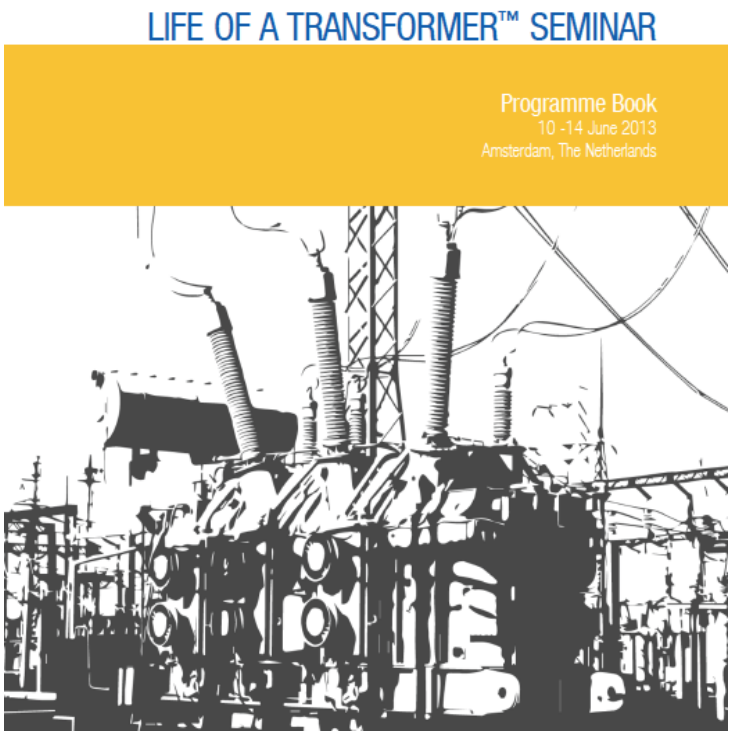
Electricity Engineers' Association
Professional Development Award 2012/13
Report on "The Life of a Transformer™" Doble seminar



By Johan Hendriks
10-14 June 2013

Acknowledgements

I would like to thank the following people and organizations for giving me the opportunity to attend the Doble seminar:

-The EEA for offering the Professional Development Award and selecting me for the 2012/13 year.
-Power System Consultants New Zealand, and in particular Barry Ireland and Warwick Glendenning, for supporting my application for the award.
-Alpine Energy Limited, and in particular Willem Rawlins, for sponsoring me with time off to attend the Doble seminar.

The Professional Development Award offered each year by the EEA is a great opportunity for New Zealand electrical engineers to gain knowledge from overseas and apply it back in New Zealand. I highly recommend any EEA members to apply for the award.

Introduction

Every year the EEA offers a Professional Development Award [1].
With a personal interest in transformers, the most appropriate was the Life of a Transformer™ Seminar offered by Doble.
This seminar has been running for some years now and was always held in the Unites States.
So in my application for the award, I listed this seminar as the preferred overseas seminar.
With winning the award at the 2012 EEA annual conference, the plan was to attend the Doble seminar in San Diego in February 2013.

At the time of the application, I was employed by Power System Consultants New Zealand (PSC NZ).
But with my departure from PSC NZ and joining Alpine Energy in February of this year, this date was no longer suitable. It was lucky that Doble had decided to hold the same seminar in Amsterdam in June 2013. So I was still able to attend the Doble seminar. This was the first time the Doble seminar was conducted outside the USA.

The Life of a Transformer™ seminar was held from 10-14 June 2013, with presentation sessions from 8am to 6pm from Monday to Thursday. Friday was set aside for the laboratory seminar.
About 200 engineers from 43 countries attended the Doble seminar. This mainly included the European countries, east Europa and Africa.
The format was ½ hour presentations by experts in their field. There was ample opportunity for networking and discussions during the breaks.

[1] http://www.eea.co.nz/section?action=View&section_id+269

The highlight was the factory tour of SMIT Transformer in Nijmegen, Holland on Wednesday afternoon. This factory is part of the SCB-SMIT group [2] and produces power transformer, phase shifters and shunt reactors from 100 to 1,200 MVA and up to 800 kV.

One unique aspect of the SMIT design is the way in which the short-circuit forces are catered for by means of an independent coil clamping structure. This structure gives each coil a pre-defined compression strength. There is also no link between the clamping structure for the coils and that of the core. This ensures the ability to withstand short circuits and results in minimal transfer of noise from core to coils.

