TRANSPOWER

# NAaN (North Auckland and Northland) Grid Upgrade Project:

# Delivering a major transmission upgrade through a busy metropolitan city

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**NAaN – Delivering a major transmission upgrade through a busy metropolitan city**

Background

The North Auckland and Northland Grid Upgrade Project (NAaN) was established to complete a ring around the Auckland isthmus that would reinforce capacity and security of supply into the Auckland CBD, and everywhere north of the Auckland Harbour Bridge. Prior to the completion of the North Island Grid Upgrade Project (NIGUP) and NAaN all supply to North Auckland and Northland was via one overhead line with two circuits. This line was supplied via Otahuhu substation which was a critical node in the Transpower network, as all 220 kV circuits supplying Auckland and further north were bussed at this location.

Approximately 16% of NZ population were dependent on this single transmission line.


**Figure 1: 220 kV transmission lines prior to NIGUP and NAaN**

The purpose of the NAaN project was to provide additional capacity for future load growth and to reinforce the network against high impact double circuit outages which would 'turn the lights out' for all those dependent on the circuits. It was the second of two major projects needed to meet the growing needs of the upper North Island. Firstly NIGUP reinforced and diversified supply into Auckland and split the critical lines supplying Auckland between the existing Otahuhu substation, a new Otahuhu GIS (Gas Insulated Switchgear) substation and new 220 kV Pakuranga substation. NAaN then reinforces and diversifies supply across Auckland and into Northland, providing additional capacity in the CBD, North Shore, and Northland.

**Figure 2: 220 kV transmission lines post NIGUP and NAaN (excluding new GXPs)**

NAaN was approved by the Electricity Commission in May 2009 with a budget of $473 million. Prior to this Transpower had secured access to the route through the CBD and North Shore and invested in the ducts required in conjunction with the project that constructed the Northern Busway well in advance of project approval.

<u>NAaN Scope</u>
The NAaN project consists of a 37 km single 220 kV circuit comprising four cable sections running between 5 substations, 3 existing and 2 newly constructed as part of the project. Enabling works were also required at Pakuranga, and Albany substations to enable the connection of the cable circuits. The existing Penrose substation was re-configured and extended to allow for cable circuit connection and to increase security of supply. Two new Transpower substations were constructed at Hobson St (Auckland CBD) and Wairau Road (North Shore) creating new grid exit points (GXPs) into the Vector network. An existing 110 kV overhead circuit was also dismantled as part of the project as it was made obsolete by the grid upgrades.

Vector also built new substations at Wairau Road and Hobson St in close co-ordination with Transpower as part of their works to reinforce their network on the North Shore and CBD respectively.

