Directlink Joint Venture

Directlink
Revenue Proposal

Attachment 7.1

PSC Consulting
Good Electricity Industry
Practice Review

Effective
July 2015 to June 2020

May 2014

Specialist Consultants
to the Electricity Industry

Directlink HVDC Facility

Good Electricity Industry Practice (GEIP) Review of Operations and Maintenance

Prepared by Leslie N. Brand

For APA Group

Reference JA4598

Date 20th May 2014

Revision Table

Revision	Issue Date	Description
0	7/4/2014	Issued for Comment
1	5/5/2014	Addressed Client Comments
2	20/5/2014	Addressed Client Comments

Reviewers

Name	Interest	Signature	Date
Andrew Robbie	Principal Electrical Engineer		20/5/2014

Approval

Name	Position	Signature	Date
Leslie N. Brand	General Manager – HVDC		20/5/2014

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Executive Summary

The Directlink facility is a High Voltage Direct Current (HVDC) facility that connects the power networks at Mullumbimby and Bungalora, both in New South Wales, via High Voltage DC cables. The facility consists of the converter stations at Mullumbimby and Bungalora, the DC cables connecting them and the AC cables, switchgear and converter transformers connecting each converter station to the nearby AC substation. Directlink utilises Voltage Source Converter (VSC) technology, and comprises three independent VSC "links" operating in parallel. Each of the three links is labelled as System 1, System 2 and System 3.

On 14 August 2012 a fire at Mullumbimby System 1 converter building resulted in the complete destruction of the System 1 converter.

Following this event, PSC Australia (PSC) was engaged to undertake a review of APA's operating and maintenance practices and procedures for the Directlink facility against Good Electricity Industry Practice (GEIP).

Context and the Effect of the August 2012 Fire Event

This engagement has been driven by the occurrence of the August 2012 fire and by observations made during the various investigations that have occurred following that event. The event had highlighted a number of concerns relating to what is considered GEIP which were addressed in this review.

The expectation of what was considered GEIP in the operation and maintenance of the Directlink facility prior to the August 2012 fire is considered to have changed following the event due to a shift in key assumptions and a change in risk profile. A change in the following key assumptions has triggered the need to re-evaluate what is considered to be GEIP in the operations and maintenance of the Directlink facility.

- Reliance on Manufacturer's O&M Recommendations;
- Limited Industry Experience with VSC Technology;
- Anticipated Consequence of a Failure of Main Circuit Equipment; and
- Potential for Fire in Main Circuit Equipment.

This review is based on what PSC considers to be GEIP only after the August 2012 fire. The recommendations developed as a result of this review and as detailed in this report are based on PSC's view that, considering that a fire has occurred, implementation of the recommendations will ensure that the asset is operated in accordance with GEIP in light of the changes in key assumptions and in the post-fire risk profile.

Approach and Methodology

The overall approach and methodology applied by PSC is described in the body of this report. In general, PSC first developed a definition for Good Electricity Industry Practice that can be applied to the Directlink asset and the principles as to how this definition shall be applied specifically to the Directlink asset. PSC then identified the keys tasks, processes and major items of equipment for the Directlink asset, and for each task, process or major item of equipment reviewed associated DJV and manufacturer's documentation, providing comments and developing recommendations. These recommendations were prioritised according to those which should be addressed immediately (defined as prior to 31st December 2013) and those which can be addressed early in 2014.

Outcome of the GEIP Review

PSC was supplied with the requested operation and maintenance documentation for the Directlink facility and performed the review of the documentation in accordance with the approach, methodology and application described in this report.

A summary of the recommendations and their assigned priority is provided in Appendix 2.

From the review, a total of 114 recommendations were developed by PSC.

The key recommendations can be summarised as:

1. Develop a new asset management plan;
2. Develop procedures for the investigation and reporting of network and trip events;
3. Develop a procedure for undertaking, checking and documenting DC cable repairs;
4. Develop a procedure for controlling and monitoring changes implemented in the control and protection system;
5. Develop a documented National Electricity Rules (NER) compliance program; and
6. Improve management of spare parts and special tools.

In addition to the above key recommendations, all recommendations can be broadly categorised into one of the following four categories:

1. Modification of an existing process or procedure;
2. Development of a new process;
3. Development of a new procedure, work instruction and/or form; and
4. Improved documentation control.

In summary, PSC is of the view that, at a high level, the asset was being operated in a manner not inconsistent with Good Electricity Industry Practice. It is PSC's view that there will always be opportunities for improvement in the operation and maintenance procedures and processes for any transmission or distribution service provider, and the outcomes of this review show that the Directlink asset is no exception. In addition, as described in Chapter 4 of this report, PSC has considered the effect of the August 2012 fire in terms of how the new knowledge generated by this event has altered the understanding of what is considered GEIP in the operation and maintenance of this unique asset and its associated technology and this has driven a number of the recommendations.

Whilst PSC has made no assessment in this report as to whether the asset was being operated in accordance with GEIP before the August 2012 Fire Event, nothing significant has come to its attention in the course of this review to indicate that, at a high level, the Directlink facility was being operated in a manner inconsistent with GEIP prior to the August 2012 Fire Event.

1. Introduction

The Directlink facility is a High Voltage Direct Current (HVDC) facility that connects the power networks at Mullumbimby and Bungalora, both in New South Wales, via High Voltage DC cables. The facility consists of the converter stations at Mullumbimby and Bungalora, the DC cables connecting them and the AC cables, switchgear and converter transformers connecting each converter station to the nearby AC substation. Directlink utilises Voltage Source Converter (VSC) technology, and comprises three independent VSC "links" operating in parallel. Each of the three links is labelled as System 1, System 2 and System 3.

On 14 August 2012 a fire at Mullumbimby System 1 converter building resulted in the complete destruction of the System 1 converter ("August 2012 Fire Event").

Following the August 2012 Fire Event, PSC Australia (PSC) was engaged to undertake a review of APA's operating and maintenance practices and procedures for the Directlink facility against Good Electricity Industry Practice (GEIP).

The Directlink facility is owned by the Directlink Joint Venture ("DJV").

2. Consultant's Brief

PSC has been engaged by the DJV to provide the following services:

- Review all documentation associated with the operation and maintenance of the Directlink facility and:
    - Comment on and/or identify areas of concern regarding alignment of the documentation and associated procedures and processes with GEIP;
    - Comment on and/or identify areas of concern regarding the suitability of the documentation and associated procedures and processes to demonstrate compliance with the National Electricity Rules (NER); and
    - Identify the actions and scope required to be performed to bring the documentation and associated procedures and processes in alignment with GEIP (recommendations); and
    - Prioritise the recommendations from highest to lowest priority.

PSC's review is to be based only on the documents provided and some discussion with APA, the operators of the Directlink facility. Whilst PSC has conducted site visits to the Directlink facility in other contexts, no site visits or inspections were undertaken as part of this engagement.

The deliverables of this review are:

1. A detailed spreadsheet identifying the review of each document and/or process, including comments and recommended improvements;
2. A spreadsheet summarising the recommendations and recommending a priority for each; and
3. This report.

3. Consultant's Team

The two key PSC staff engaged to review the documents and to provide advice on GEIP were:

- Leslie N. Brand – Les is a Brisbane based Chartered Engineer (Fellow) with over 20 years of experience in the electricity industry and the last 15 years mostly on HVDC projects. Les held key project and operational roles on the Directlink and Murraylink HVDC projects and was the Technical Advisor to the Project Inspector for the Basslink HVDC project. More recently, Les was engaged as the Operations Manager during the construction and commissioning of the Trans Bay Cable HVDC project in San Francisco, USA and prepared an operational preparedness and integration plan for AltaLink in Alberta, Canada in anticipation of the Western Alberta Transmission Link (WATL), an HVDC project currently under construction. Les has written and presented Cigre papers on the topic of the operation and maintenance of HVDC facilities, is a member of Cigre working group B4.54 "Life Extension of Existing HVDC Systems" and is the convenor of Cigre working group B4.63 "Commissioning of VSC HVDC Facilities". Les is also the convenor of CIGRE Australian Panel B4 "HVDC and Power Electronics". In addition to his HVDC engagements and accomplishments, Les has lead significant consulting engagements in other aspects of the electricity industry including the root cause analysis of a 500kV bushing failure in Phu My, Vietnam and the subsequent investigation into the serviceable condition of the GSU transformer associated with that incident.
- Andrew Robbie – Andrew is a Principal Engineer with over 20 years of experience in the electricity industry, specialising in network planning and system studies for existing systems, new network augmentations, and new generator or load connections. Andrew has worked in both New Zealand and Australia covering multiple regulatory compliance regimes, network transmission codes and rules. In particular, in his consulting role over the last 10 years in Australia, Andrew has carried out a number of studies involving the application of the National Electricity Rules, specifically involving testing compliance or requiring compliance with Chapter 5 of the National Electricity Rules – covering network connection, planning and expansion. Some key projects undertaken by Andrew during this time include generator performance and compliance testing, connection study for a major industrial customer increasing load off-take, audit of protection clearing times for 220 kV and 110 kV transmission lines and stability studies to develop and verify oscillatory stability constraint equations, and network planning studies to develop, analyse and submit projects through the New Small Network Transmission Assets arm of the Regulatory Process.

Mr Brand and Mr Robbie were supported by other specialists within PSC's team as required.

CVs for Mr Brand and Mr Robbie are provided in Appendix 1.

4. Context and the Effect of the August 2012 Fire Event on GEIP Assumptions

This engagement has been driven by the occurrence of the August 2012 Fire Event and by observations made during the various investigations that have occurred following that event. The effect of the August 2012 Fire Event itself needed to be considered during this review. The event had highlighted a number of concerns relating to what is considered GEIP which were addressed in this review.

The expectation of what was considered GEIP in the operation and maintenance of the Directlink facility prior to the August 2012 Fire Event is considered to have changed following the event due to a shift in key assumptions and a change in risk profile. These changes are explained in detail in PSC report JA4745-REPT-001 "Directlink Operating Cost Risk and Cost-Benefit Assessment". In particular, Table 2[1] describes the pre- and post-August 2012 Fire Event assumptions in relation to the operation and maintenance of the Directlink facility. Key points from this report regarding pre- and post-event assumptions are provided below.

