SINCLAIR KNIGHT MERZ

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Proposed New Large Network Asset for Reinforcement of the Electricity Supply to the Perth Metropolitan Area

DUE DILIGENCE REVIEW OF 330 KV AUGMENTATION STUDIES

- V1.1
- 4 September 2007

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Sinclair Knight Merz
ABN 37 001 024 095
7th Floor, Durack Centre
263 Adelaide Terrace
PO Box H615
Perth WA 6001 Australia
Tel: +61 8 9268 4400
Fax: +61 8 9268 4488
Web: www.skmconsulting.com

SKM

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Executive Summary

SKM has conducted a due diligence review of Western Power's network studies supporting the construction of a proposed 330kV bulk transmission asset between the South-west region and the metropolitan area. The scope of this work was to:

(1) Review the network analysis work carried out by Western Power;

(2) Examine the methodology applied by Western Power to conduct their analysis;

(3) Verify the validity of Western Power's results; and

(4) Determine whether there are alternate options that Western Power has not considered.

Western Power's preferred option for reinforcement is construction of a new switching station called Eastern Terminal and a double-circuit 330kV transmission line from Wells Terminal to Eastern Terminal (referred to as Option 6).

Having conducted the requested due diligence review SKM has reached the conclusion that:

- **The technical analysis carried out by SKM supports Western power's findings and indicates that this reinforcement option achieves acceptable reactive margins across the entire study period 2011-2016;**
- **Technically deferment of this option is possible with the installation of an SVC at the Northern Terminal, and SKM believes this may be a technically sound alternative that would allow up to two years deferment of major transmission works..**

  However, SKM recognises that the 2 year deferment of the proposed network augmentation by installation of the SVC may not be economically viable, as the cost of installing the SVC is higher than the savings accrued through the delay of the transmission line construction.
- **The IMO Statement of Opportunities released in 2007 indicates a forecast demand approximately 100 MW higher than the 2006 edition. Consequently, any works proposed by Western Power may need to be advanced in order accommodate this higher forecast. Detailed studies would need to be completed, but it is expected that the network reinforcements proposed may be required up to a year earlier than outlined in this report;**
- **Additional generation in the north of the SWIS could defer the need for additional 330 kV reinforcement between the south west and the metropolitan area. However, with the**

relatively short lead-time for generator capacity credit distribution compared to construction of major transmission projects, it would be imprudent to rely on hypothetical generation distribution to defer major reliability works; and

- **A network support agreement with metropolitan based generators, or other generation in the northern area, could postpone major augmentation works. Appropriate contracting of network support services from such power producers could potentially defer construction of additional 330 kV augmentations by up to 2 years. This may allow a grace period to clarify future generation patterns and network constraints.**

Further to the conclusions above and relevant to the scope of the investigation, SKM can offer the following additional comments on the investigations conducted by Western Power.

Verification of Western Power's Results

Further to SKM's review of Western Power's results and in summary of the outcomes described by the network operator, SKM has determined that:

(1) The technical analysis conducted indicates that, given the available information on proposed generation and expected generation development patterns, additional major network augmentation in the SWIS network is required by 2011 at the latest. Hence, based on the scenarios put forward, there is a clear need for additional augmentation in 2011, as outlined by Western Power;

(2) The methodology implemented by Western Power to reach their conclusions is sound and although there may have been some minor deviations from the Reactive Study Guidelines developed by Western Power, the end results appear to have no significant material impact on the timing and overall performance of the Western Power preferred augmentation (see more detailed comments following this section).