Courtesy Smit Transformers

The seminar did follow the theme of the life of a transformer with the sessions following the procurement, design, manufacture, testing, maintenance and scrapping.

Seminar programme summary

Monday:

8:30 – 9:00 **Welcoming Remarks**
David Zabetakis, President; Doble Engineering Company

9:00 – 9:30 **KEYNOTE: Insurance Overview**
Don Schubert, Senior Vice President; Marsh Insurance and Risk Management
This leading insurer explained how important it is for transformers to provide reliable electrical power to consumers and highlight the serious consequences when problems arise.

9:30 – 10:15 **Transformer Specification Writing**
Paul Jarman, Chairman of IEC TC14; National Grid
The transformer specification is the fundamental document that communicates the technical requirements needed for the proper functioning of the transformer in a particular system over its lifetime. A good specification will do this in a way that provides the best whole life value, promoting supplier competition and innovation, but clearly stating the necessary requirements in terms of electrical parameters, interfaces, maintenance spares, safety, environment, etc. required to operate effectively within the utility's system.

[2] http://www.sgb-smit.com

10:45 – 11:30 **Selecting Transformer Suppliers**
Laurein Cornelissen, Transformer Expert; Elia
Elia is the transmission network operator in Belgium, operating a fleet of some 1250 transformers from 555MVA 400kV to 25MVA 36kV. Elia purchases most new transformers as part of multi-year framework agreements and recently developed a new three-stage selection procedure.

11:30 – 12:15 **Design Review**
Kjetil Ryen, member of CIGRE working group A2.36; Statnett
Design review is vital in ensuring that both the user and the manufacturer have a good understanding of one another's requirements. A careful design review can avoid costly problems in service later. This session did look at one of Europe's leading utility's approach to this crucial issue.

13:45 – 15:45 **Transformer Design and Manufacturing**
Henk Fonk, Design Engineer; SMIT Transformers
This design engineer from one of Europe's leading manufacturers gave a short and clear explanation of how transformers are designed and built to meet the user's requirements. Topics included design and production of cores; design and production of windings; voltage regulation and controlling LI stress; autotransformers short circuit stress cooling.

16:15 – 17:15 **Understanding Factory Test Data**
Luc Dorpmanns, Test Engineer; SMIT Transformers
After manufacture, transformers are tested to ensure they meet the user's requirements as well as the manufacturer's quality standards. This presentation gave attendees a clear explanation of what tests can be made and what the results of these tests mean for the user. This explanation was done based on a standard routine test program. For each test the purpose was explained and the results discussed. Examples of these results were given for many of the tests done.

17:15 – 17:30 Question and Answer Session with the Presenters

Tuesday

8:00 – 8:30 **Special Transformers: The Challenge of Designing and Manufacturing a Large Quadrature Booster**
Shelia Batey, Product Manager, Large Power Transformers; Alstom Grid
The quadrature booster is a part of the phase-shifting transformer family. Large units consist of two active parts connected in such a manner as to give an angular phase shift between input and output sides of the unit. Large units pose many challenges to the designer. These include such areas as selection of an appropriate core and winding arrangement, tapchanger selection and tap winding design, fault current withstand capability and the effects of regulation at load.
Special consideration must be given to the electrical stresses during dielectric test and the inclusion of special test points to allow full proving of the combined active parts during routine and type testing.

8:30 – 9:00 **HVDC Transformers**
René Martin Wimmer, Director of Global Technology Center for HVDC Transformers; Siemens
The development, design and production of HVDC transformers differ from those of conventional transformers and pose a special challenge for manufacturers.
This presentation analysed the components of HVDC transformers and reactors in more detail and showed the influence of DC-operating conditions. The core is affected by a DC current, which can oversaturate the core and probably overheat it. Specifics are valve windings. Very high test-voltages in combination with low number of turns can be a challenge for the designer. The insulation structure between windings and to ground as well as valve side leads and bushings are different from AC-transformers. Field plots for AC-, DC- and polarity reversal describe the technical problem more in detail. Testing of HVDC-transformers is based on standards and customer specifications

9:00 – 9:30 **Shunt Reactors**
Claes Bengtsson, Global Product Manager; ABB, Ludvika
Shunt reactors are important in compensating the effect of long over-head lines or cables. They play an increasingly important role in connecting urban areas and are expected to play an increasingly important role in the connection of offshore windfarms. This presentation looked at how shunt reactors are designed, built, and tested to give us a better understanding of these important assets.

