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Paper Title **NZ Inter Island HVDC Pole 3 Project Update**

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Abstract

Transpower has commenced 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. The paper provides a description of the Project's scope, its staged development plan and an update on the works completed to date. Key measures which are being undertaken to ensure reliable operation of Pole 2 whilst Pole 3 is being constructed, and minimise the duration between Pole 1 decommissioning and Pole 3 commissioning are discussed.

The converter station layouts, seismic design, construction sequencing and audible noise measures being implemented at both Haywards and Benmore are outlined in the paper.

The main system parameters for the HVDC converter stations and associated electrical works are outlined in the paper and key performance and technical requirements for the major systems and equipment are discussed. The high level hierarchy and functionality of the new control system are also described.

1 Introduction

The first New Zealand HVDC bipole link (Figure 1) was commissioned in 1965 rated at +/- 250 kV and 600 MW consisting of mercury arc valves (MAV) between Benmore and Haywards [1]. Between 1987 and 1992, a major upgrade resulted in a 1240 MW link termed the Hybrid Link (shown in Figure 2 in its present configuration). In its original form, the hybrid link consisted of two poles, Pole 1 rated 270 kV, 540 MW using mercury arc valve groups, and Pole 2 rated 350 kV, 700 MW with thyristor valves. Pole 1 consisted of four six-pulse valve groups per station configured for 6 or 12 pulse operation. New control systems for both poles were also installed as part of the upgrade. At the time of commissioning, the Hybrid Link used a total of 4 submarine cables providing a maximum bipole capacity of 1240 MW. With the loss of one cable the capacity was reduced to 1040 MW, with Pole 2 limited to 500 MW. Half of the mercury arc valves in Pole1 were decommissioned in 2008, and the remaining half of Pole1 continues to be in service under limited operating conditions in the northwards direction only.

At Haywards, Pole 1 and 2 are connected to 110 kV and 220 kV buses respectively. The 110 kV bus feeds the Wellington load of approximately 600 MW whilst the 220 kV bus connection predominantly provides power flow to the north of Wellington. Three transformers provide an interconnecting capacity of 600 MVA between the 220kV and 110kV buses.

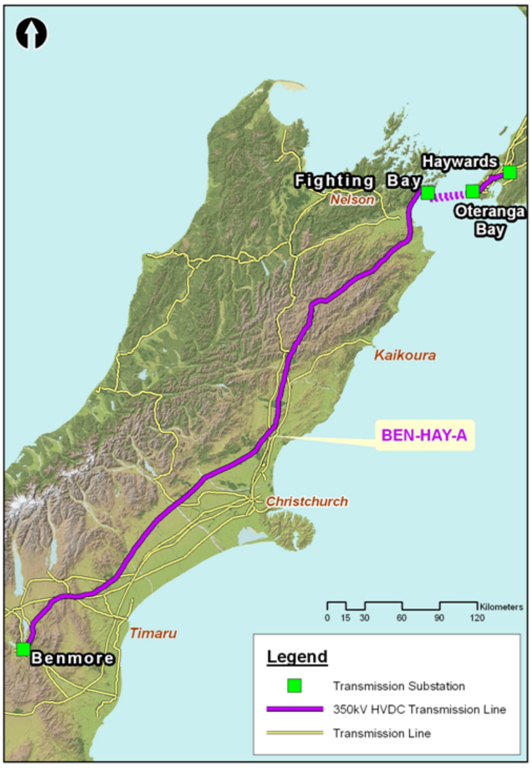

Figure 1: New Zealand Inter Island HVDC link

At Benmore Pole 1 is directly connected to hydro generators on the 16 kV bus. Interconnecting 220/33/16 kV transformers provide the interconnection to 220 kV and accommodate AC filters at 33kV. With Pole 1 out of service, the net output from these generators can be limited by interconnector capacity. Original plans made allowances for a replacement Pole 1 at Benmore and Haywards to be connected to the 220 kV bus. When implemented, this will shift a large amount of generation and HVDC capacity from the present injection points. At Haywards, approximately 500 MW will be shifted from the 110 kV bus to the 220 kV bus requiring a significant rearrangement of the AC switchyard.

The present configuration of the HVDC link is shown in Figure 2.

Regulatory approval to replace the 45 year old Pole 1 with a new state of the art thyristor valve based pole with a nominal continuous rating of 700MW as described in Transpower's HVDC Grid Upgrade Investment Proposal [2] was received in September 2008.