(3) For the majority of options, SKM agrees with the proposed timings put forward by Western Power. In some cases additional deferment may be possible but given the increase in load forecast in the latest IMO review and the application of the 5% safety margin required by the Technical Rules, such deferment may not be prudent;

(4) Analysis of a Southern Terminal – Guildford Terminal circuit outage should be considered further as it becomes the most severe contingency in later years. This outage however, may be mitigated by subsequent sub-transmission upgrade works in and around Guildford Terminal and may not require major 330kV augmentation to secure;

(5) Option 1 and its variants could also meet the requirements for long-term voltage stability over the study period. However, in some cases additional reactive scheduling would be required to

ensure the timing of reinforcements proposed by Western Power meet the voltage stability requirements outlined in the Technical Rules;

(6) Option 5 is capable of postponing major 330kV augmentation until 2013, however would require significant augmentations in 2013 and beyond to meet voltage stability requirements. Furthermore, there is some concern expressed by Western Power over sub-synchronous resonance issues within the network which may be exacerbated by series compensation. This would require complex modal analysis in order to identify any potential risks to existing or future generators. Due to these concerns this option is not considered optimal;

(7) Whilst a number of relatively minor options exist for deferment of the proposed augmentation, given the potential for a significant proportion of base-load generation to be constructed south of the metropolitan area it is expected that major 330kV augmentation would be required in the near future to support growing demand in the metro area.

(8) The establishment of the Eastern Terminal switching station along with the transmission works described in Option 6 appears to present the most suitable means of reinforcing the electricity supply to the metropolitan area of the SWIS. However, a deferment through the installation of a SVC or the contracting of generation support from metropolitan based power stations may be feasible and should be considered.

Conversely, given the increase in demand indicated by the latest 2007 IMO forecast, it is more than likely that the augmentations described by Option 6 will be required earlier rather than allow them to be deferred. Further, analysis would be necessary to qualify the need for an accelerated reinforcement programme.

Review of Western Power's Methodology

SKM has determined that in general the methodology used by Western Power in analysing the long-term voltage stability of the network is sound and in compliance with the Technical Rules. There are however, a number of issues that SKM considers may impact on the reactive margins obtained for these scenarios and used to determine the appropriate timing of reinforcements:

(1) <u>Spinning reserve requirements after the potential retirement of Kwinana A/B:</u>

Under the scenarios put forward by Western Power, where Pinjar generation is not dispatched due to demand and the historical generator merit order, the necessary spinning reserve capability recommended by the Reactive Study Guidelines is not met. Alternate sources of spinning reserve should be identified in order to meet system stability requirements, otherwise Pinjar generators may be forced to operate in order to provide the required margin.

(2) Load-scaling:

SKM was unable to categorically identify the magnitude or methodology behind the load-scaling applied to the system reactive study models, as specified by the Technical Rules. Analysis has indicated that some scaling was applied. However, the methodology used may not have been in strict accordance with the Reactive Study Guidelines. It is expected that with strict application of the guidelines, the reactive margins outlined in this report would be reduced. This may affect the timing or feasibility of some options.

(3) Network operating conditions:

The network operating conditions proposed as the worst-case situation for which the network is to remain stable includes the following major assumptions:

- Peak demand for 1 in 10 year hot summer;
- Boddington load out of service;
- Wind farm generation throughout the SWIS at maximum;
- Outage of the Southern Terminal SVC[1];
- Increased loading on 330 kV transmission lines between south west and metropolitan regions of the SWIS by 5% above 1 in 10 peak summer demand[2];
- Availability of substation shunt capacitor banks of 97%[3]; and
- Unplanned outage of a major 330kV element.

While the probability of occurrence of all the above events at time of peak or near-peak demand is likely to be low, SKM acknowledges the obligation of the TNSP to ensure a continued secure transfer of power during all possible generation and load conditions. Furthermore, while possibly not being a highly probable network condition, the above does reflect a possible network operating scenario that may occur under extreme conditions, thus addressing the requirements of the Technical Rules.

[1] The outage of the Southern terminal SVC represents the loss of the largest reactive device in the network.

[2] Western Power has used the 5%s increase in line loading to ensure an appropriate reactive margin will be maintained under severe network conditions.

