Appendix B. RPC Discussion Paper

DISCISSION PAPER

REACTIVE POWER CONTROLLER FOR THE AUCKLAND REGION

February, 2006

NOTICE

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1. Purpose

Planning studies have identified the need for a significant augmentation of the reactive power support in the Upper North Island (Auckland and North Isthmus regions) in the near future. The total reactive power support required in the region by 2010 is in excess of 1300 Mvar. The reactive support will be provided by, in addition to the generators in the region, capacitors, synchronous condensers and static var compensators.

Coordinated dispatch and control of these devices is critical for ensuring supply reliability to the regions. However, manual control of such a large number of devices in a robust and efficient manner will be difficult and hence the possibility of implementing an automated Reactive Power Controller (RPC) is considered.

The purpose of this document is to:

- Identify, at a high level, the need for a regional RPC to automate the coordinated dispatch of the reactive power devices in the Auckland region.
- Conceptually specify functionalities of a regional RPC, taking into account the past experience with the operation of similar devices in New Zealand.
- Propose a plan for further investigations required to provide input into the detailed functional specification and design of the regional RPC.

2. Background

The power transmission grid in the North Island is basically a longitudinal grid, with most of the power generation at the centre and lower North Island (including power transferred through the HVDC link) and the biggest load centre, the greater Auckland area and the North Isthmus region, at the northern end. The total load at the combined Auckland, North Isthmus and Northland regions (i.e., the upper North Island area) in peak time is approximately 1530MW/1950 MW in summer/winter peak in 2004, about half of the total North Island demand.

Power generation in the Auckland/North Isthmus area includes a single unit combined cycle plant at Otahuhu, (approximately 360 MW) and some smaller units at Southdown and Glenbrook. Huntly power station, with 4x250 MW + 1x40 MW units situated about 100 km south of Otahuhu, will also have significant impact on voltage stability in the upper North Island. A 385 MVA CCGT unit, E3P, will also be installed at Huntly and commissioned by the end of 2006.

The transmission grid supplying the region is loaded very close to its thermal capacity and voltage stability limits. With the continuous growth in demand the voltage stability limit for power transfer into the Auckland and Isthmus/Northland regions will be reached in the near future under certain operating conditions in both summer and winter. Previous studies have identified a need for additional reactive power support in the Auckland region, starting from 2006. Analysis [1] indicated that the additional reactive power support required for providing N-1 security to the Upper North Island until 2010 include:

(a) 2x50 MVAR capacitors at Hepburn Road and Penrose respectively
(b) a new ±100 Mvar SVC at Albany,
(c) a new capacitor bank of 100 Mvar at Albany,
(d) 133 Mvar of additional synchronous condensers at Otahuhu,
(e) new 2x12 Mvar binary capacitor banks at Kaitaia, and
(f) other small capacitor banks, approximately 100 Mvar in total, distributed at low voltage side of grid exit points, or embedded within distribution networks.

All reactive power support devices in the upper North Island region by year 2010, including the existing and future ones are summarised in Appendix 1.

In the future there will be many reactive power supporting devices, with diverse performance characteristics in the region which can affect the voltage profile. Some of these devices control the voltage in a discrete manner, such as the manually switched capacitor banks, while others, such as generators, the synchronous condensers and the SVC, control the voltage continuously. With all these reactive power devices in service, it is likely that the most effective and reliable way to manage the voltage and reactive power in the region is through automated coordinated dispatch of the devices.

3. Current Practice

At present, voltage management and reactive power dispatch are generally carried out manually by the System Operator, except for a few locations where automatic voltage control schemes are installed.

During morning load ramp up periods (usually between 5:30am-8:30 am), the System Operator switches in capacitor banks by monitoring the voltage level and the reactive power output from condensers. Additional capacitor banks are switched in, one at a time, to ensure that the voltage at all buses is at a “reasonable” level, and the reactive power output from the dynamic reactive power sources (generator units, condensers and SVC) are not “too close” to their maximum capacity. Similarly, capacitors are switched off as evening load ramps down, by monitoring the voltage level and dispatch of dynamic reactive power.

