

NZ Inter Island HVDC Pole 3 Project Update

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Abstract

Transpower is presently delivering a major project to replace New Zealand's Inter Island HVDC Pole 1 mercury arc valve converters with a new 700 MW thyristor converter pole. The new pole will be called Pole 3.

The Pole 3 Project will increase the north flow capacity of the HVDC bipolar link to 1,000 MW from 2012 (Stage 1) and to 1,200 MW from 2014 (Stage 2) by the addition of a STATCOM at Haywards. A third stage, involving the addition of a new submarine cable, to increase the capacity to 1,400 MW will be implemented at a later date subject to regulatory approval.

In addition to the new Pole 3 converters and STATCOM, the Project is delivering site improvements at Benmore and Haywards, new control and protection systems for the existing Pole 2 converters, new bipole and station controls, new unit connection transformers for Haywards' synchronous condensers and the refurbishment of all eight synchronous condensers at Haywards.

Site works for the project commenced in December 2009 and is now well advanced. Major civil works are nearing completion and electrical installation works will commence during the second half of 2011. Manufacture and factory testing of major HVDC equipment and systems is underway with shipment of major plant items due to commence in April 2011.

The paper provides an update on construction of the converter stations at Haywards and Benmore. Key aspects of the primary plant manufacture, seismic qualification and testing are discussed.

The key benefits of replacing the Pole 2 control systems are described in the paper and the physical implementation and factory testing of the communications and control systems is outlined.

Coordination with the other key subprojects is discussed and the planning and coordination for commissioning is introduced.

1 Introduction

In addition to the new 700 MW Pole 3 converters, the Pole 3 Project is delivering site improvements at Benmore and Haywards, new control and protection systems for the existing Pole 2 converters, new bipole and station controls, expansion of the 220 kV switchyards at both Benmore and Haywards, new dynamic reactive power equipment (STATCOM) at Haywards, new unit connection transformers for Haywards' synchronous condensers, refurbishment of all eight synchronous condensers at Haywards, and line clearance maintenance work on the HVDC transmission line. Further detail on the scope and history of the Project is described in the Pole 3 Project Update paper presented at last year's EEA Conference [1].

Major contracts for the converter station works, the Haywards site improvement works and the new synchronous condenser transformers were awarded in late 2009 and early 2010, with the major contract for the converter station works placed with Siemens. Since that time, detailed design of converter station equipment, buildings and switchyards have been completed, and equipment manufacture and testing and civil construction works are well advanced. Major civil works are nearing completion and electrical installation works will commence during the second half of 2011. Manufacture and factory testing of major HVDC equipment and systems is underway with shipment of major plant items due to commence in April 2011.

2 Construction of the Pole 3 Valve Hall, Control Building, and Transformer Bays

Excavation and construction works on the Pole 3 building foundations at Haywards commenced in May 2010. This followed the Site Improvement Works sub-project which established the physical platforms necessary for construction of the Pole 3 works.

Piling for the Pole 3 building foundations at Haywards was completed in December 2010. Eighty-four piles have been bored to solid rock; with depths ranging from 1.5 m to 26 m. Seismic accelerator arrays are being installed on some of the piles and on the building itself to monitor any displacement over time and acceleration which may occur during seismic events.