[3] The availability of capacitor banks used is based on historical data collected by Western Power.

1. Introduction

1.1 Project Background

In their report *New Large Network Asset 330 kV Transmission Line to support Electricity load in the Perth metropolitan Area* [1] Western Power have described the need to establish a new 330 kV network augmentation to facilitate the secure supply of electricity to demand centres in the South West Interconnected System (SWIS).

The aforementioned report indicates that this major augmentation for the SWIS has been proposed in response to enquiries from new generation proponents and that this proposed transmission line will achieve the necessary increase in power transfer capability between generating sources and load centres in the metropolitan region of Perth.

Western Power has identified two main options that have been considered for the new transmission line route:

(1) From Landwehr Terminal (in the Wagerup area) to a new 330 kV switching station known as South East terminal (in the Oldbury area); and

(2) From Shotts Terminal at Collie via Wells terminal (adjacent to the Boddington Gold Mine) to a new 330 kV switching station known as Eastern Terminal (in the Hackett's Gully area).

Both transmission options consist of a number of staggered smaller reinforcements. However, the ultimate configurations of the outlined transmission reinforcements, described by Western Power as Option 1 and Option 6, are shown schematically in Figure 1. The networks shown represent the existing 330 kV network and the proposed augmentations under each reinforcement strategy. Based on these two options Western Power has proposed a number of additional network reinforcement options that are variations of these two primary reinforcement strategies. Not shown are the staging of the reinforcements. The individual options are described in more detail in Section 3.

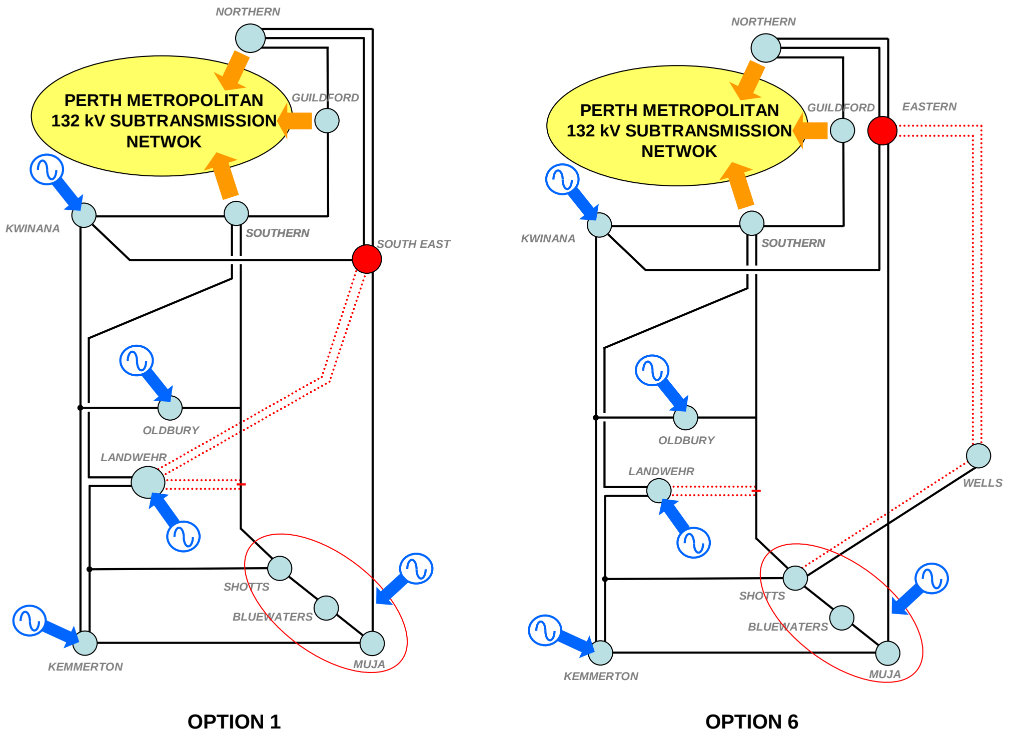

Figure 1: Proposed major network reinforcement for the 330 kV South West Interconnected System

1.2 Due Diligence Review

To support the Regulatory Test application and public consultation for this new large network augmentation Western Power have conducted power flow analysis and voltage stability studies. These investigations are aimed to evaluate the requirement for a new large network augmentation to connect future generation in the south-east of the state to major load centres in the Perth metropolitan area.

