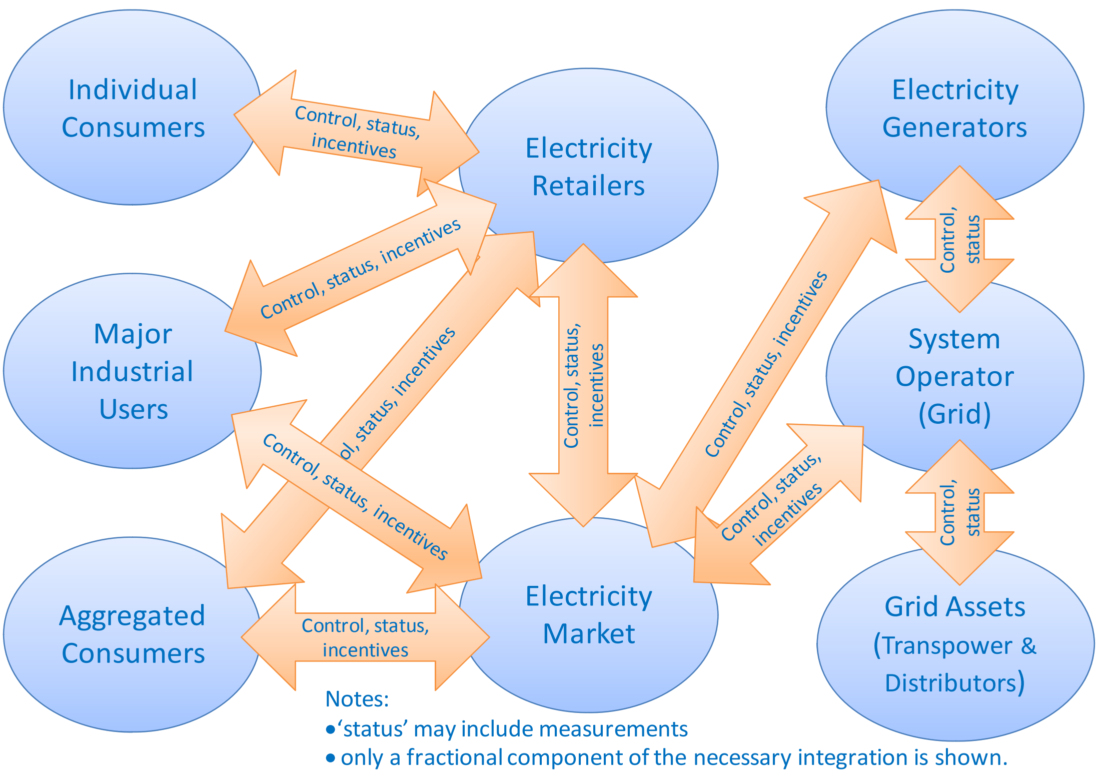
Executive Summary

Protection, automation and communications systems provide the grid and the electricity markets with the key information and control capabilities they need to operate. In the future these systems will also assist information driven Smart Grid initiatives.

But the hurdles to making this work are high.

Historic 'spaghetti' point-to-point integration between systems mean that both ends of the integration are affected by even the most minor of changes. In the absence of common standards for these transfers, each new integration brings disproportionately more change-related pain. Integrations with external parties are harder. Reaching agreement about change, coordinating and implementing it becomes a major and non-productive use of resource.

Figure 1: The Smart Grid Initiatives will Further Extend Information Integration



It is likely that scaling up to meet the reliable and secure integration needs of Smart Grids will require a different approach.

The good news is that industry and vendors have been working on the paradigm change necessary to address this. Their work has leveraged:

- High-performance and low-cost of commodity computing.
- High-speed low-cost internet protocol (IP) based communications.
- Mature and open IT industry standards for information modelling, transfer and security.

The resulting world-wide standards are ground-breaking:

1. The Common Information Model (CIM) IEC 61970.
2. Communication Networks and Systems in Substations IEC 61850.

Transpower has been working on its key Smart Grid enablers as well:

- The grid's communications network is being transformed into a resilient high speed dedicated fibre optic network linking almost all substations.
- Since 2002 ~75% of protection relays purchased are either IEC 61850 capable or can have this capability installed as on option.
- We are upgrading the grid revenue meters to enable access to a rich variety of high accuracy calibrated information in close to real time.
- We are piloting IEC 61850 substation automation with the intention of adopting this as the basis of our next generation of automation.
- We are investigating the Common Information Model (CIM) and the development of an ontology for the core New Zealand grid.
- We are upgrading our time series data historian capability and toolset to allow us to acquire, manage, analyse, visualise, report and integrate the vast amount of time series data expected. The data historian's capability to expose Transpower grid measurements and status information will be central to Smart Grid initiatives.
- We are working to gain secure remote access to a proportion of our numerical protection relays. This IEDS access will provide information needed to support asset management and post incident engineering analysis.
- We are trialling synchrophasor technology. This Smart Grid technology provides information that helps us to model and understand the dynamic performance of the grid both for asset development & operational purposes and can provide advance warning about grid stability issues.