During the trough period after morning load ramp up and before evening load ramp down, the System Operator uses transformer tap changers for voltage regulation.

An on line software tool, VSAT, developed by PowerTech Lab, has been used by the System Operator since September 2005 to calculate the voltage stability limit in real time operation.

4. Experience with RPCs

Presently there are automated RPCs in operation at Islington, Haywards and Benmore.

The RPC at Islington was designed and implemented as a part of the installation of SVC at Islington. This RPC was designed to coordinate the local voltage controlling devices in Islington substation, including the SVC, two synchronous condensers, 7 capacitor banks and the OLTC of three interconnecting transformers. The objectives of this RPC are:

- Control of the 220 kV bus voltage,
- Control of the 66 kV bus voltage,
- Optimise the operating point of SVC,
- Optimise the operating point of the synchronous condensers,
- Optimise the selection of which capacitor to switch.

During the operation of Islington RPC, it has become apparent that the dynamic performance characteristics of the devices (e.g. response times) are required to be taken into consideration in designing the RPC.

RPCs have been installed in Haywards and Benmore substations as part of the inter-island HVDC link upgrade project. In relation to reactive power management, the Haywards RPC dispatches the synchronous condensers and the reactors connected to the 220kV/110 kV interconnecting transformers, dispatches the HVDC harmonic filters and adjusts the interconnecting transformer taps. Benmore RPC controls the switching of the HVDC filters in Benmore. No significant operational issues have been identified to date with the operation of either Benmore or Haywards RPCs.

5. Voltage control in Auckland region

A large number of additional reactive power devices are proposed to be progressively installed in the Auckland region in the near future. It will become increasingly difficult for the System Operator to control the dispatch of reactive power devices and voltage manually without compromising the security and reliability of the supply into Auckland.

Under normal steady state conditions, in the absence of an automated RPC, the System Operator has to manually control the voltage controlling devices to maintain a required voltage profile. At present, the operating conditions change slowly and gradually and hence the System Operator has sufficient time to decide on operations based on previous experience. However in the future, with more reactive power devices connected to the power system, the System Operator will have to make quicker and more frequent decisions. It will be harder to coordinate and optimise reactive power dispatch in the region through manual dispatch of reactive power devices in real time.

The biggest challenge for the System Operator is to ensure that the system would be in a secure state at all times (pre and post contingency) under all operating conditions. The operating conditions are hard to predict during and following a forced event, and can change very rapidly, depending on the action and reaction of the control / protection of system components. The System Operator needs to manage reactive power dispatch appropriately, anticipating these changes pre contingency, under all operating conditions.

At present, the System Operator uses the voltage level as a major indicator in managing reactive power devices in the Auckland region. However, simulation studies have shown that the voltage level is not a good indicator for system security in the region and voltage collapse can occur when the voltage is close to the nominal voltage. In the future, with additional reactive power devices connected to the system, it is possible that voltage collapse could occur even when the system voltage is *above* the nominal voltage. Therefore the most critical factor for secure system operation is to ensure sufficient reactive power reserves are available rather than relying on maintaining the pre-contingency voltage near the nominal values.

6. High Level Functionality

It is expected that an RPC for the Auckland region should have the high level functionality described below.

The objective of the automated RPC will be to identify and dispatch the reactive needs, in both capacitive and inductive ranges, to ensure:

- supply security to the region following an outage of a transmission element or a generating unit
- pre and post contingency voltage in the grid nodes are maintained within acceptable levels
- post contingent transient voltages recover to the acceptable limits at a rate faster than a pre-specified minimum rate.
- the unavoidable supply interruptions to the connected loads are minimised
- sufficient reactive reserves are maintained in the form of static and dynamic reactive support for achieving the above.

The RPC will appropriately allocate dynamic and static reactive power reserves to the reactive power sources in the region, in real time. It may also determine the setting of the taps in the interconnecting transformers.

The dynamic reactive power reserves will need to be allocated to the connected generator units, the synchronous condensers and the SVC, based on pre-specified rules. Different types of reactive power device may be selected to serve different purposes. The synchronous condensers and generators are more effective than the SVC in helping voltage recovery and avoiding voltage collapse, while the SVC is the most effective device in suppressing voltage overshoot during transient period. Further, the RPC must be able to recognise the difference in response times associated with dynamic reactive power sources and coordinate them such that no “fighting” and /or “hunting” among the devices takes place.

