Information Management of Intelligent Electronic Devices

Master of Engineering in Management

Jinqin Lo

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Executive Summary

Background

The advent of cheaper, more powerful substation relays, now commonly known as Intelligent Electronic Devices (IEDs), will have a substantial impact on Powerco information systems. Their impact is two-fold; the sheer volume of information associated with modern relays will require a more capable relay management system than the one currently being used. The second effect is the amount of data that can be gathered and used for network improvement. Improper management of both types of information will lead to worse outcomes for Powerco reliability performance, and ultimately its financial performance. This report details two projects concerned with the management of IED information.

Relay Management System

The first project is concerned with the proposed upgrade of the Powerco relay management system.

Goals

The goals of this project are to:

- Make a determination as to whether or not the existing relay management system is adequate;
- Establish stakeholder needs and expectations;
- Identify possible solutions;
- Evaluate possible solutions against stakeholder requirements;

Issues

The existing database in use, called “ePacer”, no longer performs satisfactorily due to the limitations with the underlying Microsoft Access 8.0 format (.mdb) and its current implementation as a single file accessed by multiple concurrent users.

Issues include:

- high maintenance costs;
- inefficient overhead from duplicate manual database administration;
- lack of data integrity;
- and data corruption;

Method

Stakeholders of the upgrade were identified. Then, stakeholder requirements were gathered through consultation with stakeholders. Requirements were then prioritised using the MoSCoW method. Possible options were then identified and evaluated on their technical and economic merits. The options are then screened for viable options using the MoSCoW criteria.

Findings

The status quo of continued use of Microsoft Access for this application was clearly shown to be untenable for Powerco in the long-term.

From analysis of stakeholder requirements, modification of the existing solution or custom development of a solution would be too resource intensive and risky. The best option for Powerco is procurement of an existing solution from a third-party vendor. This has the advantages of being less resource intensive to implement, and come with proven capability, endorsed by peer Electricity Distribution Businesses in Australasia and worldwide.

Due consideration must be paid to the IS enterprise architecture and data schema, so that the solution that is eventually procured and implemented, integrates well with Powerco IS systems and business processes.

Conclusions

It is proposed that a new relay management system is implemented. An RFI was conducted to gain more information on the solutions from four major vendors of relay management software (ASPEN Inc, DIGsilent, IPS Energy, Siemens). Preliminary evaluation suggests that all of these solutions will be able to satisfy Powerco requirements, but will require more information to discern the implementation requirements and costs.

Recommendations

It is recommended that Powerco progress to the RFP stage in order to glean the desired information and engage in a formal tendering process. This is likely to be executed in Q2 or Q3 of the 2014 financial year.

A Joint Requirements Development (JRD) session is suggested sometime in April, to crystalize requirements before embarking on an RFP process.

It is also recommended that Powerco reassess its standard requirements gathering process, so that there is less opportunity for mistranslation of stakeholder requirements. More effective methods such as user-stories are recommended for investigation.

Automated Event Report Collection

The second project is focused on the deployment of automated event report collection software.

Goals

The goals of the project are to:

- Determine the costs and benefits of deploying automated event report collection functionality;
- Identify additional resources required to attain the benefits of the additional data collected;
- Recommend the substation sites which this functionality should be deployed to;

Issues

Currently, there are issues with access to network event data collected by substation relays.

This results in inefficiencies such as:

- Manual notification of events;
- Dispatch of technicians to collect event data;
- Increased time required for event analysis due to time delay in receiving event data;
- Less accurate analysis due to incomplete information on network events;

This hampers the network improvement process, negatively affecting Powerco network reliability.

The main vendor of substation relays for Powerco, Schweitzer Engineering Laboratory, have recently developed a software package, acSELerator TEAM SEL-5045, that automatically aggregates event reports from remote substation relays. This is sold as add-on functionality on a per-25 relay basis and comes with a ready-made SQL server. Pre-requisite infrastructures include, IP connectivity and a SEL data concentrator.

Findings

Deployment of acSELerator TEAM to various Powerco substations will increase the amount of data collected, which should result in improved network reliability and more efficient engineering processes. It will also allow the shifting of operational expenditure to capital expense.

Though development of a custom automated event report collection software is possible, the costs and resources required would exceed the licencing costs of the solution offered by SEL.

Recommendations

This automated event report collection has been recently deployed on a trial basis, to 75 substation IEDs across the Powerco network (January 2013). Further deployment to select Powerco substations, based on service level agreements, customer impact, and substation equipment costs is detailed in Table 5.

It is recommended that data be collected from relays monitoring higher voltage sub-transmission circuits and substation assets due to the number of customers potentially affected.

Additional resources are advised for event monitoring and analysis. The level of additional resourcing required for data analysis is yet to be determined from the January trial.

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1. Introduction

1.1. Industry Drivers

The NZ electricity sector is divided into sectors; generation, transmission, distribution and retail. Powerco is an Electricity Distribution Business (EDB), delivering electricity from the transmission grid to end-users.

New Zealand's restructuring of the electricity sector in the 1980's has resulted in highly regulated prices for the distribution and transmission entities. (Bertram, 2012) For reasons due to natural monopoly, Electricity Distribution Businesses (EDBs) are subject to regulatory provisions under the Commerce Act 1986. Part 4 of the Act, the price-quality regulation sets out a default price-quality path, which determines:

- the maximum prices/revenues that are allowed at the start of the regulatory period
- the annual rate at which all EDBs' maximum allowed prices can increase - below the rate of inflation, expressed in the form of 'CPI minus X'.
- the minimum service quality standards that must be met.

Network reliability is one of the main performance measures by which the Commerce Commission regulates electricity distribution price. EDBs may incur penalties for breaches of the price-quality paths set in Part 6 of the Act. (NZ Commerce Commission, 2009). Other industry drivers include ageing assets, reliability and load growth. (Powerco Limited, 2012). There is also a global shortage of skilled technicians and engineers, which is expected to continue for the coming decades. (Centre for Energy Workforce Development, 2012). This drives the need for more efficient work processes, as skilled labour is increasingly more valuable. Network investments in expansion and maintenance are increasingly challenging to justify due to the price pressure from regulation.

The recent Commerce Commission reissuing of a draft price setting decision signals their intent to continue with the proposed reset of regulatory controls. (NZ Commerce Commission, 2012) There has been litigation by industry peers (notably Vector) over the regulatory control changes. However, it is expected that the current price-setting regime will continue. Thus, limiting maximum allowable revenue based on network reliability, total asset valuation, WACC and input cost from generation and transmission. The regime is expected to expire at the end of 2015 financial year, but the Commerce Commission is expected to renew this regulatory scheme. (NZ Commerce Commission, 2012)

There is an imperative for EDBs such as Powerco to enhance the power delivery network through improved network security, quality, reliability and safety in order to maximize revenues.

1.2. Company Background

Powerco Limited is the second largest gas and electricity distributor in New Zealand by number of customers, the largest energy distributor by network area. The Powerco network services the upper central and lower central North Island. Powerco electricity distribution lines span a total of 27,400 km stretching from the Coromandel, Western Bay of Plenty, and Hauraki Plains to the North East Waikato and from Taranaki, Wanganui, Rangitikei, and Manawatu to the Wairarapa regions. (Powerco Limited, 2012)

Powerco distributes gas and electricity to approximately 317,000 consumers, 46% of the gas connections and 16% of the electricity connections in New Zealand. 11% of NZ's annual electricity usage flows through the Powerco network. Total revenue exceeds $350 million per annum with approximately $1.8 billion in assets. The goal for Powerco is to ensure a safe and highly reliable supply of energy to its customers.

1.3. Organizational Overview of the Sponsoring Department

The department sponsoring this project is the Protection and Control department. Protection engineering is a discipline of electrical engineering, which deals with the protection of network assets from damage under adverse conditions, by isolating the faulted section of the network. This is accomplished using fast fault detection and selective switching to isolate only the components that are under fault, whilst leaving as much of the network as possible still in operation. (Army Corps of Engineers, 1991)

The Protection and Control department plays a critical role in the reliability of the network, and therefore directly influence Powerco earnings. Whilst network planners mitigate the number of faults through network design, the minimisation of duration and impact of faults is the domain of protection and control engineers.

1.3.1. Organizational Structure

The Powerco Protection & Control Engineering team as part of the larger Electricity Distribution Design department, act as an internal consulting group to various other business groups within Powerco. Key clients include: Electricity Planning, Network Operations, as well as external groups such as TransPower and large commercial and industrial customers.

1.3.2. Strategic and Corporate Goals

The Powerco protection system is required to cost effectively manage the electricity network in a safe and timely manner through achieving the following goals:

- To provide an economic and reliable power system
- To protect company and shareholder assets
- Provide a high degree of reliability
- Provide a stable power system
- Be fast, sensitive and selective for fault conditions
- Be secure and dependable
- To provide a safe system of operation

1.4. Technological Trends

1.4.1. Numerical Relays

Network reliability is achieved through the use of protective relays, which act as logical operators where certain switching actions will be undertaken under certain network conditions. Historically, these relays used to rely on electro-mechanical mechanisms in order to detect these conditions. These soon moved to electronic relays where the underlying detection and logic operations are performed using electronics (aka numerical relays). Increasingly sophisticated, powerful and cheaper computer processing power and communications has led to the advent of smart-relays that allow much more sophisticated network protection schemes and greater protection for network assets.

1.4.2. Intelligent Electronic Devices (IEDs)

Better communications technology has allowed for more sophisticated network protection and control schemes where a connected network switch can utilize information from other points in the network to act. Historically, cruder switches/relays would rely on local information, necessitating “blunter” control schemes. Further functionality has resulted from advancements in technology, extending the monitoring and control capabilities to switches that reside outside the substation and allowing all relays on a particular section of the network to act in coordination with each other. As such, modern relays are now termed Intelligent Electronic Devices (IEDs). (Hewitson, L.G. Brown, & Balakrishnan, 2005)

1.4.3. Communications

Communications technology has moved away from analogue technology to digital technology allowing for greater data throughput and manageability. This opens up numerous applications in network control, distributed intelligence, network automation and data collection.

Powerco are working toward implementing industry standard communications protocols. For SCADA communications DNP3 is the Powerco preferred standard. Emerging protocols such as IEC 61850, which covers all aspects of substation automation, including protection and control functions as well as SCADA functions and will become more prevalent. IEC 61850 requires Ethernet and TCP/IP communications and all indications are IEC 61850 could potentially become the standard for Utility companies.

Equipment in substations is becoming more intelligent and capable of generating much more data than previously. To access this data requires increased communication bandwidth and improved sharing of communication resources, which is achieved by utilizing TCP/IP on high bandwidth digital circuits. This will enable SCADA, Protection devices, Metering etc to report real time events and data to Powerco NOC. It must be acknowledged that although there is an increasing amount of data available from IEDs, not all of that data may be required.

The increasingly digital nature of communications means that close work with IT will be required to ensure Powerco keep pace with advancements in technology while also maintaining the integrity of Powerco IT systems and networks.

1.5. Sub-Projects

This project is split into two sub-projects, each dealing with a facet of information management of substation IEDs.

The first, described in Section 2., is concerned with the specification and procurement of a relay management system to replace the current Powerco relay management system.

The second sub-project, described in Section 3., is the business case and business plan for deployment of an automated event report collection system.

Whilst the two parts are correlated, they are treated as two separate projects for the purposes of the sponsor.

2. Relay Management System

2.1. Background

2.1.1. Business Need

The proper setting of relays is “crucial” to protecting network assets and ensuring that faults on the network do not adversely affect customers. Furthermore, the historical settings of relays are often used as an indicator of growth of that portion of the network that the relay is concerned with. As such, the proper management of relay setting information is paramount to a reliable electricity network. (Henderson, 2009) The growing number of relays and increasing complexity of the protection schemes mean that the importance of such information will only grow.

2.1.2. Current Situation

The existing database, known as “ePacer”, was a custom third-party developed database, built using Microsoft Access 97. It utilises a Microsoft Access front and back-end. The existing database was designed for two concurrent editors, but this no longer meets Powerco business needs.

Known issues:

- The multi-user read and write access is unsatisfactory, with speed issues and problems with data integrity due to the use of a lock file to synchronize read/writes for multiple users using the same file. (Access Programmers, 2009)
- Lack of data schema: The data is also free-form in that the user can enter the data in any way, which results in multiple forms of what should be the exact same input. This leads to difficulties in searches and reporting. (Micosoft Access Development, 2007)
- Easily corruptible due to the way Microsoft Access is structured. (Access Programmers, 2009)
- Existing database is a complete data silo, necessitating manual input of data and manual notification of changes to concerned parties. (Jones, 2011)

Due to these issues, the Protection Engineers and data specialists act as gatekeepers to the information, necessitating manual data searches whenever information is requested. All of this contributes to inefficiencies in workflow and also contributes to job dissatisfaction.

2.1.3. Project Aim

The purpose of this project was to examine the economics and benefits of upgrading Powerco protection equipment information management systems, primarily “ePacer” and to identify any opportunities for improvement in the handling of protection equipment information and protection data. The project will also cover the high-level planning phase, preparing Powerco for the upgrade.

An investigation of Powerco Ltd’s business requirements and IED capability is required to identify inadequacies of Powerco Ltd’s current protection IED management systems as well as identify opportunities for business improvement.

This will allow Powerco Ltd to make an informed decision as to whether an upgrade to its existing systems is justifiable and as to the best-fit solution. This will also prepare Powerco Ltd’s information systems and business strategy for the significant increase in data that will result from the transition to modern protection relays (Intelligent Electronic Devices, or IED).

2.1.4. Project Objectives

The key objectives are:

- Establish the scope and purpose of new protection IED information systems.
- Establish the stakeholder needs and expectations of the new system.
- Evaluation of possible solutions against stakeholder requirements.
- Ensure that solution fits with current and future Powerco Information Systems architecture.
- Provide insight into new protection IED capability so that benefits of additional information capture and storage can be quantified.

2.1.5. Scope

High-level scope:

- Stakeholder needs of the new system gathered.
- Business requirements and technical requirements detailed to a level sufficient to send out a RFP
- Business case for the upgrade of existing system detailed.
- Likely solution options evaluated against requirements set out from above.
- High-Level strategic document outlining benefits that can be obtained from additional data captured from protection IEDs

The results of the stakeholder consultations will define Powerco Ltd's business and technical requirements for the new relay management system, as well as provide the basis for the economic and technical evaluation of upgrade options. The implemented solution will interface with other programs and make information more accessible for critical engineering decisions. There is also opportunity to improve the current work process through more efficient organisation of data.

2.1.6. Benefits for Powerco

This process should result in:

- improved customer satisfaction due to consideration of business and user requirements in solution specification.
- Reduced costs of integration and maintenance due to better architecture fit of new protection database and data acquisition systems.
- Stakeholders and decision makers will be better informed of facts, costs, benefits and details so that a decision can be made as to whether or not to migrate to a new system.

Ultimately, the new relay management system should free up precious engineering time, and result in greater work efficiencies and job satisfaction for the Powerco Protection & Control department and its internal customers.

2.2. Methodology

2.2.1. Gathering Requirements

To ensure that the new relay management system, whether procured or developed, fits Powerco business needs, stakeholders must first be identified, then their needs and expectations detailed. This will require **extensive consultation with possible stakeholders**.

As the new system will have to be implemented and administered by the Powerco Information Services (IS) department, the new database will have to integrate into existing Powerco IS infrastructure, whilst bearing in mind future state architecture. Therefore one of the first requirements that needs to be gathered are the **architectural requirements of Powerco IS.**

Other requirements that will need to be gathered include the **users' expectations of performance, function and form** of the new system. These will be delivered in what is known as functional requirement form to differentiate them from the minimum technical specifications, also known as non-functional requirements.

Business requirements such as Service Level Agreements and training will have to be negotiated with vendors in the tendering process. This will require consultation with the stakeholders on the functions and performance needs of the new system. These are subject to negotiations, and as such, will be left out of the analysis until they are finalised in the RFP and tendering process.