9:30 – 10:00 **Service and Maintenance: Key Factors for Electric Arc Furance and Rectifier Transformers**
Renato Gamba, Technical Solutions Developer & Export Sales Engineer &
Ernesto Sommaruga, Sales Manager; Tamini
The furnace transformer is one of the key assets in a steel production plant and its unavailability usually leads to an outage of the production plant. Even though it is advisable to acquire spare units due to its importance in order to minimize outages when they occur, this does not always happen. Partly this is due to transformers usually being considered to have a very low failure rate. This opinion - deriving from the service performance of network transformers – does not seem realistic when furnace transformers are involved in the severe stresses to which these units are subjected. This statement has found corroboration in experience gained all over the world by the main transformers manufacturers, including Tamini, where both network and EAF transformers have been installed. The reason for the occurrence of failures can be found mainly in the very different service conditions to which furnace transformers are subjected as compared to the network units. Tamini transformers have demonstrated excellent performance in terms of behavior and life duration; they have been in service for many years with little care, reduced maintenance and no need for particular checks on site. Nonetheless, recent developments in monitoring techniques in the field of transformers could usefully be applied to the transformers in order to improve their performance and prevent the risk of unavailability.

10:30 – 11:00 **Medium Power Transformers**
Milijenko Hrkac; ABB, Monselice
Smaller and simpler than large power transformers, medium power transformers are increasingly designed and built using automated methods. This presentation covered the new design concept behind medium power transformers.

11:00 – 11:30 **Dry Type Transformers**
Bernhard Goerlich; SGB / SMIT
Dry-type transformers are used for a variety of specialist applications, especially indoors. This presentation did look at how dry-type transformers are designed, built, and tested.

11:30 – 12:00 **High Temperature Liquid-Immersed Transformers**
Jan Declercq, Chief Technical Officer; Crompton Greaves Power Systems
High-temperature liquid immersed transformers are used for a variety of specialist applications, especially in wind turbines. This presentation did look at how these specialty transformers are designed, built, and tested.

12:00 – 12:30 **Shell Type Power Transformers – A Well Mastered Technology**
Jácomo Ramos, General Manager Technology; EFACEC
Shell type transformers are widely used in the United States and in several other countries all over the world including Europe. The geometry, construction, and design approach of these transformers make them a unique solution with characteristics that enhance their behavior under surge transients and severe thermal and mechanical stresses. This presentation did show some particulars of design and construction.

14:00 – 14:45 **Transformer Components – Tapchangers**
Moritz Werner, Regional Sales Manager Asset Management; Maschinenfabrik Reinhausen GmbH
Ageing substations, various transformer brands and sizes, diverse on-load tapchanger types, different transformer accessories and operational concepts, load behavior and ambient influences are a result of the enormous increase of energy demand within the last 30 years. In order to keep operational reliability and to integrate obsolete systems into modern substation concepts, it is of vital importance to develop particular asset management and maintenance strategies for power transformers. On the search for technically and economically feasible solutions, the modernization of ageing power transformers becomes an important option. Since the reliability of power transformers depend much on the condition of the on-load tap-changer, this important transformer organ deserves particular attention during the design of new transformers but also in transformer modernization concepts. Modern vacuum interrupter technology allows maintenance-free operation of on-load tap-changers and thus contributes to equipment reliability throughout the transformer lifecycle. State-of-the-art transformer accessories are required to protect the transformer from failures and accelerated ageing. At the same time, they make the condition of the transformer visible. Their contribution to a reliable operation of a transformer must not be underestimated.

14:45 – 15:15 **Other Components**
Moritz Werner, Regional Sales Manager Asset Management; Maschinenfabrik Reinhausen GmbH
All transformers are equipped with a variety of small components such as breathers, temperature indicators, etc. A suitable choice of small components can ensure high availability and reliability in future. This presentation did explain the choices available with special emphasis on the most advanced technologies, for example maintenance free breathers.

15:15 – 15:45 **On-site Testing of Transformers By Means of Static Converters and Innovations like Mobile Compensation Banks**
Patrick Jansen, Area Sales Manager; Highvolt
The life of installed transformers grows as transformers reach and surpass their dedicated lifetime. Newly installed transformers always need important works before commissioning on site. Small mistakes can result in major failures. High voltage on-site tests, as they are already standard for the commissioning of medium voltage and high voltage cables, and GIS/GIL, can be helpful tools to get a better picture of the present status of old transformers as well as to assure the proper installation of new units. This presentation did describe the design of a mobile transformer test systems, which fulfills all relevant IEC standards as well as the experience with their application and customer's benefits.