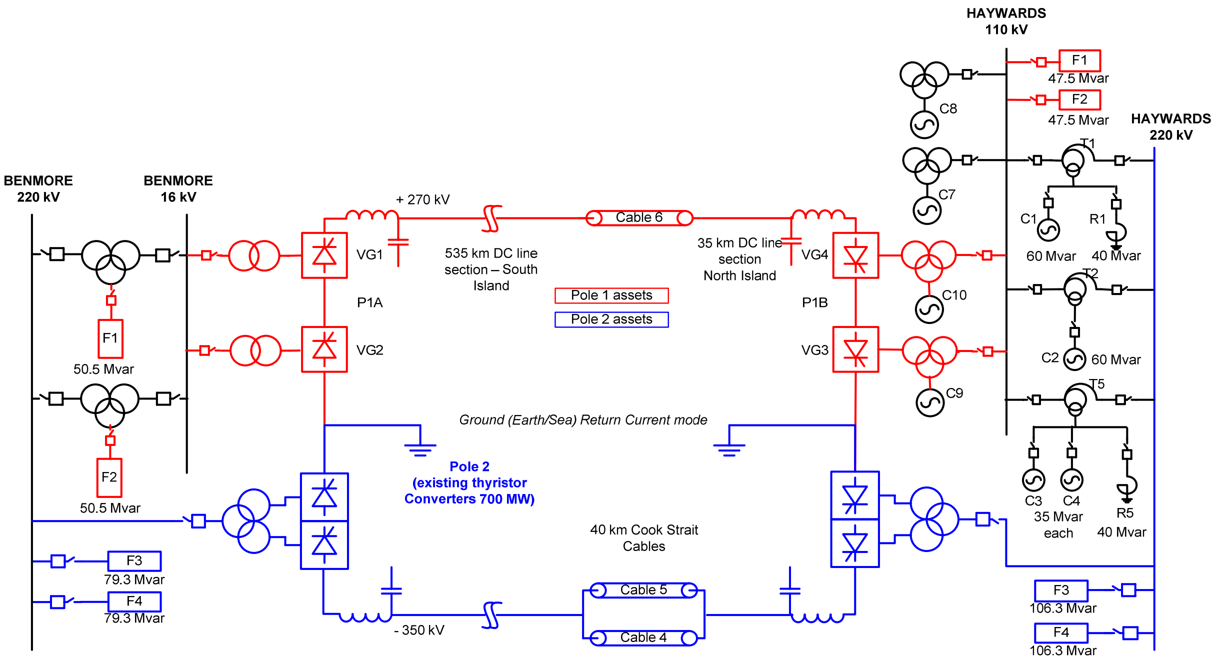

Figure 2: Present Configuration of the NZ Inter Island HVDC Link

2 Pole 3 Project Scope

The new pole will be called Pole 3 and consequently the full programme of works to replace Pole 1 is referred to as the "Pole 3 Project", even though the project scope is much larger than the works required to engineer, procure and construct the new Pole 3 converters. The broader scope of the Pole 3 Project is illustrated in Figure 3 and includes replacement of the Pole 2 and bipole control systems, expansion of the 220kV switchyards at both Benmore and Haywards, new dynamic reactive power equipment at Haywards, significant site improvements (seismic strengthening), new synchronous condenser transformers and refurbishment of the synchronous condenser at Haywards, and line clearance maintenance work on the HVDC transmission line.

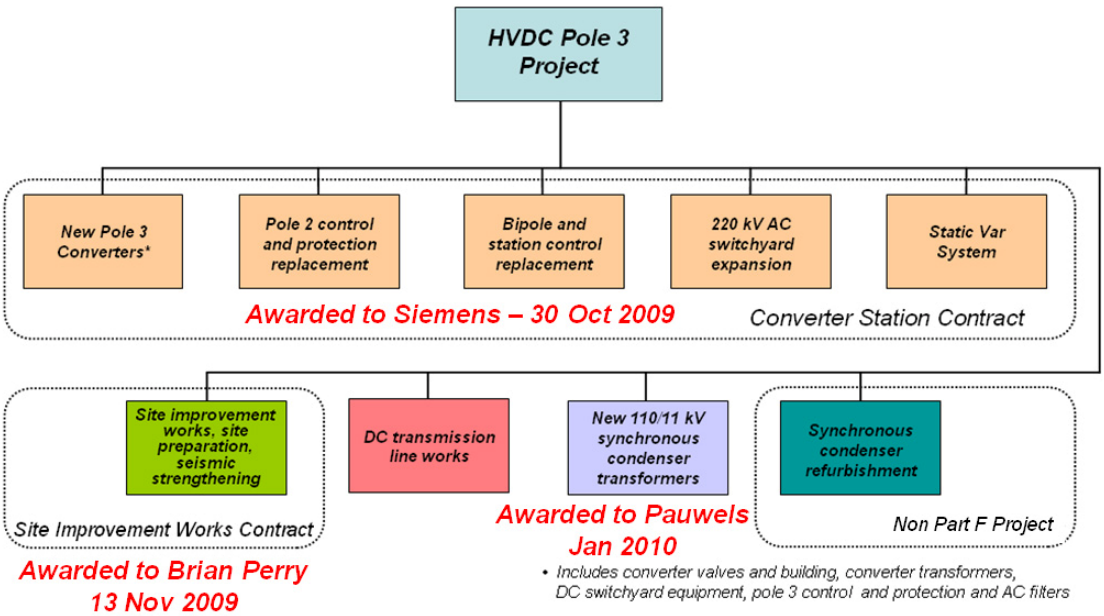

Figure 3: Pole 3 Project Scope

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 as shown in Figure 3.