To estimate the efficiency gains that can be made in the business processes, transactional costs were sourced from user estimates, as there is no formal time measurement for such tasks.

2.2.2. Request for Information

A RFI process was undertaken to assess the capabilities of various suppliers, in order to determine if there is an existing solution that will fit Powerco requirements with minimal customisation. The suppliers' responses were then evaluated against Powerco requirements in order to determine suitability for procurement. This will be followed in the future by a formal tendering process, if the existing solutions on offer closely match Powerco requirements.

2.3. Requirements Analysis

2.3.1. Stakeholders

The following stakeholders were identified, with the corresponding impacts of the project, at a high level:

Table 1 - Project Stakeholders and Impacts of Successful Project

Stakeholder	Primary Impact
Protection & Control Engineers	Direct improvements in workflow efficiency
Project Office	Have to resource and carry out implementation
IS Architecture	Integration of solution into systems
IS Data	Less time spent working around data inconsistencies
NOC	Greater data fidelity
SCADA	Reduction in information overload
Electricity Planning	Possibility to automate transfer of protection settings to network simulation software, thereby removing manual data entry.

2.3.2. Requirements

<u>See Appendix C and Appendix D</u> for the full list of functional and non-functional requirements.

An overview of the requirements of the new relay management system is as follows:

- Provide comprehensive integrated database for management of Powerco protection relays;
- Exchange data with ESRI ArcGIS, acSELerator SEL-5045, Seimens PSS Sincal;
- Be implemented on IS industry standard hardware, software and infrastructure platforms;
- Provide high levels of redundancy and security;

- Provide capability to import protection settings files from relays commonly used on the Powerco network;
- Provide change-log functionality for historical settings of protection devices;
- Provide customisable reporting tools;
- Incorporate the existing Powerco network device identifiers;
- Utilise existing Powerco infrastructure deployments and investments;
- Sufficient capacity to store current volume of records;
- Allow for future growth of Powerco business;
- Supply non-proprietary open architecture;
- Be supported by the Vendor (including patches and upgrades) for a minimum period;
- Consistent, satisfactory performance regardless of system load or access location;

2.4. IS Architecture Requirements

Current Powerco IS applications run on Windows Server 2008 R2 and are delivered by virtualization using Citrix. Therefore any solution considered would have to be compatible with these delivery platforms.

In addition, an open database and query methods are required so that the internal IS team may develop custom query and reporting tools that would be best suited to its own user needs, as these may not be economical for the solution vendor to develop. The current preferred database management system is MS SQL Server.

2.5. Evaluation Criteria

2.5.1. Screening Criteria

The solution **must**:

- Integrate into Powerco IS Structure
- Be able to be implemented on existing Powerco standard computer and networking hardware
- Be scalable to Powerco business needs
- Meet investment objectives, desired outcomes, business needs and service requirements
- Be likely to be delivered given the organisations capacity to respond to the required level of change
- Match the level of available skills that are required for successful delivery.
- Meet the sourcing policy of the organisation given funding constraints

Options that do not adequately address these specific criteria cannot be considered viable.

2.5.2. Essential Evaluation Criteria

The solution **should** address these criteria at a minimum:

- Alignment
- Costs
- Implementation
- Capacity
- Risk
- Benchmark
- Policy
- Standard considerations

2.5.3. Desirable Evaluation Criteria

Options will be evaluated on:

- Cost of implementation
- Resources required for implementation
- Fit with IS infrastructure and work processes

2.6. Possible Options

2.6.1. Status Quo

Maintaining the status quo would involve continuing to use the existing MS Access based solution. The database is implemented in .mdb format with VBA front-end, which requires MS Access 2003 or earlier, which is only supported up to Windows XP and Windows Vista.

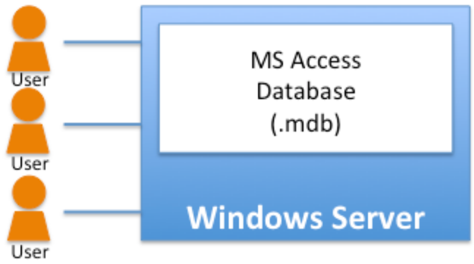


Figure 1 - Current architecture

2.6.2. Modify Existing

This would involve splitting the database and front-end so that each user would have a separate front-end containing the queries, forms, reports, macros etc., linked to a back-end database stored on a shared drive. (FMS, Inc., 2007). Modifications can be made to the front-end to force user inputs into a certain data structure.

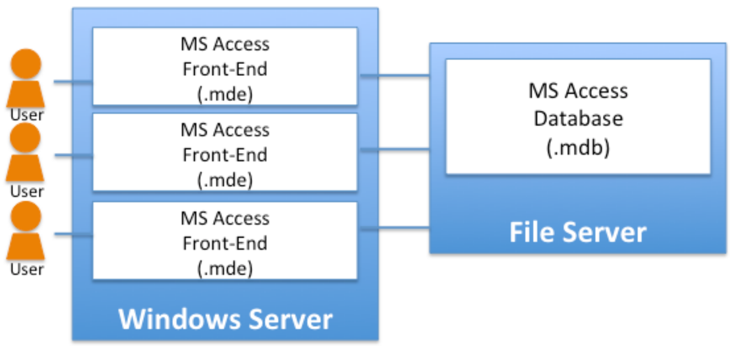


Figure 2 - Split database

Another option is to abandon the MS Access front-end entirely in favour of a web-based application, while maintaining the MS Access back-end. (S. Harkins, 2008) Doing so creates an ad-hoc server-side database that handles transactions on the server (using custom code of choice). Requests from the client are in Hyper Text Transfer Protocol (HTTP) format.

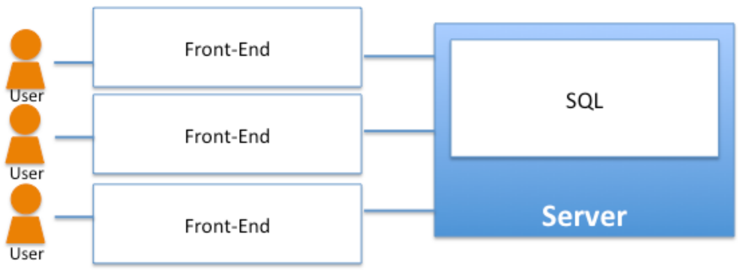


Figure 3 – Client-Server architecture

There is the option to migrate the data into an SQL database, which would provide the database performance Powerco is seeking. (Haught, 2004)

2.6.3. Buy

This option involves the procurement of a solution being offered by several vendors, purpose made for relay information management. There are 4 main suppliers of off-the-shelf relay databases for power systems:

Vendor	ASPEN Inc	DIGsilent	IPS Energy	Siemens
Solution	ASPEN Relay Database	Stationware	IPS-EPIS	PDMS

There are also relay manufacturer specific solutions from: SEL, GE, Alstom, ABB (there are many other relay manufacturers, but these are the predominant brands which comprise the Powerco numerical relay fleet).

2.6.4. Build

This option involves the development or modification of a similar system to meet the business needs of Powerco. For example, modification of a general-purpose relay databases built by vendors such as ENOSERV (Powerbase) and RES Software (Workspace Manager Relay Server), which are not specific to the power industry but may be repurposed with some effort.

The other options include commissioning development from the current SCADA systems provider for Powerco, OSI. This has the advantage of integrating better with the existing SCADA systems.

Oracle UODM is a database solution recently developed by Oracle for smart grid device management. It is a new product and its capabilities more suited for consumer facing devices such as smart meters. It only interfaces with communication relays, and as such its capabilities are not suited for the desired application. (Oracle, 2012). It is developed in Oracle database formats which Powerco are looking to retire.

2.7. Screening of Options

User requirement statements were prioritised using the MosCoW method (Haughey, 2000), with the most important requirements designated a “M” priority. The “M” stands for Must, and denotes that requirement as critical to meeting business needs and project success. Therefore, any solution that does not meet a requirement marked with “M” should be discarded as unviable.

2.7.1. Status Quo

As of now, the Protection and Control team spend a total of 4% of their total annual man-hours administering the database alone. This does not include the extra time spent by a dedicated data specialist from the IS department, cleansing data and performing queries to attain the information. It is estimated that inefficiencies arising from data integrity, costs anywhere from 2-24 man-hours a month to extract the desired information because some of the data is not easily accessible. That represents a significant drag on resources that could be liberated for more useful work.

There is also the additional work created by the manual process of notifying various groups of relevant changes to the settings database. E.g. As-built drawings going to GIS operators to update the GIS data would require an as-built form being filled out which would take whoever was filling out the form 5-10 minutes, in addition to the 30 minutes or so it would take the GIS operator to update the data. There is additional unnecessary work created by the manual entry of that data into multiple databases. Consider the doubling up of work on the protection engineers, entering the settings changes into the protection database and filling out a paper form for issue to technicians to apply to the appropriate relay.

Since Powerco is moving to a purely Windows 7 environment (upgrade deployment schedule commences on 11 February 2013) and already uses MS Office 2010, supporting ePacer would require additional support for the aging MS Access 2003. It should also be noted that Microsoft are ending extended support for MS Access 2003 by April 2014. (Microsoft, 2013). Given that the number of settings is going to increase exponentially due to the number and complexity of newer relays, this is going to amplify the effects of the current issues.

2.7.2. Modifying Existing Solution

Splitting the database may solve many of the problems currently experienced by the users. However, it does not address underlying concerns of data integrity and future Powerco requirements due to the inherent problems with MS Access.

There may also be use cases where the data may need to be made accessible on the web or to remote users, in which case is a good reason to abandon the investment in the MS Access front-end. For example, Powerco may desire technicians or SCADA engineers to have access to settings information, in which case it is prudent or even most efficient way of making accessible that information.

This web-based front-end has the advantages of simplified security, and transfers the work to the server side, freeing up network bandwidth and speeding up queries. It also obviates the need for MS Access licences, a potential saving. (S. Harkins, 2008). However, this is still a relatively novel technique that will require development on the part of Powerco. Powerco have stated their preference against such development efforts.

Migrating to an SQL back-end will address performance concerns and data integrity issues. (Microsoft Corporation, 2003). However, this requires significant development work preparing data schema and relay settings templates. Such costs are probably on par with licencing costs from an off-the-shelf solution without advantages such as system support, implementation speed, and proven capability.

2.7.3. Buy

Whilst expensive, the ready-built solutions on offer would require less resources than a custom developed solution, and gives some assurance as to its reliability and fitness for purpose as these solutions would already be in use by other network operators similar to Powerco. Other advantages include proven data schema and templates for setting configurations already built into the solution. (Henderson, 2009)

The relay manufacturer specific solutions will not have the capacity to accommodate the entirety of the Powerco protective relay asset base and therefore fail to meet business requirements.

2.7.4. Build

These are unlikely to offer much customisation advantages compared to off-the shelf options listed in section 2.6.3. Any customisation required to get another product fit for IED management purposes is unlikely to meet cost objectives. There are also the added risks due to the developmental nature of such a project.

Table 2 - Option Screening Summary

Options	Screening Summary	Rational
Option 1: Status Quo	Discounted but retained as baseline	For comparison with viable options.
Option 2: Modify Existing	Discounted	Does not address underlying data integrity issues
Option 3: Buy	Viable	Proven application with existing customers. Less resource intensive
Option 4: Build	Discounted	Too costly and too resource intensive

2.8. Viable Options

2.8.1. Status Quo

Even though maintaining the status quo was ruled out as a viable option, it still forms the base case and must be included for economic analysis.

Table 3 – Estimated economic cost of maintaining status quo

Addressed inefficiency	Time saving (FTE)	Stakeholder impacted
Database administration	0.20	Protection and control engineers
Slow or inaccurate database queries	0.10	Information Services
Manual notification of setting changes	0.76	All stakeholders
Maintenance of legacy software	0.10	Information Services

2.8.1. Buy

A formal RFI process was initiated, with invitations to respond sent to the 4 vendors listed in section 2.6.3.

Three of the four vendor solutions offer Oracle based databases, whilst all four indicated that their solutions supported implementation in Microsoft SQL Server. Two of the four vendors indicated that their solution supported an alternative file-server implementation using a Microsoft Access back-end. This is similar to the "Modify Existing" option suggested in section 2.6.2, but has the advantage of ready built templates and data schema.

Migrating from a MS Access based database to an SQL structured one is most probably prudent given the data integrity concerns and the likely growth in the number of settings per device, as well as device proliferation itself. This aligns with Powerco preferred practice of using SQL server as well as Powerco future state enterprise architecture.

All ready-built solutions considered in this section meet most of the core requirements expressed by Powerco stakeholders. The vendors offering these solutions are well established and stable with many references in the electricity industry utilising their product.

Other information is needed in order to further define the internal resources required to implement the solutions on Powerco IS architecture.

A preliminary evaluation of vendor solutions against Powerco stakeholder requirements can be found in Appendix E.

Vendor responses and indicative pricing schedules have been omitted due to the commercially sensitive nature of the information supplied.

Figure 4 and Figure 5 (in standard BPM notation) show the simplification in work-flow that results from a better connected database. Tasks highlighted in green are those that have been automated, thereby saving