- **Reliance on Manufacturer's O&M Recommendations** - The DJV relied heavily on the manufacturer, ABB, for ongoing operation and maintenance advice, even though ABB themselves had little operational experience with this design. The DJV had assumed that maintenance in accordance with the manufacturer's recommendations satisfied GEIP requirements. Since the August 2012 Fire Event, some of the manufacturer's procedures now may not be considered adequate for the current design as they did not prevent the converter building fire. Some of the O&M procedures and practices employed prior to the fire event may no longer be considered to be in accordance with GEIP.
- **Limited Industry Experience with VSC Technology** - At the time of design and construction, Directlink was the first VSC commercial HVDC installation utilizing Voltage Source Converter (VSC) technology and limited operational experience was available. Until 2010, ABB was the only manufacturer of VSC technology and, due to ABB's desire to protect its intellectual property, there was very little reliable fault and failure information available in the public domain on which the DJV could have modified its practices. In August 2012, with only three commercial manufacturers of VSC technology globally, this was still the case.
- **Anticipated Consequence of a Failure of Main Circuit Equipment –** Prior to the August 2012 Fire Event, the expectation was that the worst outage condition for a failure of main circuit equipment would involve the installation of a replacement of that item of equipment (on the basis that a spare was available). It was assumed that the installed protection systems would protect the equipment from damage. The ABB reliability and availability documents had not anticipated a major fire and loss of the entire converter building due to the failure of main circuit equipment within the building (or for any reason). At the time it was considered prudent to manage the risk of failure using maintenance practices after consultation with the manufacturer. Since the August 2012 Fire Event, it has become apparent that a failure of an item of main circuit equipment within the building may result in a significant impact on the availability of Directlink, due to the loss of a complete system for close to three years after the event and the assumption of a relatively short outage to repair or simply change out the equipment is no longer valid. The protection systems have proven not to be able to prevent a fire. A fire of similar magnitude and consequence must now be considered as a possibility without the implementation of associated mitigations.

[1] PSC Report, JA4745-REPT-001, Table 2.

- **Potential for Fire in Main Circuit Equipment** - Equipment within the converter buildings are, in the majority, of outdoor type. In the event of equipment failure, localized damage was assumed and that any resultant fire would self-extinguish. Adjacent equipment was not considered a risk of being a fuel source to propagate a fire. Since the August 2012 Fire Event, it can no longer be assumed that an equipment failure/fire within the building will be limited to the failed equipment.

The change in assumptions described above (and described in more detail in JA4745-REPT-001) has triggered the need to re-evaluate what is considered to be GEIP in the operations and maintenance of the Directlink facility.

It is important to highlight that this review is based on what PSC considers to be GEIP only after the August 2012 Fire Event. PSC has made no assessment in this report as to whether the asset was being operated in accordance with GEIP before the August 2012 Fire Event. The recommendations developed as a result of this review and as detailed in this report are based on PSC's view that, considering that a fire has occurred, implementation of the recommendations will ensure that the asset is operated in accordance with GEIP in light of the changes in key assumptions and in the post-fire risk profile described in detail in JA4745-REPT-001.

5. Methodology and Approach

The overall approach and methodology applied by PSC is described as follows:

1. Receipt of documentation. PSC provided the DJV with a list of documents required to be reviewed, including:
    a. Organisational charts.
    b. Asset Management Plan.
    c. A document list showing all O&M procedures, work instructions, forms, records etc. associated with the asset.
    d. Electronic copies of these procedures, work instructions, forms. .
    e. HV access procedures and training materials.
    f. A spare parts inventory list.
    g. Tools and equipment inventory list and copies of calibration records.
    h. Documents summarising the OHS&E policies for the site including any OHS&E procedures that apply to the site and to electricity assets.
    i. Copies of registers that are used to monitor and track training records, access and work authorisations, inductions, first aid etc.
    j. Details of the contractors engaged, including the sub-contract arrangement, copies of training records and authorisations, company information etc.
    k. The annual maintenance plan.
    l. Samples of completed work orders, forms and records including a complete set from the last annual maintenance for Directlink.

    The necessary documents were supplied by the DJV or by APA, the operators of the Directlink facility.

2. Locate and develop a definition for GEIP that can be applied to the Directlink facility and develop the principles as to how this definition shall be applied specifically to the Directlink facility.
3. Undertake a review of all received documentation against GEIP, following the process described in item 4 below, including the following:
    a. Check the documentation for completeness and check that all key and major documentation, processes and procedures are in place.
    b. Identify key elements of the plant and confirm operating procedures and work instructions are in place for each element.
    c. Review operating procedures and work instructions for completeness and identify areas where GEIP may not be followed.
    d. Review operating procedures and work instructions identified as being required to monitor and ensure compliance to the NER and identify any gaps and areas for improvement.
    e. Recommend additional processes, procedures, work instructions and/or changes to existing.
4. Identify the keys tasks, processes and major items of equipment for the Directlink asset, and for each task, process or item of equipment:
    a. Identify and review the associated DJV procedures, work instructions and/or forms;
    b. Identify and review the associated manufacturer’s documentation and recommended maintenance interval (if applicable);
    c. Review the DJV Maintenance Plan and identify the maintenance interval currently applied;
    d. Provide a list of comments on the reviewed documentation (in accordance with item 5 below);
    e. Identify any missing documents;
    f. List any questions associated with the review and discuss with APA staff; and
    g. Develop recommendations.
5. The review described in item 4 above will be based on:
    a. The principals for the application of the definition of GEIP as described in item 2;
    b. The increase in likelihood and consequence of a failure of an individual item of equipment as evidenced by the August 2012 Fire Event;
    c. Comparison to applicable codes and standards, including:
        i. The NER;
        ii. Applicable state and federal codes and laws;
        iii. Australian standards;
        iv. Australia codes and practices (e.g. ENA NENS);
        v. International standards; and/or

vi. Cigre, IEC or IEEE codes, standards and brochures.

d. The experience of the authors in the operation and maintenance of HVDC (and more specifically VSC technology) assets;

e. The experience of the authors in identifying and confirming compliance of high voltage facilities to the NER; and

f. Where applicable, discussions with owners and operators of similar assets.

6. Review, collate and group as required the various recommendations into a series of recommendations.
7. Prioritise recommendations according to those which should be addressed immediately (defined as prior to 31st December 2013) and those which can be addressed in early 2014.

6. Good Electricity Industry Practice (GEIP)

6.1 Defining GEIP

PSC has used the definition of GEIP provided in the National Electricity Rules, repeated as follows:

> "The exercise of that degree of skill, diligence, prudence and foresight that reasonably would be expected from a significant proportion of operators of *facilities* forming part of the *power system* for the *generation*, *transmission* or *supply* of electricity under conditions comparable to those applicable to the relevant *facility* consistent with *applicable regulatory instruments*, *reliability*, safety and environmental protection. The determination of comparable conditions is to take into account factors such as the relative size, duty, age and technological status of the relevant *facility* and the *applicable regulatory instruments*."[2]

The items italicised are defined in the NER.

The definition of *power system* from the NER is:

> "The electricity *power system* of the *national grid* including associated *generation* and *transmission* and *distribution networks* for the *supply* of electricity, operated as an integrated arrangement."

The definition of *national grid* from the NER is:

> "The sum of all *connected transmission systems* and *distribution systems* within the *participating jurisdictions*."

The definition of *participating jurisdictions* from the NER is:

> "A jurisdiction that is a "participating jurisdiction" under the *National Electricity Law*."

PSC is of the view that the reference to national grid in the definition applies to the states and territories within Australia to which the National Electricity Law applies.

The definition of *facility* from the NER is:

[2] National Electricity Rules, Version 62, Page 1130.

"A generic term associated with the apparatus, equipment, buildings and necessary associated supporting resources provided at, typically:

a) a *power station* or *generating unit*;

b) a *substation* or *power station switchyard*;

c) a *control centre* (being a AEMO *control centre*, or a *distribution* or *transmission network control centre*);

d) facilities providing an *exit service*."

6.2 Applying GEIP to the Directlink Facility

PSC has considered the GEIP definition provided in the NER and how it could be interpreted to apply to the operation and maintenance of the Directlink facility. PSC's view in this respect is provided in Table 1.

Table 1 - Applying the GEIP Definition to the Directlink Facility

GEIP Definition Part	PSC's Opinion
…degree of skill, diligence, prudence and foresight that reasonably would be expected…	PSC believes that the retrospective application of GEIP needs to consider the information known at the time and the environment and historical context in which decisions were made. Looking ahead, the application of GEIP requires that all information available be considered and that enquiries and investigations be undertaken as would reasonably be expected of a prudent operator of similar facilities. Where this degree of "skill, diligence, prudence or foresight" is not available internally, the operator may seek this from external parties, including the original equipment manufacturer (OEM).
…a significant proportion of operators of *facilities* forming part of the *power system*…	The Directlink facility includes equipment that is identical or very similar to those being operated and maintained by other generation, transmission and distribution operators in the Australian National Electricity Market (NEM). This equipment will include the outdoor AC switchgear, transformers, cables and filter reactors, resistors and capacitors. The cooling system may be similar to cooling systems used by generating units. There is a significant amount of experience in the NEM in operating and maintaining this plant and therefore it would be prudent to compare the operations and maintenance of this equipment with these Australian operators. For other equipment, there is limited or virtually zero operating experience in Australia (aside from the Directlink and Murraylink facilities). These includes the IGBTs and the phase reactors, as well as the Mach 2 control and protection system. In the case of IGBTs and the Mach 2 system (or similar systems), there are some new operators of this type of equipment, for example Powerlink have recently installed IGBT-type SVCs in Queensland –although this experience will be very limited. For the phase reactor – whilst there are other operators in the NEM, particularly transmission and distribution operators, who have reactors in service (for example, fault limiting reactors or filter reactor), PSC is of the view that the Directlink phase reactors are very different in terms of manufacture, role and duty than these other reactors. A comparison to NSPs in the NEM who operate and maintain air core, outdoor AC reactors would not be appropriate in this instance. It is PSC's opinion that input should be sought from the OEM or other operators of similar phase reactors, such as Gotland Electric AB (GEAB) who own an almost identical VSC facility to that of Directlink.