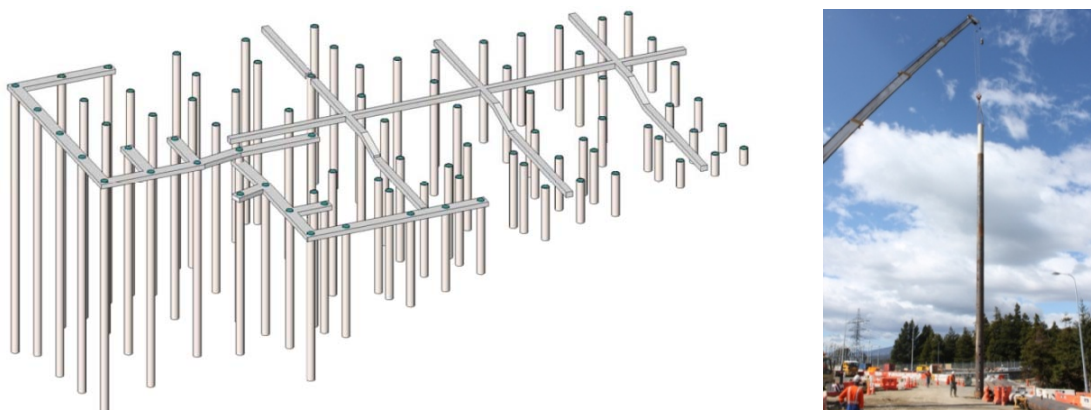


Figure 1: Haywards pile design (left) and Pile 05 at 26 m long (right)

At Benmore, excavation and construction works on the Pole 3 building foundations commenced in June 2010. The Benmore foundation is a raft slab design so no piling was

necessary. Apart from the foundations, the design and construction methodologies for the Haywards and Benmore Pole 3 buildings are very similar.

At both sites the construction of the basement foundation and base isolation plinths is complete and the lead rubber bearing and slider plate base isolation systems have been installed. The thyristor valve hall, two-storey control, services and facilities building, and bays for three converter transformers (weighing 330 tonnes each) are all constructed on a single floating slab that sits on top of the base isolation system.

The transformer bay, valve hall, and control building walls are of precast concrete construction. The larger precast panels, 300 mm thick and weighing up to 50 tonnes each, were cast onsite and the remaining panels were cast offsite at Otaki (for Haywards) and at Oamaru and Christchurch (for Benmore).

The structural steel for the roof of the valve hall was also manufactured offsite at Gracefield in Lower Hutt (for Haywards) and Timaru (for Benmore) and was pre-assembled into sections and painted before being transported to site. For programme efficiency and safety reasons, the entire roof structure, weighing approximately 140 tonnes, was constructed at ground level and lifted into place in a two-crane super-lift. The roof structure will support the 50 tonne weight of the three suspended quadruple valves. Seismic dampers will be installed in the valve hall floor to control the swaying of the quadruple valves during seismic events.



Figure 2: Base isolation system (left) and valve hall roof structure (right) at Benmore

By the time this paper is presented, construction of the valve hall and control building will be almost complete and ready for installation of the thyristor quadruple valves, transformers, and control and auxiliary systems.

3 Switchyards, AC Filter Banks, and STATCOM

Works have commenced in the AC switchyards at both Haywards and Benmore starting with the foundations for the 220 kV AC busbars, 220 kV connection bay equipment, and aerial gantries. Works continue with the excavation and construction of the foundations for the 220 kV filter banks, DC switchyard equipment, and Haywards STATCOM. The Pole 3 and switchyard electrical equipment is scheduled to start arriving at site from June 2011.

4 Construction Management and Site Safety

Transpower has full-time representation at both Haywards and Benmore for the duration of the project. At each site a Site Manager and a Site Engineer ensure that the works are constructed safely and to specification. In addition a Safety Assurance Officer covers both sites to ensure safety is at the forefront of construction and that safety requirements are being adhered to.

A yellow card reporting system (suggestion box format) was implemented during the Site Improvement Works sub-project at Haywards, and has continued at Haywards and been implemented at Benmore for the Pole 3 Project works. The system has been an effective tool for achieving buy-in and obtaining feedback from workers on safety observations and suggestions of ways to continually improve site safety.