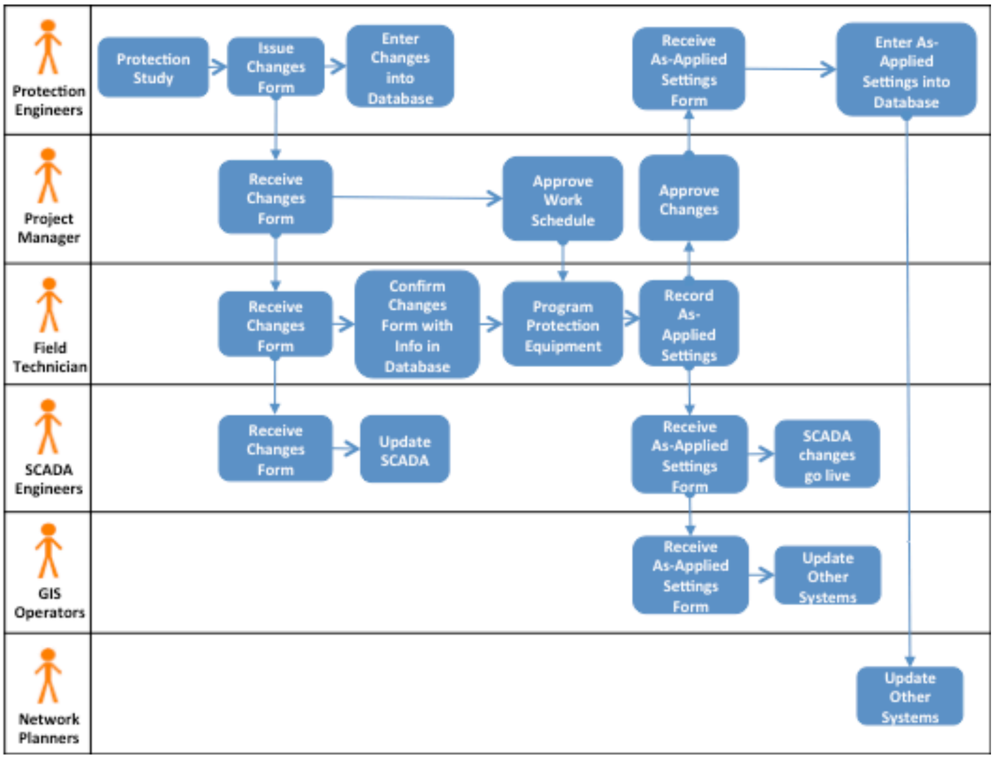


Figure 4 - Current protection settings change work-flow

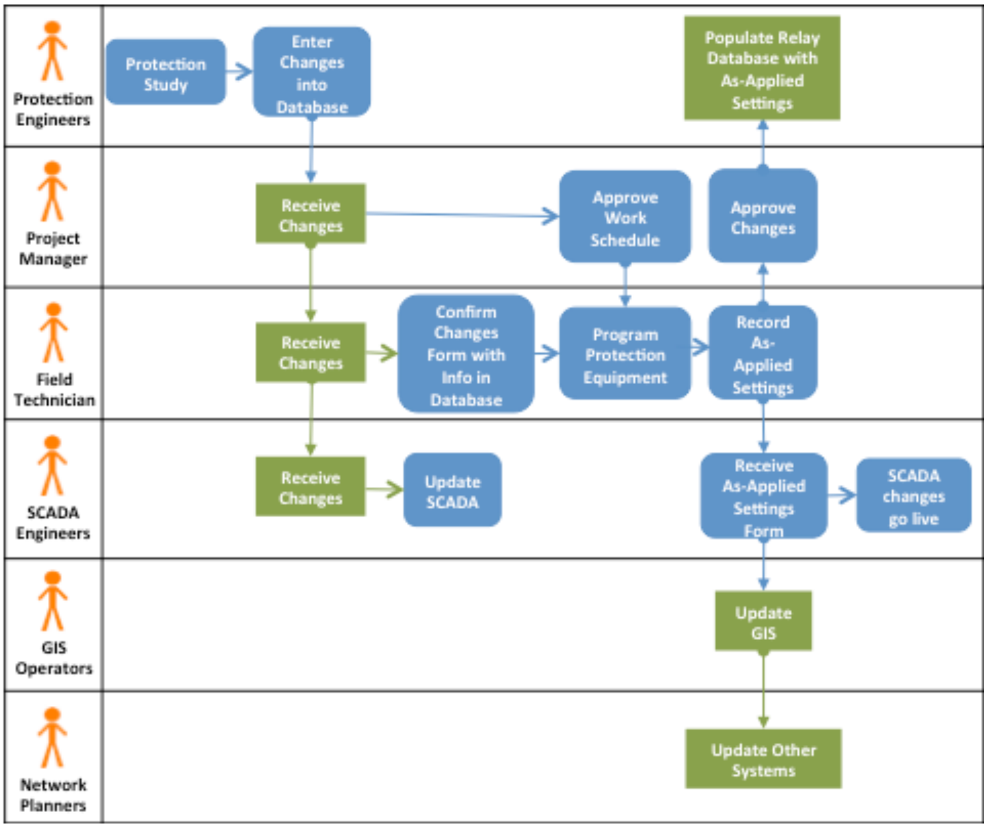


Figure 5 - Improved protection settings change work-flow using connected database

2.9. Conclusions

2.9.1. Status Quo Not Viable

Maintaining the status quo is untenable. There will be continuing problems with data integrity and inefficiencies arising from difficulty extracting information from the database. Equally clear is that modifying the existing solution won't eliminate the systematic inefficiencies due to the inherent limitations of Microsoft Access.

2.9.2. Viable Options

Procurement of a ready-built relay management database should address most users' concerns. From the preliminary requirements gathering stage and RFI responses, it looks like the solutions from all the vendors will fit Powerco requirements with little customisation. This is not surprising as these are already in use by many other utilities companies, who are likely to have similar operating requirements.

2.9.3. Procurement of Solution

At this stage, there is too little information to make a decision to procure a solution given that the cost of integrating the different solutions has not been clearly defined yet. Other clarifications will need to be sought from vendors as to whether the other requirements are satisfied by their respective solutions.

An RFP or other commonly accepted form of solicitation would allow Powerco to elicit more pertinent information and inform its future tendering efforts.

2.9.4. Risks

The data schema may not fit Powerco protection settings workflow. Because the relation model databases that the commercial packages offer are relatively rigid in data structure. Great care must be taken to model the business processes comprehensively and translate these so that the data schema fits user requirements. Failure to do so will result in non-trivial amounts of IT effort and time to add new fields to the data tables.

Particular attention should be paid to the types of models used to capture data semantics and constraints. Certain models may exclude certain business processes due to the manner in which information is presented. (Ramakrishnan, 1999)

There could be a risk that the designed capacity may be exceeded by actual workload as greater input volume may be afforded by the greater efficiency of the new system.

2.10. Recommendation

As Powerco are still in the early stages of procurement, and have not officially issued an RFP, there is still time to crystallize requirements and seek other options. **When Powerco are satisfied that the requirements gathered are comprehensive, they should proceed to the RFP stage** to get a clearer picture of the resources required for integration and implementation.

A Joint Requirements Development (JRD) session is suggested to sharpen the requirements before submission to vendors. Given the amount of work pre-Christmas and the months leading up to April used to prepare regulatory reports, **further consultations and a JRD are suggested for April 2013.**

2.10.1. Data Cleansing

A data "cleansing" exercise will have to be undertaken for any of the "non-status quo" options to remove corrupt or erroneous records, and align the data into a structure which makes it easy to search, thereby eliminating the time consumed by the formulation of stop-gap measures. This will also make it easier to migrate the data from Access to SQL Server. (J.I. Maletic, 2000)

Each relay record will have anywhere between hundreds to thousands of settings depending on relay sophistication, the number of changes and the complexity of the protection schemes. Based on historical work-rate for record checking and correction, **data cleansing will take approximately 1200 man-hours, or 0.6FTE.** This one-off expense should be planned and budgeted for once the data schema is finalised.

2.10.2. Implementation Plan

The next step in the process is a formal tendering process. The preferred method (for Powerco) for software tendering processes is to **distribute Requests for Proposals to a narrowed set of likely vendors.** This will allow Powerco to get a more precise "picture" of the costs and effort required of the internal IS department to implement and integrate the new system. An RFP has already been drafted based on the requirements gathered from stakeholder consultation so far.

Powerco Project Office (the implementers of any new software) has indicated that sufficient budget and **resources will be available for procurement and implementation sometime between Q2 and Q3 of the 2014 financial year.** This gives ample time to review requirements and go through the formal RFP process to select a likely vendor. Planning for the upgrade can then be undertaken.

In terms of performance tracking, Powerco should see improvement in the workflow efficiency. This can be measured by the time spent by the protection engineers on database administration. This is already logged as a separate task item for time tracking.

2.10.3. Process Improvements

The list-form of requirements that Powerco required may not be the optimal way to present its requirements to potential vendors. Whilst the list was very short, relative to that used in much larger, more complex projects, some potential issues were evident in the application of this particular method.

The list form does have several advantages: it provides an easy checklist for Powerco to check that its requirements have been recorded; it is easily convertible into contractual form; requirements are easily categorized and assigned to different development groups.

However, the abstraction necessary to translate requirements to list form mean that dependencies and relationships, be they between stakeholders or system components, are lost. These are critical in more complex systems to describe how the requirements fit together. Lack of a holistic view for the developer may result in a less than optimal solution that the issuer of the tender may require.

The list form also requires substantial effort from the person(s) liaising with the stakeholders in order to capture a comprehensive list. It is overly reliant on stakeholders to point out gaps in the list. What was discovered during the project was that the checklist style required paramount communication between stakeholder and liaison. Ideal/success of such a project relies on the needs of the stakeholders being translated perfectly, from the stakeholders themselves to the business analyst/project manager/liaison, and from the liaison to the vendor/developer via the requirements. Any improvement that can be made in order to improve the fidelity of the requirements throughout the entire process would result in a more efficient process.

The contractual nature of the list form also might mean that the issuer of the tender may preclude certain solutions which may meet the needs of the issuer, but do so in an unorthodox manner which may not conform to the listed requirements. Other difficulties may include ensuring that technical domain language is translated to a form that will allow the vendors to present a solution that fits the user needs. Great care is needed to ensure this does not happen, which often requires the liaison to have knowledge of both domains.

This project is somewhat unique in that custom development or modification of an existing solution is not preferred due to resource constraints on this activity. Powerco also has a preference for conservative approaches for mission-critical databases, and the proven capability carries a lot of weight. However, for more complex projects or custom projects, these hazards around the check-list form of requirements could significantly influence the direction and quality of the solution, or require additional expense to further develop the solution so that it is fit for purpose.

It is recommended that Powerco investigate the incorporation of requirements gathering techniques such as user stories or the “Agile” method. These techniques remove part of the process involving translation of user requirements. Instead they pose questions aimed at elucidating the root problems encountered by users rather than what solutions users envision will solve the problem. (P. Abrahamsson, 2002) This also allows greater flexibility for tendering parties to offer a solution that may solve the problem in an unorthodox manner, but one in which the solution better fits user needs than if a traditional requirements gathering process was used. (VersionOne Inc., 2008)

3. Automated Event Report Collection

3.1. Background

3.1.1. Project Background

This project is concerned with the collection of data generated by abnormal events on the distribution network. At the moment, more modern numerical relays collect and store the waveforms of network events locally. Each of these event files store data such as the phases involved, duration and relay elements affected by the fault. This data makes fault analysis easier and allows improvement in protection scheme design. Access to this sub-cycle data is by way of remote access via HSPA+ enabled UMTS modem, or dispatch of a technician to the physical site to download the information. The advancement of technology has allowed for the real-time monitoring and recording of network behaviour via communication between "smart relays" or "Intelligent Electronic Devices" (IEDs), and a central repository where event reports are automatically collected. In some cases, such event records may be requested for auditing purposes by regulatory authorities or for utility insurance purposes.

SEL have developed a program that will automate collection of event reports from SEL branded relays. The program is called "acSELerator TEAM SEL-5045". It provides the infrastructure for communication with SEL relays, automatic collection of data, creation of reports, warnings and alarms. It also provides a central SQL database, remote configuration of relays, importing of settings. This automated event report collection has been recently deployed on a trial basis, to 75 substation IEDs across the Powerco network (January 2013).

3.1.1. Business Need

Network protection improvement is an iterative process involving periodic reviews and the integration of protection scheme performance data into future design decisions. However, a lot of data is not gathered or categorised. Only events that develop into hard faults, or are deemed to be unusual tend to be investigated. This requires an investigation to be requested of the protection engineering team by other parties, usually network planners or NOC for more urgent matters. This reactive approach precludes data collection for a lot of intermittent faults, which still contribute to the Powerco SAIDI footprint and may also be symptomatic of systematic network behaviour that may develop into further outages. Where data is collected, there is often a large backlog of data from multiple events. This makes it difficult to attribute event data from protective relays with that from the SCADA system.

Currently, network events are recorded after they happen and require manual reporting or dialling up a relay to obtain fault records, these delays in obtaining event files increases the amount of time required to resolve faults on the network. Other factors include the limited number of technicians available, which may exacerbate the time between event and report collection.

To improve network reliability, Powerco would like greater insight into fault inception so that the root causes of difficult to diagnose faults may be addressed before an actual disruption to electricity supply manifests. Implementation of automated report collection on the worst performing feeders will give greater transparency into events and reduces administration work required of NOC in notifying the Protection engineering team of events. It is proposed that the automated event report collection system be further deployed to capture this previously ignored data.

3.1.2. Project Aim

The aims of this project are:

- To prioritise Powerco substations for implementation of acSELerator TEAM functionality;
- Explore the costs and benefits of automated event report collection;
- Elucidate further actions and resources required to fully leverage the data collected.;

3.1.3. Scope

The number of possible numerical relays after replacing all obsolete relay types is 1467, not including relays in substations that will be built in the future. Given a licencing cost of NZ$3500 per 25 devices for the life of the device. This represents a possible licencing spend of $206,500, not including prerequisite infrastructure such as data concentrators and IP connectivity, which would bring possible spending over NZ$1,000,000.

Powerco has budgeted $50k per year for implementation, to be spread across all components required to get SEL-5045 operational at each substation.

The project will not take into account additional costs for additional resources required to leverage the data. Instead, these will be highlighted for future analysis.

Estimation of benefits will be strictly limited to qualitative analysis due to dependency on magnitude of random events.

3.2. Methodology

Reliability figures, where available, are taken from the 2012 network fault register. Improvements in reliability are notoriously difficult to measure due to the random nature of faults. They can only be measured on a long-term basis for the data to be statistically meaningful. It would be more meaningful to use substation security ratings, as these are the service levels Powerco has to uphold. Only then is historical reliability and magnitude of impact used to prioritise the substations within their respective security classes.

The costing figures used in the analysis were derived from historical spending/costs. These should closely represent likely future costs. These won't take into account the varying exchange rate. SEL headquarters are based in Washington, USA and all purchases are paid in US$. When Powerco purchase relays, SEL normally quote an adjusted exchange rate based on the spot price in the market. As such, the price of SEL products varies with the strength of the NZD/USD exchange rate. As of the time of writing, the purchasing power of the NZD is historically strong. For the purposes of this study, a relatively conservative estimate of $NZ1 to $USD 0.72 was used.

The primary quantifiable savings, as stated in the cost-benefit analysis section is the technician dispatch time. Costing information from this was derived from the standard charge-out rates for travel and labour. Installation of IP connectivity and data concentrators were then prioritised based on distance to substation from technician depot. The only meaningful breakeven point that can be calculated is the number of technician dispatches on a per-site basis before the cost of modem/modem + data concentrator is recovered.

Assets considered here will have no residual value, and have a life of 15-30 years.

3.2.1. Dependencies

IP connectivity and a SEL data concentrator are prerequisite infrastructure for acSELerator TEAM functionality. The near-term plan will have to factor in the cost of furnishing substation sites without these components.

Consideration must be given to the replacement of switchboards, to ensure that no inefficiencies arise from the installation of relays into a switchboard that will be replaced within 5 years. A comparison is to be performed between the Protection Asset Management Plan and the Asset Renewal Plans to ensure that such conflicts are resolved before work is undertaken.

3.3. Cost – Benefit Analysis

3.3.1. Benefits

The added data will help validate network models and designs, aid in disturbance investigations and help in assessing system protection performance. (New York Independent System Operator, 2011)

Early detection of high transient faults allows proactive investigation of events before they develop into outages. It also **reduces the time required for fault analysis** as delays in investigations can be caused by delays in retrieving event files. The collected **data can also be analysed for further improvements** to the network such as improving accuracy of distance-to-fault protection schemes.

Where causes of **faults previously undiagnosed are identified and remedied**, will represent a network reliability improvement. These faults are most often intermittent and often go undiagnosed or unrecorded as they do not immediately develop into a hard fault, thereby reducing their urgency.

There is also **time saved from the reduced need for the Network Operation and Control (NOC) to request investigations or for Protection engineers to dispatch a technician.**

Figure 6 - Current event reporting workflow

The current workflow necessitates screening of which events are investigated by NOC. This introduces a delay between event occurrence and when data is collected. The prolonged time between event and report collection, may sometimes lead to event data being over-written from multiple events occurring before report collection, due to limited relay memory. .

This selective process also biases the data set, and there may be hidden symptoms that go unaddressed as a result. Other issues such as time-stamp syncing between SCADA records and relay records are introduced due to this delay.

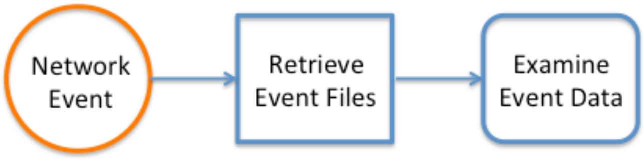


Figure 7 - Automated event reporting workflow

Implementation of an automated event report collection system will **reduce the manual notification and event report collection workload.** The automated collection of data will also **turn the network improvement process from reactive to proactive**, which may translate to improvements in network reliability.

One of the economic benefits of deploying SEL TEAM software is the **reduced need to dispatch technicians** to substation sites to download event information. This will represent the main quantifiable economic driver by which IP connectivity and data concentrators will be assessed. The substitution of technician dispatch with IP connectivity and data concentrators, means that the **expense of obtaining event data can be capitalised instead** of viewed as operational expense.

The value of the functionality is dependent on the accessibility of the substation and the value of the information. The value of the information increases with the number of intermittent faults and for circuits with lower reliability. Since Powerco would like the data from intermittent faults, we base the value of the information on the time that could have been spent by the technician to gather that information. The value of that information is highly dependent on the underlying cause of the fault and if that is systematic, identifiable and can be "designed against".