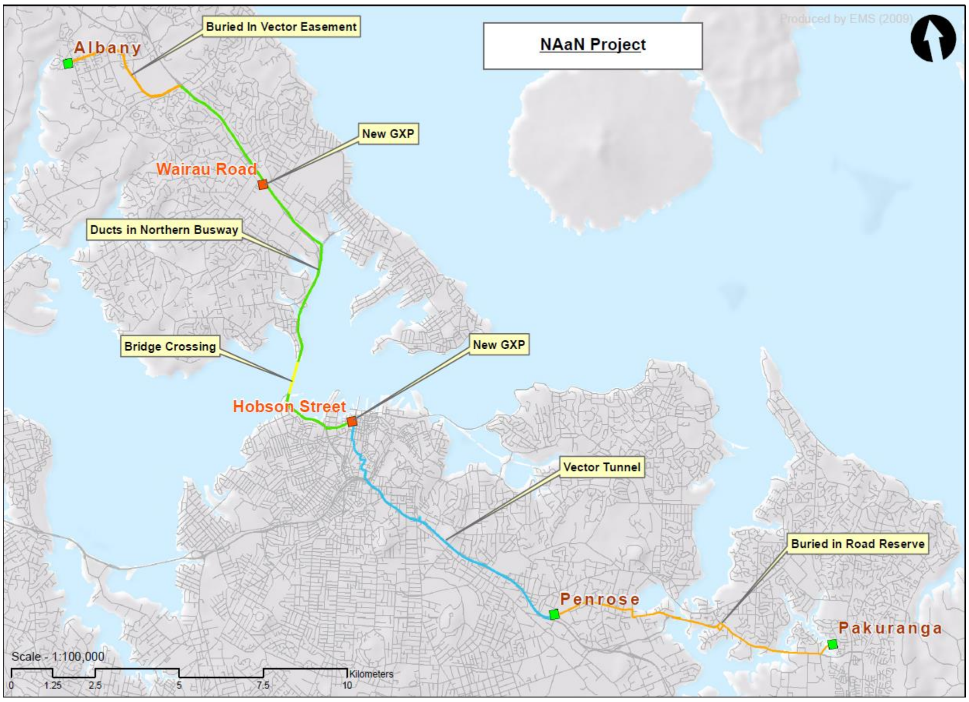


**Figure 3: NAaN project scope**

Cable Section 1

Cable Section 1 begins at Albany connecting into the new 220 kV bay constructed at the substation and runs through to the new Wairau Road substation terminating into the indoor GIS. The circuit runs approximately 4.3 km underground through the North Shore Transmission Corridor before entering the Northern Busway at Constellation Interchange and continues 4.1 km down to Wairau Bridge into the new GXP.

The Extra High Voltage cables are constructed from 9 layers including 2500mm$^2$ enamelled copper conductor, cross linked polyethylene insulation and corrugated Aluminium sheath. Cables are designed to a maximum cyclic loading of 2070A, are cable of operating up to core temperatures of 90° C. The cable circuit consists of 3 single phase cables jointed at approximately 700 m sections, with the aluminium sheath earthed by a combination of cross bonding and direct earthing.

Construction in the Transmission Corridor encompassed installation of 6 concrete jointing chambers connected with 250mm PE ducts for the power cables and 110mm ducts for the fibre optic fibres. Ducting was installed by open trenching, at times up to 4m deep and 3m wide. Ducts were fusion welded together with each section inspected with CCTV to ensure smooth transitions and integrity of the internal surfaces. Flowable Thermal Backfill was poured and vibrated around cable ducts to ensure good (and consistent) thermal resistivity around cables to achieve desired ratings as well as providing physical protection.

The circuit crossed 8 local roads, numerous streams, parks and sports fields, sediment ponds, commercial premises, the grounds of Rosedale Water Treatment Facility and hundreds of other underground services. Given all are publicly accessible areas, safety and security were paramount considerations as was traffic management to ensure impact to stakeholders was minimised.

Environmental considerations were worked into construction plans to ensure appropriate mitigation was included for the effects of the construction. This included planting over 3000 trees, in close consultation with Park arborists. Frogs and eels were relocated from streams during construction and programmes were developed at times around nesting birds. Local residents were consulted throughout the works with regular interactive correspondence and a 24/7 phone line was made available with escalations to the appropriate contacts.

Strong relationships were forged between Transpower, Auckland Council, NZTA, Watercare, Vector, Contractors and local resident/businesses during works to provide a platform to discuss concerns and adjust construction methodology where possible to mitigate concerns.

Although ducting had been installed under the Northern Busway during construction of the carriageway, excavation was required to open and extend the jointing bays by 15 m at each end to meet the jointing design which included ‘snaking’ and restraining cables into the joints. This significant activity needed to be carefully planned and executed to minimise disruption to the busway operations and the commute of thousands of users of the busway. Close consultation occurred with NZTA, Auckland Transport and the busway operations during preparation of traffic management plans and construction methodology. Regular weekly co-ordination meetings were held to review work progress and delays to the bus networks to ensure the work hadn’t caused unacceptable delays to the bus operators.

The work required an efficient, multi-disciplined team working concurrently on multiple work sites to ensure the work was expedited while protecting NZTA’s assets. Two cable support structures were fabricated and attached to NZTA structures at Tristram and Wairau Bridges to support the cables across spans and into the substation at Wairau Road.