Our protection and substation automation device fleet is ageing with 155 out of 337 RTUs have reached the end of their book life and the average age of our protection relays is 17 years. Having held off major investment programmes we are well placed to undertake future replacement programmes that leverage the new standards.

This paper's core message is that all information driven Smart Grid initiatives that use Transpower sourced grid information will need to be well integrated to succeed. The paper recommends the Common Information Model (CIM) be the default information model for this integration, both internally within Transpower and beyond.

Q.1 Transpower is progressing plans to roll out next generation substation automation. How does this fit with and affect your plans?
Q.2 What type of information and control capability do we need to supply for you to develop your plans?
Q.3 Currently each organisation within the power industry uses multiple information models relating to their components of grid. These models typically exist for SCADA, market & retail systems, asset management, asset capability, engineering, device configuration management, scenario development, data warehouses and reporting systems. History conspired, and as a result these models often overlap and contain information that my be inconsistent or out of date. ***Is this approach sustainable and will it enable information driven Smart Grid initiatives?***

Q.4 The innovation and participation inherent in Smart Grid initiatives requires integration to flourish. ***So how can we enable easy and secure integration within individual organisations, across organisations and beyond?***
Q.5 New generations of technology, devices and personnel will be present in the time frames being contemplated. ***What are the key considerations arising from this and how should they be addressed?***

1 Relevant Background & Context

1.1 Document Purpose and Scope

This Transmission 2040 (T2040) document addresses the future use of protection and automation.

This topic has been logically segregated into four areas:

1. Automation and Remote Control
2. System Monitoring, Special Protection Schemes (SPS) and Wide Area Protection (WAP)
3. Classical Protection and Monitoring
4. Asset, Information and Support Management

Where possible the forward views being developed are classified into one of three divisions:

- 2009-2020: Firm
- 2020-2030: Fluid
- 2030-2050: Fuzzy

1.2 Key Inputs into this Document

- Grid Development plans
- Transpower Information Systems Strategic Plan (ISSP)
- Transpower Standards
- Transpower Policies
- Cigre WG
- IEC Standards
- External Customers
- Generator Owners
- Power Companies.

1.3 Harmonised Substation Automation Standards & IEC 61850

Traditionally substation automation has been proprietary and focused on the operational remote control function. As a result it has been comparatively expensive and fairly low in features and performance.

To improve this situation, recent moves have been made toward more open standards. These have culminated in a new worldwide standard for substation automation called IEC 61850 ‘Communication Networks and Systems in Substations’. This standard leverages modern commoditised technology and standards like internet protocol (IP) and extensible mark up language (XML) to build a ‘plug and play’ interoperable automation environment.

As scale and complexity of grids world-wide has increased so has the complexity of the automation and remote control systems. IEC 61850 is a direct response to this.

A key differentiator of IEC 61850 is that it allows the important low-churn long-term information and definition of the Grid to be abstractly separated and protected from the increasingly high-churn hardware, platforms, software, vendors and service providers.

Transpower has chosen to pilot IEC 61850 in a number of substations. Given the relative youth of the standard and the critical function provided by substation automation the deployment will be staged and measured in a conservative manner.

1.4 A Standardised Common Information Model (CIM) for the Entire Electricity Industry

The Common Information Model (CIM) is a standard developed by the electric power industry that has been officially adopted by the International Electrotechnical Commission (IEC) within IEC 61970. Its purpose is to allow application software to exchange information about the configuration and status of electrical networks.

This means that grid measurements and status can be transferred along with their context via a standardised interface description.