3 Staging

The Pole 3 Project will increase the northflow 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 Static Var System (SVS) 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. The planned configuration of the NZ Inter Island HVDC Link at the completion of each stage is shown in Figure 4.

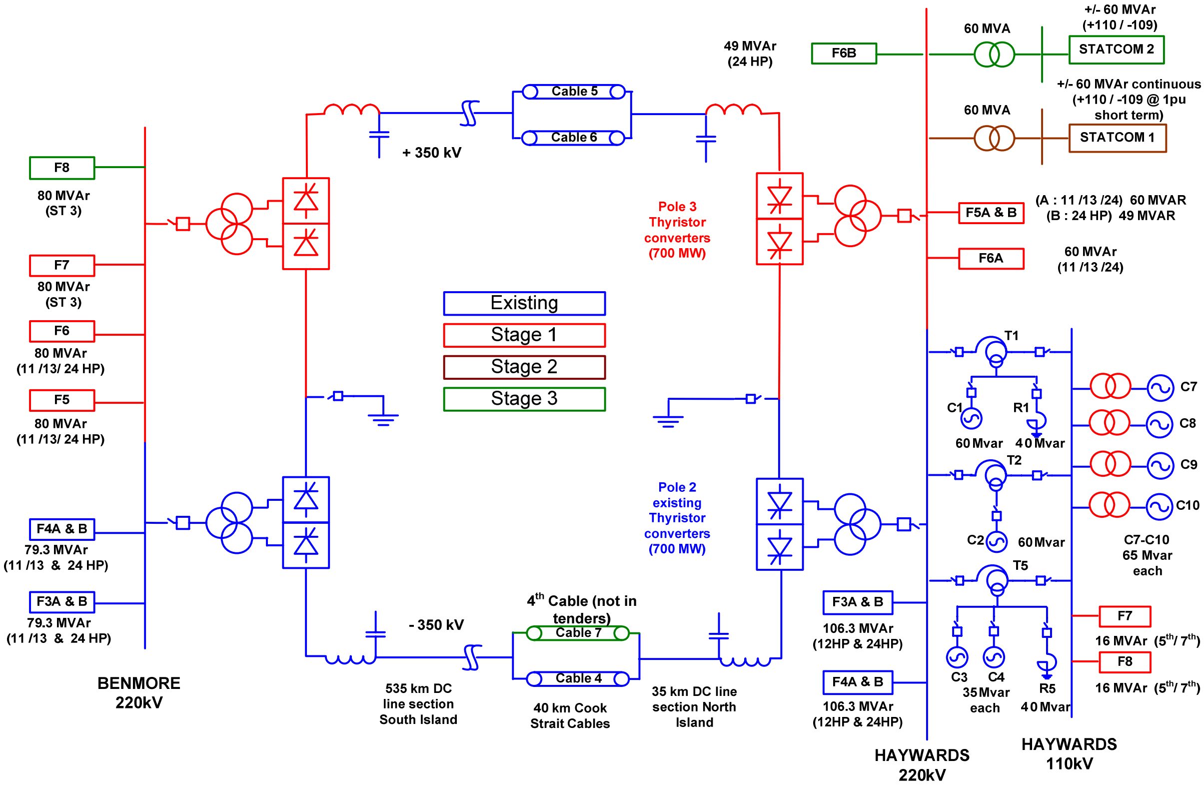

Figure 4: Future Configuration of the NZ Inter Island HVDC Link

Stage 1 (1000 MW) works involves the construction and installation of AC Switchyards (extension of 220 kV busbars), valve halls and thyristor valves, converter transformers, DC switchyards, AC harmonic filters (220 kV and 110 kV), control buildings and controls (new Pole 3, upgrade Pole 2, new Bipole & Station control) and station services at both Haywards and Benmore. New 110kV filters and two synchronous condenser unit transformers will also be installed at Haywards.

Stage 2 (1200 MW) works at Haywards includes the construction and installation of a Statcom and two synchronous condenser unit transformers. No major Stage 2 works is required at Benmore.

In addition to a new submarine cable, the future Stage 3 (1400MW) (not yet approved) works will likely include the construction and installation of additional AC harmonic filters (220 kV) at both sites as well as an additional Statcom at Haywards or elsewhere in the Wellington region in close electrical proximity to Haywards.

4 Key Staging Issues

Site works for the Pole 3 Project has commenced and is being planned and carried out so as to minimise the impact on the availability of the existing assets, notwithstanding the very congested conditions at Haywards. This is particularly critical given the predominantly monopolar nature of the HVDC link and the market's present reliance on Pole 2.