**Figure 4: Work in the North Shore Busway**

Wairau Road

At Wairau Road, Transpower constructed a new 220 kV / 33kV substation on an area of vacant land alongside the existing Vector substation. The substation consisted of new 220 kV gas insulated switchgear (GIS), that bussed the two new cable circuits, a new 220 kV / 33 kV 120 MVA transformer, and 33 kV cabling to Vectors new 33 kV GIS switchboard.

This project had numerous issues to deal with including regular floods, poor ground conditions and being undertaken in conjunction with Vector's new 33 kV substation project at the same site. Wairau Road is covered by another paper at the conference prepared by Brett Stark where further details can be discovered.

**Figure 5: Wairau Road substation**

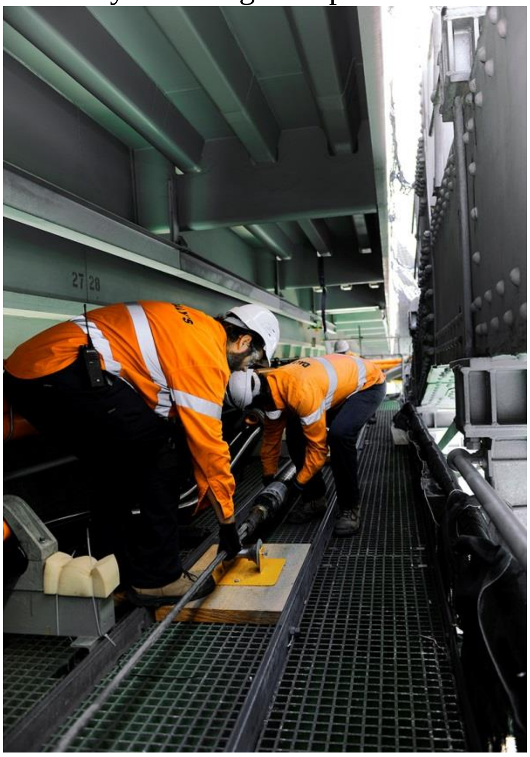
Cable Section 2

Cable Section 2 connected Wairau Road and Hobson Street substations and involved the continuation of cables down the Northern Busway onto the Motorway Bus lanes, across Auckland Harbour Bridge and along Westhaven and Fanshawe Streets into the new GXP. In addition to the Harbour Bridge there were two further crossings at Onepoto Bridge and Tank Farm Culvert which required construction of marine structures to support cables.

Crossing the Waitemata Harbour was a significant task; firstly to design a cable route and structure to support cables and secondly to install the 200 tonnes of cables and steelwork across the Bridge. Along with the weight restrictions for the structure, the design needed to allow for thermo-mechanical movement of both the bridge and cable system and could not impede operation and maintenance activities on the bridge. Localised strengthening was required to upgrade structural elements of the bridge.

The cable route had to negotiate other services, tourist operator activities (including the bungy pod), and the many other unique features and configurations across the bridge. To mitigate the need for a cable joint on the bridge, the 1600 $mm^2$ copper conductor cable was procured from Nexans factory in Belgium and was manufactured to lengths of 1.3 km. Thermo-mechanical tests were performed by Victoria University in Australia and resulted in cables snaked and clamped in position with two expansion mechanisms at the Bridges major expansion points.

Installation of the cables involved up to 70 staff on the bridge. Captive rollers guided the cables across the bridge while being pulled by a winch truck on the north side of the bridge and hydraulic caterpillar tracks located across the bridge. A fibre reinforced plastic barrier was fabricated and installed around the cables to provide clear demarcation and ensure bridge maintenance staff are protected from magnetic fields. Again, careful planning was required with input from major stakeholders to ensure cables were installed safely and did not adversely affect regular operation of the Harbour Bridge.