At present, the regional RPC in Auckland is still in a conceptual design stage. Further investigation is needed before a functional specification for the RPC can be written and detailed design commence.

7. Further Work

Further actions needed before completing a functional specification for the RPC and commencing detailed design include, but are not limited to:

1. Identifying and resolving any possible issue associated with the implementation of the Auckland regional RPC. Issues may include the possible need for rule changes in relation to the real time dispatch of the reactive power as per the RPC instructions and the impact on other System Operator automation projects.

2. Investigating the design and operational experience of RPCs from other utilities and manufacturers (preferably in a similar situation to the Auckland region), (by end of March 2006)

3. Refining / confirming assumptions, performance criteria and reliability standards for dynamic analysis of voltage stability, (by end of March 2006)

4. Confirming the staged reactive power augmentation plan for the Auckland region (including the need for staged implementation of the RPC) and complete reworking if there is any significant change in assumptions and performance criteria (by end of May 2006),

5. Confirming the functional specification of the Auckland regional RPC (for stage 1) (by Nov 2006).

    - Confirm the need and performance objectives of the RPC,
    - Establish guidelines for allocating the reserve to various reactive power devices.
    - Complete high level studies to confirm the viability/feasibility of a conceptual design
    - Complete system studies to confirm the adequacy of conceptual design of the RPC.

8. Conclusion

Taking the transient performance of the power system in the upper North Island into account, additional reactive power devices of different types, including SVC, new condensers and capacitor banks, will have to be installed in the Auckland region in the next 2-5 years.

On top of maintaining steady state voltage profile, a more difficult operating task will be managing the dynamic reactive power reserves in the system to maintain system security following a transmission or generation fault. This will include the calculation of total dynamic reactive reserve requirements for the region and allocation among the diverse dynamic reactive power sources in an optimal manner. It is impractical for the System Operator to reliably carry out this task manually given the complexity of the reactive power management in the future.

It is believed that the present approach used for voltage and reactive power management in the Auckland region needs to be automated in the future for a more secure and reliable operation. A regional reactive power control (regional RPC) is recommended to be designed and installed in the Auckland region for carrying out this task. Given the uncertainties regarding the need for additional reactive power beyond 2010, the implementation of the Auckland regional RPC may need to be a staged process.

A significant amount of technical investigations need to be carried out prior to completing a functional scope and detail design of the RPC. The investigation will require approximately nine months and is expected to be completed before the end of 2006.

9. Reference

[1] "Auckland Reactive Power Requirement by 2010", Grid Planning Report No NP306, Oct. 2005

Appendix 1

Table: the existing reactive power support in the upper North Island region

Substations	Voltage	Existing Reactive Support		Future Add, Reactive Support	
Grid connected	**(KV)**	**Static (MVAr)**	**Dynamic (MVAr)**	**Static (MVAr)**	**Dynamic (MVAr)**
Kaikohe	11	20			
Kaitaia	33			24	
Albany	220			100	100/-100
Albany	110	50			
Albany	11	60			
Hepburn Road	110			50	
Henderson	11	60			
Henderson	220	75			
Otahuhu	220	100			
Otahuhu	110	100			
Otahuhu	11	90	2x33/-29		1x33/-29,2x50/-2
Penrose	220	75			
Penrose	110			50	
Marsden	11		1x60/-20		
	Total	**630**	**126 / -68**	**224**	**233/-173**
Network connected					
Wairu Rd.	33	48			
Albany	33	9			
Dargaville	11	2			
Henderson	33	12			
Hepburn Rd.	33	22			
Kensington	33	1			
Mangere	33	3			
Maungatapere	33	2			
Maungaturoto	33	2			
Otahuhu	22	9			
Pakuranga	33	6			
Penrose	33	66			
Penrose	110	15			
Mt Roskill	22	3			
Mt Roskill	110	15			
Takanini	33	6			
Wellsford	33	6			
Wiri	33	15			
	Total	**240**		**100**	