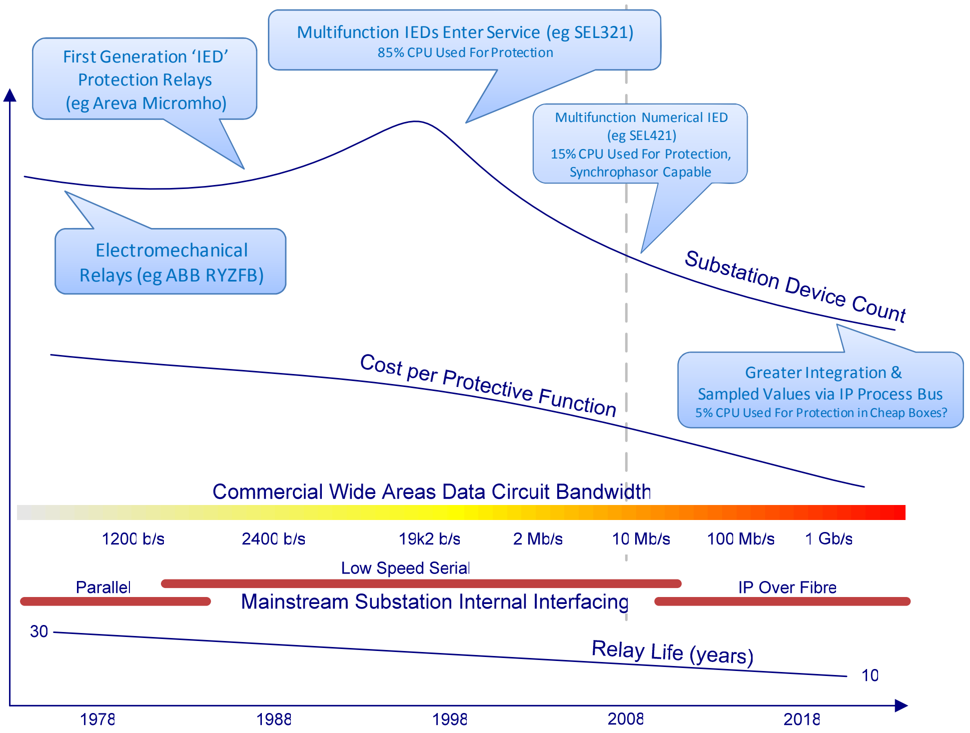
The key differentiator of the CIM, like IEC 61850, is that it allows the important low-churn long-term information and definition of the Grid to be abstractly separated and protected from the increasingly high-churn hardware, platforms, software, vendors and service providers.

The CIM is significant across the entire industry and is under active development for application into new areas. The CIM is extensible, allowing it to meet local and special requirements.

2 The Current State

As seen in Figure 2 the progression of technology has a profound impact upon substation capability. We expect this trend will continue into the future.

Figure 2: Communications & the Evolution of Protection IEDs



At the present time Transpower has:

- ~3,500 protection relays[1] with an average age of 17 years. Currently around 75% of new protection relays purchased are IEC 61850 capable or capable via an upgrade. By June 2009 this will result in ~200 protection relays potentially having IEC 61850 capabilities (1).
- ~337 remote terminal units (RTUs) in 184 substations (2). The current generation of RTUs are proprietary embedded types with a number of issues relating to limited CPU, memory, ports and communications capability that require close management. Transpower proposes to progressively replace the current RTU fleet with IEC 61850 capable substation management systems (SMS) with initial deployments occurring late 2009. 155 out of 337 RTUs have reached the end of their book life.
- Our inter-site communications are presently based on low speed serial technology and proprietary protocols. Work is underway to migrate onto a dedicated and resilient high speed fibre optic based network utilising open protocols.

Therefore:

∴ **2009-2020:** Protection relays having native IEC 61850 support will remain in the minority.

∴ **2009-2020:** Transpower substation automation will progressively migrate to native IEC 61850 based Substation Management Systems that

[1] Some of these comprise multiple sub-relays.

will need to support legacy protocol connections to the older protection relays.

∴ **2020-2030:** Almost all substations are operating natively with IEC 61850.

3 Automation and Remote Control

Automation and remote control was implemented to provide the capability to remotely operate and manage the grid. This capability replicated some, but not all, of the capability of a human operator located on site.

This capability comprises three main elements:

- Protection relays (also know as IEDs): these undertake protective functions such as switching off overloaded equipment, provide measurement and status information from the grid and controlling substation.
- Remote Terminal Units or RTUs (also know as IEDs): these communicate with the protection relays on site and present the substation status to the SCADA system.
- Supervisory Control and Data Acquisition (SCADA): this set of applications runs in the control centres, providing the coordinators with the capability to observe status and to control the grid.

However SPS blur these traditional boundaries and can be expected to at some stage in the future to operate across all three.

Figure 3: Simulation of the Drury Switching Station – Our First IEC 61850 Deployment

Observing status and responding operationally as needed in real-time is the core function of the grid's automation and remote control and will remain so into the future.

Therefore:

∴ **2009-2020:** Transpower's resilient fibre optic based network will be a significant enabler for future substation automation and remote control. Fibre optic networking in the yard will continue this trend within individual substations, leading initial deployments of IP based process buses in the latter part of the period.