…under conditions comparable to those applicable to the relevant *facility* consistent with *applicable regulatory instruments*, *reliability*, safety and environmental protection…	PSC is of the opinion that the "conditions comparable to those applicable to the relevant facility" is a key differentiator in the case of Directlink. For example, in the case of the phase reactors, PSC is unaware of any other indoor, forced air cooled reactors within the NEM. The conditions that are applicable to these reactors will differ substantially to those associated with outdoor air core, naturally air cooled (or water cooled) AC reactors. Further, the fact that the phase reactors are located in series as a key part of the main circuit equipment, means that a prudent operator would implement strategies that consider reliability and availability of the link more so than the operators of outdoor, filter or fault level limiting AC reactors. Similarly, the nature of the design of a typical HVDC converter station means that there is little redundancy in the primary equipment – requiring outages where inspections and maintenance are required to be performed. For other transmission and/or distribution utilities, such outages would be managed through alternative supply sources in the meshed network.
… the determination of comparable conditions is to take into account factors such as the relative size, duty, age and technological status of the relevant *facility* and the *applicable regulatory instruments*…	PSC believes that whilst the overall operation of APA (the operator of the Directlink facility) could reasonably be compared to that of a smaller DNSP, there are some key differentiators that need to be considered in terms of relative size, duty, age and technological status: **Relative Size:** Whilst it is expected that some of APA's overall processes for their gas assets could be applied to the electricity assets (for example, the Maintenance Management Information System (MMIS)), PSC considers that it would be unreasonable to expect APA to have the level of supporting staff and infrastructure for the Directlink facility held by a DNSP for the operation of two interconnectors. PSC is of the view that it is a common benchmarking activity to use the number of persons per circuit kilometre when comparing organisations. It is PSC's opinion that a more appropriate comparison would be to the operator of a single or a small number of point to point HVDC links or to utilities that also operate HVDC links. Within the NEM, this would include the Basslink HVDC facility. Outside of the NEM, comparisons could be drawn to the international operators of the Cross Sound Cable (CSC Co), Trans Bay Cable (TBC Operations), East-West Interconnector (Eirgrid) or Gotland (GEAB). **Duty:** The duty of the Directlink facility would be similar to that of any other point to point transmission line, with the exception that the Directlink facility is controllable and dispatchable. In the latter case, the day to day dispatch, monitoring and operation would be more comparable to a generator than a distribution or transmission utility. **Age:** The Directlink facility was built in 1999, so is approximately 14-15 years old. Other Australian utilities, including transmission and distribution companies, will have a range of asset ages and will commonly have some very old assets requiring more maintenance, inspection, repair and replacement. An analysis of GEIP for Directlink therefore must consider the fact that the assets are all relatively new in comparison to other NSW based power utilities. **Technological Status:** At the time of its commissioning (2000), the Directlink facility was only the second Voltage Source Converter (VSC) of its kind in the world and was

	the first commercial installation. Whilst this technology has developed much over the last 15 years, the equipment is still high technology and the facility is comprised of items of equipment not normally operated or maintained by transmission and distribution entities in the NEM. This includes phase reactors, SF6 wall bushings, IGBTs, DC XLPE cables and microprocessor based control and protection systems. In recent years, some Australian transmission and distribution utilities have commissioned Static Var Compensators (SVCs) which include IGBTs, wall bushings and microprocessor based control and protection systems although the Australian operating experience with these installations is limited.

PSC will apply the following principles in reviewing the operations and maintenance processes and procedures for the Directlink facility against GEIP:

- Compare to a smaller DNSP in the NEM for “typical” AC equipment and for processes and practices not associated specifically with items of equipment unique to the VSC converters or otherwise not typically operated by DNSPs in the NEM (“Unique Items”).
- Compare to operators of a single or a small number of point to point HVDC links or to utilities that also operate HVDC links and/or SVCs in the case of the Unique Items. This would apply to operators within the NEM and to those of very similar facilities outside of the NEM.
- Due to the non-redundancy built into each Directlink system for the main circuit equipment, consider issues such as reliability and availability when considering what a prudent operator would do.
- At any point in time, all information available to be considered and that reasonable enquiries and investigations be undertaken as would reasonably be expected of a prudent operator of similar facilities.
- Consider the increase in likelihood and consequence of a failure of an individual item of main circuit equipment evidenced by the complete destruction of the Mullumbimby System 1 converter building.
- Involvement of the equipment designer/manufacturer or industry specialist where the “degree of skill, diligence, prudence and foresight” is not available within the DJV or its advisors.

7. Outcome of the GEIP Review

PSC was supplied with the requested documentation and performed the review of the Directlink facility operations and maintenance documentation in accordance with the approach, methodology and application described in Sections 4 and 6 of this report.

The outcomes of the work undertaken in accordance with steps 3, 4 and 5 of the methodology of Section 4 of this report was provided in a separate detailed spreadsheet which was a deliverable of this engagement.

In summary, PSC is of the view that, at a high level, the asset was being operated in a manner not inconsistent with Good Electricity Industry Practice. It is PSC’s view that there will always be opportunities for improvement in the operation and maintenance procedures and processes for any transmission or distribution service provider, and the outcomes of this review show that the Directlink asset is no exception. In addition, as described in Chapter 4 of this report, PSC has considered the effect of the August

2012 Fire Event in terms of how the new knowledge generated by this event has altered the understanding of what is considered GEIP in the operation and maintenance of this unique asset and its associated technology and this has driven a number of the recommendations.

Whilst PSC has made no assessment in this report as to whether the asset was being operated in accordance with GEIP before the August 2012 Fire Event, nothing significant has come to its attention in the course of this review to indicate that, at a high level, the Directlink facility was being operated in a manner inconsistent with GEIP prior to the August 2012 Fire Event.

A summary of the recommendations and their assigned priority is provided in Appendix 2.

From the review, a total of 114 recommendations were provided by PSC.

7.1 Key Recommendations

Of the 114 recommendations, PSC considers the following as being major or otherwise key, and of the highest priority.

7.1.1 Develop a New Asset Management Plan

PSC reviewed the Asset Management Plan (AMP) currently in use and noted missing elements normally associated with an AMP including key roles and responsibilities, an operations and maintenance team structure, call out philosophy, contractors under contract, which staff/contractors are used for which work, location of staff, plant and equipment, storage location of spare parts and consumables, overall maintenance philosophy (preventative, reliability centred) and the interface with the Maintenance Management Information System (MMIS).

Also, noting a general shift in the Australian electricity industry to adopting the PAS 55 standard ("Specification for the optimized management of physical assets"), PSC recommended a lifecycle planning approach be applied to the asset including dividing the equipment into classes and for each class identifying risks associated with the equipment, taking into account the redundancy of each element, spares availability, strategy for managing the asset class and maintenance strategy.

7.1.2 Develop Procedures for the Investigation and Reporting of Network and Trip Events

There were no documented procedures observed to ensure that every AC network event and/or trip of the Directlink facility is appropriately investigated and the response of the Directlink facility is confirmed to be as expected.

The control and protection functions of the Directlink facility are implemented within a microprocessor based control and protection system, unique to HVDC converters and similar SVC units. Such systems are not subject to the degradation in settings over time typical of electro-mechanical relays and are difficult to test individually on an annual basis. Instead, a common method for determining the correct operation of these systems is to implement a process whereby known AC network events close to the facility and/or trips of the converter are thoroughly investigated and documented. The expected correct response of Directlink under these circumstances is determined and compared to the actual response and the details of the investigation and outcomes documented.

For each event, the report shall:

i. State whether the response of the Directlink control and protection systems was the correct designed action or not;

ii. State whether or not Directlink has met the performance obligations and is compliant with the NER, and

iii. Identify that if discrepancies or a non-compliance is detected then the requirements of NER rule 5.7.4(a3)-(a4) shall be applied.

Such investigation and documentation can be useful in ensuring the correct operation of the control and protection systems and to monitor and ensure ongoing compliance of the Directlink facility with the requirements of the NER.

7.1.3 Develop a Procedure for Undertaking, Checking and Documenting DC Cable Repairs

PSC observed that there was no documented procedure for managing, monitoring the progress of and documenting the satisfactory performance and testing of the DC cables in the event of a DC cable fault. To date, there has been heavy reliance on the expertise of the cable repair contractor (who have been repairing the cables for a number of years) to complete the works. PSC considers it GEIP for the operator to observe the works at key points in the process, inspect the completed repair prior to backfill, inspect the remediated repair location, witness the final testing of the cables and document these in a quality control manner. PSC recommended a new procedure and cable repair checklist be developed to ensure these activities are undertaken and documented.

7.1.4 Develop a Procedure for Controlling and Monitoring Changes Implemented in the Control and Protection System

The integrity of the settings of the microprocessor based control and protection system need to be maintained by ensuring that, if required, only authorised personnel may make changes and only then through a well-documented process involving an investigation of the effect of those changes on compliance of the control and protection systems to the NER and identification of any testing that may be required if a possible effect on compliance is identified. PSC recommended that new processes and procedures be developed to manage this.

7.1.5 Develop a Documented NER Compliance Program

The operation of the Directlink facility will have an effect on power system security. The DJV will therefore need to institute and maintain a compliance program as required under NER Clause 5.7.4. PSC has reviewed the available documentation and is of the view that a compliance program that addresses the requirements of these clauses does not exist.

NER Clause 5.7.4 specifically applies to:

1. Protection systems;
2. Control systems for maintaining or enhancing power system stability;
3. Control systems for controlling voltage or reactive power; and
4. Control systems for load shedding.

PSC is of the view that items 1, 2 and 3 apply to the Directlink facility. Item 4 would not apply as Directlink does not have loads associated with it.

The compliance program will need to satisfy the following requirements of the NER Clause 5.7.4:

1. Include monitoring of the performance of the facilities;
2. Include provision for periodic testing of the performance of those facilities upon which power system security depends;
3. Provide reasonable assurance of ongoing compliance of the facilities with the relevant performance requirements of schedule 5.1; and
4. Be in accordance with good electricity industry practice.

PSC is of the view that Item 2 above (period testing of control and protection systems) could be addressed through the investigation and documentation of Directlink's response to AC network events and internal trips as described in Section 7.1.2 and through controlling and monitoring changes to these systems as described in Section 7.1.4.

7.1.6 Improve Management of Spare Parts and Special Tools

PSC could not identify clear procedures and processes around the monitoring of the spare part levels and identification of what these levels should be for various items of equipment. No process for adjusting levels according to recent failure rates could be located. PSC recommended a process be documented for logging in and out of spare parts (maintaining an accurate inventory) and for triggering the procurement of new spare parts when required. Failure rates should be fed back into this process, and the modification of required spare parts holdings should be documented.

Similarly, a process should be established for managing the tools and equipment used on site, including recording calibration dates, filing calibration certificates, recording the result of physical inspections and triggering an event when calibration is due.

7.2 Broad Recommendation Categories

The scope of the 114 recommendations can be broken down into a number of broad categories, including:

1. Modification of an existing process or procedure;
2. Development of a new process;
3. Development of a new procedure, work instruction and/or form; and
4. Improved documentation control.

7.2.1 Modification of an Existing Process or Procedure

The recommendations in this broad category vary from correcting simple typographical errors, to the correction of referencing and in some cases contradictions between various documents.

Some key recommendations in this category include:

1. Fixing technical and operational errors and inconsistencies;
2. Key points of clarification to avoid confusion or misunderstandings;
3. Identification and correction of inconsistencies or contradictions between documents of similar topics;

4. Removal of repetition to ensure two procedures or work instructions do not cover the same ground and when they do, provide detail in one and reference the other to avoid having to effect changes in more than one location;
5. Identification of responsibilities and accountabilities;
6. Corrections or additions to existing operational forms;
7. Consistency nomenclature and definitions used throughout the documentation

7.2.2 Development of a New Process

In some cases, PSC has identified various new processes that should be developed and established. Many of these new processes will ensure improved attention, monitoring and documentation of key activities and events. The recommendations included in this category include:

1. Development of the new processes described in Sections 7.1;
2. The introduction of photographic evidence (before and after) whenever contractors or staff are undertaking repairs and replacements; and
3. Implementation of a permit log system.