Figure 3: Pole 3 building construction progress at Haywards (left) and Benmore (right), at the end of March 2011

5 Primary Plant

The Pole Three Project scope includes the following items of primary electrical plant:

- 271 MVA three winding, single phase, converter transformers
- 60 & 10 & 1.6 MVA three phase transformers for STATCOM and auxiliary power
- 350 kV DC, 12 pulse thyristor bridges and associated cooling plant
- 350 kV and 20 kV DC current and voltage measuring devices
- 350 kV DC switchgear, wall & roof bushings and smoothing reactors
- 220 kV AC Instrument transformers and switchgear
- 220 kV AC and 350 kV DC bus work, gantries and towers
- 220 kV AC filter capacitors, reactors and resistors
- 60 MVA multilevel IGBT STATCOM valve, reactors and associated cooling plant
- Medium voltage metal enclosed switchgear and cabling; and
- Spares for the above

6 Primary Plant Manufacturing

Most of the plant has been or is being manufactured in the main Contractor's factories or subsidiary factories in Europe, Canada and Brazil. Procurement of some items of plant have been sub contracted to other specialist manufacturing companies in Europe.

Six of the converter transformers are being manufactured in Nurnberg, Germany with the remaining two being manufactured in Zagreb, Croatia. Identical design, quality systems, materials and sub supplied items have been used. Presently three transformers in Nurnberg have passed their factory acceptance tests and are awaiting shipping and three are in the process of being manufactured. The first Zagreb transformer will start factory acceptance testing in early May.

All the valves associated with the 12 pulse bridges have been manufactured, appropriately tested and are awaiting shipping to the sites. Manufacturing of most of the remaining items of primary plant has started.



Figure 4: Thyristor quadruple valve impulse testing at University of Karlsruhe, Germany (left) and converter transformer factory impulse testing at Nurnberg (right)

7 Primary Plant Quality

Significant focus has been placed on ensuring that primary plant meets the specified technical, manufacturing quality, and testing requirements before it leaves the respective factories. These efforts have included:

- Review of Contractor's design documents
- Review of Contractor's specification documents for sub-suppliers
- Review of Contractor's factory inspection and test plans
- Monitoring factory testing
- Review of plant drawings
- Review of plant factory test results
- Auditing Contractor's document control
- Auditing Contractor's manufacturing and testing systems

As well as using its own staff Transpower has engaged the services of specialist consulting engineers to help with the design reviews, factory inspections, factory acceptance and type test witnessing, and independent advice.

Due to the number and different types of primary plant being manufactured for this project, the remoteness of the factories from New Zealand, and that multiple independent factories are manufacturing and testing within a narrow time frame; Transpower used a risk management approach to monitor factory testing. Where items of plant were considered to be high risk due either to unique design, new technology, new factory, high capital value or strategic importance to the project, then a Transpower Project Engineer witnessed type tests and factory acceptance tests. Where items of plant were considered to be medium risk to the project, then consultants were hired as Transpower's representatives during type or factory acceptance tests. For items of low risk, Transpower relied on accepting the quality system integrity of the factories involved. Transpower was involved with design reviews of high risk items before manufacturing started.

8 Seismic Qualification

The plant is specified to qualify to stringent international seismic requirements and this is verified by either modelling and calculations or by subjecting the plant to shake table testing. The large and bulky items like the converter transformers, mounted on base isolated foundations have been qualified by calculation because shake tables large enough for the task are not available. Smaller items, like instrument transformers and switchgear mounted on non-base isolated foundations, are being qualified by subjecting them to shake table testing at independent test facilities in Europe and America. This equipment is first electrically factory routine tested, then shake table tested, and then factory routine tested again to confirm that the electrical characteristics have not changed.



Figure 5: DC smoothing reactor mounted on seismic dampers at the Canadian factory; to enable a seismic pull test to verify calculations.

9 Transportation Planning

Transportation of high capital value plant items with long procurement lead-times has been carefully planned so as to minimise the risks of incurring equipment damage or late delivery, and thereby minimise consequential risks which could impact project completion. For example, no more than two converter transformers will be transported to NZ on the same ship.

Given the size and weight constraints involved, practical oversized transportation equipment and routes are being sourced and planned to be available to transport the transformers to their respective sites when they arrive in NZ. The transportation route to Benmore is relatively straight forward and will be similar to that used for the Pole 2 transformers 20 years ago. However, recent changes to railway lines, motorways and bridges in the Wellington area means that the route to Haywards will be different to that used for the Pole 2 transformers. Transportation planning has involved the Contractor, transportation sub-contractors, relevant Statutory Authorities, Local Body Authorities and other interested parties.