The **possibility to diagnose faults before the faultman arrives/searches for the fault** can represent some savings, but that possibility is dependent on the resources assigned to such "on-call" analysis. This assignment of resources is yet to be determined and as such the costs and benefits of this will not be included in the business case.

3.3.2. Costs

The effort already expended in setting up the trial should be considered as sunk cost, especially SEL TEAM software setup. This work will not need to be replicated and further rollout of SEL TEAM to other devices can be considered as marginal incremental costs.

As the cost reductions can only be attained in substations utilizing SEL relays, only these and future installations utilizing SEL relays shall be considered in the economic analysis. This also means that if another relay manufacturer were to be used, additional spending will have to be made to achieve similar functionality and benefits. Further more, these sites must have an Ethernet connection (or similarly fast IP connection, e.g. Unimax modem, fibre) in order for SEL TEAM to be able to work. This cost will have to be factored into sites not already utilizing these for other purposes.

IP connectivity from the substation to the central report server can be accomplished using optical fibre connection or **Unimax modems are approximately NZ$1000 per unit with a further $500 associated with installation.**

SEL TEAM licences are sold on set number of devices per licence scheme, at NZ$3500 (exc. GST) per 25 devices. These licences are static to the device for the life of that device. SEL's sales representative for NZ, Fraser Engineering have indicated verbally that further licence cost reductions can be attained for mass purchase of licence. This has not been taken into account and the standard rate of NZ$3500 per 25 devices has been used as the licencing costs.

The **cost of a SEL 3530 data concentrator is NZ$9038,** (latest figure, circa March 2012, project EE 10 203). Substations with an existing SEL 2030 or SEL 2032 data concentrator won't have to be upgraded for SEL TEAM functionality, and any upgrades will be considered external to this costing exercise.

Table 4 - Cost components for all items required to deploy acSELerator TEAM

Item	Units	Cost (NZ$ exc. GST)
IP Modem (Unimax)	1 (per substation)	$1500
Data Concentrator (SEL-3530)	1 (per substation)	$9038
acSELerator TEAM Licence	1 (per 25 relays)	$3500

All dollar amounts quoted are exclusive of GST.

See Appendix F for equipment breakdown by substation.

3.4. Sensitivity Analysis

3.4.1. Variance in Benefits

The various potential benefits of the acSELerator TEAM software are highly dependent on the duration, frequency, location, and nature of outages on the network. These parameters are random by nature, by definition, making them impossible to forecast in the long term. As such, the benefits can only be measured retrospectively, after they have occurred and estimating what would have happened given the circumstances and conditions.

3.4.2. Variance in Costs

The costs of equipment are unlikely to vary much in the near-term, given that a conservative long term NZ/USD exchange rate has already been taken into account in the above analysis. Labour rates for installation are unlikely to vary much in the short term.

The cost of monitoring and analysing incoming data may well outstrip the cost of the licences alone. There is a lot of uncertainty about the volume of data that could be received as this varies depending on many factors. Likely volume of data that can be gathered will only become clearer after the January trials.

As of now, Powerco has 633 of 2079 relays in its substations are “numerical” type. 603 of that 633 are SEL branded. The remaining relays are of obsolete Electromechanical or Static type, and are to be replaced with newer numerical relays. Whilst not strictly exclusive, Powerco current practice is to use SEL relays in substations. This means that any additional costs at this stage are marginal as the initial overhead required to setup the report server et al. will not need to be repeated.

3.4.3. Alternatives

An alternative method of obtaining the desired event data would be to write custom programs to automate the remote dial-in and download of relay event data. However, the cost of building and implementing a custom report server is likely similar to or exceeds the potential software licence fees for the entirety of the Powerco network. Development of custom software also carries major cost overrun risks for Powerco.

3.5. Conclusion

3.5.1. Benefits

The procurement of a real-time automatic fault report collection system will increase event response time, resulting in greater network availability and increased efficiency in Protection Engineering time/work. There are also reliability benefits from network improvements that previously were not possible due to lack of accurate data.

Such functionality does have value for Powerco. Given the implementation costs and effort is relatively small for the amount of data gained, this functionality is worth deploying to substations with requisite infrastructure in place. For substations without data concentrators and require significant travel time for the technician to access it, the savings from remote engineering access outweigh the costs of installing a data concentrator.

3.5.2. IP Connectivity and Associated Benefits

Based on current trajectory, Powerco communications infrastructure will tend towards IP in the future. This is aligned with the work that will go into connecting substation relays to a central database using SEL TEAM and IP connectivity. This background infrastructure also opens up many applications, which can utilise the IP connection with the addition of a router or switch.

The greater IP connectivity also allows faster, finer tuned distributed automation schemes, potentially resulting in greater reliability savings.

3.5.3. Additional Engineering Resources

There is additional engineering time required for monitoring of event reports received from the automated reporting system. This cost has not been included in the analysis, but it is expected that the additional benefit of detecting events before they develop into faults will more than cover the cost. However, it is difficult to quantify the additional man-hours/FTEs required for this monitoring effort, as this is highly dependent on the type and number of faults.

In the future, due to the sheer volume of information that can be gathered, will exceed the engineering time available for analysis. There will be a requirement for automated software analytics to automatically categorise different types of events. The possibility of such a capability should be investigated, once the findings of the current trial are compiled and analysed.

Assignment of more resources to data mining capabilities will increase the value of the data collected. Further investigation is required to determine the cost and benefit of better data mining capabilities. At this stage however, it is not clear what additional resources are required to analyse all the data that will be collected.

3.6. Recommendation

Since the trial is less than a month old, as of the time of writing, the additional engineering time required to analyse the collected data is unclear. This will need to be measured as part of the trial and taken into account at the next review stage. For now, deployment should be scheduled cautiously until the full resource implications are studied.

Presented below is a tentative deployment schedule for the next 3 years:

Table 5 - Recommended deployment schedule

Year	Substation	Unimax Modem Required	Data Concentrator Required	Number of Licenses Required	Total Cost
2013	Whangamata	1	0	3	$46,500
	Tauranga	1	1		
	Omokoroa	0	0		
	Te Ore Ore	1	1		
	Taihape	1	1		
	Akura	1	0		
	Sanson	0	0		
2014	Milson	1	1	2	$49,150
	Norfolk	0	0		
	Awatoitoi	1	1		
	Pongoroa	1	1		
	Wanganui East	1	1		
2015	Whitianga	1	0	3	$54,150
	Kelvin Grove	0	0		
	Otumoetai	1	0		
	Kempton	1	1		
	Bell Block	0	1		
	Gladstone	1	1		
	Mangamutu	1	1		
	Clareville	0	0		

- The substations targeted in this schedule are those with inherently poor reliability and where data is scarce. This is likely where the automation of event data collection will make the greatest impact.
- The deployment schedule should be reviewed once a year, each time changing the parameters based on reliability figures and asset renewal profile.
- Expenditure on this project should be funded from the Capital works budget as the infrastructure can be capitalised.
- Training of engineers to utilise acSELerator TEAM should be allocated in the budgets to be able to take full advantage of software functionality and data collected.
- Additional research and development time is suggested for investigation of automated fault identification software.
- Collection of data from relays monitoring higher voltage sub-transmission circuits and substation assets must proceed by virtue of number of customers potentially affected, even though they are by design more reliable.

4. After Action Review

4.1. Relay Management System

4.1.1. What was planned?

The purpose of this project was to investigate the possibility of upgrading the existing Powerco relay management system or replacing it. The original objectives were to:

- Make a determination as to whether or not the existing relay management system is adequate;
- Establish stakeholder needs and expectations;
- Identify possible solutions and evaluate those against stakeholder requirements;
- Follow through with an RFP process

The stakeholder requirements gathering process was originally scheduled for the first two weeks.

4.1.2. What actually occurred?

The requirements gathering process took much longer than expected. This delayed the RFP process such that it was no longer was possible to complete before the end of February 2013. An RFI was used instead to gain information on the identified options, sufficient to make a preliminary evaluation of 3rd party solutions.

4.1.3. What went well and why?

Constant consultation with certain stakeholders resulted in several revisions of particular requirements. The assumptions underlying certain requirements were constantly challenged. This meant a stakeholder requirements list that would more closely resemble Powerco business needs.

4.1.4. What can be improved and how?

The stakeholder consultation processes could have been streamlined by explicitly stating to each stakeholder the level of commitment expected of them in the requirements gathering phase. At times, this was not clear to certain stakeholders, which resulted in the “brushing off” of a few consultation sessions.

4.2. Relay Management System

4.2.1. What was planned?

The purpose of this project is to explore the costs and benefits of deploying acSELerator TEAM across the Powerco electricity distribution network. This was originally planned as an investigation into the types of data that could be collected from network monitoring. The value of the data was supposed to be quantified.

4.2.2. What actually occurred?

It became clear that quantitative analysis of benefits would be inaccurate as the benefits are reliant on the occurrence of random network events. This forced the direction of the project to change, and it was decided that the costs and benefits of acSELerator TEAM would be the focus of the project.

4.2.3. What went well and why?

The prioritisation of substations for deployment of the software was relatively trouble-free once the existence of pertinent equipment was ascertained. This is due to the strong regulatory framework developed by Powerco for prioritisation of different load types.

4.2.4. What can be improved and how?

The analysis could be extended to include future substations to provide a more comprehensive plan.

References

Access Programmers. (2009, January 1). *Corruption Issues.* From Access Programmers: http://www.access-programmers.com/corruption-issues.aspx

Army Corps of Engineers. (1991). *Coordinated Power Systems Protection.* Washington DC: Headquarters U.S. Army Corps of Engineers.

Bertram, G. (2012, April 13). Paths Not Taken in Electricity Restructuring: Alternatives to the Asset Sale Programme. Wellington, Wellington, NZ: Institute of Policy Studies, Victoria University of Wellington.

Centre for Energy Workforce Development. (2012, February 15). Gaps in the Energy Workforce Pipeline. *2011 CEWD Survey Results* . Washington DC, Maryland, USA.

FMS, Inc. (2007, May 1). *Splitting Microsoft Access Databases to Improve Performance and Simplify Maintainability*. Retrieved November 5, 2012 from FMS: http://www.fmsinc.com/MicrosoftAccess/DatabaseSplitter/

Haughey, D. (2000, June 2). *MoSCoW Method*. Retrieved October 28, 2012 from Project Smart: http://www.projectsmart.co.uk/moscow-method.html

Haught, D. (2004, August 20). Strategic Initiatives: Evolving Microsoft Access Applications to Microsoft SQL Server. Vienna, Virginia, USA.

Henderson, B. (2009). Protection Relay Settings Management in the Modern World. *SEAPAC* (pp. 1-7). Melbourne: CIGRE.

Hewitson, L.G. Brown, M., & Balakrishnan, R. (2005). *Practical Power System Protection.* Boston: Newnes.

J.I. Maletic, A. M. (2000). Data Cleansing: Beyond Integrity Analysis. *Proceedings of the 2000 Conference on Information Quality* (pp. 1-10). Memphis: University of Memphis.

Jones, A. (2011). Breaking Down the Silos - Data Management Across the Enterprise. *SAS Global Forum 2011 - Data Integration* (pp. 136-144). Cary: SAS Institute Inc.

Micosoft Access Development. (2007, May 29). *Common Database Problems*. Retrieved November 4, 2012 from Microsoft Access Development: http://www.msaccessresource.com/?q=node/6

Microsoft Corporation. (2003, December 12). *Use the Upsizing Wizard*. Retrieved November 9, 2012 from Microsoft Office: http://office.microsoft.com/en-nz/access-help/use-the-upsizing-wizard-HP005273009.aspx

Microsoft. (2013, 1 1). *Microsoft Support Lifecycle*. Retrieved 1 15, 2013 from Microsoft Support: http://support.microsoft.com/lifecycle/default.aspx?LN=en-nz&x=8&y=4&p1=2509

New York Independent System Operator. (2011). *System Protection Manual.* New York: New York Independent System Operator.

NZ Commerce Commission. (2012, December 14). *2010 - 2015 Default Price-Quality Path*. Retrieved December 27, 2012 from Commerce Commission: http://www.comcom.govt.nz/2010-2015-default-price-quality-path/

NZ Commerce Commission. (2009, November 30). *Electricity Default Price-Quality Path*. Retrieved November 5, 2012 from Commerce Commission: http://www.comcom.govt.nz/electricity-default-price-quality-path/

NZ Electricity Commission. (2010). *Links Between Price and Service.* Wellington: NZ Electricity Commission.

Oracle. (2012, July 26). *Oracle Utilities Operational Device management*. Retrieved November 14, 2012 from Oracle Utility Business Solutions: http://www.oracle.com/us/products/applications/utilities/business-solutions/operational-device-management/overview/index.html

P. Abrahamsson, O. S. (2002). *Agile Software Development Methods: Review and Analysis.* Technical Research Centre of Finland. Espoo: VTT Publications 478.

Powerco Limited. (2012). *2012 Asset Management Plan - Information Disclosure for Electricity Networks 2012 - 2021.* New Plymouth: Powerco Limited.

Powero Limited. (2008). *Network Project Approval Memorandum Preparation Guide.* New Plymouth: Powerco Limited.

Ramakrishnan, R. (1999). *Database Management Systems.* Columbus: McGraw-Hill Education.

S. Harkins, D. W. (2008). *Turning Access Applications into Web-based Applications.* San Francisco: TechRepublic.

Schweitzer Engineering Laboratories, Inc. (2007, November 1). *SEL-2032 Communications Processor - Data Sheet.* Retrieved December 3, 2012 from Schweitzer Engineering Laboratories: https://www.selinc.com/SEL-2032/

Smellie, P. (2012, August 21). *Long Running Battle Over Power Line Prices Coming to a Head*. Retrieved November 21, 2012 from Scoop: http://www.scoop.co.nz/stories/BU1208/S00744/long-running-battle-over-power-line-prices-coming-to-a-head.htm

VersionOne Inc. (2008). *3rd Annual Survey:2008.* Alpharetta: VersionOne Inc.

Appendix A – Glossary of Terms

As-Built	Drawings that show the existing conditions as they are, as opposed to proposed design.
BaU	Business as Usual
BPM	Business Process Modelling
FTE	Full-time employees – a measure of labour required / spent
IS	Information Services (formerly known as ICT)
NOC	Network Operations Centre
RFI	Request for Information
RFP	Request for Proposal
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SEL TEAM	acSELerator SEL-5045, a software add-on that allows automation of report collection from SEL branded relays into a centralised server.

Appendix B – Protection Work Breakdown

MAN-HOURS BREAKDOWN BY JOB CLASSIFICATION

Over 11 month period, starting February 2012:

DESCRIPTION OF WORK	Reference	%	MAN-HOURS
Setting Reviews, no construction/IR no., initiated by Planning	Planning	13%	1151
Setting Calculations/Study for Distribution Protection; Capital Projects - Technical Support, Scheme/Design Review	Capital Projects	66%	5658
Fault Investigations & Setting Reviews initiated by NOC	NOC	7%	586
CIW - Distribution & Generation	Customer Initiated Works	4%	308
ePacer, Setting Register Updates	Database Administration	4%	300
Standard Development & Review	Standards	5%	419
Special Projects (AUFLS, GEM-GIS)	Special Project	2%	130
TOTAL			**8551**

Number of Protection Database Record Changes per Month

Based on number of changes made to ePacer records.

	Issued	Applied
Jan-13	21	5
Dec-12	6	18
Nov-12	44	26
Oct-12	39	57
Sep-12	49	22
Aug-12	48	25
Total	207	153

Appendix C – Stakeholder Requirements – Functional

The MoSCoW method:

- **M** - MUST: Describes a requirement that must be satisfied in the final solution for the solution to be considered a success.
- **S** - SHOULD: Represents a high-priority item that should be included in the solution if it is possible. This is often a critical requirement but one which can be satisfied in other ways if strictly necessary.
- **C** - COULD: Describes a requirement, which is considered desirable but not necessary. This will be included if time and resources permit.
- **W** - WON'T: Represents a requirement that stakeholders have agreed will not be implemented in a given release, but may be considered for the future.