7.2.3 Development of a New Procedure, Work Instruction and/or Form

PSC has also identified where new procedures, work instructions or operational forms should be developed. In some cases, this is associated with splitting out procedures and work instructions that are currently covered by others but not given the depth or consideration of technical differences that it requires. In others, these procedures or work instructions are needed to ensure improved attention, monitoring and documentation of key maintenance and activities are undertaken and that the manufacturer’s recommendation and Australian GEIP are followed.

Some key items in this category include:

1. New procedures required for the new processes described in Sections 7.1;
2. Pre-energisation procedures and check-lists for the valve containers and the converter building following maintenance activities;
3. The inspection and maintenance of the zero sequence and phase reactors;
4. The inspection and maintenance of certain main items of equipment, including wall bushings, transformers, disconnectors, earth switches, spark gap and cable terminations;
5. Responding to specific events, including high and low ambient temperature events and fire events;
6. The inspection and maintenance of IT assets; and
7. The inspection and maintenance of auxiliary systems, including IT asset, earthing systems, emergency lighting and the valve cooling system.

7.2.4 Improved Documentation Control

The final broad category is that involving the improvement to the performance, completion, monitoring and storage of key items of documentation. Recommendations in this area include:

1. Improving the control of site documentation to ensure operational staff have the latest versions of key documents while working on site;
2. Improving the recording of authorisation levels and documentation of training and certifications;
3. Locating and filing manuals for the IT systems;
4. Identifying, archiving and indexing documents that demonstrate NER compliance;
5. Checking "as built" status of drawings and documents used within the Directlink "PlantDoc" system; and
6. Ensuring forms are filled out correctly using clear and legible writing, proper dating of the forms, completeness etc.

Appendix 1 – CVs of Key Staff

Les Brand
Chief Executive Officer

THE ART OF POWER

Specialist Consultants to the Electricity Industry

Fields of Special Competence:

- The specification, design, construction, installation and commissioning of HVDC converter stations
- Submarine cable manufacture, installation, commissioning and manufacture
- Conceptual engineering and development of cost estimation techniques for high voltage substation and transmission line projects
- Investigation and cause analysis of transmission incidents
- Project development, construction, commissioning and management

Qualifications and Affiliations:

Chartered Professional Engineer, Engineers Australia (CPEng)

Fellow, Engineers Australia (FIEAust)

National Professional Engineers Register (NPER) - Electrical

APEC Engineer in Electrical Engineering (Australia)

Member IEEE

Individual Member, Asset Management Council of Australia

University of Western Australia, 1993
- Bachelor of Engineering (Electrical) with First Class Honours
- Bachelor of Commerce (Management)

Career History:

2010 –	Chief Executive Officer / Electrical Engineering Manager, PSC Australia
2008 – 2010	Operations Manager, Trans Bay Cable, TBC Operations LLC
2006 – 2008	Director, Power Networks and Renewable Energy, PB Power (Singapore)
2003 – 2006	Manager, HV Networks Group / Senior Electrical Engineer, PB Power (Brisbane)
2002 – 2003	Manager, Operations, Maintenance and Trading, TransÉnergie Australia
1999 – 2002	Project Manager, Murraylink HVDC Light Project / Project Engineer, Directlink HVDC Light Project, TransÉnergie Australia
1996 – 1999	Site Electrical Engineer / Electrical Project Engineer, Robe River Mining Co
1993 – 1996	Graduate Engineer, Western Power Corporation

Introduction

Les Brand's 20 years' experience in the high voltage electricity industry has encompassed a broad range of roles ranging from the electrical engineering design, project management, installation and commissioning of high voltage AC and DC transmission systems, through to senior management within the power systems industry throughout Australia, Asia and the United States.

Les is very experienced in all aspects of power systems engineering and has a high technical knowledge of HVDC transmission, including the associated auxiliary equipment and control systems. Les has had key roles in the installation of several HVDC projects in Australia and the United States. The broad range of experience gained from these projects and his ability to meet tight completion dates and communicate with all levels of the power industry has added considerable value to the projects he has been involved with. Les is the Chief Executive Officer for PSC Australia and is responsible for the day to day management of PSC's business operation throughout Australia.

Chief Executive Officer / Electrical Engineering Manager

PSC Australia (2010 - present)

Les is responsible for building PSC Australia's capability in electrical engineering, transmission lines and HVDC. In the CEO role PSC Australia, Les is responsible for the operation, management and growth of the business.

Billable work includes:

- Development of the technical specification and negotiation of the technical solutions for the replacement of a Voltage Source Converter (VSC) converter station, including detailed discussion and negotiation with the preferred vendor.
- Investigation into options for replacing a VSC converter station, including development of options, interacting with vendors to obtain pricing, detailed analysis of options and recommended solution.
- Assistance to the owner and operator of a VSC converter station in the analysis of their O&M practices and recommendations for improvement.
- Review of the feasibility study costing and key technical assumptions for the proposed Purari HVDC project between Papua New Guinea and Queensland, Australia.
- Technical advice to developer of a potential HVDC (voltage source converter) HVDC project in the USA. Tasks include development of technical requirements, liaison with OEMs for technical and pricing information and assistance in responding to government tender.
- Development of an Operational Readiness or Integration Plan for the Western Alberta Transmission Link (WATL) project in Alberta, Canada, including developing recommendations on how to resource the operations and maintenance of the new HVDC technology, developing a schedule and budget for the integration.
- Desktop analysis into the cost of 800kV and 1,100kV long distance HVDC projects.
- Representation of PSC at Cigre events, including Cigre B4 panel "HVDC and Power Electronics". Presentation of a tutorial at the 2011 Cigre HVDC colloquium.
- Final review and consistency check of the 2010 Electrical Statement of Opportunities (ESOO) before publication.
- Transmission study to supply a remote mine site in Mauritania, including comparison of both AC and HVDC options.
- Scoping and cost estimation of transmission options to reinforce the Te Awamutu area in New Zealand.
- Scoping and cost estimation of selected substation and transmission lines projects in Queensland.
- Scoping and cost estimation of transmission line O&M projects and upgrades in South Australia.
- Technical Due Diligence of the Copperstring transmission project in Queensland, a significant EHV transmission line project in Australia.

Operations Manager

Trans Bay Cable (TBC) Operations LLC (2008 – 2010)

As Operations Manager for the Trans Bay Cable (TBC), a HVDC link from Pittsburg CA to San Francisco CA during the construction phase, Les was responsible for the following:

- Preparation for operations and maintenance of the Trans Bay Cable HVDC facility in San Francisco, CA, and management of TBC Operations LLC, a new Californian company under contract to operate and maintain the Trans Bay Cable HVDC Facility.
- Analysis of design studies and test reports for the primary and secondary AC and DC equipment for the converter stations.
- Technical Witness of FPT/DPT testing of control and protection systems for the Siemens HVDC Plus system in Erlangen, Germany.
- Witness of submarine cable Factory Acceptance Tests in Arco Felice, Naples, Italy and submarine cable installation manager.
- Recruitment, manning and training of the commissioning and operations team for the project.
- Development of all operational procedures and training program for personnel for ongoing operations of the facility.
- Development of Operation and Maintenance budgets and documentation for regulatory rate case.

Director Power Network & Renewable Energy

PB Power – Singapore (2006 – 2008)

Les was the Director of the Power Networks (transmission and distribution), Renewable Energy (wind and solar) and Environmental Engineering components of the business for the Asia region, including recruitment of staff, developing business plans and budgets, business development initiatives, project leadership and managing staff on a day to day basis.

Manager, HV Networks Group / Senior Electrical Engineer

PB Power - Brisbane Australia (2003 – 2006)

Les managed an expanding group of professional engineers specialising in transmission and distribution. He completed conceptual design for substations in South Australia and technical review and advice for transformer tenders, planning reports and generation station proposals. Les was also the Project Inspector Technical Services for the Basslink HVDC, Tasmania – Victoria interconnector for over 2.5 years where he reviewed technical documentation, monitored construction and cable laying progress, and completed certification of major project milestones.

Manager, Operations Maintenance & Trading / Project Manager – Murraylink HVDC Project

TransÉnergie Australia (2000 – 2003)

Murraylink HVDC Facility, Victoria-South Australia Interconnector – Management of the commissioning, operations and maintenance for the Murraylink HVDC facility and for trading of electrical energy. This included the development of all operating protocols with third parties including TNSPs, operating procedures, maintenance procedures, HV switching procedures and training of O&M staff. During commissioning, completed supervision and coordination of personnel and the review and analysis of commissioning test results.

Project Engineer, Directlink HVDC Project

TransÉnergie Australia (1999 – 2000)

Directlink HVDC Facility, NSW-QLD Interconnector – Owner's Commissioning Engineer. Responsibilities included the development of commissioning schedules, procedures and liaison with NEMMCO and other third party control centres during system and transmission tests, review and analysis of commissioning test results. Les was also the owner's engineer for the design, installation and commissioning of AC network augmentation for this project, including a new substation at Bungalora in NSW and extensions to two existing substations at Mullumbimby and Terranora.

TBC Operations LLC

Operations Manager, July 2008 – March 2010

As Operations Manager for the Trans Bay Cable (TBC), a HVDC link from Pittsburg CA to San Francisco CA during the construction phase, Les was responsible for the following:

- Preparation for operations and maintenance of the Trans Bay Cable HVDC facility in San Francisco, CA. Tasks included development of manning and recruitment strategies, interfacing with CAISO and PG&E, development of operating and maintenance procedures and monitoring of design and manufacturing progress.
- Management of TBC Operations LLC, a new Californian company under contract to operate and maintain the Trans Bay Cable HVDC Facility. The role included setting up the company structure, procurement of tools and equipment, development of personnel and employment policies and development of quality procedures for the company.
- Technical assistance to the EPC Contract, including reviewing technical documentation, factory inspections in Germany and Italy, review of critical studies including RAM Study, analysis of design to local OH&S requirements.
- Analysis of design studies and test reports for the primary and secondary AC and DC equipment for the converter stations.
- Technical Witness of FPT/DPT testing of control and protection systems for the Siemens HVDC Plus system in Erlangen, Germany.
- Witness of submarine cable Factory Acceptance Tests in Arco Felice, Naples, Italy. Submarine cable installation manager – monitor and inspect manufacturing progress for the XLPE submarine cable at Arco Felice in Italy. Review of cable installation methodologies and management of on-board representatives. Addressing technical issues associated with the manufacture, loading, transportation and installation of the submarine cables.
- Recruitment, manning and training of the commissioning and operations team for the project.
- Development of all operational procedures and training program for personnel for ongoing operations of the facility.
- Development of Operation and Maintenance budgets and documentation for regulatory rate case.
- Submarine cable installation manager – monitor and inspect manufacturing progress for the XLPE submarine cable at Arco Felice in Italy. Review of cable installation methodologies and management of on-board representatives. Addressing technical issues associated with the manufacture, loading, transportation and installation of the submarine cables and liaising with the owner's for services crossed during the 53 mile installation.
- Commissioning Support – supporting the owner's commissioning manager during commissioning of the converter stations, including witnessing of testing, technical investigations, troubleshooting and management of the EPC contract.