∴ **2009-2020:** The expected blending of the communication, automation & protection functions will need support from some new & appropriate competence, process and technology.

3.1 Getting Smart – The Common Features of Most Smart Grid Initiatives

Beyond real-time operational needs, Transpower requires information about asset condition, asset performance and non-operational data such as waveforms and power quality information. Accessing and managing this data will be a key component of the new Substation Management Systems (SMS).

Being *smart* is a common feature of Smart Grid initiatives both within Transpower and beyond. As such, they rely on information and context so that they can analyse and respond appropriately.

While the time frames and locations will vary there are three key common elements:

1. Having a common language and information model at each end of each information transfer.
2. Having access[2] to measurements and status information that are fit for the purpose(s) they are being used for.
3. Having communications capabilities that are fit for the purposes they are being used for.

It would be hard to understate the importance of the combination of these three items in the context of Smart Grids, they become a recurring theme. Achieving rapid Smart Grid initiative uptake requires each of these three items to be resolved. The need for open interfaces that allow the transfer of both information and its context within the Grid has been foreseen and lead to the development of the Common Information Model (CIM) as a worldwide standard; IEC 61970. The CIM is extensible, allowing it to meet local and special requirements such as Smart Grid initiatives.

Transpower's automation and remote control system will be expected to play a central role in supporting Smart Grid initiatives nationwide, primarily through the provision of the rich information required for informed participation by the System Operator, Electricity Market and demand side users.

In addition to Smart Grid initiatives a number of internal non-operational business needs are queued, awaiting mature and cost effective solutions that will extend information driven engineering and asset management decision support.

Therefore:

- ∴ **2009-2020:** Transpower will progressively advance its IEC 61850 based automation.
- ∴ **2009-2020:** Transpower will by default use the Common Information Model (CIM) for new deployments of grid related applications and interfaces unless there are exceptional reasons not to do so. To achieve this Transpower will evolve a Transpower specific CIM ontology and acquire the toolsets necessary to maintain and enhance the ontology over time.
- ∴ **2009-2020:** Transpower will use a time series data historian to provide Smart Grid initiatives, both within Transpower[3], and beyond with the necessary measurements and indications, via CIM compliant interfaces.
- ∴ **2009-2020:** During the next upgrade of its GXP revenue meters Transpower will gain access to high accuracy real-time revenue metering, voltage, current and power quality measurements. These will be used via the time-series data historian's analytical capability to

[2] A Transpower time-series historian capability is required as it enables the safe and secure collection, management and distribution of grid related time-series information.

[3] Smart Grid initiatives within substations will source data from the substation rather than the time series historian.

enhance the accuracy and confidence of SCADA sourced measurements.

∴ **2009-2020:** During its next or the following major upgrade, Transpower's SCADA will become native CIM compliant.

∴ **2009-2020:** We can expect significant demand side participation in Smart Grid initiatives as market mechanisms.

4 System Monitoring, Special Protection Schemes (SPS) and Wide Area Protection (WAP)

To allow higher grid loadings to be achieved without the need to section the grid or to install load current diverting reactors special protection schemes (SPS) are currently used. Each SPS has a set of automatically operated pre-planned contingency actions – typically runback and intertripping. These SPS are Smart Grid initiatives that operating today.

Like most early initiatives, Transpower's SPS schemes have been applied to areas where the benefits are easily achieved. In the future the challenge is that schemes will generally be more complex, risky and will tend to offer less – in essence later schemes will be further up the risk to return ratio curve.

Driving this risk down to an acceptable level will, as a recurring theme, require better models, measurements and communications. IEC 61850 has much to offer in this area, however an interim solution is required that will address configuration and management of the schemes themselves.

Achieving this will require better tools to manage, analyse, visualise and report. In particular:

1. Access to high accuracy, calibrated and traceable measurements from revenue meters. This allows SCADA and IED measurements to be routinely cross checked and validated.
2. A time-series historian application that includes tools for analysis, visualisation, reporting.
3. The ability to remotely access information from protection relays – in particular sequence of event information and waveforms.

Transpower is using phasor measurements to calibrate and validate system modelling. Overseas work is underway to use phasor measurements within automatically operated WAP schemes. As both the need for and the maturity increases we can expect their use in New Zealand.

Therefore:

∴ **2009-2020:** Transpower will significantly improve its ability to manage, analyse, visualise and report time series data.

∴ **2009-2020:** The expected blending of the communication, automation & protection functions required by SPS & WAP will need support from some new & appropriate competence, process and technology.

5 Classical Protection and Monitoring

Classical protection and its application continue to evolve with new numerical techniques, functions, IEDs, instrument transformers and systems.