Market reliance on Pole 2 introduces key issues which have been addressed during the planning of the Pole 3 Project. Critically, operation of Pole 2 must not be detrimentally impacted during the construction and commissioning of Pole 3. To manage this situation as effectively as possible, several measures are being undertaken, including:

- Constructing a new control building for Pole 3, physically separate from the existing Pole 2 control building (Figures 5 & 6). This approach significantly reduces the level of physical activity (e.g. cubicle installation, cable pulling etc) around Pole 2's control and protection systems during installation of the Pole 3 control systems;
- Managing the site to ensure Pole 3 construction work is physically segregated from existing Pole 2 facilities where possible.

Figure 5: New Site Layout Planned for Benmore (Pole 3 buildings shown in yellow)

In addition, it is planned for:

- Pole 1 to remain available for emergency operation throughout the construction of Pole 3 for as long as practicably feasible. At this stage, Pole 1 is scheduled to be decommissioned at the beginning of November 2011, prior to completing construction of Pole 3 as the existing Pole 1 dc filter will be re-used with Pole 3;
- the duration between Pole 1 decommissioning and completion of Pole 3 trial operation to be keep as short as practically feasible;

- Pole 3 to prove its operational availability at (or above) target levels prior to replacing the Pole 2 control & protection systems; and
- Pole 3 to not be detrimentally impacted during replacement of the Pole 2 control & protection systems.

5 Site Layouts

The post-Pole 3 Project site layouts for Benmore and Haywards are shown in Figures 5 and 6 respectively, with new assets shown in colours and existing assets shown in grey. At Haywards (Figure 6), two new switchyards are being developed. The new harmonic filters for Pole 3 will be located in switchyard D (the present location of Pole 1 – middle left of Figure 6) and switchyard C (SW corner) will serve as the connection point between switchyard B (SE corner) and switchyard D. Switchyard C incorporates a 6m high 140m long earth bund at its southern boundary which, combined with landscaping, reduces both audible noise and visual effects at the southern boundary. The new Stage 2 Statcom will be located in the north eastern corner of switchyard B.

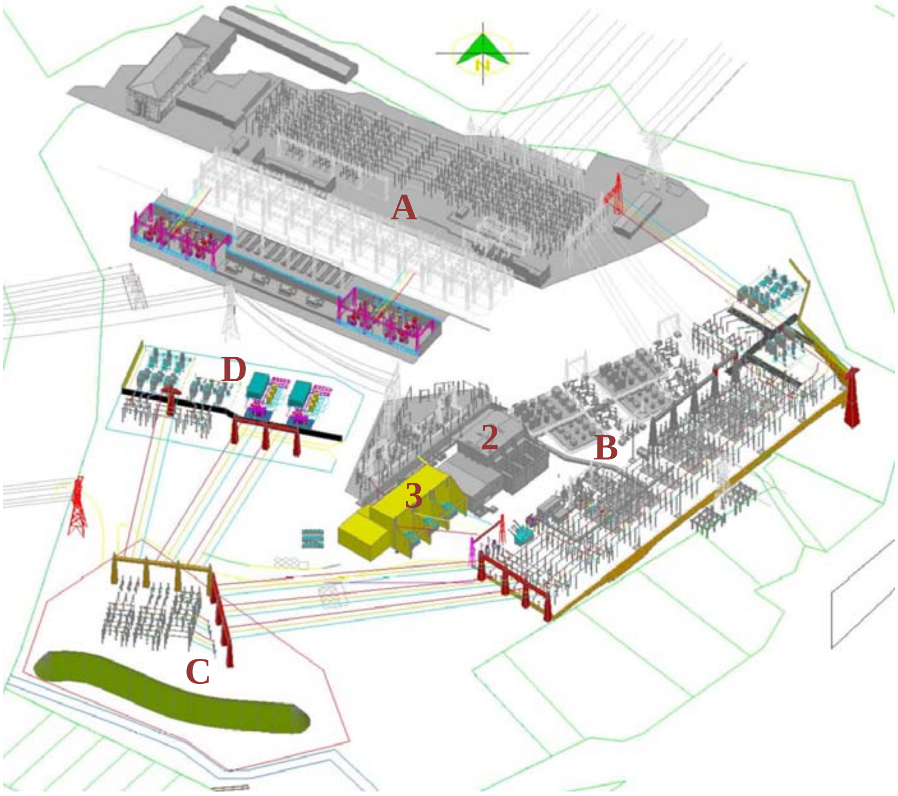

Figure 6: New Site Layout Planned for Haywards (Pole 3 buildings shown in yellow)

6 Works Progress

6.1 Site Establishment

Site works for the Pole 3 Project commenced with site establishment at Haywards and Benmore in December 2009 and March 2010 respectively. Prior to commencing site establishment works at each site, planning work was carried out to:

- determine how the site should be segregated to allow ongoing operation and maintenance works to be carried out without being impeded by Pole 3 construction works, and vice versa; and

- develop access control measures, including segregating the site into different zones according to the safety hazards within those zones; and
- determine the location and layout of the site village (i.e. single area for the site offices and amenities for Transpower, all contractors and all subcontractors on the site) at each site. This approach has been taken to encourage open communication and co-operation between all individuals working on site.