PB Power – Singapore

Director Power Network & Renewable Energy, 2006 – July 2008

Director of the Power Networks (transmission and distribution), Renewable Energy (wind and solar) and Environmental Engineering components of the business for the Asia region, including recruitment of staff, developing business plans and budgets, business development initiatives and managing staff on a day to day basis to ensure high productivity. Specific roles included:

- Technical advisor insurance company regarding transmission line damage caused by Rime Ice during ice storms in Southern China during January-February 2008.
- 500kV transformer bushing failure investigation, Vietnam – Root Cause analysis of transformer bushing failure, including investigation and inspection of dismantled transformer in factory and condition assessment.
- Lenders Engineer and final certification for 115kV AC interconnection between Thailand and Cambodia on behalf of the ADB including three 115/22kV substations. This is the first transmission connection to Siem Reap and surrounding cities.

- Project manager and lead engineer for the technical due diligence of the National Transmission Corporation (Transco) in the Philippines for a confidential client. Developed the due diligence report, Opex and Capex scenarios and technical inputs to the financial model. Presented the results to the Client's CEO and senior management team.
- Technical due diligence of the Mindanao and Masinloc coal fired power plants in the Philippines for confidential clients. Reviewed any electrical issues associated with the grid connection, the transmission network and the power transformers.
- Development of electrical specifications for high voltage plant for upgrading of existing hydro plants at Pantabangan and Masiway in the Philippines.
- Technical due diligence for the Basslink HVDC facility in Australia. Lead engineer, including review of technical documentation, development of the report, review of Capex and Opex figures, investigations into link capacity.

PB Power Brisbane Australia

Manager, HV Networks Group, 2004 – 2006

Senior Electrical Engineer, 2003 – 2004

Les managed an expanding group of professional engineers specializing in transmission and distribution.

- Feasibility study for power generation and supply options for a major resort island development in far north Queensland. Lead engineer for technical and economic comparison of options including diesel and gas generation, wind power, solar power and submarine cable including combinations of technologies.
- Basslink HVDC, Tasmania – Victoria Interconnector, Project Inspector Technical Services. Conventional HVDC project, including review of technical documentation, monitoring of construction and cable laying progress and certification of major project milestones. An ongoing role for over 2.5 years that also included the following:
    - Review all aspects of design, including study reports provided by the EPC contractor.
    - Detailed investigation into damage incurred on the converter transformers.
    - Detailed investigation into the laying methodologies and issues associated with the installation of the HV submarine cables.
    - Analysis and review of the reliability, availability and capacity issues
    - Witnessing of commissioning tests and analysis of all technical issues.
    - Attendance to HVDC cable testing laboratory at CESI, Milan, Italy to witness cable type testing.
    - Development of detailed reports for commissioning and project completion.
- Murraylink HVDC facility, completed technical due diligence and development of the projected capex and opex plans.
- South Australia substation conceptual design, scope of works and cost estimate, including development of scope, high level project schedule and outage planning for the following projects:
    - Brinkworth substation – 275kV and 132kV augmentation works, including new 200MVA 275kV/132kV transformer.
    - Cherry Gardens substation – 275kV and 132kV substation augmentation works.
    - Tungkillo substation – Greenfields 275kV switching station.
- Tomago Peaker Plant – Owners Representative to the transmission utility to negotiate technical access standards and develop connection requirements for a 250MW gas turbine in NSW at 330kV. Project Manager for the system studies (load flow, stability and fault level) and for development of the technical specifications for the connection substation (330kV).
- Lender's engineer, transmission connection for the Walkaway wind farm in Western Australia.
- Rowville and Moorbool 1000MVA Transformer Tender – Owners engineer and technical advisor to the Client in the development of a bid to build, own and operate two 500kV/220kV 1000MVA transformers in Victoria, including review of fire protection requirements and review of proposed EPC Contractor's technical submission.

- Review of year 04/05 capital plan for major transmission and distribution utility in Western Australia including solutions proposed for network constraints and review of costs and justification for individual transmission, distribution and SCADA projects.
- Review of 10 year planning report and capital expenditure for major distribution utility in South Australia including solutions proposed for network constraints and review of distribution projects.
- Review the relevant sections in the National Electricity Code and Victorian Electricity System Code in relation to new connections, and assist a utility in the development of procedures for connection applications.
- Technical due diligence for windfarms in Tasmania and Victoria in Australia and Korea.

TransÉnergie Australia

Manager, Operations Maintenance & Trading, 2002 – 2003

Project Manager – Murraylink HVDC Project, 2000 – 2002

Murraylink HVDC Facility, Victoria-South Australia Interconnector – Management of the operations and maintenance for the Murraylink facility and for trading of electrical energy. This included the development of all operating protocols with third parties including TNSPs, operating procedures, maintenance procedures, HV switching procedures and training of O&M staff.

- Murraylink HVDC facility, Owner's Commissioning Manager. Responsibilities included the development of commissioning schedules, procedures and liaison with NEMMCO and other third party control centres during system and transmission tests. Supervision and coordination of Owner and Contractor personnel during commissioning and review and analysis of commissioning test results.
- Murraylink HVDC facility, Owner's Project Manager. Responsibilities included Owner's representative to EPC Contractor, review of technical capabilities of the plant, quality, OH&S, environmental control and compliance of construction and design to Australian Standards and permit conditions during construction, negotiations with TNSPs on technical schedules for connection agreements, liaison with NEMMCO and TNSPs on technical requirements for connection to NEM, development of remote control "run-back" schemes in SA, Victoria and NSW.
- Murraylink HVDC facility, Owner's Engineer for the design, installation and commissioning of the Monash Substation in South Australia, including a 6km 132 kV transmission line and 132 kV distance protection modifications to incorporate a "tee" section. Investigation into network augmentations, including the installation of current limiting reactors at Mildura, and protection modifications required on the 66 kV network in Victoria.
- Murraylink HVDC facility and Directlink HVDC facility, Manager Physical Trading. Works included the development and operation of NEM bidding systems, written submissions on NEM consultations affecting the operation of Market Network Service Providers (MNSP) in the NEM, development of daily trading strategies and opportunities for MNSPs. Les developed a working knowledge of the NEC and NEM dispatch processes including the dispatch of MNSPs in the NEM.

TransÉnergie Australia

Project Engineer, Directlink HVDC Project, 1999 – 2000

- Directlink HVDC Facility, NSW-QLD Interconnector – Owner's Commissioning Engineer. Responsibilities included the development of commissioning schedules, procedures and liaison with NEMMCO and other third party control centres during system and transmission tests, review and analysis of commissioning test results.

- Directlink HVDC Facility, NSW-QLD Interconnector – Senior Electrical Engineer for Owner. Responsibilities included the coordination and design of Directlink's ControlNet interface to NEMMCO, technical input with the Owner's and Contractors Engineering Departments, responsibility for Environmental, Health, Safety and Quality issues, all communications for the converter sites, development of safety and quality plans, and project management procedures including document and drawing controls for the project, witnessing and supervising the factory system testing (FST) of the control system in Sweden. Also included the determination of MNSP trading strategies, the development of O&M procedures and training of O&M staff.
- Directlink HVDC Facility, NSW-QLD Interconnector – Owner's Engineer for the design, installation and commissioning of AC network augmentations, including a new substation at Bungalora in NSW, and extensions to the existing substations at Mullumbimby (132 kV) and Terranora (110 kV).

Robe River Mining Company

Site Electrical Engineer, Pannawonia, 1996 – 1999

Electrical Project Engineer, Perth, 1996

Mesa J Mine site and Pannawonia Town site, Western Australia. As the only electrical engineer on site, responsibilities included electrical support for the 30Mtpa mine site (110V – 132 kV), day to day management of mine and town transmission and distribution system, responsibility for cable detections, responsibility for electrical statutory issues and liaison with the Department of Mines and Office of Energy.

Western Power Corporation

Graduate Engineer, 1993 – 1996

Cadet Engineer, 1992 – 1993 (part time)

- The development of and training of personnel in a windows program called "LVDESIGN" used to calculate voltage drop, current flows and protection requirements for LV (415V) power reticulation systems. This program is now available commercially.
- Modeling, testing and commissioning of LV capacitor banks to improve voltage profile.
- Other distribution related projects.

Papers, Presentations and CIGRE Participation

- Convenor, CIGRE Australian Panel B4 "HVDC and Power Electronics"
- Regular member, CIGRE Working Group B4.54 "Lifetime Extension of HVDC Assets".
- Convenor, CIGRE Working Group B4.63 "Commissioning of VSC HVDC Schemes".
- Presentation of a tutorial "HVDC in AC Networks - Australian Experiences" at the SC B4 2011 Colloquium, Brisbane Australia in October 2011.
- L. Brand and M. Eccles, "Transition from Project Delivery to Operation of HVDC Facilities", presented at the CIGRE SC B4 2011 Colloquium, Brisbane Australia in October 2011.
- C. Duerr and L. Brand, "Planning for the Integration of HVDC Facilities" presented at the 2013 CIGRÉ Canada Conference in Calgary, Canada in September 2013.

Andrew Robbie
Principal Electrical Engineer

THE ART OF POWER

Specialist Consultants to the Electricity Industry

Fields of Special Competence:

- 20 years experience in the electrical power industry
- System studies including load flow, short circuit, dynamic stability and harmonics
- Market constraint equations, Grid code compliance investigations, Generator connection studies
- Substation design and layout
- Project scoping and estimating

Qualifications and Affiliations:

Member IEEE

University of Canterbury:

Master of Engineering (Electrical & Electronic), 1993
Bachelor of Engineering (Electrical & Electronic), 1992

Career History:

2010 –	Principal Electrical Engineer, PSC Australia
2004 – 2010	Specialist Electrical Engineer, PSC Australia
2000 – 2003	Senior Consultant, Maunsell Ltd (formerly Meritec Ltd)
1997 – 1999	Design Engineer, ESBI Engineering (UK) Ltd
1993 – 1997	Development Engineer, Transpower New Zealand Ltd

Introduction

Andrew Robbie has 20 years of experience in the electrical power industry, specializing in system studies. After graduating with an ME from the University of Canterbury, Andrew joined Transpower New Zealand where he carried out system studies for generation connections, new capacitor banks, and the static var compensator at Islington substation. He then joined ESBI Engineering in the United Kingdom where he was responsible for the electrical design of 132 kV substations. Andrew then returned to New Zealand and joined Meritec Ltd, primarily providing services to Transpower. He has been with PSC for nine years providing system study services both within Australia and New Zealand.