This will see the current fleet of many individual function relays being replaced by fewer multifunctional that have greater ability and accuracy. For example numerical bus bar protection is becoming more commonly used. Transformer differential relays offer thermal modelling.

Presently we expect protection signalling between Transpower sites to occur only at 110kV and above. However the presence of appropriate and cost effective solutions and need may lead to wider application, possibly into generation and distribution sites.

Optical fibre NCTs and Rogowski coils continue to promise increased performance and cost savings. The future use of such innovations for economically enhancing grid capacity will be considered. NCTs are likely to be particularly attractive at higher voltages where they increase reliability and their installations costs can be significantly lower that conventional transducers.

In the medium term IEC 61850 adoption by vendors will see:

- Extension of the standard to include interfaces to all substation devices eg disconnectors etc.
- Greater use of differential protection.
- Greater use of digital protection signalling eg intertrips for tee connected wind farm connections and locations with weak infeeds.
- Protection elements for stability due to system run harder (power swing block and out of step tripping)
- Change of protection groups to cater for different situations (maybe different circuit configurations or dynamic loading) will occur in the future. Currently use of this is limited to summer and winter settings.
- Sampled CT and VT measurement values being provided via an internet protocol (IP) process bus. This displacement away for conventional analogue CT & VT connections to a single IED will enable simultaneously access to the measurements by multiple protection and automation functions.

Once this occurs the protection focus will likely shift from IED 'boxes' into delivered protection function, of which multiple instances may be co-located on a IP connected commoditised industrial hardware platform.

The substation protection function is vital for both safety and grid performance. Transpower will be conservative in its approach, using only well tested and proven approaches.

Therefore:

∴ **2009-2020:** Transpower will progressively advance its IEC 61850 based automation. Procurement continues to require IEC 61850 function.

∴ **2009-2020:** The amount of data provided by substations will increase, particularly in the areas relating to grid and asset performance. Standardisation via IEC 61850 and the CIM should result in improvements in the data to information ratio over time.

∴ **2009-2020:** Inter substation signalling will occur only at 110kV and above.

∴ **2009-2020:** Some instances of dynamic rating may be applied as initial Smart Grid initiatives.

∴ **2020-2030:** Standards based SPS and WAP may extend between Transpower, generators and distribution company substations to improve delivered performance of the grid and allow deferred investment. In essence SPS will be come 'Normal PS' via IEC 61850 and CIM standardised function.

∴ **2020-2030:** We can expect standards based dynamic ratings to come into operation. Back-end modelling tools to support this will use the same CIM based information models.

∴ **2020-2030:** We expect sampled values delivered via IP based process bus per IEC 61850. This should start a trend downward in substation IED device count.

∴ **2009-2040:** Substation protective functions having human safety implications will remain within substations – ie will not be delivered across a wide area communications network.

6 Asset, Information and Support Management

Asset information and support management is a strong area of focus for CIGRE as it is an essential component of risk management as grids run harder and smarter.

Smart Grids will initially lead to an apparent explosion of complexity. This will, over time, be abstracted away as the standards and vendor products mature.

The key areas of focus for Transpower will be:

- Education, important as schemes more multifunctional and complex.
- Standardisation of designs, improved documentation, configuration management and maintenance.
- Process improvement and training; co-ordination, schemes, settings and testing methods.
- Reviewing and testing of the new technology and standards prior to adoption.

6.1 Generational Change in Protection Relays

With the deployment of modern numerical protection relays the challenge is the orderly migration from older electromechanical devices that required regular testing, maintenance and calibration while providing small quantities of information to modern IEDs that are close to the opposite.

The modern protection relays can simultaneously accommodate multiple configurations, provide vast amounts of data about device status, grid measurements and condition information about the connect plant.

The protection relay settings are an important variable within grid modelling. Transpower is currently implementing a protection settings and configuration management system that allows protection settings to be provided electronically to the modelling toolset. The chosen product has an upgrade roadmap that supports IEC 61850 and the CIM.

6.2 Generational Change in Device Management

Configuration and management of substation devices was initially achieved using hand tools and then more recently using portable computers. To date uploading new settings and firmware into IEDs using portable computer has presented few problems and has been the only realistic option.

With the use of IP based networking within substations the use of potentially compromised portable computers will have to stop, probably replaced by a secure centralised remote management infrastructure that also provides secure remote engineering access[4] to IEDs.

[4] This infrastructure will be applied to providing secure remote access to many of Transpower's legacy protection relays to gain access to events files, waveforms, asset and engineering information that cannot be provided via SCADA

6.3 People Change – Up Skilling on IEC 61850 & the CIM.

Migration to the next generation of automation devices and technology will require a change in skills and competence. For Transpower this will likely relate to both substation automation and the Common Information Model (CIM).