This focus on safety, community and uninterrupted maintenance operations resulted in site establishment plans for each site including drawings (Benmore shown in Figure 7) detailing the locations of the site village (shown in light green), new maintenance access roads (shown in orange/red), vehicle access routes (shown in green), reduced speed limits, car parking areas (shown as hashed), and new semi-permanent fencing (shown in pink and aqua) segregating the site into different zones including live switchyard areas, areas segregated from live equipment by fencing but still within the substation and non-live/public areas. The competency requirements for workers within each safety zone are clearly defined and zone access is actively controlled.

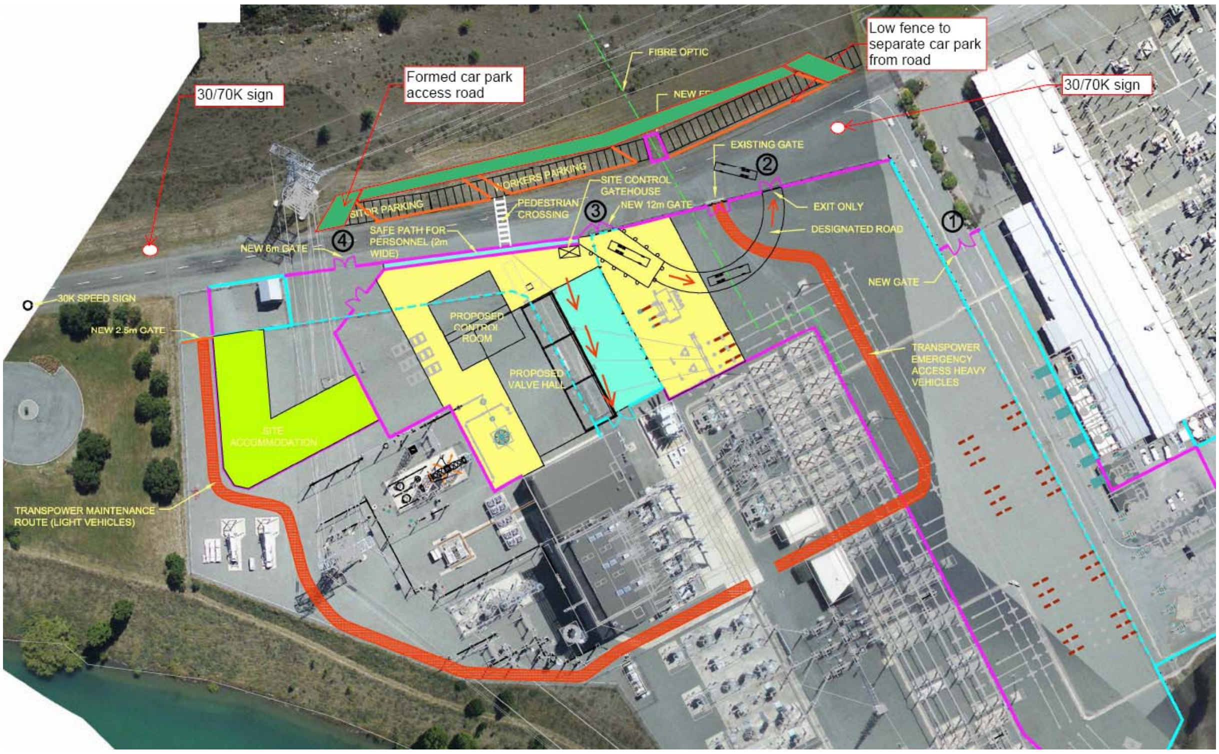

Figure 7: Benmore Site Establishment Plan

Given the size of both sites, and at the initiative of Brian Perry Civil (BPC) at Haywards, safety kiosks have been introduced to the project to ensure safety information and equipment is kept as close as possible to each work face within the site. Information and equipment contained within a safety kiosk includes a local hazard board; work plans, job safety & environment analyses (JSEA) and induction & sign on sheets for work being undertaken in that area; first aid kit, sun block, ear plugs, an oil spill kit and a recycling bin for scrap metal.

6.2 Site Improvement Works

Site improvements works at Haywards commenced in December 2009 and is now nearing completion. These works have established the physical platform necessary for the new Pole

3 buildings (including a new piled retaining wall – Figure 8 left), the piled retaining walls and platform required for the new switchyard C (Figure 8 right) and the clearing and development of half of switchyard D following the removal of Pole 1A outdoor equipment. The site improvement works also includes seismically strengthening existing retaining walls and upgrading the water mains throughout the entire Haywards site.