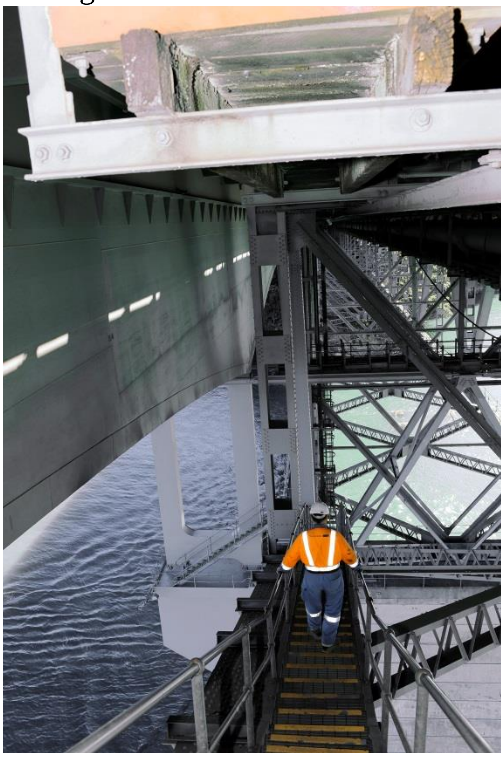


**Figure 6: Installing cables on Auckland Harbour Bridge**

Possibly the most significant challenge of Cable Section 2 was installation and jointing of cables in Fanshawe Street at the busiest exit of the State Highway 1 Motorway. A detailed Traffic Impact Assessment and Strategy was produced in consultation with NZTA, Auckland Motorway Alliance and Auckland Transport which included major adjustments to the motorway off-ramp. This significant package of work was done over the Christmas period during the lightest traffic loading and involved working around the clock with multiple teams to complete the work as quickly as possible.

The work had the potential for major disruption to CBD traffic and the Motorway itself and included a number of mitigations and contingency plans. A significant media campaign and close monitoring of the work by Motorway operations (JTOC) and the Traffic Management team on the ground ensured that the traffic was kept moving. The interagency co-ordination and co-operation was impressive and testament to the importance of the Project.

Technology such as ground penetration radar was used in planning to ensure no surprises were encountered during construction and two way public communication was employed to ensure everything possible was done possible to keep stakeholders informed and engaged.

Hobson St

At the existing Vector Substation site bordered by Fanshawe and Hobson Streets in the middle of the Auckland CBD, a joint development project between Vector and Transpower saw the construction of two new substations as part of the wider NAaN project. The Transpower substation connects cable section 2 and 3 together via the new 220 kV GIS and provides a new 250 MVA grid exit point into Vector's CBD network. Vector also constructed a new 110 kV GIS substation on the site to provide greater security and flexibility of their supply. The Transpower substation consisted of a 3 storey GIS building and attached transformer enclosure building.

The site for the new substation was an extremely prominent central city location, which made stakeholder and public safety a major project consideration. Due to the site's prominent location, and surrounding high rise buildings, there were eyes everywhere overseeing the construction works. The site was bordered by an apartment building containing the Grand Chancellor Hotel, which became a key stakeholder of the project and with which an extremely positive relationship was able to be maintained throughout the project.

Major challenges on the project were the constrained site, two principals completing projects on site simultaneously, the live substation and cable tunnels on site, and its brownfield nature. To make life more difficult for the designers they also had to design the project to meet a 100 year design life and to withstand a 2500 year return period earthquake.

The Hobson St site has been involved in the electrical industry since around the turn of the $20^{th}$ century, with its earliest incarnation been the generation plant for the city tram network, with waste energy utilised to warm the tepid baths across the road. Over the next 100 years the site has developed a number of times and unfortunately it was discovered during the project that old obstructions and foundations had been covered and left for the project to encounter! The obstructions included old chimney bases, concrete piles, mass concrete foundations, old sumps, and tunnels.

The site is only 3000 $m^2$ and already incorporated an existing Vector substation, two cable tunnels supplying the CBD, and the cable shaft and tunnel of the Penrose-Hobson cable tunnel. Constructing the three new buildings and two new cable tunnels within the limited area on site, amongst the live assets, and with no laydown area made planning a crucial element of the project. The project could not have been delivered within the timeframes required without the support of Auckland Council and Auckland Transport. By working with these key stakeholders the project team was able to streamline the consenting process and to gain lane closures, either permanently or daily, of all three roads bordering the site.