In particular greater understanding will be needed of the standards & technologies that will allow integration and aggregation.

The challenge appears may be for the industry to gain a deeper understanding of:

- The Common Information Model (CIM) IEC 61970.
- IEC61850 'Communication Networks and Systems in Substations'.
- Utility Integration Bus (UIB), integration "middleware" and components[5].
- Best of breed time series data historian applications, their use and integration.
- Understanding both the "time series" and "measurement" chains and how they relate to current/future business need and Smart Grid initiatives.

And then, understanding their own organisation's demographic issues, to make informed decisions about how best to progress.

6.4 Service Change – Seamless Support of Information Models, Measurements and Communications

The future holds a much more integrated approach to all types of protection, automation and information integration. To support this, our provision of support and management services will need to be more integrated as well.

Transpower is one of the few Transmission & Distribution organisations within Australasia already having combined their IT and SCADA/substation automation groups. However the Secondary Assets Team which is responsible for considerable amounts of automation including interlocking, intertripping, remote access, SPSs and more is not part of this group.

The challenge will be to provide seamless end-to-end support over a larger context - within the substation environment, within the enterprise environment and beyond.

Maintaining a federated model of the grid within the CIM will require some new skills and a new tool set.

[5] Technical architecture issue. Suggested study includes Integration brokers, COM, DCOM, XML, Web Services; SOAP, WSDL & XHTML.

7 Future Vision – Substation Protection, Automation and Communications

Figure 4 illustrates a native IEC 61850 substation. For some time into the future Transpower will be operating in a hybrid environment that features legacy protocols to the support older protection relays. A key feature is the ability for both operational and non-operational data to be provided directly to the time series historian,