 

Figure 8: New Platform and Retaining Wall for Pole 3 (left) and New Platform for Switchyard C (right) at Haywards

6.3 HVDC Converter Stations and Associated Electrical Works

The new Pole 3 converter stations (including valves, valve halls, converter transformers, control buildings, ac filters, dc yard expansion etc), new Pole 2 and bipole control systems and 220kV switchyard expansion at both Haywards and Benmore and a new static var system at Haywards are being delivered by Siemens under an EPC (engineer, procure, construct) style contract (Figure 3).

Main system parameter design for Pole 3 is complete and detailed design for associated HVDC plant and the control and protection systems are progressing. Shake table testing verifying seismic performance of new Pole 3 and Pole 2 control cabinets and equipment was completed in May 2010.

Foundation excavation works for the new Pole 3 buildings at Haywards and Benmore commenced in May and June 2010 respectively.

Looking forward, construction and finishing of the new Pole 3 building at both Haywards and Benmore will continue through to early in the second half of 2011 and manufacturing of the converter transformers and values will take place during the second half of the 2010 and the first half of 2011. Installation of Pole 3 plant and equipment is scheduled to commence toward the end of the first half of 2011 with completion at the end of 2011 ready for commissioning works to commence in early 2012.

6.3.1 Seismic Design – Foundations, Buildings and Equipment

Given the site locations, in particular Haywards, specific measures are being undertaken to ensure suitable seismic designs (and seismic diversity) for the buildings, equipment and structures being constructed or installed at each site. Overarching seismic design requirements include:

- New Pole 3 to have a high level of seismic resilience
- Structural form and materials of buildings

- Locating Pole 3 on rock or suitably strengthened ground
- Incorporating seismically robust and resilient design in the Plant and buildings
- Natural frequencies and damping systems in the plant and buildings
- Diversity between Pole 3 and Pole 2 where possible
- Seismic risk management strategy supported by failure analysis modelling
- Supply and safe storage of a suitable number and type of spare components

In addition, buildings and plant are being designed and tested in accordance with:
- The NZ Building Code;
- Transpower's seismic policy in conjunction with site-specific spectra; and
- IEEE Std 693-2005 Recommended Practices for Seismic Design of Substations

In case of the Pole 3 building (including the valve hall, the control buildings and the transformer bays), base isolation (i.e. use of lead-rubber bearings as shown Figure 9) is being installed.

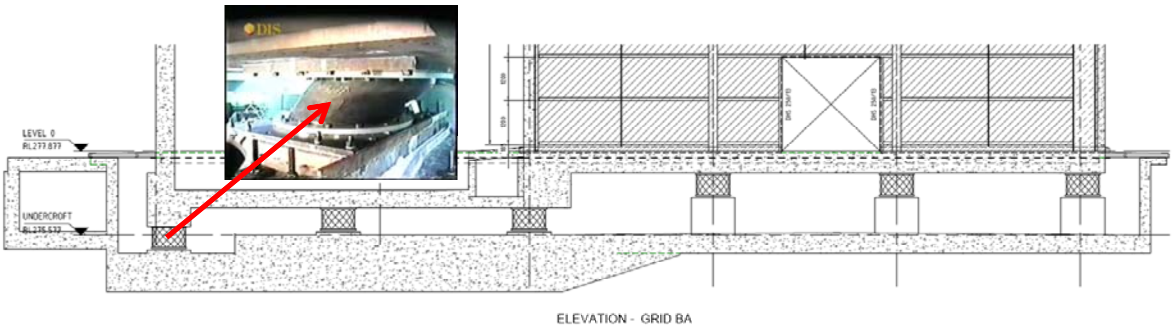

Figure 9: Base Isolation for Pole 3 Valve Hall, Transformer Bays & Control Building

6.3.2 Main System Parameters

Pole 3 will have a nominal continuous rating of 700MW in both directions and short-time (30min) overload rating of 1000MW. A high level comparison of the main system parameters and physical dimensions of the converter transformers and thyristor valves for Pole 2 and Pole 3 are provided in Appendix 1.

6.3.3 Control Functionality and Hierarchy

The control and protection systems at each converter station consist of a remote control facility (RCI gateway in Figure 10), local station HMI systems, a Station Control system, the HVDC control systems, the Valve Base Electronics for thyristor gating and monitoring, AC substation automation system, event and fault recording equipment, various protection systems and various station internal and station-to-station communication systems.

The HVDC control systems are sub-divided into three separate systems – Pole 2 Control, Pole 3 Control and Bipole Control. The separate Station Control system implements Reactive Power Control and Runback Control. Each of these systems (with the exception of the Statcom control) is being implemented in redundant configurations.

The high level functionality provided by each of these systems is outlined in Figure 10.