Andrew's experience with system study tools includes DIgSILENT PowerFactory, SiemensPTI PSS/E, PSCAD/EMTDC, and harmonic analysis software. Andrew has completed a number of studies for several clients including Western Power, Transend Networks and the Australian Energy Market Operator (AEMO) in Australia, and Transpower in New Zealand.

System Studies

Andrew has had extensive experience with classical system studies including Load Flow, Short Circuit, Stability, and Harmonic studies. These studies have been based mainly on DIgSILENT PowerFactory or SiemensPTI PSS/E software, and have included model writing and development for dynamic simulation for both products.

Andrew has recently completed a number of studies for Australian clients, including:

- Network planning studies in Western Australia for 132/22 kV zone substation capacity at Balcatta, and also for the Rockingham City area, both involving identification of issues, compliance with Technical Rules, technical and economic analysis of augmentation options.
- Generator and major load connection studies in Western Australia, involving identification of thermal, voltage, and short circuit constraints against the Technical Rules, and mitigation options to enable connection.
- A project for the Australian Energy Market Operator (AEMO) concerning planning considerations and technical options for long distance transmission line extensions to enable the potential connection of “remote” renewable energy resources to the Australian shared transmission network. The first part of this work package provided a list of planning considerations for the connection of generation over long distances while the second part involved a case study looking at various options for connecting large scale (up to 5000MW) baseload generation at Innamincka in the north-east region of South Australia.
- Review of AEMO’s FCAS tool and design of an over frequency generator shedding scheme for Queensland and South Australia. The OFGS schemes were to manage over frequencies resulting from separation events during high export from either Queensland or South Australia.

For New Zealand clients, Andrew was recently the technical lead for a generator model validation project for at Mokai power station Genasure (end client was Mighty River Power) which included development of new governor and AVR/excitation models in PowerFactory and comparing with the tested response obtained by Genassure on site to validate the models.

The following system studies have been carried out both as a consultant to, and directly for Transpower New Zealand and have covered:

- Thermal and stability limits for potential grid upgrades in the lower South Island, and for a potential 1000 MW wind farm development.
- Generation connection studies for a 150 MW gas turbine station, and a 90 MW wind farm.
- Testing of generator compliance with existing grid codes and the proposed new electricity governance rules for the electricity industry.
- Harmonics studies for 2 x 60 MVAr 11 kV capacitor banks at Bromley, 1 x 25 MVAr 110 kV capacitor bank at Mount Maunganui, and two 50 MVAr 220 kV filter banks at North Makarewa.

Project scoping and estimating

Andrew has carried out independent project scoping and estimating for Powerlink as an independent check on their own internal cost estimates and to support their revenue reset application. For this job a cost estimating database was created from the ground up, to create a range of ‘building block’ costs which can be combined to form a project cost estimate to within +/- 30% accuracy.

Design Engineer

Andrew has had experience as a design engineer for ESBI Engineering (UK) Ltd in the United Kingdom where he was responsible for 132 kV substation electrical design covering: substation layouts, earthing design, protection schemes, drawings, equipment specifications, tendering and procurement.

Development of Market Equations

Andrew worked with Transend Networks in Tasmania to develop constraint equations for the Australian National Electricity Market. The development of these equations involved writing a Matlab program to directly calculate thermal constraint equations from a PSSE raw file, as well as detailed system studies to formulate voltage and stability constraints.

System Studies

The following studies have recently been completed for Power & Water Coporation in Northern Territory, Australia:

- 2011/12: Development of a new power system dynamics simulation model for the Alice Springs Power System. Project manager and technical lead – work included initial development of a preliminary model, recommendations for generator tests required and a generator test plan, with subsequent validation of the model once test results were available.
- 2012: Generator testing at Alice Springs. Project manager and technical lead – work included project managing a team to develop a generator test procedure, engage sub-contractor with testing expertise and equipment to carry out the testing, scheduling of test windows and client liaison, and budget control.

The following studies have recently been completed for Western Power in Australia:

- 2012: Planning study and Business Case for a Network Control Service (NCS) at Albany in Western Australia. The work involved assessment of a proposed new NCS generator for capacity required and prospective energy dispatch, and an economic analysis of the total cost of the NCS service including capital, investment in the generation plant, running costs, and connection costs. The regulatory aspects were also considered. Andrew drafted a Business Case to for the preferred NCS generation option for Western Power to progress through the regulatory process.
- 2012: Investigation of high fault levels at Northern Terminal 132 kV substation. The analysis included identifying the under cause and theory behind the high fault levels and then detailed studies to analyses mitigation options and carry out an economic and technical justification to identify and recommend a preferred option to implement.
- 2011: Major load connection study – identification and analysis of network thermal, voltage and short circuit constraints against the Technical Code, and mitigation options to enable the major load customer to connect to the 330 kV network. Generator connection study – identification and analysis of network thermal, voltage and short circuit constraints against the Technical Code, and mitigation options to enable a 60 MW generator to connect to the 132 kV network.
- 2010: Investigation of use of increased transformer capacity at 132/22 kV zone substations.
- 2010: Network planning – identification of issues, technical and economic analysis of augmentation options for 132/22 kV zone substations at Balcatta (including drafting of a Business Case) and for the Rockingham City area.

The following studies have recently been completed for the Australian Energy Market Operator (AEMO) in Australia:

- 2012/13: Andrew was engaged to carry out a review of the accuracy of AEMO's Frequency Control Ancillary Services (FCAS) Tool which was used for Tasmania. In addition two over frequency generator shedding (OFGS) schemes were designed (one for Queensland and one for South Australia), to help manage over frequencies associated with separation events during high export from these regions. Each OFGS scheme required consideration of the unique characteristics of the region it was to be implemented in.
- 2009: Andrew completed a project for the Australian Energy Market Operator (AEMO) concerning planning considerations and technical options for long distance transmission line extensions to enable the potential connection of "remote" renewable energy resources to the Australian shared transmission network. The first part of this work package provided a list of planning considerations for the connection of generation over long distances while the second part involved a case study looking at various options for connecting large scale (up to 5000 MW) baseload generation at Innamincka in the north-east region of South Australia.

Resume – Further Details

The following studies have recently been completed for Transend Networks in Tasmania, Australia:

- 2012: Formulated a report discussion the issues associated with changing from PSS/E to PowerFactory as the main platform for system studies. This included estimating the conversion costs, re-training of engineers time and cost, and software costs.
- 2010: Design of an automated voltage control scheme for George Town substation featuring capacitor bank switching, and reactive power dispatch of generators, and took account of all Basslink operating modes. This included commissioning of the scheme and monitoring during a trial operation period. Also a subsequent review of enhancements made by Transend after approximately two years of operation.
- 2009: Connection study for a major industrial customer increasing load off-take.
- 2008: Design review of the Tasmanian under-frequency load shedding scheme in preparation for the impending change to the Tasmanian frequency standard, including impact of modification to the Basslink frequency control objective function.
- 2008: Updating and enhancing Transend's PSS/E user model of Basslink, with as commissioned changes, modeling of additional control/protection limits required for accurate simulation of the Tasmanian system, as well replacing the converter equation and cable model sections of the code.
- System planning studies for Annual Planning Report 2007
- Transient voltage rise study to identify impact on a major industrial customer after tripping of Basslink HVDC scheme.
- Dynamics simulation of the backup Network Control System Protection Scheme, to test timing and coordination of circuit tripping to relieve thermal overloads. This involved writing dynamics models for the five protection units for simulation in PSSE.
- Audit of protection clearing times for 220 kV & 110 kV transmission lines to determine compliance with the National Electricity Rules. This also involved testing of the actual protection clearing times in dynamic studies of the Tasmanian system to determine the critical clearing times.
- Planning studies to formulate 10 year and 30 year development plans for the Tasmanian system.
- Analysis and submission of projects through the New Small Network Transmission Assets arm of the Regulatory Process.
- Development of an algorithm to calculate thermal constraint equations to control flow on transmission lines for use in the National Electricity Market.
- Development and verification checking on oscillatory stability constraint equations for the Tasmanian system.

The following system studies have been carried out both as a consultant to, and directly for Transpower New Zealand and have covered:

- 2009: Stability limits for potential grid upgrades in the lower South Island, including the effects of the increase in capacity for the upgrade to the New Zealand HVDC link and response to system faults.
- 2007: Transmission limits, both thermal and stability, for a potential 1000 MW wind farm development.
- Generation connection studies for a 150 MW gas turbine station, and a 90 MW wind farm. The wind farm study, included implementation and testing of the wind turbine manufacturer 's dynamics models with the North Island grid.
- Transfer of dynamics system model for the North & South Islands from PSSE format to DIgSILENT PowerFactory. Also required developing custom models for use in DIgSILENT PowerFactory.
- Calibration of governor models with tested results for generator reserve simulation.

- Testing of generator compliance with existing grid codes and the proposed new electricity governance rules for the electricity industry. Creation of a database monitor and track all compliance information.
- Harmonics studies for 2 x 60 MVAr 11 kV capacitor banks at Bromley, 1 x 25 MVAr 110 kV capacitor bank at Mount Maunganui. PSCAD/EMTDC was also used to determine surge arrester energy capability for restrikes.
- Brydone Substation Project - designed and specified the ratings of new 11 kV 5 MVAr Capacitor Banks for a new Medium Density Fibreboard manufacturing plant. The design took into account effects of various harmonic-producing loads in the MDF plant, and harmonic resonance with the HV network.
- North Makarewa Project - design and specification of ratings for two 50 MVAr 220 kV Filter Banks. These were designed to sink 5th harmonic currents in the 220 kV network and provide reactive power support. Determination of the ratings involved on-site measurements of harmonic currents and detailed harmonic modeling of the 220 kV system.
- Islington Upgrade Project - While the project was in the design phase his role was as Technical Manager reporting to the Project Manager. This involved responsibility for all technical issues involved with the project, involving a new 250 MVA 220/66/11 kV transformer, two 60 MVAr 220 kV Capacitor banks, and associated 220 & 66 kV switchgear was installed. Part of the upgrade was installation of a -50/+60 MVAr Static Var Compensator, for which he carried out studies to evaluate impact of SVC harmonic filters on a Power Company's 175 Hz ripple control system, including checking performance of blocking filters to ensure signal levels unaffected by the SVC. During the construction phase of both projects, to gain site experience, he worked on site at Islington Substation solving design problems, liaising between various contractors and grid control for commissioning work. On-site he was reporting to the Site Engineer.
- Oamaru Project - Involved at end of project to investigate harmonic interference with telecommunication circuits. He carried out on-site harmonic measurements to match and validate a computer simulation of the situation. He also determined harmonic interference design limits, which the telecommunications company would have to specify its new equipment to.