Figure 4: Future IEC 61850 Substation Dataflows

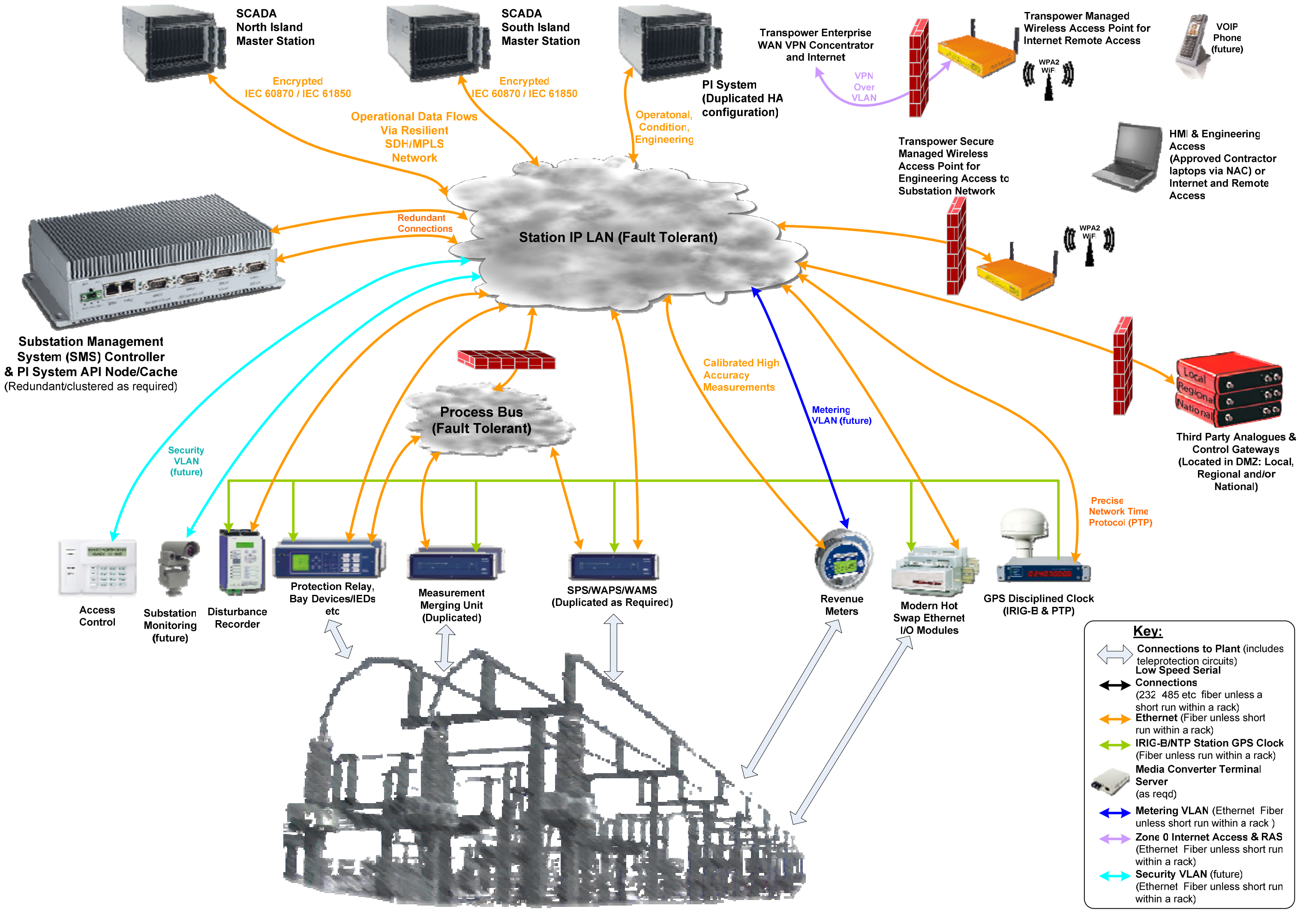
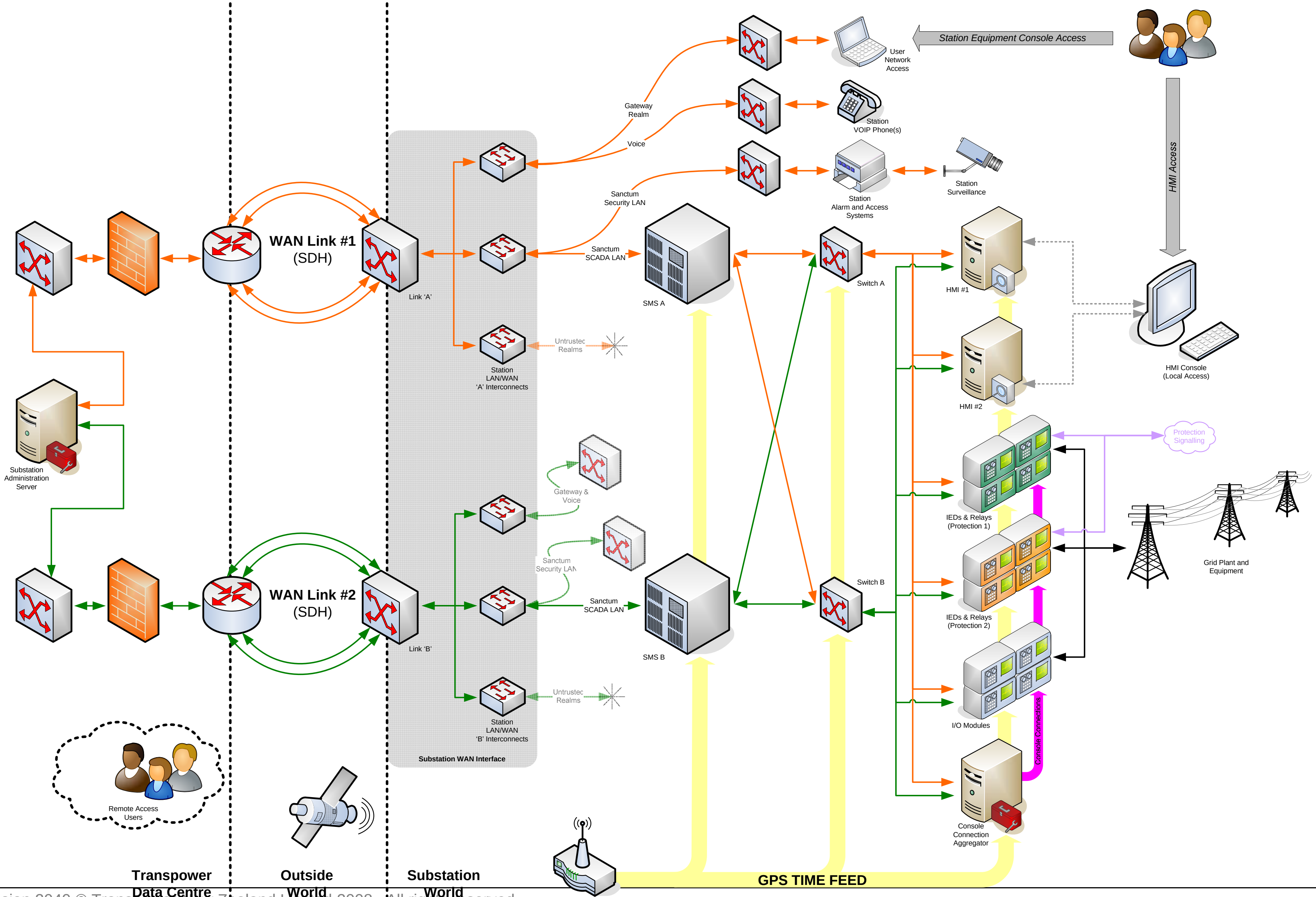


Figure 5: Drury Substation: Simplified Device Level View of Proposed IEC 61840 Native Automation, Protection & Communications



Appendix A Bibliography

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2. —. *Sites Database Ad-Hoc Quiery.* Wellington : Transpower, 29 August 2008.