6.4 Synchronous Condenser Refurbishment and new Transformers at Haywards

The synchronous condenser works at Haywards includes the replacement of the existing Pole 1 converter transformers with new unit connection transformers connecting the synchronous condensers C7-C10 to the 110 kV AC system in switchyard A. In addition, all eight synchronous condensers (last refurbished 20 years ago) at Haywards will be refurbished. The refurbishment works includes mechanical/electrical overhaul, replacement of excitation, monitoring and control/protection systems, and upgrade of hydrogen cooling systems and fire protection systems. Refurbishment of the first synchronous condenser (C1) is scheduled to commence early in the second half of 2010 and the first new unit connection transformer for the first outdoor synchronous condenser (C7) is expected to be commissioned in early 2011.

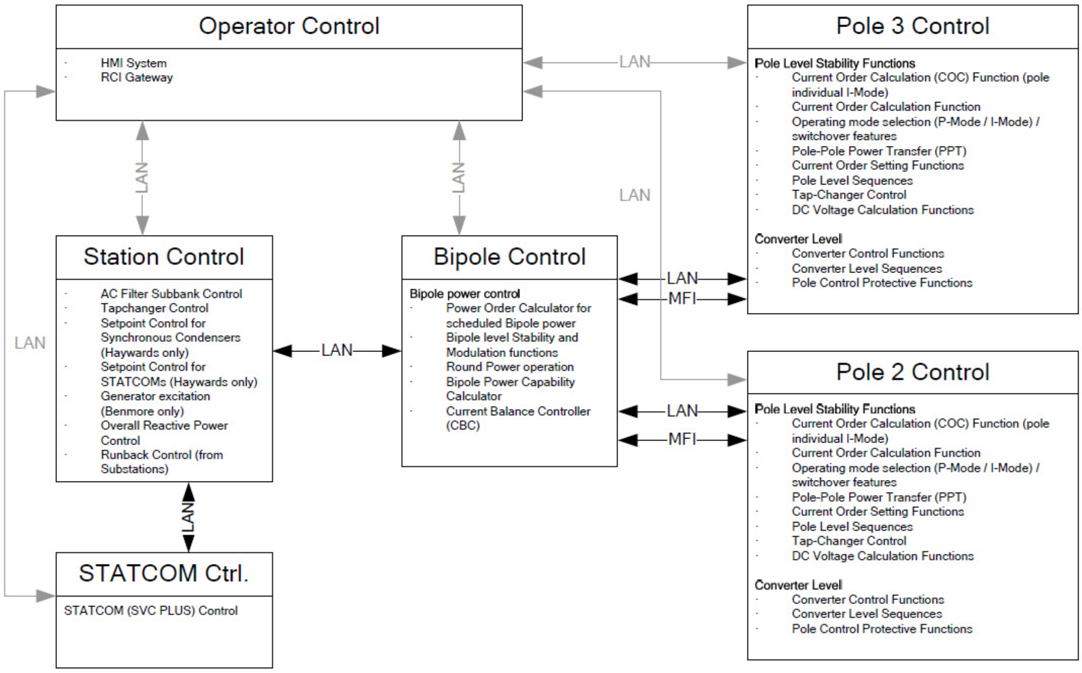

Figure 10: Control System Hierarchy and Functionality

6.5 HVDC Transmission Line - Clearance Maintenance

The Pole 3 Project does not change the rating of the line from that at the completion of the HVDC Hybrid link, however, improved survey techniques (e.g. Aerial Laser Survey (ALS)) have identified possible line clearance issues. Design work to select appropriate rectification methods at various locations is currently being completed. Rectification works will be undertaken as part of ongoing maintenance activities in the areas affected.

7 Timeline

The current project timeline is outlined in Figure 5. Commissioning of Pole 3 is planned to begin in January 2012 with Pole1 being decommissioned permanently in early November. Commissioning, which will include system acceptance testing and trial operation, is expected to be completed by the end of April 2012 (Stage 1 – Part A as per Figure 5).

Once Pole 3 is operational, and subject to it meeting or exceeding target availability levels over the winter of 2012, the Pole 2 control system will be upgraded. These works are expected to commence at the end of September 2012 and will require Pole 2 to be out of service for at least three weeks. Following this outage, Pole 2 will be recommissioned and the HVDC link's bipole controls will be upgraded (Stage 1 – Part B). Pole 3 will be available throughout the period required to upgrade and commission the new Pole 2 and bipole control systems.