16:15 – 17:00 **Transformer Components – Bushings**
Ralf Hartings, Global Product Manager for Bushings; ABB Components
The availability and reliability of transmission and distribution grids is essential to ensure a safe power supply to the industry and consumers. Therefore it is important for the user to ensure that the high reliability and maintenance requirements of the system are transferred to all parts of the system such as transformers and their bushings. From a cost point of view, bushings represent only about 5% of the total transformer cost, but are typically a focal point in the majority of transformers outages. This presentation did discus several important bushing characteristics and requirements and showed that it is not just one single design feature of a bushing, which is responsible for a superior performance and reliability. It is the combination of thermal-, dielectric- and mechanical requirements and how these are fulfilled together, which guarantees the performance and reliability. A good availability and reliability can be obtained with different basic bushing insulation technologies, like Oil Impregnated Paper (OIP) bushings, Resin Impregnated Paper (RIP) bushings and Resin Impregnated
Synthetics (RIS) bushings and gas filled bushings. However, the different technologies offer different advantages, depending on the need of the user.
Similarities and differences of various insulation technologies will also be discussed.

17:00 – 17:30 **Transformer Components – Oil**
Nils Herlenius; Ergon
Naphthenic mineral oils have been used as electrical insulating oils for well over a century. They are well suited to provide several functions for the transformer: (1) insulate energized parts and prevent “discharge”, (2) transfer heat from the core to the shell for dissipation, (3) be stable over long periods and (4) maintain the moisture balance within the transformer. Naphthenic mineral oil refiners begin by selecting wax-free naphthenic crudes. The crude oil is separated or fractionated into either atmospheric or vacuum gas oils via atmospheric or vacuum distillation. The gas oils are then further refined to base oils which are used to produce naphthenic mineral transformer oils. There are three types of electrical insulating oils: (1) uninhibited, (2) trace inhibited, 0.08 weight percent antioxidant and (3) inhibited, 0.3 or 0.4 weight percent antioxidant. For uninhibited oil, no synthetic antioxidants are allowed. The uninhibited oils rely solely on the natural inhibitors, generally sulfur containing compounds, which remain in the oil after refining to provide minimal oxidation stability.

17:30 – 17:45 Question and Answer Session with the Presenters

Wednesday

8:00 – 9:00 **Transporting Transformers**
Stuart Rawcliffe, Director; JB Rawcliffe & Sons Ltd.
Doug Kemp, Sales Manager, United Kingdom; Wilson Transformer Company
Transportation and installation of transformers has been a necessary activity since transformers where first manufactured. This presentation did outline some of the options, challenges and considerations required when transporting and installing transformers from receipt of the initial invitation to tender through to delivery at a designated port in a foreign country. Emphasis was placed on route identification, transformer preparation and the pitfalls that can occur along the way.

9:00 – 9:30 **Installation and Commissioning**
Renato Gamba, Technical Solutions Developer & Export Sales Engineer; Tamini
After the manufacturing process and tests in factory, the transformer is delivered to the site. Depending on its dimensions and weight, and considering possible transport limits, it can occur that the transformer has to be delivered disassembled and without oil. Therefore it will be necessary to properly reassemble it once positioned in its final location and verify that it didn't suffer damages due to the transport. During the manufacturing process the transformer is treated and dried with special ovens or vapor phases, this equipment is not available on site. In order to properly carry out the installation it is mandatory to provide a kit of dedicated accessories and tools, such as oil treatment machine or vacuum group, for preventing moisture or external elements to enter in contact with the transformer active part, thus damaging it. Once finished with the assembly procedure, a list of tests and checks have to be carried out in order to certify that the installation of the transformer went according to plan and to establish a set of fingerprints of transformer parameters for future comparisons during its life.

9:30 – 10:00 **Establishment of a Life Assessment and Decision**
Methodology for Critical Network Transformers / Reactors
Gerhard Myburgh, Engineer; NamPower, Namibia
Maintenance is an integral part of asset management. To maintain a high state of asset reliability, an organization have to implement a formal asset management philosophy and base decision making on minimizing equipment maintenance cost and maximizing asset benefits. The criticality of network transformers within the electricity supply industry necessitates a hierarchical approach to asset life assessment. This will enable prioritization, focused gathering of detailed condition information as well as providing a uniform methodology for correct maintenance decision-making. This presentation focused on an investigation of the maintenance philosophy at Namibian Power Corporation (NamPower) and included practical recommendations that will facilitate the life assessment and decision methodology.