The o's in MoSCoW are added simply to make the word pronounceable, and are often left lower case to indicate that they don't stand for anything.

ID	Requirement	Description of Problem	Impact of Meeting Requirement	Suggested by Stakeholder	Priority (MoSCoW)
SFR-001	Centrally stored database, if possible in non-proprietary format. If not, easily convertible to non-proprietary.	Current MS Access format makes access and reporting fraught with difficulties. Information is easily corrupted. Multi-user access non-satisfactory.	Database more resilient to corruption. Improve access speed.	IS Data Specialist	MUST HAVE
SFR-002	Settings information changes time-stamped with user info	Old settings being used to program field devices can result in improper protection.	Greater data fidelity. Less error prone. Less re-work required. Better network reliability.	Planning Team / Protection Team	MUST HAVE
SFR-003	Storage and relation of device condition tests, last tested date etc.	Information on device condition often unknown.	Enables implementation of more cost effective maintenance schedules for protection devices	Planning Team	SHOULD HAVE
SFR-004	Firmware and manufacturer of each device stored and automatically updated	Firmware of specific devices is unknown. Makes translation of setting files impossible. Settings have to be recorded by field staff and manually entered by Protection engineers.	Enables automated population of protection device database. Increases Powerco efficiency by reducing the amount of database administration. Allows planning of firmware rollout.	Planning Team / Protection Team	MUST HAVE
SFR-005	Capture of other device information such as serial number, manufacturer, model no., manufacture date etc.	Lack of device unique identifiers makes differentiating between similar devices on the same location difficult.	Less errors. Less time spent cross-checking device info. Common enterprise-wide device identifier enables better integration with other Powerco information systems.	IS Data Specialist / Protection Team	MUST HAVE

ID	Requirement	Description of Problem	Impact of Meeting Requirement	Suggested by Stakeholder	Priority (MoSCoW)
SFR-006	Automatic notification of relevant setting changes to different user groups.	Setting changes currently passed onto relevant users via emailing of protection change forms (manual administration). Error prone.	Greater data fidelity. Less error prone. Increase Powerco efficiency by reducing amount of time spent administrating other information systems, which use protection device information.	SCADA Team	SHOULD HAVE
SFR-007	Be able to store disparate types of devices and settings, dynamically.	Current database stores very generic information about devices. Losses of information as users have to force information to fit templates. Manual handling of different device types resulting in redundant categories.	Greater data fidelity. Easier to search database. Less time spent administrating database.	Planning Team / Protection Team	MUST HAVE
SFR-008	Ability to search for devices based on any attribute (and multiple attributes)	Some information stored as strings which are hard to sort.	Less time spent by staff searching for devices in database.	Protection Team	MUST HAVE
SFR-009	Different access and display of information to user depending on user roles.	Currently, all details displayed to users regardless if information is relevant.	Increase company efficiency by reducing time spent searching for relevant information.	All Stakeholders	SHOULD HAVE
SFR-010	Adequate system performance for 20 concurrent users.	Speed of access worsens with increasing number of concurrent users	Reduce employee frustration.	All stakeholders	MUST HAVE
SFR-011	Ability to upload historical settings and device information	Setting history stored in separate change log,	Data is easier to locate. Greater data fidelity. Less administration of database. Reduce employee frustration.	Protection Team	MUST HAVE
SFR-012	Ability to link to other Powerco systems (GIS, PSSSincal) directly or through middleware.	ePacer has no ability to link to other Powerco systems.	Greater data fidelity. Less error prone. Increase in company efficiency through the reduction in entering the same information into multiple databases.	All Stakeholders	MUST HAVE

ID	Requirement	Description of Problem	Impact of Meeting Requirement	Suggested by Stakeholder	Priority (MoSCoW)
SFR-013	Ability to link to important related files such as relay setting files and setting configuration reports, and relates the uploaded data to a specific device	Data stored in external files. Search and reporting tools limited. Manual updating of database	Greater data fidelity. Less error prone. Increase in company efficiency through the reduction in entering the same information into multiple databases.	Protection Team / IS Data Specialist	MUST HAVE
SFR-014	Current and historic settings linked to location/site	If device is changed to another, historic settings are lost.	Less time spent locating previous settings.	IS Data Specialist	MUST HAVE
SFR-015	Ability to create and configure custom templates for different device types and models	Database entry of multiple devices with similar attributes is currently done manually or with crude templates.	Greater data fidelity. Less error prone. Increase in company efficiency through the reduction in entering the same information multiple times	Protection Team	MUST HAVE
SFR-016	Ability to configure and display different status for entered protection information.	Current database allows recording of status of the protection settings (issued or applied, and who and when).	Greater confidence in data.	Protection Team	MUST HAVE

Appendix D – Stakeholder Requirements – Non-Functional

ID	Type	Name	Description	Priority
NFR-001	Usability	User friendliness	The solution must be easy and intuitive to use (as assessed by a standard group of users).	MUST HAVE
NFR-002	Usability	User friendliness	The solution should allow users to modify the appearance of the interface where feasible and to save modifications to their user profile – e.g menu and toolbar settings, screen layout, function keys, colours and fonts, and other user preferences	SHOULD HAVE
NFR-003	Usability	User friendliness	The overall user experience in using the solution should not be substantively different between using the system in a smaller WAN connected office or at Junction Street	MUST HAVE
NFR-004	Usability	User Interface	All error messages produced by the solution must be meaningful and should ideally be accompanied by explanatory text with options so that users can decide how to correct the error or cancel the process	SHOULD HAVE
NFR-005	Usability	User Interface	The solution must be consistent in its operation – e.g. Windows used, menus, selection boxes, option and appearance.	MUST HAVE
NFR-006	Usability	User Interface	The solution must allow for configuration drop down menus or 'pick lists' of metadata element values with auto-suggest for data entry and search. The content of these lists must be configurable by the administrator.	MUST HAVE
NFR-007	Usability	User Interface	Frequently executed processes must be designed so that they can be completed with a small number of interactions (e.g. mouse clicks or keystrokes)	MUST HAVE
NFR-008	Usability	User Interface	The solution must provide help throughout the entire system. Optimally this should provide visual guidance hints.	SHOULD HAVE
NFR-009	Usability	User Interface	The solution shall allow users to filter on all searches, reports and screens where records are listed	SHOULD HAVE
NFR-010	Reliability	Availability	The solution should aim to be available to users between normal business hours (within the current bounds of the supporting infrastructure i.e. servers, storage, networking etc).	MUST HAVE
NFR-011	Reliability	Availability	The planned downtime for the solution should not exceed 23 minutes per rolling month period. Planned outages should occur as part of the pre set Powerco change control on a Wednesday evening	MUST HAVE

ID	Type	Name	Description	Priority
NFR-012	Reliability	Availability	Solution availability within core hours should be approximately equivalent to 99.995%	MUST HAVE
NFR-013	Reliability	Availability	In the event of any unmitigated software failure or significant data corruption, it must be possible to restore the solution to a known state no longer than 2hrs in the production environment	MUST HAVE
NFR-014	Reliability	Accuracy	The solution must execute all data activities with 100% accuracy in respect of searching, filtering and reporting.	MUST HAVE
NFR-015	Reliability	Accuracy	The solution must update record changes with any network changes immediately.	MUST HAVE
NFR-016	Reliability	Change Log	The system shall maintain a history of changes to the information contained within, and the corresponding users who made those specific changes.	SHOULD HAVE
NFR-017	Reliability	Error Handling	The solution needs to write all errors to an event log that is audible by the system administrator	SHOULD HAVE
NFR-018	Performance	Response time	The solution must provide adequate response times to meet business needs for commonly performed functions under standard conditions: • 100% of the total anticipated user population logged on and active • 100% of the anticipated total volume of records managed by the system • Consistency of performance (‘adequate’ should be interpreted as a sub second times for interactive use e.g opening menus, accessing features)	MUST HAVE

ID	Type	Name	Description	Priority
NFR-019	Performance	Response time	The solution must be able to: • Display and be able to make changes to records within 3 seconds of startup • Return the results of a search within 2 seconds • Record save within 5 seconds • Navigation between screens which require minimal loading/processing of system data should appear instant to the user (sub-second) • Generation of system reports and outputs should not exceed 10 seconds Regardless of • The storage capacity / number of files or records on the system • Where geographically the test is being performed • Current load on the system	MUST HAVE
NFR-020	Performance	Stress Requirements	The solution must allow all system users to be simultaneously logged in and executing activities. The solution will allow changes to be made "on the fly" (i.e. without the need to take the application out of service).	MUST HAVE
NFR-021	Supportability	Scalability	The solution and hosting environment must allow for expansion of the solution to manage the quantity and type of information required by Powerco	MUST HAVE
NFR-022	Supportability	Scalability	The solution must be capable of handling system upgrades that ensure the existing information can be continued to be accessed without changes to the content	MUST HAVE
NFR-023	Supportability	Scalability	It must be possible to expand the solution in a controlled manner to meet organisational needs while still providing continuity and high quality of service	MUST HAVE
NFR-024	Supportability	Expected changes	Migrating solution software changes/patches and data between the environments should be inherently supported and straightforward	MUST HAVE
NFR-025	Supportability	Expected changes	Any changes to the solution to reflect Powerco requirements must be able to remain intact after any given upgrade.	MUST HAVE
NFR-026	Supportability	Configurability	The solution must be able to be have components added or removed in a modular manner	SHOULD HAVE
NFR-027	Supportability	Configurability	The solution must allow functions to be turned 'On' or 'Off' by users or by user profile	SHOULD HAVE

ID	Type	Name	Description	Priority
NFR-028	Supportability	Configurability	The following system roles are required; • System Administrator - Full system access, viewing and configuration • System Editor - Full system access and viewing of all records • System Viewer - Read only viewing and report generation	MUST HAVE
NFR-029	Supportability	Installation	The implementation of the solution shall be supported by detailed installation and configuration guides (as-build documentation) for all key components including (but not limited to) the operating system, web server/application server, and database choice	SHOULD HAVE
NFR-030	Supportability	Installation	The implementation process must include appropriate training at all levels but specifically operational staff must be trained to maintain and trouble shoot all area of the configuration	SHOULD HAVE
NFR-031	Supportability	Installation	The implementation of solution must not disrupt existing integration between applications	MUST HAVE
NFR-032	Supportability	Installation	The solution installation must be continually supported by the provider accessible during core hours	MUST HAVE
NFR-033	Supportability	Compatibility	The solution must provide support for the widest range possible of protection devices used by Powerco and where possible, the associated export file formats of intelligent electronic devices (IEDs). Manufacturers of IEDs used on Powerco network include: Alstom, Cooper, GE Multilin, Noja, Nulec, SEL, Siemens.	MUST HAVE
NFR-034	Supportability	Compatibility	Indication by the vendor is to be given as to whether the databases used in the proposed solution are proprietary, or industry standards such as ORACLE or MS SQL	SHOULD HAVE

ID	Type	Name	Description	Priority
NFR-035	Supportability	Compatibility	The system offered should include industry standard data exchange support to enable data to be exchanged with external databases and systems. Indication is to be given as to whether the solution is able to interface with: • ESRI ArcGIS • SEL Team Software	
NFR-036	Supportability	Compatibility	The solution must be compatible with the Citrix application delivery platform	MUST HAVE
NFR-037	Supportability	Compatibility	All interfaces must inherently support the running in a consistent and acceptable manner in any one of the user scenarios: • WAN connected offices (Mount, Palmerston North, Lower Hutt) • Connection via remote access over the Citrix Access Gateway	MUST HAVE
NFR-038	Supportability	Compatibility	The solution must support the configuration of users via Active Directory integration	MUST HAVE
NFR-039	Supportability	Compatibility	The solution components must be compatible with the following Operating systems: • Windows 2008 R2 Platform • VMware	MUST HAVE
NFR-040	Supportability	Compatibility	The solution will allow sign on using Powerco system wide user credentials (i.e. single sign-on)	MUST HAVE
NFR-041	Supportability	Compatibility	The system must be able to link to current Powerco IS systems. Consideration must also be given to Powerco IS future architecture	SHOULD HAVE
NFR-042	Supportability	Capacity	The solution must be able to support the full compliment of concurrent licence users, including at least 3 system editors/administrators, without any need to make changes to application software or impact on standard operation of the application. Concurrent editors/administrators shall have full access to make changes within the system without other users experiencing locked records and/or extended wait times.	MUST HAVE

ID	Type	Name	Description	Priority
NFR-043	Supportability	Capacity	The solution must have the capacity to store: • 4400 protection devices (and associated historical and on-going records) migrated over from ePacer • 300 additional devices (and associated historical and on-going records) per year on an on-going basis	MUST HAVE
NFR-044	Supportability	Backup / Recovery	The solution configuration, user information, data and all other associated components must be backed up at least once daily	MUST HAVE
NFR-045	Supportability	Backup / Recovery	The solution data must have a comprehensive backup/restore strategy that protects the data and supports the System Availability Requirements, with a specific emphasis placed on support for disaster recovery requirements	MUST HAVE
NFR-046	Supportability	Backup / Recovery	The solution platform needs to support database/record rollback and roll forward without significant impact to the user. The expectation is that the database can be rolled back to a known point in time, after a fault or service event, easily and without overtly complex support process	SHOULD HAVE
NFR-047	Supportability	Support	Vendor response times to initial calls = 2 hours Vendor response times to resolve calls = 1 business day	SHOULD HAVE
NFR-048	Supportability	Support	Full support and installation documentation must be provided with the solution	SHOULD HAVE
NFR-049	Supportability	Training	System roles will all receive training specific to their role including new processes, system functionality.	MUST HAVE
NFR-050	Supportability	Security	The solution shall balance security of information with the need for easy access. Where data is transferred via the internet it will be protected to prevent access from unauthorised parties.	MUST HAVE
NFR-051	Supportability	Security	The protection data must be secure and only accessed by authorised users.	MUST HAVE

ID	Type	Name	Description	Priority
NFR-052	Supportability	Long Term Preservation	The solution must have features which actively support and check the integrity of the data kept for the service and provides options for recovery and /or repair beyond restoring the entire database.	MUST HAVE

Appendix E – Preliminary Evaluation of Requirements

This matrix is a preliminary evaluation of the vendors and their offered solutions, against the requirements listed in Appendix C and Appendix D, based on their responses to the RFI. Each requirement is weighted according to importance to the stakeholders and the weighting of the stakeholders themselves.