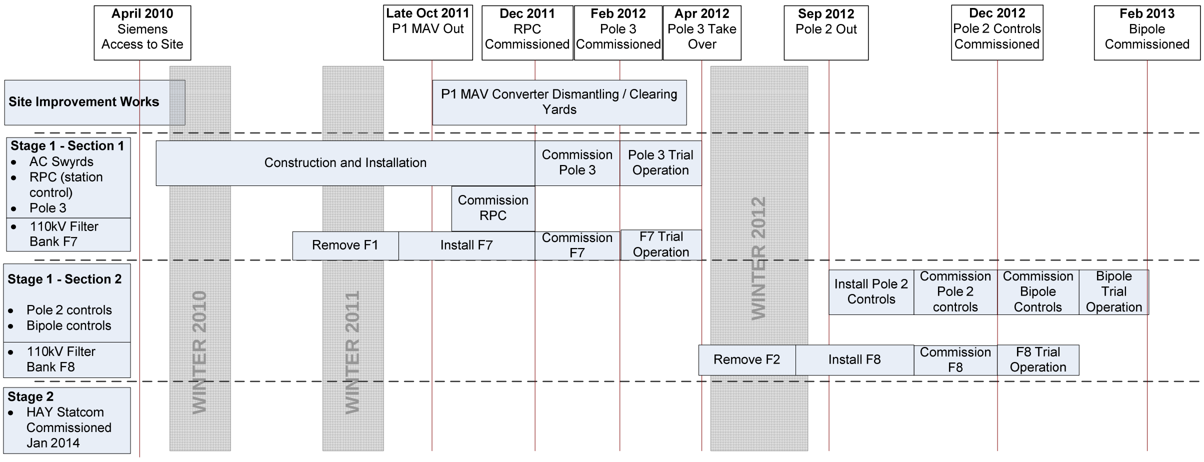

Figure 11: Pole 3 Project Timeline - Staged Delivery

Outage plans and specific outages required to commission Pole 3 and upgrade the Pole 2 and bipole control systems are presently being developed.

8 Summary

Site works for the Pole 3 Project commenced with site establishment at Haywards and Benmore in December 2009 and March 2010 respectively. Site improvements works at Haywards is nearing completion, and has established the physical platforms necessary for the new Pole 3 buildings (including a new retaining wall) and a new switchyard. These works are also seismically strengthen existing civil structures and upgrading the water mains throughout the Haywards site. Foundation excavation works for the new Pole 3 buildings at Haywards and Benmore commenced in May and June 2010 respectively. Main system parameter design for Pole 3 is complete and detailed design for associated HVDC plant and the control and protection systems are progressing. Shake table testing verifying seismic performance of new Pole 3 and Pole 2 control cabinets and equipment was completed in May 2010.

Looking forward, construction and completion of the new Pole 3 building at both Haywards and Benmore will continue through to early in the second half of 2011 and manufacturing of the converter transformers and values will take place during the second half of the 2010 and the first half of 2011. Installation of Pole 3 plant and equipment is scheduled to commence toward the end of the first half of 2011 with completion at the end of 2011 ready for commissioning works to commence in early 2012.

In addition to the Pole 3 converter station works at both Haywards and Benmore, refurbishment of the first synchronous condenser (C1) at Haywards is scheduled to commence early in the second half of 2010 and the first new unit connection transformer for the first outdoor synchronous condenser (C7) is expected to be commissioned in early 2011.

References

[1] Mohamed Zavahir, Peter Griffiths ‘Planning for New Zealand’s Inter-Island HVDC Pole 1 Replacement’, Cigre paper B4-108, Paris Session 2008.

[2] Transpower, ‘HVDC Grid Upgrade Investment Proposal - Grid Upgrade Plan 2007 – Instalment 3’ submitted to the Electricity Commission, May 2007

Appendix 1: Comparison of Main System Parameters for Pole 2 and Pole 3

Main System Parameters	Pole 2	Pole 3
		
Nominal rating	560 MW	700 MW
Continuous overload rating *without and **with redundant cooling	700 MW	735*/770** MW
Short term overload rating	840 MW for 5s	1000 MW for 30min
Synchronous Condenser @ HAY	240 Mvar	
STATCOM @ HAY	-	2 x +/-60 Mvar
Filter nominal ratings at HAY (existing and future) @ 220 kV	2 x 106.3 Mvar	2 x 109 Mvar
Filter nominal rating at BEN (existing and future) @ 220 kV	2 x 79.3 Mvar	4 x 80 Mvar

Converter Transformers	Pole 2	Pole 3
		
Number of Converter Transformers	8 (3 + 1 spare / end)	8 (3 + 1 spare / end)
Nominal rating	217 MVA / phase	271 MVA / phase
Converter transformer mass (with /without oil)	324 t / 216 t	330 t / 232 t
Oil volume / converter transformer	85,000 litres	91,000 litres
Conv. Trans. enclosure footprint	26 x 15 m	38 x 11 m

Thyristor Valves	Pole 2	Pole 3
		
Thyristor type	4" diameter electrically triggered	5" diameter light triggered
Valve max cont current rating	2,000 A	2,860 A
Thyristor peak reverse voltage	5.5 kV	>7.5 kV
Thyristors per valve	66	52
Thyristors per quadrivalve unit	264	208
Thyristors per end of the link	792	624
Quadrivalve mass	20 t	17 t
Valve Hall foot print	29 x 19 m	42 x 16 m