Appendix B Glossary of Terms Used & Related Terms

Term	Meaning	Additional Comment
CIM	Common Information Model	The Common Information Model (CIM) is a standard developed by the electric power industry that has been officially adopted by the International Electrotechnical Commission (IEC) within IEC 61970 to allow application software to exchange information about the configuration and status of an entire electrical network. The CIM is extensible, allowing it to meet local and special requirements.
CMDB	Configuration Management Data Base	Information about devices, communications etc that documents variables and design decisions, permissions etc. The CMDB is a key risk mitigation and an essential component for meeting Transpower's high availability requirements.
COTS	Common Off The Shelf	Commercial configure (not build or modify) software. Often referred to as 'shrink wrap' software.
DC	Direct Current	-
DNP3/DNP3i	Distributed Network Protocol	Open protocol for substation communications. It is robust but not secure. The 'i' signifies it is being carried over IP.
'Events'		Abnormal grid occurrences that lead to alarms and status updates.
ICCP	Inter Control Centre Protocol	-
IEC 61850 'Communication Networks and Systems in Substations'		The ideas behind IEC 61850 are also applicable in areas of automation such as control and monitoring of distributed generation. The use of IEC 61850 in areas of water and gas is being discussed.
IED	Intelligent Electronic Device	A substation device than may provide measurements, control protection and/or automation functions. Modern IEDs include protection relays, bay controllers, revenue meters, RTUs and fault recorders.
Incidents		An occurrence that may or may not lead to an event.
Integrated Protection and Control		The integration of traditional protection with dynamic control (eg trip current vs temperature) to achieve higher utilisation while maintaining full protection.
IRIG-B	Inter Range Instrumentation Group – time code standard, format B.	IRIG-B synchronisation uses a low speed serial interface typically achieves ±100us accuracy.
ISSP	Information Systems Strategic Plan	-
IST	'Information Services & Technology' a Division of Transpower	-
LAN	Local Area Network	-
NCT	Non Conventional Transformer	Current transformers or voltage transformers that use different means of detecting the currents voltages being measured. These promise increased dynamic range, accuracy, bandwidth

Term	Meaning	Additional Comment
		and phase accuracy while significantly reducing long term sensor drift. At higher voltages they also promise improved cost and reliability.
Ontology		An ontology is a model for describing something (eg the Transpower Grid) that consists of a set of types, properties, and relationship types. For the purpose of integration the ontology must be precise.
Rogowski Coil		A non-conventional current transformer with greater dynamic range than conventional CTs. Its major weakness is that it needs an external computing function to integrate its output.
RTU	Remote Terminal Unit	An automation device for gathering information from remote sensors and providing control at a remote location.
SOE	Sequence of Events	Time stamped information from an IED that provides detail on a sequence of event that occurred. Often presented by IEDs as a file.
SPS	Special Protection Scheme	SPS are used to allow higher grid loadings to be achieved without the need to section the grid or to install load current diverting reactors. Each SPS has a set of automatically operated pre-planned contingency actions – typically runback and intertripping. SPS are Smart Grid initiatives that operating today.
Telecontrol		The processes, equipment and communications (collectively) required to provide remote control of substation devices. Often referred to as ‘forward control’.
Teleprotection		The processes, equipment and communications (collectively) required to allow two protection relays to communicate to allow enhanced protection capability.
UPS	Uninterruptible Power Supply	Typically a combination of rectifier, battery and inverter that are designed to provide continuous clean electricity through ac power disturbances and short interruptions. The use of UPS should be avoided wherever possible within infrastructure environments due to reliability and fault discrimination limitations.
VOIP	Voice/Video over IP	Method of carrying telephony traffic over IP networks.
WAMS	Wide Area Management System	Typically involves wide area synchrophasor measurements to provide greater understanding of the grid for modelling purposes and may later lead to automated operation of predefined contingency to prevent collapse of the grid.
WAPS	Wide Area Protection Scheme	This is probably occupies the middle ground between the smaller SPS (runback, intertripping, etc) and the synchrophasor WAMS systems.
WAN	Wide Area Network	-