Key:

C = Comply

NC = Non-Compliant

[blank] = indeterminable from response or marketing information

ID	Weighting	ASPEN Inc. - ASPEN Relay Database	DIGsilent - Stationware	IPS Energy - IPS EPIS	Siemens - PDMS
NFR-001	9				
NFR-002	5	C	C	C	C
NFR-003	8				
NFR-004	5	C	C	C	C
NFR-005	8				
NFR-006	10	C	C	C	C
NFR-007	9				
NFR-008	7				
NFR-009	8				
NFR-010	10				
NFR-011	9				
NFR-012	9				
NFR-013	9				
NFR-014	10				
NFR-015	10	C	C	C	C
NFR-016	10	C	C	C	C
NFR-017	8	C	C	C	C
NFR-018	9				
NFR-019	9				
NFR-020	9	C	C	C	C
NFR-021	10	C	C	C	C
NFR-022	9				
NFR-023	10	C	C	C	C
NFR-024	9				
NFR-025	10				
NFR-026	6				
NFR-027	10	C	C	C	C
NFR-028	10	C	C	C	C
NFR-029	7	C	C	C	C
NFR-030	7	C	C	NC	C
NFR-031	10				
NFR-032	7	C	C	C	C
NFR-033	8				

NFR-034	8	C	C	C	C
NFR-035	9				
NFR-036	10	C	C	C	C
NFR-037	10	C	C	C	C
NFR-038	10	C	C	C	C
NFR-039	10	C	C	C	C
NFR-040	8	C	C	C	C
NFR-041	8				
NFR-042	10	C	C	C	C
NFR-043	9	C	C	C	C
NFR-044	8	C	C	C	C
NFR-045	10	C	C	C	C
NFR-046	8				
NFR-047	6				
NFR-048	6		C		C
NFR-049	8				
NFR-050	10				
NFR-051	10				
NFR-052	10				

ID	Weighting	ASPEN Inc. - ASPEN Relay Database	DIGsilent - Stationware	IPS Energy - IPS EPIS	Siemens - PDMS
SFR-001	10	C	C	C	C
SFR-002	10	C	C	C	C
SFR-003	6	C	C	C	C
SFR-004	8				
SFR-005	10	C	C	C	C
SFR-006	7	C	C	C	C
SFR-007	9	C	C	C	C
SFR-008	10	C	C	C	C
SFR-009	7	C	C	C	C
SFR-010	8				
SFR-011	10	C	C	C	C
SFR-012	9				
SFR-013	8	C	C	C	
SFR-014	10				
SFR-015	10	C	NC	C	C
SFR-016	10	C	C	C	C

Appendix F – Substation Equipment & Licences

Key:

Substations highlighted in YELLOW already have acSELerator TEAM SEL-5045 functionality deployed to them, as per trial. As such, they will have all pre-requisite infrastructure as well.

Substation	ICPs	# IP modem required	# Concentrators required	Number of licences	Upfront cost of licences	number of future devices (1st lot),	Date of upgrade	number of future devices (2nd lot)	Date of upgrade	number of future devices (3rd lot)	Date of upgrade
Akura	5128	1	0	15	$2,100.00	2	2014				
Alfredton	341	1	1	0	$-	4	2017				
Aongatete	1385	1	0	5	$700.00	11	2018				
Arahina	3092	1	0	0	$-	10	2013				
Atuaroa Ave	1067	1	0	8	$1,120.00	0					
Awatoitoi	621	1	1	2	$280.00	3	2014				
Baird Rd	2845	0	0	0	$-	6	2013	7	2017		
Beach Rd	48	0	0	11	$1,540.00	5	2014	3	2015	3	2017
Bell Block	3056	0	1	0	$-	9	2019	8	2020		
Bidwells		1	1	3	$420.00	0					
Blink Bonnie	1469	0	0	7	$980.00	0					
Brooklands	3147	0	0	20	$2,800.00	0		0			
Browne St	2310	1	0	10	$1,400.00	3	2015				
Bulls	1421	1	1	0	$-	6	2015				
Bunnythorpe		0	0	6	$840.00	2	2014				
Cambria	5388	0	0	15	$2,100.00	4	2012				
Cardiff	553	1	1	0	$-	5	2013				
Castlecliff	3898	0	0	12	$1,680.00	1	2016	1	2017		
Chapel	4259	0	0	15	$2,100.00	0					
City	2879	1	1	0	$-	17	2017				
Clareville	4190	0	0	7	$980.00	2	2023	6	2027		
Cloton Rd	4196	1	1	0	$-	14	2015				
Coromandel	2350	1	1	5	$700.00	3	2015				
Douglas	971	1	1	0	$-	6	2022				
Eltham	2194	0	0	11	$1,540.00	0					
Farmers Rd	368	1	1	0	$-	3	2019	4	2020		
Featherston	2066	1	1	0	$-	12	2018	6	2019		
Fielding	7372	0	0	15	$2,100.00	3	2017				
Gladstone	676	1	1	2	$280.00	7	2020				
Greerton		0	0	11	$1,540.00	0					
Hamilton St	1260	0	0	24	$3,360.00	0					
Hatricks Wharf	2999	0	0	19	$2,660.00	1	2014				
Hau Nui	188	1	1	0	$-	6	2015				
Inglewood	2435	1	1	12	$1,680.00	0					
Kai Iwi	822	1	1	7	$980.00	0					
Kairanga	6035	1	0	7	$980.00	10	2015				
Kaponga	888	1	1	10	$1,400.00	2	2015				
Kapuni	328	0	1	0	$-	18	2023				
Katere		0	0	16	$2,240.00	0					
Katikati	2358	1	0	7	$980.00	0					
Kauri Point	1207	0	1	0	$-	2	2017				

Keith St		0	0	22	$3,080.00	0			
Kelvin Grove	4689	0	0	11	$1,540.00	6	2016		
Kempton	1969	1	1	3	$420.00	6	2016		
Kerepehi	3146	1	1	0	$-	12	2016		
Kimbolton	1614	0	1	6	$840.00	0			
Lake Rd	1094	1	1	0	$-	8	2021		
Linton		0	0	5	$700.00	0			
Linton Camp		1	1	0	$-	3	2013		
Livingstone	1480	1	0	8	$1,120.00	0			
Main St		0	0	26	$3,640.00	3	2013		
Mamaku Rd		0	1	0	$-	6	2014		
Manaia	1595	0	0	7	$980.00	0			
Manawatu Beef Packers		1	1	0	$-	5	2013		
Mangamutu	3022	1	1	5	$700.00	6	2022		
Mangorei Regulating		1	1	6	$840.00	0			
Maraetai Rd	4066	1	1	3	$420.00	11	2015		
Martinborough	1959	1	0	0	$-	14	2019		
Massey		1	1	0	$-	4	2013		
Matapihi	3484	0	0	25	$3,500.00	0			
Matatoki	819	1	1	0	$-	7	2020		
Matua	4388	0	1	3	$420.00	8	2017		
McKee	164	1	1	6	$840.00	3	2014		
Mikkelsen	3900	1	1	3	$420.00	9	2014	2	2016
Milson	4042	1	1	6	$840.00	2	2014	10	2015
Morrinsville	1572	1	1	0	$-	10	2015		
Motukawa	465	1	1	0	$-	6	2013	4	2023
Moturua	9383	1	1	0	$-	12	2019		
Mt Maunganui		1	1	8	$1,120.00	3	2022		
Ngariki	646	0	0	4	$560.00	0			
Norfolk	249	0	0	7	$980.00	3	2014		
Oakura		0	0	4	$560.00	0			
Ohakea		1	1	0	$-	6	2013		
Omanu	4206	0	0	18	$2,520.00	0			
Omokoroa	3902	0	0	9	$1,260.00	0			
Otumoetai	6807	1	0	16	$2,240.00	0			
Paeroa	3137	1	1	0	$-	15	2017		
Papamoa	9795	1	1	6	$840.00	4	2013	4	2014
Parkville	1063	1	1	2	$280.00	4	2023		
Pascal St	2013	0	0	21	$2,940.00	0			
Peat St	5619	0	0	13	$1,820.00	11	2014		
Piako	3845	0	1	0	$-	18	2013		
PN Hospital		1	1	0	$-	2	2016		
Pohokura		0	0	7	$980.00	0			
Pongakawa	3845	1	1	0	$-	8	2021	4	2023
Pongoroa	715	1	1	0	$-	6	2014		
Pukepapa	1382	0	1	0	$-	8	2013		
Pungarehu	1336	0	0	3	$420.00	9	2013		
Putaruru	3421	1	1	0	$-	9	2016	4	2020
Rata		1	1	2	$280.00	4	2014		
Roberts Ave	2412	1	1	0	$-	9	2017		

Sanson	3133	0	0	10	$1,400.00	2	2020		
Strathmore		1	1	0	$-	3	2025		
Tahuna	1529	1	1	0	$-	6	2014		
Taihape	3135	1	1	8	$1,120.00	1	2014		
Tairua	4265	1	1	7	$980.00	8	2013		
Tasman	1941	0	0	8	$1,120.00	7	2012		
Tatua		1	1	7	$980.00	0			
Taupo Quay	1604	1	1	6	$840.00	8	2016		
Tauranga	10988	1	1	9	$1,260.00	0			
Te Matai		0	1	2	$280.00	2	2014		
Te Ore Ore	3258	1	1	4	$560.00	10	2013	3	2018
Te Puke	4681	1	1	5	$700.00	8	2015		
Thames	4983	1	1	0	$-	6	2019	9	2020
Tinui	653	1	1	2	$280.00	3	2014		
Tirau	1378	1	1	0	$-	8	2016		
Tower Rd	2754	1	1	3	$420.00	8	2018		
Triton Ave	3979	1	0	8	$1,120.00	9	2024		
Tuhitarata	1039	1	1	2	$280.00	3	2013	3	2017
Tui Milk		1	1	0	$-	7	2013		
Turitea	2043	0	0	7	$980.00	5	2013		
Waharoa	442	1	1	5	$700.00	0			
Waihapa	4	1	1	0	$-	2	2020		
Waihi	3793	1	1	2	$280.00	17	2020		
Waihi Beach	2898	1	1	0	$-	5	2020		
Waihi Rd	5720	1	0	15	$2,100.00	0			
Waiouru	979	0	0	2	$280.00	5	2014		
Waitara East	2284	1	1	5	$700.00	4	2015		
Waitara West	1834	1	1	0	$-	18	2023		
Waitoa		1	1	0	$-	15	2017		
Walton	1321	1	1	0	$-	8	2018		
Wanganui East	3043	1	1	0	$-	13	2014		
Welcome Bay	7930	1	1	0	$-	6	2013	9	2020
Whangamata	6063	1	0	12	$1,680.00	0			
Whareroa	1677	1	1	3	$420.00	12	2015		
Whitianga	8474	1	0	4	$560.00	2	2015		

Appendix G – Substation Security

Zone Substation Security Classification

Substation Classification	Average Duration for First Interruption	Average Duration for Second Interruption
AAA	None	50% to 100% load, 60 minutes Remainder, repair time
AA+	15 seconds	50% to 100% load, 60 minutes Remainder, repair time
AA	60 minutes	Repair time
A1	Isolation time	Repair time
A2	Repair time	Repair time

Zone Substation Security Level Selection

Load Type	Zone Substation Maximum Demand			
	< 1MVA	1 – 5MVA	5 – 12MVA	>12MVA
F1	AA	AA	AA+	AAA
F2	n/a	n/a	AA+	AAA
F3	n/a	AA	AA	AA
F4	A1	A1	A1	n/a
F5	A2	A2	n/a	n/a

Distribution Feeder Classifications

Classification	Description
F1	Large Industrial
F2	Commercial / CBD, town population > 10,000
F3	Urban Residential, town population > 5,000
F4	Rural
F5	Remote Rural

Security levels for large customers are agreed upon by negotiation.

Substations without Security Class field filled out are GXP class, therefore relays will most likely be owned by Transpower, not Powerco. This means that can't deploy SEL TEAM functionality to relays not under Powerco ownership

Substation	weighted SAIDI + SAIFI*68	Actual Security of Supply	Desired Security Class	Technician Charge	Payback (number of site visits)
Akura	7.82	AA+	AAA	$42.90	**35.0**
Alfredton	3.53	A1	A1	$498.34	**21.1**
Aongatete	2.46	AA	A1	$273.74	**5.5**
Arahina	3.73	AA	AA	$271.24	**5.5**
Atuaroa Ave	1.68	AA	AA+	$136.48	**11.0**
Awatoitoi	10.43	A1	A2	$217.59	**48.4**

Baird Rd	1.03	AA	AA+	$619.37	**0.0**
Beach Rd	0.92	A1	AA+	$47.89	**0.0**
Bell Block	11.27	AAA	AAA	$107.78	**83.9**
Bidwells	0.00				
Blink Bonnie	1.54	A1	A1	$36.66	**0.0**
Brooklands	15.84	AAA	AAA	$43.52	**0.0**
Browne St	2.39	AA	AA+	$279.98	**5.4**
Bulls	1.02	A2	AA	$303.69	**34.7**
Bunnythorpe	0.00				
Cambria	7.19	AA	AAA	$454.67	**0.0**
Cardiff	1.69	A1	A1	$303.69	**34.7**
Castlecliff	2.34	AA	AA+	$62.86	**0.0**
Chapel	1.42	AA	AAA	$52.26	**0.0**
City	5.10	AAA	AAA	$61.62	**171.0**
Clareville	7.69			$111.53	**0.0**
Cloton Rd	8.05	AAA	AA+	$268.12	**39.3**
Coromandel	2.05	A2	AA	$704.22	**15.0**
Douglas	1.82	A1	A1	$435.95	**24.2**
Eltham	3.40	AAA	AA+	$335.50	**0.0**
Farmers Rd	0.00	AA	AA	$112.15	**94.0**
Featherston	3.99	A1	A1	$255.02	**41.3**
Fielding	6.19	AAA	AAA	$132.74	**0.0**
Gladstone	11.49	A1	A2	$148.96	**70.7**
Greerton	0.00				
Hamilton St	0.28	AAA	AAA	$96.55	**0.0**
Hatricks Wharf	5.84	AA	AA+	$54.75	**0.0**
Hau Nui	7.01	A2	A1	$435.95	**24.2**
Inglewood	2.25	AA+	AA	$145.84	**72.3**
Kai Iwi	1.19	A2	A1	$173.92	**60.6**
Kairanga	18.78	AA	AAA	$98.43	**15.2**
Kaponga	0.90	AA	A1	$386.04	**27.3**
Kapuni	0.52	AA	AA+	$454.67	**19.9**
Katere	0.00	AAA	AAA	$82.83	**0.0**
Katikati	0.00	A1	AA+	$317.41	**4.7**
Kauri Point	1.08	A2	A1	$348.61	**25.9**
Keith St	0.00	AAA	AAA	$41.65	**0.0**
Kelvin Grove	15.31	AAA	AAA	$54.75	**0.0**
Kempton	7.83	A1	A1	$186.39	**56.5**
Kerepehi	2.18	A2	A1	$261.26	**40.3**
Kimbolton	4.68	A1	A1	$138.98	**65.0**
Lake Rd	0.99	A1	A1	$321.15	**32.8**
Linton	0.00				
Linton Camp	0.00				
Livingstone	1.79	AAA	A1	$623.12	**2.4**
Main St	0.00	AAA	AAA	$59.12	**0.0**
Mamaku Rd	0.00				
Manaia	4.32	A1	AA	$454.67	**0.0**
Manawatu Beef Packers	0.00				
Mangamutu	10.06	AAA	AA+	$267.50	**39.4**
Mangorei Regulating	0.00				

Maraetai Rd	0.58	A2	AA+	$641.83	**16.4**
Martinborough	3.70	A1	A1	$304.93	**4.9**
Massey	0.00				
Matapihi	1.40	AAA	AAA	$54.75	**0.0**
Matatoki	1.27	A2	AA+	$323.65	**32.6**
Matua	2.11	A1	AA	$112.15	**80.6**
McKee	1.77	AA	AA	$279.98	**37.6**
Mikkelsen	1.62	AA	AA	$67.85	**155.3**
Milson	10.30	AAA	AAA	$69.73	**151.1**
Morrinsville	0.00	A2	AA+	$167.05	**63.1**
Motukawa	0.88	A2	A2	$251.90	**41.8**
Moturua	14.90	AAA	AAA	$85.95	**122.6**
Mt Maunganui	0.00				
Ngariki	0.65	AA	A1	$317.41	**0.0**
Norfolk	4.18	AA	AA+	$70.97	**0.0**
Oakura	0.00				
Ohakea	0.00				
Omanu	0.63	AAA	AAA	$59.74	**0.0**
Omokoroa	5.83	A2	AA	$192.63	**0.0**
Otumoetai	3.92	AA	AA	$131.49	**11.4**
Paeroa	1.85	AA	AA	$167.68	**62.8**
Papamoa	3.91	AAA	AAA	$85.32	**123.5**
Parkville	10.89	A1	A1	$454.67	**23.2**
Pascal St	2.48	AAA	AAA	$75.97	**0.0**
Peat St	7.66	AA	AAA	$71.60	**0.0**
Piako	2.04	AA	AA	$155.20	**58.2**
PN Hospital	0.00				
Pohokura	0.00	AA	AA	$173.92	**0.0**
Pongakawa	2.04	A1	A1	$246.29	**42.8**
Pongoroa	9.84	A1	A1	$585.68	**18.0**
Pukepapa	1.19	A1	A1	$274.36	**32.9**
Pungarehu	2.80	AAA	A1	$354.84	**0.0**
Putaruru	2.62	A2	AA	$492.10	**21.4**
Rata	0.00	A2	A1	$473.38	**22.3**
Roberts Ave	1.34	AA	AA	$87.82	**120.0**
Sanson	3.57	A2	AA+	$201.37	**0.0**
Strathmore	0.00				
Tahuna	0.98	A2	A2	$192.63	**54.7**
Taihape	20.19	A2	A1	$716.70	**14.7**
Tairua	2.05	A2	AA	$573.21	**18.4**
Tasman	8.16	AAA	AA+	$419.73	**0.0**
Tatua	0.00			$127.75	**82.5**
Taupo Quay	1.76	AA	AA+	$44.77	**235.4**
Tauranga	7.98				
Te Matai	0.00				
Te Ore Ore	11.67	A1	AA	$148.96	**70.7**
Te Puke	6.01	AAA	AAA	$153.33	**68.7**
Thames	1.34	AA	AA	$377.93	**27.9**
Tinui	2.19	A1	A2	$148.96	**70.7**
Tirau	1.74	A2	AA+	$398.52	**26.4**