10:30 – 11:30 **Workshop Transformer Repairs**
Reinfried Hadlich, Head of Engineering Service; Siemens
The failure of a transformer can have serious consequences for the operator.
There could be injury of personnel, production loss, supply bottlenecks, environmental risks, like emissions, oil spelling and so on. Beside the injury of personnel there could be

bad public relations on of the most critical issues, for example in an atomic power station. These issues were considered in this presentation.

13:30 – 19:30 **Transformer Works Tour at the SMIT Transformer Factory in Nijmegen**
In partnership with our main sponsor, delegates were given the opportunity to visit one of Europe's leading manufacturers and see large transformers in build and during tests.

Thursday

8:00 – 9:00 **Oil Testing**
Paul Griffin, Vice President of Consulting and Testing Services; Doble Engineering Company
Most medium and large transformers are liquid-immersed with the most popular insulating liquid still oil. Oil testing can be used to detect a wide range of developing problems with the oil itself and with the transformer. The presenter, a leading international expert, did explain what tests can be made and what the results mean.

9:00 – 9:45 **Off-Line Testing of Transformers**
John Lapworth, Senior Principal Engineer; Doble Engineering Company
A wide range of electrical condition assessment tests are available for use on transformers in the field. This presentation included a review of the most popular condition assessment tests available and examined three case studies.
These case studies included one dielectric fault, one mechanical fault and one thermal fault – which were diagnosed using a combination of different electrical condition assessment tests, together with oil tests from regular samples and online monitoring systems. The case studies showed the importance of combining oil and electrical tests with design knowledge of transformers.

9:45 – 10:30 **On-Line Monitoring**
Carl Johnstone, Condition Monitoring Lead; National Grid
On-line condition monitoring is continually increasing in capability and in its use by industry. It is being increasing used within the context of SMART, but how smart is it being used? Historically there has been a widely held perception by users that more time and money was spent on the condition monitoring than on the asset, and when it did alarm it turned out to be false information. Although there is some fact to support this perception it does not paint the whole picture.
Many of the issues surrounding on-line monitoring have been based around its implementation and support.
The world of asset management is in various states of maturity moving from time based maintenance and replacement onto condition based, and now including risk into the decision due to continual demands from an informed customer expectation. National Grid have spent many years in understanding the capability and limitations of on-line monitoring and has driven innovation in techniques and processes by working with its partners to create an holistic approach with its implementation. This presentation gave an overview of how it has implemented on-line monitoring of transformers, and when appropriate on-line monitoring solutions are applied. It also covered some case studies where key asset management challenges have been solved with the use of on-line monitoring.

11:00 – 12:45 **Partial Discharge in Transformers**
Sebastian Coenen, Product Lifecycle Manager; Monitoring & Condition Assessment; Siemens
Falk Werner, Senior Field Engineer; Doble Engineering Company
Over the past 30 years, great strides have been made in on-line monitoring and health assessment of high voltage apparatus. Specifically partial discharge (PD) measurements and monitoring offer excellent methods of assessing the condition of various HV components under actual in-service stress such as load and temperature. With these advances and a greater understanding of the mechanism of PD, a more informed decision can be made about the condition of their associated insulation systems. These advances include better digital acquisition systems, noise rejection methods, sensor technology and in particular advanced approaches in analysis and interpretation. This presentation focused on the mechanisms of partial discharge in HV apparatus, in particular in transformers, and analysis and interpretation for health assessment of a transformer covering factory testing and in on-line service applications.

13:45 – 14:30 **Transformer Asset health review**
Richard Heywood, UK Manager; Doble Engineering Company
It is becoming increasingly difficult to manage the aging and deteriorating transformer fleets in many countries. This created consequences for both transformer reliability and network performance. Significant capital investment in new transformers or in refurbished and upgrading existing transformers will be required. There is a need to ensure that this capital investment is directed as wisely as possible, so as to give best value to network operators and other interested parties.
Doble and their customers together have developed a framework of transformer asset health/risk review to improve the valuation of the condition of power transformers, to support the best allocation of capital investment by network operators. This presentation considered the best ways of performing a transformer asset health/risk review based on the experience of Doble with various customers.

14:30 – 15:15 **Failures and Forensics**
Simon Ryder, Principal Engineer; Doble Engineering Company
Transformers are known as being amongst the reliable items of equipment used in the electricity generation, transmission, and distribution. When failures occur, they provide an opportunity to learn both the root causes of the particular failure and how similar failures can be prevented in future. The most effective means of doing so is a forensic examination of the failed transformer. However failures are not the only opportunities to learn, and much can be learned from forensic examination of transformers that have not failed. This presentation considered how best to conduct a forensic examination. The presentation also gave an extended case study, showing how much can be learned from forensic examination following a failure and how this learning can be applied to managing sister or similar transformers.