10 Control System Overview

Along with the new control system being delivered as part of the new Pole 3, a replacement of the existing controls on Pole 2 is also being carried out. These existing controls are at the end of their life. By including the Pole 2 controls replacement as part of the project it has been possible to introduce new control functionality across the Bipole as well as providing flexibility for future upgrades.

The controls themselves are distributed across the Station Control, Bipole Control and Pole Control systems. Station Control implements the reactive power controls and runbacks, Bipole Control implements a majority of the stabilisation functions such as frequency stabilisation along with the core power transfer functions, and Pole Control implements pole level protections, interfaces to the valve and fast modulations for fault recovery.

11 Physical Hardware and Control System Design

Hardware design is based on a digital control system utilising the Siemens TDC system. This is a modular system made up of a rack and a number of input/output, processor, and communications cards (Figure 6) depending on the needs of each control system. A similar approach was implemented with the existing HVDC control system delivered 20 years ago, however the new controls make a much greater use of digital communications networks rather than using analogue and digital signal exchange between systems. Field bus communications are used to gather status information from the various AC and DC plant items and to issue control signals to field plant. Ethernet and specialised high speed networks are used between the core control systems to share information, implement logic and action protective functions.



Figure 6: TDC controls in Bipole Control (left) and HMI screen example (right)

All of the core control systems are redundant to ensure a highly available system is in place. Physical diversity is also provided through the communications cables being laid separately and having the Bipole and Station control systems located in different buildings to avoid common physical failure modes. The human machine interface (HMI) is presented through the Siemens WinCC system (example screenshot shown in Figure 6). HMI's will be located in the pole buildings at Haywards and Benmore for local control and at the Regional Control Centre in Christchurch which will be the normal control location for the HVDC. These

systems have been designed to be as similar as possible to the existing National SCADA HMI to provide a familiar environment for the operators.

12 Communications and System Integration

Inter-station communications is critical for the operation of the controls and coordination of the various protections systems. This is implemented over Transpower's new fibre wide area network. This will enable the HVDC control system to operate over a very low latency communication network with high availability.

Connectivity also needs to be provided to a number of Transpower's existing systems for operation and maintenance of the system. This includes the SCADA system for operational telemetry, control and integration to the Electricity Market system and a historian system for capturing long term performance and support data from the HVDC system. These interfaces are being provided through a secure network connection into the HVDC systems.

13 Factory Testing of the Controls

A critical aspect of the overall control system qualification process is the factory acceptance testing (FAT) or off-site testing which is planned to start in May 2011 and last for 3 months. These tests are all carried out in Erlangen, Germany in a 26m by 15m room with all of the 56 core control cubicles that are to be delivered to Haywards and Benmore in operation (see photo from this area in Figure 7). For these tests the control equipment is interfaced with a real time digital simulator for power system simulation and switchyard simulation equipment.

During this phase of the project physical proof of controls, protection and logic functions and performance of the overall interconnected AC and HVDC system will be provided. The key objectives of this process are to confirm the dynamic performance and models relevant to system security; ensure that protection systems function correctly and meet performance requirements; and to complete tests which will not be able to be undertaken on-site for system or safety reasons.



Figure 7: Photo of layout in the FAT area

14 Co-ordination with Other HVDC Works and Planning for Commissioning

To successfully commission Pole 3, significant HVDC related work needs to be coordinated and completed. This work includes:

- completing the build, livening, testing and commissioning of the new HVDC Pole 3 converter stations and associated electrical equipment at Haywards and Benmore;
- decommissioning Pole 1 at Haywards and Benmore, which will occur immediately after the Rugby World Cup, to make way for the final stage of Pole 3 construction;
- replacing the HVDC overhead conductors on both Poles between Haywards and Oteranga Bay in the lower North Island, which have reached their end of life;
- replacing both conductors on the electrode line between Haywards and the coast near Makara;
- replacing, or raising of, 94 HVDC towers in the South Island, to resolve clearance issues and to enable the line to carry the full 1200 MW after Stage 2 of the Pole 3 project is completed in 2014, and significant foundation strengthening; and
- refurbishing the eight Synchronous Condensers at Haywards, including replacement of a stator winding on at least one of the condensers which has been completed in February.