Other studies that have been carried out for other clients or companies include:

- 2013: Lead Engineer for dynamic simulation model development for governor and AVR systems at Mokai geothermal power station in New Zealand. This work involved modeling of governors and AVR's and tuning the models to match the tested responses of the actual plant obtained by others, to determine compliance with the Electricity Industry Participation Code.
- 2013: For ElectraNet Andrew was the job manager and part of the engineering team carrying out a high level impact assessment for a new series capacitor installation in South Australia. The work involved managing a number of engineers, responsibility for the budget and deliverables, and also contributing to the study.
- 2010: Feasibility of wind generation connections for Genesis Power in New Zealand, involving identifying possible stability constraints in the network and potential limitation on amount of wind generation able to be connected.
- A theoretical analysis of a 275 kV reactor switching for Electranet SA.
- Load flow studies on the New Zealand 220 kV power system, investigating providing supply to an energy deficient area of the network – carried out for Meridian Energy Ltd. Options studied included new transmission lines, upgrading existing lines and inclusion of series capacitors into existing circuits.
- At Power Technologies Inc (PTI) he worked on 2 projects, the 1st compiling a database for carrying out fault and dynamic stability studies on the Dominican Republic's power system. The 2nd project was carrying out dynamic stability studies for a new generator connection on New York's Long Island power system.

Project Scoping and Cost Estimating

Andrew has completed the following project scoping and estimating jobs:

- 2012: ElectraNet, Australia. Independent construction contract cost estimation for a new 220/66 kV substation. A detailed cost estimate was developed to within a target +/-10% accuracy to enable comparison with a Contractor price.
- 2012: ElectraNet, Australia. Independent cost estimation for a number of transmission projects. A detailed cost estimate for each project was developed to obtain a cost estimate to within +/-30% accuracy, as an independent check for the client's own internal cost estimates. The results contributed to ElectraNet's revenue submission to the Australian Energy Regulator.
- 2011: Powerlink, Australia. Independent scoping and cost estimation of 275 kV and 132 kV transmission lines and 275 kV substation projects. A detailed scope for each project was developed to obtain a cost estimate to within +/-30% accuracy, as an independent check for the client's own internal cost estimates. For this job a cost estimating database was created from the ground up to create a range of 'building block' costs which can be combined to form a project cost estimate.

Design Engineer

Andrew has had experience as a design engineer for ESBI Engineering (UK) Ltd in the United Kingdom where he was:

- Responsible for all aspects of 132 kV substation electrical design covering: substation layouts, earthing design, protection schemes, drawings, equipment specifications, tendering and procurement.
- Gained proficiency in use of AUTOCAD for CAD work and also carried out factory inspections/ witness testing.
- A major project he worked on was the Spango Valley/ Devol Moor project (£3.5 million contract) involving a new 132 kV substation at Spango Valley and refurbishment of an existing 400/132 kV substation at Devol Moor, both near Glasgow, Scotland.

Appendix 2 – Summary of Recommendations

Ref	Priority (1-3)	Recommendation	Affected Process or Equipment	DL Doc Ref
1	1	Include signature boxes for all checklists including someone from APA to inspect and verify satisfactory completion of the work.	Operating Procedures and Work Instructions	
2	1	Include a process that drives obtaining photographic evidence of issues of concern, and how to store and recall these images easily	Operating Procedures and Work Instructions	
3	1	Develop a procedure for documentation control including the control of site documentation to ensure on site staff are operating from the latest versions of each document and to encourage the use of the manufacturer's documentation through easy access	Control of O&M Documentation	DL-DO-02
4	1	Fix DL-WI-02 diagrams and instructions to identify that there is no earth switch in the WT yard.	Site Access and Control of Authorised Personnel	DL-WI-02
5	1	Modify DL-WI-03 to include checks that water valve positions are checked and confirmed opened and that corona rings are checked for tools and debris before closing up a valve enclosure	Site Access and Control of Authorised Personnel	DL-WI-03
6	1	Check section 3.2 of the DL-WI-09 as to why there is a need to lock OPEN the earth switches and that there is no reference to locking the earth switch CLOSED.	High Voltage Switching and Access Procedures	DL-WI-09
7	1	If no record of authorisation levels exist, then ensure that these are maintained and available to system control	Authorisation Levels Register	
8	1	Recommend redoing the Asset Management Plan to address the key comments. The plan should include: a. Missing elements normally associated with an AMP - key roles and responsibilities, operations and maintenance team structure, call out philosophy, contractors under contract, which staff/contractors are used for which work, location of staff, plant and equipment, storage location of spare parts and consumables, overall maintenance philosophy (preventative, reliability centred etc), interface with the MMIS etc b. Missing elements normally associated with a Lifecycle Plan for the asset such as breaking the equipment into classes, identifying risks associated with the equipment, redundancy vs. non-redundancy, spares availability, strategy for managing the asset class and maintenance strategy. c. More detailed identification of asset management risks and associated mitigations.	Asset Management Plan	ML & DL EII Asset Management Plan
9	1	Consider developing separate asset management and maintenance strategies for each asset class (e.g. transformers, filter equipment, IGBTs, cables, cooling system etc)	Asset Management Plan	ML & DL EII Asset Management Plan
10	1	The recommendations for the maintenance plan will depend on which recommendations are adopted by APA for the Asset Management Plan above. Breaking the various items of equipment into asset classes and developing individual asset management and maintenance strategies for each class is recommended. These documents may be able to be used across both Directlink and Murraylink (i.e. the strategy for the converter transformers may be applied to all converter transformers including those at both Directlink and Murraylink).	Maintenance Plan	Extract from MMIS
11	1	Update DL-SP-01 to provide guidance as to how to conduct an investigation (e.g. evidence, interviews with staff shortly after the event) etc and which form shall be completed for record purposes	Electrical Incident Investigation	DL-SP-01
12	1	Update DL-SP-02 to provide instruction on how to document and record instructions from the NSP and actions taken by APA in the case of future investigations.	Electrical Incident Investigation	DL-SP-02
13	1	Update Chapter 12 of DL-OP-06 to refer to which form shall be completed in the event of an electrical accident	Electrical Incident Investigation	DL-OP-06
14	1	Develop procedures for the investigation and reporting of Directlink response to AC network events to demonstrate compliance to NER requirements.	Investigation and Reporting of Directlink Response to External AC N	DL-OP-20
15	1	Develop procedures for the investigation and reporting of Directlink protection trip events to demonstrate compliance to NER requirements	Investigation and Reporting of Directlink Protection Operations	DL-OP-20
16	1	Develop a more detailed public electrical safety plan, perhaps using the Essential Energy plan as a guide and/or comparing back to the requirements of this plan. It may be possible to combine a plan for all APA's transmission assets (e.g. Directlink and Murraylink	Public Electrical Safety Awareness Plan	NMP 23/5/2013
17	1	Compare the Bush Fire Risk Management Plan against the requirements.	Bush Fire Risk Management Plan	NMP 23/5/2013
18	1	Develop documented procedures for undertaking cable repairs including an inspection by APA personnel and sign off that the repairs have been completed and tested in accordance with the procedure	Fault Detection and Cable Repair	
19	1	Develop and issue a checklist for the preparation of the valve enclosures for re-energisation follow working in the valve enclosures	Pre-Energisation Inspection - Valve Containers	
20	1	Expand the inspection in DL-WI-44 to cover inspection of the rest of the building prior to energisation.	Pre-Energisation Inspection - Converter Building	DL-WI-44
21	1	Increase the instructions in DL-WI-44 beyond simply dealing with the moisture issue. Include inspections for tools and debris for example	Pre-Energisation Inspection - Phase Reactors	DL-WI-44
22	1	Create work instructions for the maintenance of the zero sequence reactors and remove references to these items from DL-WI-29	Zero Sequence Reactor	DL-WI-29
23	1	The table in DL-WI-38 needs a column for capacitance measurement.	Capacitors	DL-WI-38
24	1	Specify which manufacturer document applies to each reactor and be specific about which reactors are covered by DL-WI-29	Trench type reactors	DL-WI-29
25	1	Establish a pre-energisation checklist to ensure no water valves are left closed after IGBT replacements.	Valve IGBT Bank	DL-WI-13
26	1	Create a work instruction for the maintenance of the phase reactors and remove reference to these items from DL-WI-29	Phase reactor	DL-WI-29
27	1	Establish an annual work instruction for the maintenance of the SF6 Wall Bushings	SF6 Wall Bushing	
28	1	Establish a work instruction for yearly transformer maintenance in accordance with Section 8.4 of ABB document 000169568 Rev. 00	Power Transformer (3 ph). Including 2 x Current Transformers	
29	1	Confirm how/if Directlink IT assets are managed and maintained?	Control and Protection Systems	
30	1	Locate any additional manuals delivered with PCs and review for maintenance instructions.	Control and Protection Systems	
31	1	If IT maintenance procedures do not exist, put in place maintenance work instructions and IT/Control system procedures that follow good electricity industry practices	Control and Protection Systems	
32	1	Check all maintenance instructions for out of date document numbering (Some references to TEA documents can be found)	Operating Procedures and Work Instructions	
33	1	Check the procedures of the existing contractor meet all requirements outlined in the manufacturer documentation and create a work instruction for circuit breaker maintenance. This work instruction should be broken down into sections for the 3, 6 15 and 30 year circuit breaker maintenance.	Circuit Breaker	
34	1	Archive and maintain on hand the original test and commissioning documents that demonstrate compliance with the requirements of the NER.	Chapter 5 NER Review	
35	1	Develop a documented process for controlling and monitoring any changes implemented in the protection and control systems and confirmation of the NER compliance following such changes	Chapter 5 NER Review	