15:45 – 16:30 **Protection Relays: Your Last Chance to Save Your Asset**
Mauro Borrielli, Client Support Engineer; Doble Engineering Company
Electrical protection is important for the safe operation of both transformers and the wider power system. The presenter considered what types of protection are used for transformers, how they function, and how they are integrated with wider system

protection.

16:30 – 17:15 **Quantitative Method of Allocating Resource for Spares Investment**
Michael Chandler, Assistant Electrical Engineer; RWE npower PLC
Electrical plant failure can lead to system downtime, loss of production, reputation and financial income. A failure's impact can be exacerbated by inadequate provision of spare parts in particular if the failed item is expensive, has a long lead time, if available spare parts have been improperly stored or maintained, or are stored away from the site of failure. This presentation introduced a quantitative method of allocating resource for spares procurement in which the risks associated with plant failure are balanced against the cost of mitigation. The importance of incumbent plant reliability, potential for reducing outage duration, trading forecasts, and the number of berths in which the spare could be deployed are discussed. The method presented is suitable for all types of plant and has applications beyond the electricity industry.

17:15 – 17:45 **Transformer Recycling**
Iain Kerr, Depot Manager; Celtic Recycling
There is no question that the life expectancy of a transformer can be maximized with careful monitoring and regular maintenance, inevitably there will come a time that the equipment will need to be replaced. Once discarded, transformers and associated equipment are legally deemed as waste. The vast majority of which are classified as hazardous waste in international law. It is important to utilize a contractor who can manage the recovery operation and subsequent recycling process ensures compliance with a whole host of health, safety and environmental legislation. Recycling obsolete equipment can save energy and natural resources, reduce pollution and ultimately, divert valuable resources from landfill. When correctly managed and administered, recycling can also provide a means of generating revenue and increase a company's profitability through investment recovery. End of life electrical equipment consists of valuable materials such as copper, aluminum, steel and oil – all of which can be recovered for manufacturing new products or components. One of Europe's leading transformer recycling specialist will provide an in-depth account of live-site dismantling, recovery and transportation operations, followed by a description of the specialist processing facilities required, for material recovery and segregation.

17:45 – 18:00 Question and Answer Session with the Presenters

Laboratory Seminar

The laboratory seminar was held on the Friday from 8 am to 5:15 pm and included:

1. Dissolved gas-in-oil Analysis
2. Water in transformer oil
3. Condition assessment of cellulosic insulation
    a. Dissolved gases in oil
    b. Degree of polymerization (DP)
    c. Furanic compounds
4. Metals in oil
5. Quality of new and service aged oils
6. Load tap changer and oil circuit breaker diagnostic

7. Sampling
8. Case studies from participants

This laboratory seminar was extremely informative and provided many good practical tips for condition analysis.

Conclusion

Overall the Doble seminar was well organized with a very full agenda. Not all presentation provided new information, but at least 90% that did. Talking to the other participant it was clear that everything in New Zealand is on a smaller scale, but the issues are still the same.
The best presentation was on the topic of prioritization of maintenance expenditure on power transformers.
This method first uses a combination of risk assessment and asset condition information and then processes all requirements using the Analytic Hierarchy Process to determine priority of expenditure. On my return to New Zealand, I am planning to implement this prioritization process to Alpine Energy's capital expenditure project.
There were also many references to Cigre publications.

Issues Relevant to New Zealand Electricity Supply Industry

In essence all the topics covered are relevant to New Zealand. New Zealand has no different issues related to transformers as in Europe. Here in New Zealand we are also dealing with aging transformers and where transformers require uprating or replacing with larger units and ensuring reliability at lowest life cycle cost.
In many ways ensuring that New Zealand buys well manufactured transformers and that we have the knowledge and resources to look after the transformers to bets industry practice is more important to us. This is because of the remoteness of New Zealand from manufacturers and support.
Also with the emphasis on more alignment to say PAS 55 through the AMMAT requirements in accordance with the information disclosure requirements set by the Commerce Commission, we need to embrace the techniques available to asset managers.

Over the next six months, I will be exploring ways to implement the acquired knowledge in Alpine Energy and will report on the outcomes to the EEA Executive.

End.