Tower Rd	2.57	A2	AA	$269.37	**39.1**
Triton Ave	0.28	AAA	AAA	$78.46	**19.1**
Tuhitarata	6.81	A1	A1	$274.99	**38.3**
Tui Milk	0.00				
Turitea	5.01	AA	AAA	$94.68	**0.0**
Waharoa	0.28	AA	AA	$230.07	**45.8**
Waihapa	0.83	A2	AA	$342.37	**30.8**
Waihi	2.98	AA	AA	$304.93	**34.6**
Waihi Beach	0.11	A1	A1	$354.84	**29.7**
Waihi Rd	1.77	AAA	AAA	$114.02	**13.2**
Waiouru	5.53	A2	A1	$36.66	**0.0**
Waitara East	1.39	AA	AA	$160.19	**65.8**
Waitara West	0.68	AA	AA	$152.70	**69.0**
Waitoa	0.00	AAA	AAA	$100.30	**105.1**
Walton	1.66	A1	A1	$230.07	**45.8**
Wanganui East	3.27	A1	AA	$79.71	**132.2**
Welcome Bay	3.82	AA	AA	$102.79	**102.5**
Whangamata	3.51	A2	AA	$454.67	**3.3**
Whareroa	1.75	A1	AA	$481.49	**21.9**
Whitianga	8.17	A2	AA	$822.76	**1.8**

Appendix H - Reflective Summary

My background is that of a recently graduated electrical engineer. I have had no prior experience in database engineering, project management or requirements engineering. My personal learning goals for the project were to broaden my knowledge base and learn about taking a business problem or users needs and developing a project that will result in a satisfactory solution. The projects helped me realise a number of important lessons regarding success in any outcome realisation process.

For the relay management system project, my initial preconceptions were that gathering stakeholder requirements would take the least amount of time, and that most of the work would be in the interfacing with possible solution suppliers. This reflected in my initial project work schedule.

This turned out to be a severe underestimation. Upon arrival at the sponsoring company's headquarters, I realized that stakeholder engagement was going to be the determining factor in whether or not the end-solution fit the company's business needs. Since requirements gathering and analysis is an iterative and collaborative process, I was reliant on constant feedback from stakeholders.

Real-world practicalities such as stakeholder time constraints started to become apparent, and the task turned out to be more time-consuming. However, this emphasised the importance of the requirements gathering stage. Accuracy of the stakeholder needs gathered and translated into requirements is paramount to achieving a solution that best fits the business needs.

The other lesson I learnt was the engagement of stakeholders right at the beginning of any project or change process. The two guide the outcomes of the project and are major factors in determining success. Even identifying stakeholders was a process of discovery as persons I might not have assumed had a stake in the project, turned out to be major stakeholders, and vice versa.

Another particularly salient lesson was the importance of having clearly defined and commonly understood purpose, objectives, outcomes, and scope for the project is at the outset. It is extremely important that these are explicitly stated to each stakeholder so that they are not left to draw assumptions when guiding the requirements gathering process.

The worst possible result would have been if user requirements keep changing after procurement and implementation of a particular vendor's solution. It is better to ensure that these are comprehensive and encompass all current and future business needs before one is committed to implementation of a particular solution.

I've learned that communication skills are far more critical in engineering than an undergraduate degree in engineering would lead you to believe. Direct, succinct language not only makes any project more efficient, but also is fundamentally vital to its success. In the role as liaison between the solution developers and the end-users, it is vital to be well versed in the language of both domains, lest a requirement is miscommunicated or misconstrued.

The projects challenged my notion of engineering success and the engineering field itself. My initial belief was that a successful engineering project was dependent solely on the engineering capability and the fit of the chosen design with that of the environment at the time. As I learned however, there are far more nuanced factors that prime a project for success. That is, clearly defined and communicated purpose, objectives, outcomes and scope; all possible stakeholders are identified and engaged from the outset; all requirements comprehensively documented in language relevant to each stakeholder. These lessons will stay with me for life.

Literature Review

Introduction

This literature review explores the information management requirements of the modern utility and the general factors which affect the design and perforance of such systems. The scope of this review includes the development of Intelligent Electronic Devices (IEDs), relay management systems and the underlying databases and information systems in relation to power distribution network efficiency.

This paper discusses the philosophy and requirements for a manufacturer independent relay settings database software to actively manage all relays in a power or industrial network. The challenges for such a system include changes tracking, architecture, data schema and user requirements. It is envisaged that such a relay management system could have a huge benefit for an electricity network utility or large industrial company, creating significant cost and time savings and ensuring a more reliable electrical system.

Background

New Zealand's restructuring of the electricity sector in the 1980's has resulted in highly regulated prices for the distribution and transmission entities.

For reasons due to natural monopoly, Electricity Distribution Businesses (EDBs) are subject to regulatory provisions under the Commerce Act 1986. Part 4 of the Act, the price-quality regulation sets out a default price quality path which determines:

- the maximum prices/revenues that are allowed at the start of the regulatory period
- the annual rate at which all EDBs' maximum allowed prices can increase - below the rate of inflation, expressed in the form of 'CPI minus X'.
- the minimum service quality standards that must be met.

EDBs may incur penalties for breaches of the price-quality paths set in Part 6 of the Act.

Network investments in expansion and maintenance are increasingly challenging to justify due to the price pressure from regulation. In addition to the restructured electricity markets, there are additional power quality demands due to the increasingly digital society.

As a result, there is an imperative for EDBs such as Powerco to enhance the power delivery network in order to maximize revenues and the price increase. Powerco aims to increase its network security, quality, reliability and safety through the implementation of Smart Grid concepts.

Smart Grids

Whilst Smart Grid development is expected to be slow, distributors such as Powerco and their systems must be prepared to handle this eventuality, given the large costs associated with changing software systems and other infrastructure. This requires improvement in power system monitoring, control and protection.

The Smart Grid will require a more diverse and wider array of sensors throughout the network to monitor conditions in real time. This will benefit utilities and consumers through the following:

- **Safety:** Real time monitoring and communication of equipment conditions enables proactive safety measures to be put in place in case of component failure.
- **Outage Response:** Personnel can be deployed proactively to at risk areas of the network.
- **Condition-Based Maintenance:** enables reliability centred maintenance programmes instead of interval based schedules.

- **Asset Management:** Better management of assets through historic performance and condition information.

The increased amount of information including failure data and operational data allows better allocation of resources:

- **Increased Asset Utilization:** More precise, real-time knowledge of the asset's condition can be used instead of more conservative static ratings.
- **Forensic and Diagnostic Analysis:** Capture of pertinent information for rigorous analysis.
- **Probabilistic Risk Assessment:** probabilistic, rather than deterministic contingency analysis allows more accurate risk assessments.

Substation automation and use of advanced IEDs is a critical part of Powerco's wider Smart Grid initiative. Powerco has for many years been adopting Smart Grid technology (albeit under the names of SCADA, automation and load control).

Due to the slow nature of network development, distribution networks are usually comprised of diverse technologies, spanning multiple technological generations. This makes technological changes challenging as new technologies are required to integrate with legacy equipment, whilst aiming to meet the needs of tomorrow. Cost efficient solutions for sensors, actuators, communications and local network management competence are critical to continued operation of a reliable electricity grid. Many organisations are looking to the integration of IEDs with existing MV and LV installations, to meet increasingly demanding reliability regulations.

IEDs

IED in the Power Engineering vernacular stands for Intelligent Electronic Device which encompasses any power system equipment incorporating micro-processors, that has the capability to receive or send data and control from or to an external source. IEDs receive data from sensors and power equipment, and can issue control commands, such as tripping circuit breakers if they sense voltage, current or frequency anomalies, or raise/lower voltage levels in order to maintain the desired level.

Common types of IEDs include protective relaying devices, On-Load Tap Changer controllers, circuit breaker controllers, capacitor bank switches, recloser controllers, voltage regulators, etc.

(e.g., protective relay, electronic meter, controller, circuit breakers, transformers, and capacitor banks).

IED devices supersede cruder electro mechanical relays in that they are capable of recording a much larger amount of data and providing much more information than earlier electromechanical relays and remote terminal units (RTUs) of supervisory control and data acquisition (SCADA) system were used. If data from different IEDs is integrated and automatically analysed, full advantage of the data may be taken. Extracted information obtained from data recorded by each device through automated processing can be merged in customized reports and sent directly to different utility groups. The data may be pre-processed and sent to the Control Centre as additional data for new applications or redundant data for improvement of existing applications. IED data employed in this way can drastically improve efficiency and decision making capabilities of the utility personnel responsible for analysing faults, reporting nature of disturbances, repairing damaged equipment and restoring the system.

Benefits of IEDs:
- Improved Power quality and service reliability (SAIFI, SAIDI)
- New energy related services and business areas
- Lower cost of service

- Better decision making
- Lower installation and panel assembly cost
- Shorter commissioning and maintenance times
- Shorter system recovery time after a disturbance
- Less revenue loss due to wrong settings and IED malfunction
- Higher system reliability due to automation, integration and adaptive settings

Differences in paradigm due to pervasiveness of IEDs in smarter grid

Old Grid	Smart Grid with IEDs
Customer calls the utility to let them know where the outage occurred	Utility knows the power is out. Restoration is usually automatic
Distributed generation cannot be managed safely	Can manage distributed generation safely
High renewable energy penetration difficult to manage	No problem with higher renewable energy penetration
Power loss in transmission and distribution on the order of 10%	Power loss is reduced by 2+ %, lowering emissions and customer bills
Network investment is determined by peak demand	The utility suppresses demand at peak, lowering cost and reducing CAPEX

Powerco is planning to greatly expand the number of advanced Intelligent Electronic Devices as well as the range and type of data collected. In order to do so, Powerco's information and business systems need to be upgraded in order to take advantage of the large amount of data that will be generated due to the increased capability of advanced IEDs.

IEDs will require some changes in order for their capabilities to be available. For example, with the old low-speed serial protocols, communications is often limited to master/slave scheme, making true peer-to-peer communications between IEDs unfeasible for most legacy substations. New, more capable communications technologies and processes are required.

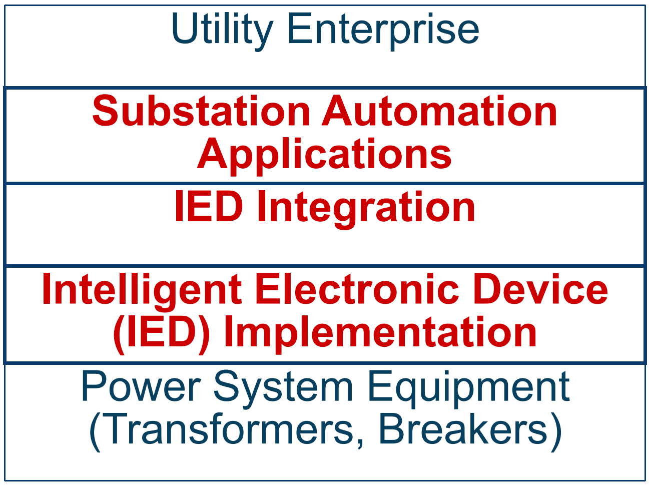
Protection Engineering

The industry standard method of improving network reliability is to limit the duration of outages by isolating faulted sections of the network. This protects network assets from damage, and confines the outage to customers in the direct area served by the network, and ensures that other customers continue to receive power. It also aids in finding the faulted component, resulting in faster restoration times.

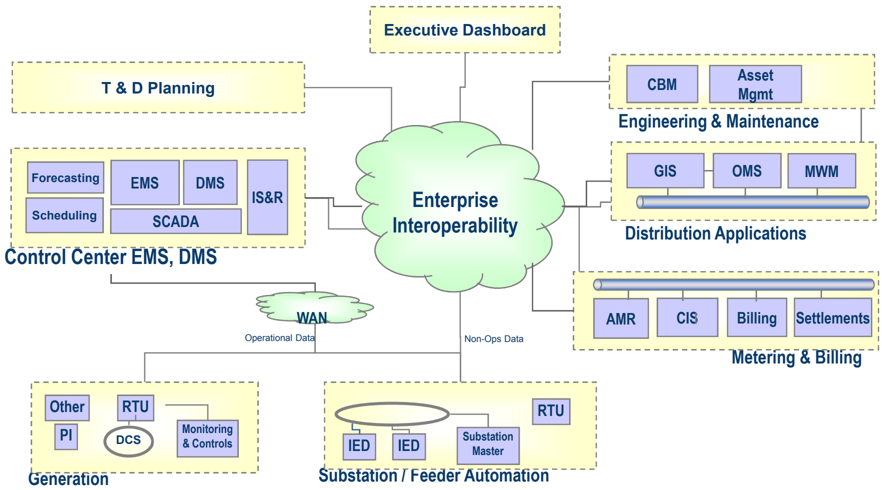
This is accomplished using fast fault detection and selective switching to isolate only the components that are under fault, whilst leaving as much of the network as possible still in operation. Network control and protection devices therefore play critical roles in the reliability of the network, and directly affect potential revenue allowed under. The correct setting and configuration of these protection relays is critical in the minimisation of duration and impact of faults.

IED Information Management

Figures below show where IEDs sit in the overall utility information systems



IEDs and Automation integration within electricity distribution information systems



Enterprise Interoperability

Protection Relay Settings Management

Increasing speed and memory capabilities of computer processing power and communications technologies has resulted in ever more sophisticated protection relays. One collorary effect is that, the complexity and number of settings available in each relay is increasing. Common parameters for relays now include distance protection, directional over-current and earth fault, under-voltage, under-frequency, negative phase sequence etc. Other relevant settings include settings for relay communication and software configuration.

Nowadays, protection relays are associated with the collection of increasingly complex network records from various event monitoring functions to measurement and power quality. These settings, recorded data and events history must be managed by power systems engineers. This can be a formidable task especially if there are many different relays, both in type and number.

Historical Context

Historically, the timing mechanisms in protection relays were first implemented using electromechanical principles. These have been in use for a long time and most EDBs still have maintain and use these in their networks. They detect network current fluctuations through current flowing in windings. Typical electromechanical relays have between ten and a hundred settings, making the historical practice of storing relay settings information on paper or digital spreadsheets, pragmatic.

These electromechanical relays have been progressively superseded, firstly by static analogue relays then by digital relays, more commonly known as numerical relays. Numerical relays achieve network protection, using digital signal processing in combination with fast communications and computing power. Switch activations are made by assessing the results of input currents and voltages using logic internal to the relay. Protection functionality and trip conditions are configured with settings files uploaded to the relay.