Figure 8: Haywards Synchronous Condenser C1 – New Stator Winding

In addition to this, regular maintenance outages are required for both existing poles and a major bushing replacement at Fighting Bay (where the undersea cables come ashore in the South Island). Except for the synchronous condenser work, all these works must be completed before the commissioning of Pole 3. To carry out these works and ultimately commission Pole 3, it has been necessary to enter into a period of significant outages on the HVDC link since the end of March 2011. In particular, the line work requires extended outages of at least one Pole if the work is performed conventionally. However, the following steps are being taken to minimise outages:

- For the North Island HVDC line reconductoring, Transpower has worked with local landowners to build temporary 270,000 volt bypass lines. This means that both Poles can continue to run: one side of the HVDC line will be reconducted (with the other side live), while the second Pole is run on the bypass line. Total transfer capacity when using the bypass line (about eight to ten weeks in total) is slightly reduced by the capacity of the bypass conductor.
- The electrode line conductors are being replaced one by one (with the other remaining in service). This reduces the electrode line capacity for a period, leading to some reduction in total HVDC transfer capacity.
- To raise or replace the South Island towers, an outage would normally be taken. However, because of the long periods of HVDC unavailability (i.e. bi-pole outage) that

would result, it is planned to do this work live, using a combination of cranes where access is available, and new tower jacking devices where crane access is not possible. In some instances, towers will be raised with the live conductors attached; in others, the live conductors will need to be moved across to temporary towers.

Doing the work in this manner is very resource intensive. Experienced line workers and equipment have been brought in from around the country, but resources are stretched because of the work we have elsewhere. The work is also very dependent on weather: many of the sites cannot be reached in wet weather, and re-conductoring can't take place in windy weather. Thus, the timing of the line-related outages will inevitably move around (particularly the shorter bi-pole outages still necessary to connect and disconnect the bypass line). Regular maintenance and early Pole 3 work is being scheduled to coincide with these outages.

The major Pole 3 construction and commissioning outages are expected to start in the summer, and include extended bi-pole outages. As the work progresses, it is possible that outside factors could impact on the completion of the work. In particular, changes to scheduled outage times for major generators could have an adverse effect. To ensure that these types of issues are shared, discussed and addressed, Transpower has been running a Commissioning Advisory Group with the industry (see www.gridnewzealand.co.nz/hvdc-industry-participation) to keep industry participants fully informed about outages, and other system requirements that Pole 3 construction and testing will require. This group will continue to operate until all work being delivered under the Pole 3 Project is commissioned.

15 Summary

Major civil works are nearing completion and electrical installation works will commence during the second half of 2011. Manufacture and factory testing of major HVDC equipment and systems is underway with shipment of major plant items due to commence in April 2011. Factory acceptance testing (FAT) of the new Pole 3, Pole 2, Bipole and Station controls will start in May 2011. The FAT is critical for proving the functionality and dynamic performance of the control and protection systems and ensuring readiness for commissioning on the live network, prior to them leaving the factory and being shipped to New Zealand.

The remaining site construction and commissioning work for Pole 3 is presently being coordinated with other HVDC related works which involves a period of increased outages on the HVDC link until Pole 3 has successfully completed system acceptance testing. To keep industry participants fully informed about outages, and other system requirements which Pole 3 construction and testing will require and associated risks and issues, Transpower is running a Commissioning Advisory Group with the industry. This group will continue to operate until all work being delivered under the Pole 3 Project is commissioned.

References

- [1] Peter Griffiths and Mohamed Zavahir, 'NZ Inter Island HVDC Pole 3 Project Update', EEA Conference 2010, Christchurch.