Ref	Priority (1-3)	Recommendation	Affected Process or Equipment	DL Doc Ref
36	1	Develop a documented and defined process for undertaking the analysis of the response of the HVDC Assets to external (AC network) faults in close proximity and internal protection trips, using the information available from the SER and TFR and other systems, concluding whether or not the HVDC Assets protection and controls have operated/responded correctly and as per design. Each investigation report shall: i. State whether the response of the HVDC Asset control and protection systems was the correct designed action or not; ii. State whether or not the HVDC Asset has met the performance obligations and is compliant with the NER, and iii. If discrepancies or a non-compliance is detected then NER rule 5.7.4(a3)-(a4) apply.	Chapter 5 NER Review	
37	1	Locate any commissioning documents that state specifically the results comply with the specification, CA or NER, for example fault clearing times or power quality.	Chapter 5 NER Review	
38	1	Clarify Section 4.3.1 of the Directlink Network Management Plan, which states that supply quality standard are monitored 24/7 at the control centre, and whether harmonics (CA Schedule 11, item 4) are covered by this monitoring.	Chapter 5 NER Review	
39	1	Check the Essential Energy CA to determine if testing intervals for protection systems (if any) and the agreed protocols for maintenance coordination are defined within it and if not that these be defined during the next review of the CA.	Chapter 5 NER Review	
40	1	Update the Directlink Network Management Plan and/or Asset Management Pla to document that APA will cooperate with any testing required by the respective NSP's for the connection asset protection and control systems and the ECSs.	Chapter 5 NER Review	
41	1	Develop a documented compliance program document specific for the Directlink protection and control systems covering how APA will demonstrate ongoing compliance with the NER, the periodic testing regime and the rationale behind the testing regime.	Chapter 5 NER Review	
42	1	The control system drawings embedded in the 'Plant Docs" system be updated to reflect the current "as built" status. It is noted that some changes made in 200 to the protection and control system have not been implemented in these drawings.	Chapter 5 NER Review	
43	1	Establish work instructions for the 1, 3 and 5 year maintenance of the various disconnectors and earth switches	Disconnectors and Earth Switches	
44	1	Create a four monthly maintenance work instruction to cover items in Section 8.3 of ABB document 000169568 Rev. 00	Power Transformer (3 ph). Including 2 x Current Transformers	
45	1	Review the fire system maintenance contractor procedures to ensure all manufacturer requirements are being me	Fire Detection Controller	
46	1	Add the four year replacement of lead acid batteries to fire system maintenance if this is not already covered in the existing schedule	Fire Detection Controller	
47	1	Consider a form included with the IGBT Replacement Form to ensure the Switching and Communication tests are performed on all IGBTs in a stack where an IGBT has been replaced	Maintenance Documentation	
48	1	Consider including a place in the IGBT Replacement form for the leakage current tests being performed on the faulty and adjacent positions.	Maintenance Documentation	
49	1	Modify the forms to allow more room for legible comments	Maintenance Documentation	
50	1	Discuss with staff regarding filling out forms correctly - clear and legible writing, dating the forms, identifying the sites, completing forms as required	Maintenance Documentation	
51	2	Include a section in all Work Instructions on which items of plant the WI applies to.	Operating Procedures and Work Instructions	
52	2	Where two procedures or work instructions cover the same ground, ensure one refers to the other rather than repeating and risking contradictions.	Site Access and Control of Authorised Personnel	
53	2	Ensure that instructions in DL-OP-06 and DL-OP-01 (tagging procedure) align. Some differences have been found that should be addressed	Site Access and Control of Authorised Personnel	DL-OP-06
54	2	Refer to where personnel can find the Safe Approach Distances referred to in DL-WI-02.	Site Access and Control of Authorised Personnel	DL-WI-02
55	2	Modify DL-OP-18 to include approvals and revision log. Be clear in this procedure on which application form to be used, how to obtain a "permit" and whether a risk assessment is mandatory or no	Site Access and Control of Authorised Personnel	DL-OP-18
56	2	Update Section 11 of DL-OP-05 to refer to DL-WI-02 and remove potential contradictions.	High Voltage Switching and Access Procedures	DL-OP-05
57	2	Update DL-OP-06 to address the various comments made.	High Voltage Switching and Access Procedures	DL-OP-06
58	2	Check consistency and ensure no double up between DL-OP-06 and other WIs.	High Voltage Switching and Access Procedures	DL-OP-06
59	2	Update DL-OP-05 to comply with how Directlink is currently being operated and dispatched.	Control Room Operations and Dispatch	DL-OP-06
60	2	Remove any contradictions or doubling up with other Wis in DL-OP-05.	Control Room Operations and Dispatch	DL-OP-05
61	2	Include a section in DL-OP-05 on how to respond to ambient temperatures belo zero degrees.	Control Room Operations and Dispatch	DL-OP-05
62	2	Update DL-DO-04 to provide clear instruction as to who is responsible for recording the outage and how	Recording and Reporting Outages	DL-DO-04
63	2	The use of the Operations Logs (DL-OF-16) may not be appropriate as the outage may get lost in other events. Suggest using DL-OF-17 the Outage Register and referring to it	Recording and Reporting Outages	DL-OF-16
64	2	Establish a contract for the periodical inspection of the cable route as stated in the NMP.	Bush Fire Risk Management Plan	NMP 23/5/2013
65	2	Develop a procedure for the periodical inspection of vegetation along the cable route and in the vicinity of the converter stations	Bush Fire Risk Management Plan	NMP 23/5/2013
66	2	Develop procedures for contractor management, if not covered by APA's overal systems. Include a process for receiving, reviewing and managing procedures used by specialist contractors	Contractor Management	
67	2	Modify DL-OP-18 according to comments in Directlink GEIP checklists	Easement Management	DL-OP-18
68	2	Include an explanation as to how to obtain a Permit in DL-OP-18	Easement Management	DL-OP-18
69	2	Develop an application pro-forma for the procedure in DL-OP-18	Easement Management	
70	2	Develop a procedure for the management of vegetation along the cable route/easement as identified in the NMP	Vegetation Control Surrounding the GST	
71	2	Develop a procedure or work instruction for the Maintenance and Testing of Earthing Systems	Maintenance and Testing of Earthing Systems	
72	2	Fix DL-WI-44 of errors and unclear instruction	Pre-Energisation Inspection - Converter Building	DL-WI-44
73	2	Modify DL-WI-34 so that they are clear as to which surge arresters are covered and which manufacturer document applies to each arreste	Surge Arresters	DL-WI-34
74	2	Check all capacitors covered by DL-WI-38 for unbalance protection. Establish annual capacitance measurement for those without unbalance protection	Capacitors	DL-WI-38
75	2	Correct errors under document references in DL-WI-29.	Trench type reactors	DL-WI-29
76	2	Change DC filter reactor document reference in DL-WI-29 from MI-99.01.0050 Rev. 00 to MI-201.01.0050 Rev. 00	Trench type reactors	DL-WI-29
77	2	Confirm correct manufacturer documentation for AC reactor WA-Z1-L1	Trench type reactors	DL-WI-29
78	2	Correct reference to PLC noise filter reactor documentation in DL-WI-29	Trench type reactors	DL-WI-29

Ref	Priority (1-3)	Recommendation	Affected Process or Equipment	DL Doc Ref
79	2	No maintenance instructions were included in the manufacturer documentation for the tuning units WT-Z(1,2). Locate maintenance requirements and include in a work instruction.	AC PLC Filter Tuning Unit	
80	2	Confirm that UPS system SCE is included in the six monthly inspection of UPS supply A and B.	UPS System SCE (Exide Prestige 1500VA)	
81	2	Confirm that UPS system for DC disconnector is included in the six monthly inspection of UPS supply A and B.	UPS for DC Disconnector (Powerware 2000VA)	
82	2	Check if the AC switchyard lighting maintenance is included in the emergency lighting maintenance	AC switchyard lighting	
83	2	Review the fire system maintenance contractor procedures to ensure all manufacturer requirements are being me	NT Fire Panel	
84	2	Review daily and weekly operator procedures to ensure the checks detailed in WFS-NTF-GB2202 Section 5 are being performed	NT Fire Panel	
85	2	Include a maintenance instruction for the eye wash station in DL-WI-17.	Eye wash station	DL-WI-17
86	2	Include a maintenance instruction for the spill kit in DL-WI-17.	Spill kit	DL-WI-17
87	2	Develop a work instruction for weekly cooling system inspection.	Valve cooling system	
88	2	Add a check of running hours for the valve cooling system pump since last oil change to DL-WI-17 Section 1.4.2. Alternatively, establish a three month work inspection that covers the requirements of the manufacturer document 8-1000-150/E.	Valve cooling system	DL-WI-17
89	2	Establish work instructions for the 1, 2 and 5 year valve cooling system maintenance	Valve cooling system	
90	2	Check existing 2 and 5 year maintenance for replacement of Ion-exchange resin and cleaning of strainers	Valve cooling system	
91	2	Check if the valve cooling system oxygen testing can be performed while the converters are deblocked and include a monthly oxygen test in DL-WI-17.	Valve cooling system	DL-WI-17
92	2	Correct header of DL-WI-33. It currently states that the work instruction is for an outdoor post type CT.	DC Cable Screen Current Transformer	DL-WI-33
93	2	Confirm the correct manufacturer documentation for the DC cable screen current transformer and update document reference in DL-WI-33	DC Cable Screen Current Transformer	DL-WI-33
94	2	Establish a work instruction for the six month check of the emergency lighting	Emergency Lighting	
95	2	DL-WI-28 - Three Year Capacitor Maintenance - the Forms are clearly not sufficient for all readings. It is recommended to redo these forms to align with th readings taken in the field	Maintenance Documentation	DL-WI-28
96	2	Fix header of document DL-WI-25. It currently states the work instruction is for a capacitive voltage transformer.	Valve Dehumidifier	DL-WI-25
97	2	Establish a work instruction for the 3 month clean of the dehumidifier filter.	Valve Dehumidifier	
98	2	Alter DL-WI-25 to include annual maintenance of the dehumidifier.	Valve Dehumidifier	DL-WI-25
99	3	Standardise on the name/title of the control centre (e.g. DLSC, Directlink System Control?)	Operating Procedures and Work Instructions	
100	3	Check definitions. For access and site control related procedures and work instructions, refer to definitions of DL-OP-06.	Site Access and Control of Authorised Personnel	DL-OP-06
101	3	Update DL-OP-05 to remove references to NorthPower, NEMMCO etc	High Voltage Switching and Access Procedures	DL-OP-05
102	3	Ensure that an accurate and up to date inventory of spare parts is maintained.	Spare Parts Inventory	
103	3	Ensure that a procedure exists and is followed that logs spare parts in and out and triggers the procurement of new spares where required. It should also identify who is responsible for the procurement decisions related to new spare parts.	Procedure for Managing Spare Parts Inventory	
104	3	Ensure that a procedure exists for managing special tools, including recording calibration dates, keeping certificates and ensuring the need for new calibration is triggered.	Procedure for Managing Special Tools	
105	3	Create an annual work instruction for cable ends. This will likely be limited to a clean and inspection	Cable Ends	
106	3	Include a reference to document XL 300 021-243 Rev. 01 in DL-WI-34 for arrester WA-Z1-F1	Surge Arresters	DL-WI-34
107	3	Include a check and record of the surge arrester operation counters in DL-WI-34	Surge Arresters	DL-WI-34
108	3	Establish a work instruction for periodic checking of the spark gap and procedur if flashover of spark gap should occur	Spark Gap	
109	3	Check on the maintenance requirements of the two CTs shown with P1-WT2-T1 No maintenance information was found for these items	Power Transformer (3 ph). Including 2 x Current Transformers	
110	3	Implement a permit log system to track permits issued and ensure unique numbering of permits	Site Access and Control of Authorised Personnel	
111	3	APA should have a copy of the training materials provided for HV Switching Course, even though this is provided by an external provider. The training content may be audited or otherwise may need to be referred to in the event of an incident	High Voltage Switching and Access Procedures	
112	3	Introduce a register of training undertaken to flag and record the performance of annual competency assessment and any re-training	High Voltage Switching and Access Procedures	
113	3	Maintain a record of authorisation levels exist, then ensure that these are maintained and available to system contro	Authorisation Levels Register	
114	3	Implement the annual assessment of competency into MARCUS.	Authorisation Levels Register	