Safety was a key focus on the project and the most stringent of Vector's and Transpower's rules were applied to the site. Client Project Managers were based on site so they could engage with the contractors and their work force on the project to help drive safety performance. Hazard and incident reporting was actively encouraged with awards to individual workers for leading by example. The Transpower works on the project were completed with no lost time injuries, despite over 250,000 hours on site.

The project involved some complex elements due to the constrained nature of the site and the need to maximise space for the development. This included constructing the new Vector substation walls within and tied into existing site retaining walls. The need to reserve the ability to construct a future 15-story high rise building on the site, and the strict design requirements, led to some significant piling and strengthening of the foundations which wouldn’t normally be required for buildings of this size.

Construction works commenced on site in July 2011 and the first cable section (from Wairau Road), GIS, and interconnecting transformer, were livened in September 2013. The substation was fully commissioned in February 2014 when the Penrose cable was available. To keep the project on track for the NAaN commissioning dates, multiple head contractors worked together on site as construction and electrical installation works were overlapped. Up to 120 workers occupied the site for a significant part of the construction period to keep the works on programme.


**Figure 7: Hobson Street substation**

<u>Cable Section 3</u>

The cable for section 3 was a 220 kV 2500 $mm^2$ enamelled copper XLPE cable with copper screen wires and an aluminium polymer laminated sheath (APL). The oversheath for this cable is a fire retardant HDPE. This cable was installed in the Vector CBD tunnel between the new 220 kV GIS at Hobson substation and the Penrose substation. The cable route length is approximately 9300 metres. The cables are installed in a trefoil arrangement on wall mounted brackets.

This cable section is within a tunnel approximately 3 metres in diameter and 9 km in length containing a number of existing Vector sub-transmission cables.  The tunnel by its very nature is a confined space requiring the development of suitable procedures to manage the entry and exit to the space. These procedures also had to consider the co-ordination of both the construction works and the normal maintenance activities of Vector.

In order to minimise the number of personnel in the tunnel the cable installation was undertaken using a specialist Cable Installation Machine (CIM). The cable drum, weighing approximately 60 tonnes with 1400 metres of cable, would be brought to the shaft top at Penrose. From the drum the nose of the cable was fed down the access shaft into the tunnel.

At this point it would be fed on to a train of cable trolleys attached to the CIM. The CIM would then pull the cable and trolley train along the tunnel to the correct location. Then the CIM would reverse over the cables lifting the cable up to the cables brackets at 1500 mm above the tunnel invert. As the CIM proceeded to place the cables on the brackets a ‘snake’ was introduced into the cable that would allow for expansion of the cable under load.

In order to enable the CIM to operate in the tunnel the irregularities in the tunnel invert had to be levelled by the installation of timber packing.