Technological advancements in computer processing, signal processing and communications has allowed lower costs and greater functionality expected of numerical relays. Increasingly sophisticated communications also allows communication with other relays, allowing more complex network protection and control schemes utilising distributed intelligence and automation.

Numerical relays can have hundreds to thousands of settings. An order of magnitude greater than that of older static or electromechanical relays. These settings are often stored in proprietary file formats and must be configured using proprietary software from relay manufacturers. Historical records of these settings must be maintained so that replacements can be commissioned quickly or analysis performed quickly for malfunctioning relays. Each relay may have multiple settings files associated with it due to historical archives and different release statuses such as issued or as-applied. A utility such as Powerco may have upwards of 4000 relays on its network. This makes tracking the tens of thousands of settings files an arduous task. This is most often accomplished using a repository / database, along with some database management system.

The Existing Process

Most utilities have a combination of the following for relay settings management:

- Paper records - only basic settings and relay information is stored, primarily used for electromechanical relays;
- Spreadsheets - only relay information and simple settings are stored;
- Databases and file repositories - relay settings files are directly stored and organized;

Paper solutions are only feasible for small networks utilising few relays and few complex protection and control schemes. The limited number of settings the EDBs have to manage may make this a practical solution. Though, if this grows to more than a few dozen numerical relays, the overhead cost of such a system may grow too large.

Spreadsheet systems are a natural extension of paper-based systems, allowing administrators and protection engineers to manage a larger number of settings and devices. These compute based management systems can record a significant amount of information about each relay such as make, manufacturer, location, protected circuit/s and some basic settings.

However, they suffer from lack of data structure and integrity, making device searches difficult. Also, there may be data fidelity issues due to the lack of change logging or data locking. These not only result in higher administration overhead, but may also lead to more serious effects such as incorrect settings or errors in protection scheme design. These may result in improper operation of network protection, ultimately risking damage to network assets or even risking human lives.

Alternative solutions include spreadsheet-database hybrid systems. Commonly referred to relay attributes such as manufacturer, model, functions, substation protected circuit/s, voltage level etc, may be stored in these spreadsheets. Reference is then made to settings files stored on a file server or database. This does require careful maintenance of links and updating of the information within the spreadsheet and the database. This requires high administration overhead and manual data entry.

Such a system can work well but it requires significant administration to keep the data updated and maintain the appropriate links. A higher administration overhead requires more manual entering of data by engineers that often leads to inconsistencies in the data. For example, common relay attributes such as instantaneous over-current have multiple standard notations, many of which are commonly used though may not be entirely interchangeable. A spreadsheet that has such an over-current function field, can have several different representations of the same information. This can lead to confusion and often requires the checks against the settings file for relay attributes. This results in inefficiencies in the protection engineer's work flow.

Other limitations include, lack of auditability, limited information sharing with analysis tools or other core information systems. Spreadsheets are also notoriously poor at representing complex information such as the interaction between complex relay arrangements.

Modern Relay Management Systems

The purpose of relay management systems is to reduce complexity so that operators and managers can effectively and efficiently operate a grid with increasing number of variables. The improvement of information management system provides significant opportunity to improve work efficiencies.

As the development of real-time and two way communications and availability of more information, the task of information management system becomes more complicated. Information management system includes several functions: collection and processing, analysis, integration, improved interfaces, information security.

Most utilities, not just power distribution companies, share many key requirements for relay settings management systems. These are:

- Storage of all relay settings in non-proprietary format;
- Remote access;
- Flexible user management;
- Change auditing;
- Close representation of relay related business processes;
- Automatic storage and linking to relevant records not able to be stored directly in the system;
- Customisable reporting and query tools
- Automatic information sharing to relevant analysis packages
- Non-Proprietary format

Different relay manufacturer use different data format to store settings configurations. These are often proprietary in order to lock the utility in to certain software packages. In many cases, a single manufacturer may have several different formats, due to technological development or business acquisitions.

Utilities often use relays from a variety of relay manufacturers, resulting in several different data formats that the utility has to manage. This often results in complex management systems to keep track of relay settings files and other information. It is not unusual to come across combinations of paper, spreadsheets and ad-hoc databases.

There is a real need to store all relay settings files in a single data format for ease of information management. It will make data consistent across various information systems and allows data integrity to be easily maintained for relay ifnromation from multiple manufacturers.

However, to achieve this, many relay management systems utilize a conversion tool to translate manufacturer specific settings into the data schema used by the relay management system. The IEC standard 61850 is aimed at removing this protocol barrier, but this is yet to be fully adopted by relay manufacturers.

Remote Access

In order for the relay management system to be useful, the information stored within must be accessible from any of a utility's many remote substations. This is commonly achieved through a web-based front end for the database. Where internet access is unavailable, the relay management system should allow for asynchronous database management.

Auditing

In protection relay settings management, the status of the settings information in the database and a history of the changes made is critical to the protection settings process. The relay management system should keep track of changes.

The Protection Settings Process

Most electricity distribution businesses will have a protection workflow that normally proceeds as follows:

Protection and network analysis;

- Settings designed;
- Settings reviewed;
- Settings issued;
- Settings applied in the field;
- Settings recorded in the database;
- Settings information propagated to other information systems.

All while keeping track of changes and user accountability for all database transactions.

It is important that the relay management system aligns with this work process.

Data Repository

To avoid the work inefficiencies ascribed to hybrid paper-spreadsheet-database systems described above, the relay management system must provide a data repository for all information relevant to a particular relay. This will include protection relay manuals, settings calculation sheets, test reports and other pertinent information.

Data integration

A lot of manual work is necessitated by the transfer of information between silos. This deprives engineers of time available for data mining and analysis required to improve the electricity network. In fact, data integration is now considered by many organizations, not just utilities, to be key to business success. It is estimated that 40% of the cost associated with information systems is due to data integration problems.

By integrating the relay management database with other core information systems such as GIS for asset management and technical analysis software, engineers can perform urgent network analysis, aiding in outage restoration times and speeding up the network improvement process.

Factors that Affect Database Performance

Database Design

Database performance relies heavily on the close representation of the databse structure with that of the work processes the database is supposed to serve. The closeness of that representation is dependent upon the gathering and translation of business needs and user requirements to a form used by developers.

In this process, it is of paramount importance that stakeholders are engaged early and often in the development process. Studies of software development projects consistently show that user engagement early on in the development process is a significant factor in project success. When systems are designed without the users, a lack of user engagement may result in the developed product not being able to meet business needs. This will usually require additional development effort, usually a costly exercise.

Data Schema

Utilities have to manage thousands upon thousands of relays, each with thousands of setting configurations. These attributes must be searchable and easily formed into reports such that much manual effort is removed from these processes.

The formulation of a strict data schema is allows information to be easily sortable. This means removing flexibility in input such that naming variations for fields are restricted to certain data types only. This also vastly increases the performance of the database, removing a lot of fustration on the part of the protection engineer.

Data integrity is also improved, allowing users of the information to put more trust in the database and reduce the amount of “double-checking” that is often required of lesser databases.

Database Architecture

The choice of front and back end for the database has a significant effect on the performance of the database.

A split database architecture, in the client-server manner removes the burden of processing from the client machine to the server. This is often achieved using industry standard architectures such as data repository – database – front end configurations.

Compared with the traditional file server architecture used by Microsoft Access which routes multiple users to the same file front and back end, performance is consistent and fast. The amount of bandwidth required to process queries and data entry is also significantly reduced. It also has the advantage of reducing database corruptibility and making database maintenance much easier.

Most commonly, a web-based front-end is chosen for universal accessibility. This also has the advantages of off-loading requests to the server side, and forcing queries to be received as in HTTP protocol, saving bandwidth.

Conclusion

This review has highlighted some of the typical issues utilities face in managing large numbers of protection relays. Utilities have relied on ad-hoc systems comprising of paper, spreadsheets and file servers to manage their relay settings. These limitations of these systems are increasingly tested by the increasing functionality of modern relays. This has resulted in increased administration overhead and data integrity issues.

Sometimes the limitations of these systems do not allow utilities to fully utilise the full potential of the analysis software, asset management software or even the full capabilities of the protection relays themselves. This review discusses the general information management requirements of the modern utility with regards to protection. A relay management system, designed with the factors outlined above, has the potential to save a utility precious engineering time, money, improve safety and network reliability.

Bibliography

A. Middleton, e. a. (2007). Intelligent Power System Protection Data Management: How Should India Embrace Best Developed Practice? Delhi: GE.

ABB. (2012). Electrical Integration in Power and Water Industries. Genova: ABB.

Bertram, G. (2012, April 13). Paths Not Taken in Electricity Restructuring: Alternatives to the Asset Sale Programme. Wellington, Wellington, NZ: Institute of Policy Studies, Victoria University of Wellington.

Burger, J. (1999). The Utility Initiative for Interoperability Between Intelligent Electronic Devices in the Substation - goals and status. Columbus: IEEE.

C.L. Hor, P. C. (2005). Knowledge Extraction from Intelligent Electronic Devices. Transaction on Rough Sets , 82-111.

Centre for Economics and Business Research Limited. (2012). Data Equity: Unlocking the Value of Big Data. London: SAS UK & Ireland.

Duvelson, E. (2007). Integrating Utility Legacy Devices into a Modern IP-Based Communications Infrastructure. Boonton: RFL Electronics.

eMeter Siemens, GTM Research. (2012). AMI for Improving Distribution Operations. San Francisco: Greentech Media Inc.

Eurelectric. (2012). The Smartness Barometer - How to Quantify Smart Grid Projects and Interpret Results. Brussels: Eurelectric.

European Commission. (2009). ICT for a Low Carbon Economy: Smart Electricity Distribution Networks. Brussels: European Commission.

G.W. Scheer, D. D. (2011). Comparing the Reliability of Ethernet Network Topologies in Substation Control and Monitoring Networks. Pullman: Schweitzer Engineering Laboratories.

Gartner Inc. (2012). Hype Cycle for Big Data. Stamford: Gartner Inc.

GE. (2012, July 23). The Advantages of Enterprise Historians Over Relational Databases (Part 1). Retrieved November 5, 2012 from Manufacturing Business Technology: http://www.mbtmag.com/articles/2012/07/advantages-enterprise-historians-over-relational-databases-part-1

Global Smart Energy. (2008). The Electricity Economy: New Opportunities from the Transformation of the Electric Power Sector. Chevy Chase: Global Environment Fund.

Henderson, B. (2009). Protection Relay Settings Management in the Modern World. SEAPAC (pp. 1-7). Melbourne: CIGRE.

IBM Software Group. (2012). Managing Big Data for Smart Grids and Smart Meters. Somers: IBM Corporation.

IMS Research Analyst. (2012, August 21). Smart Grid Tradeshows in Europe Shifting Focus. Retrieved October 28, 2012 from IMS Research: http://imsresearch.com/blog/Smart_Grid_Tradeshows_in_Europe_Shifting_Focus/198

Ingram, D. (2011). Test and Evaluation System for Multi-Protocol Sampled Value Protection Schemes. IEEE PES Trondheim PowerTech 2011 (pp. 1-). Trondheim: IEEE.

IntelliGrid Architecture. (2004). System and Network Management Services. Retrieved November 5, 2012 from http://www.intelligrid.info/IntelliGrid_Architecture/High_Level_Concepts/HLC_Network_Management.htm

International Electrotechnical Commission. (2008, February 19). IEC61850 Technical Issues Overview. Geneva, Switzerland.

J. See, W. C. (2003). Real Time Distribution Analysis for Electric Utilities. IEEE.

Kezunovic, M. (2011). Integration of Substation Data. 18th IFAC World Congress. Milano: IFAC.

M. Adamiak, D. B. (2008). Design and Interoperability Testing of a Network IED: A Manufacturer's Perspective. Malvern: GE Power Management.

M. Kezunovic, e. a. (2010). The 21st Century Substation Design. Tempe: PSERC.

M. Kezunovic, M. B. (2008). IED Data Utilization for Operations, Protection and Maintenance. Tempe: IEEE.

M.L. Brodie, J. L. (2010). The Power and Limits of Relational Technology in the Age of Information Ecosystems. On The Move Federated Conferences (pp. 1-). Heraklion: National University of Ireland.

M.S. Thomas, A. N. (2010). Knowledge Discovery in Database from Substation for Decision Support. 2010 Joint International Conference on Power Electronics, Drives and Energy Systems (PEDES & 2010 Power India (pp. 1-6). New Delhi: IEEE.

McDonald, J. (2012, February 7). Smart Grid Substation and Feeder Automation. Retrieved October 28, 2012 from Fierce Smart Grid: http://www.fiercesmartgrid.com/story/smart-grid-substation-and-feeder-automation/2012-02-07

Musaruddin, M. (2011). Automatic Fault Analysis in Power Systems via Application Service Provider. Adelaide: University of Adelaide.

National Institute of Sandards & Technology. (2010). Wide Area Monitoring, Automation, Communications and Control for the Bulk Transmission System. National Institute of Standards & Technology.

NERC. (2010). Reliability Considerations form the Integration of Smart Grid. Princeton: NERC.

Newton-Evans Research Company. (2012). Worldwide Study of the Protective Relay Marketplace in Electric Utilities: 2012-2014. Ellicott City: Newton-Evans Research Company.

NZ Commerce Commission. (2012, December 14). 2010 - 2015 Default Price-Quality Path. Retrieved December 27, 2012 from Commerce Commission: http://www.comcom.govt.nz/2010-2015-default-price-quality-path/

Powerco Limited. (2012). 2012 Asset Management Plan - Information Disclosure for Electricity Networks 2012 - 2021. New Plymouth: Powerco Limited.

Preuss, C. (2012, January 28). Remote Monitoring of Substation Equipment. Retrieved October 28, 2012 from Electric Energy Online: http://www.electricenergyonline.com/?page=show_article&mag=1&article=3

R. Meredith, P. O. (2010). A functional model of social media and its application to business intelligence. Proceedings of the 2010 Conference on Bridging the Socio-Technical Gap in Decision Support Systems: Challenges for the Next Decade (pp. 129-140). Amsterdam: IOS Press.

R.P. Gupta, S. S. (2003). Technology Development and Implementation for Power Distribution Automation System. Kanpur: Indian Institute of Technology Kanpur.

S. Hsu, A. G. (2008). Intelligent Electronic Device Data Extraction at Hydro One. Eskom Southern Africa Power System Protection Conference 2008. Markham: Hydro One.

Siemens. (2012, January 1). Intelligent Electronic Devices Increase Availability, Power Quality in Power Distribution Networks. Retrieved October 28, 2012 from Utility Products: http://www.utilityproducts.com/articles/print/volume-16/issue-01/product-focus/alternative-power-construction/intelligent-electronic-devices-increase-availability-power-quality-in-power-distribution-networks.html

Smart Grid Australia. (2012). Submission on the Draft Energy White Paper. Canberra: Smart Grid Australia.

Szykier, A. (2010). Smart Grid Data Analytics for Electric Utilities. Maps Capital Management.

T. Sezi, B. D. (1999). New Intelligent Electronic Devices Change the Structure of Power Distribution Systems. Raleigh: IEEE.

Unison. (2012, August 2012). World Class Solution Heading to Unison's Regions as Smart Grid Enabler. Unison Press Release . Hastings, Hawkes Bay, New Zealand: Unison.

V. Giordano, e. a. (2012). Guidelines for Conducting a Cost-Benefit Analysis of Smart Grid Projects. Joint Research Centre. Westerduinweg: Publications Office of the European Union.

Vittal, V. (2012). Technology Challenges in Designing the Future Grid to Enable Sustainable Energy Systems. Tempe: PSERC.

Zeiss, G. (2012, January 24). Distributech Utility University: Substation Automation and Enterprise Data Management. Retrieved November 5, 2012 from Between the Poles: All About Infrastructure: http://geospatial.blogs.com/geospatial/2012/01/distributech-utility-university-substation-automation-and-enterprise-data-management.html