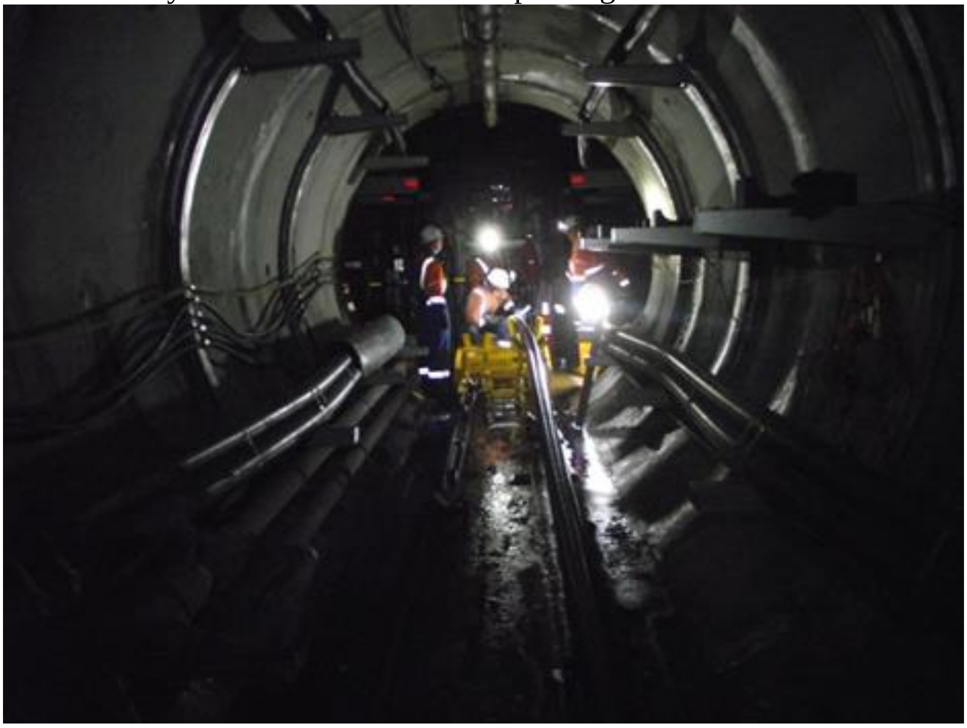


**Figure 8: Installing cables in the HOB-PEN tunnel**

Pakuranga to Penrose Dismantling

The Pakuranga to Penrose existing overhead line was removed as part of the project as it had been made redundant through the upgrade of Pakuranga to 220 kV (part of the North Island Grid Upgrade project). The overhead line went partly through the local community and partly within an existing transmission corridor so the removal of the line was of great value to the local community.

Removing an existing overhead transmission line through suburban streets, parks and back yards was not a simple job and had significant public safety risks. Months of planning by Transpower and its contractor was put into the various stages of removal to ensure the safety of workers, the public and other assets.

In total, the project removed 8.5 km of transmission line and 35 steel towers that were first commissioned back in September 1940. The works were completed through the use of cranes and numerous elevated work platforms, and included significant night work to remove road crossings at times more convenient for commuters. The dismantling project was completed with no major incidents and no significant injuries.

**Figure 9: Tower dismantling (PAK-PEN)**

Cable Section 4

The cable for section 4 was a 220 kV 2500mm$^2$ enamelled copper XLPE cable with a corrugated aluminium sheath. The oversheath for this cable is an HDPE. This cable was installed between the new Penrose substation extension and Pakuranga substation. Approximately 2000 metres of the cable route lay within an existing transmission corridor with the remaining 7000 metres being laid in public roads.

To achieve the required load capability the section 4 cables were installed in a flat arrangement with the phases transposed at each joint bay. In order to minimise the disruption in public roads arising from the excavation works, the cables were installed in HDPE ducts.

To complete the design of the trench dimensions, the thermal resistance of the native ground along the cable route had to be determined by site measurement. In designing the trench dimensions, specifications for the backfill material thermal resistivity and compressive strength were defined. To ensure that there were no localised changes to the thermal environment, any locations where the cables passed under other utility services had to be identified and modifications to the trench design developed. The mutual heating influence and the effects on the respective ratings of other power cables were also determined.

With the cable route being in Ti Rakau Drive, one of the busiest roads in east Auckland, a robust communication plan was developed. This required communication with local government bodies, local business organisations, bus companies and the general public. By commencing this communication well in advance of the construction works, negative comments from both media and the public were minimal.

The preconstruction geotechnical survey identified that there were lengths of trench that would be constructed through hard rock. The majority of these were identified as being in the transmission corridor. A small number of unidentified lava tongues were encountered across the cable route in Ti Rakau Drive which caused delays to the construction.

Commissioning

Commissioning all the new substation equipment and four cable circuits into the existing Transpower network, and livening the new Vector assets was a significant component of the project. A Commissioning Manager was assigned and a commissioning steering group established with representatives from appropriate areas of both Transpower and Vector. A common electrical commissioning contractor was appointed across all elements of the project to ensure consistency and co-ordination. The focus and time spent planning the commissioning and communicating with the rest of the businesses proved to be well spent with a very successful series of commissioning events which concluded the very successful NAaN Project.