The results of these network evaluations form the basis of Western Power's proposal for a new large network augmentation, and the submission that Western Power will make to the Economic Regulatory Authority (ERA) will benefit from having been reviewed by independent parties. Indirectly such due diligence reviews are also supported by clause 2.3.7.4 which states:

"The Network Service Provider must take all reasonable steps to ensure that the results of the simulation and modelling of the power system in accordance with requirements of clauses 2.3.7.1 to 2.3.7.3 and Section 3 are valid."

Consequently Western Power has engaged SKM to conduct a due diligence review of Western Power's network studies supporting the construction of new large network assets in the Perth metropolitan area to support the load in this region of the SWIS..

1.3 Scope of the Review

This due diligence review aims to:

- Conduct a high level review and comment on Western Power's report: "Proposed Major Augmentation to the Electricity Network – 330 kV Transmission Line to Support Electricity Load in the Perth Metropolitan Area", dated May 2007;
- Perform a high level review of Western Power Power's network models and assumptions; and
- Establish whether other viable network reinforcement options are available to address the transmission network constraints identified by Western Power.

More specifically, this investigation seeks to conduct technical analysis to:

- Confirm the transmission network constraints identified by Western Power within the SWIS for the time period 2011 – 2016 using voltage stability analysis;
- Evaluate the impact of high demand and generation dispatch pattern on the reactive reserves of the SWIS network in the period 2011 – 2016 under system normal and contingency scenarios;
- Ascertain whether Western Power's proposed network augmentation options can successfully address potential transmission network constraints and provide capacity for additional generation to supply the Perth metropolitan area from the south of the SWIS beyond 2011;
- Determine whether the network constraints presented by potential voltage instability following loss of a transmission element can be addressed by an appropriate reactive schedule, and the overall benefit of further conventional reactive compensation within the SWIS network;
- Determine whether the proposed variations of Option 6 are technically viable alternatives that address potential transmission network constraints;
- Assess the benefit of additional dynamic compensation in the form of a Static VAr Compensator at the Northern Terminal (Option 4) or additional fixed series compensation (Option 5); and
- Conduct a technical comparison of the proposed network reinforcement options, based on the results of the power system analysis performed.

1.4 Voltage Stability

As detailed in Western Power's report [1], the SWIS is characterised by large load centres around the Perth metropolitan area supplied by remote base-load power stations in the Collie region. Additionally there are some gas fired power stations at Kwinana and Pinjar, close to the metropolitan region. A 330 kV transmission network forms the backbone of the electrical network and is used to transfer bulk power from the generating sources to the demand centres.

Western Power have stated that with increased amounts of generation to the south-east of the network, the power transfers across the 330 kV transmission system between the Collie region and the Perth metropolitan area can reach levels where, in case of loss of a critical element of the transmission network, the system voltage may no longer be controllable, leading to possible blackouts and loss of load.

A short summary of the methodology applied in determining the stability and controllability of network voltages under certain operating conditions is included in Appendix A.

Ultimately, the stability of network voltages can be improved by adequate reactive support through shunt compensation, the reduction of reactive power losses through generation of power closer to the demand centres, establishment of additional transmission corridors, demand side management etc.

2. Review of Methodology

The following section has been included to describe the parameters and the sources Western Power has used to establish the need and timing for augmentations in the SWIS.

Western Power has produced two documents that describe aspects of the network requirements of the SWIS pertaining to voltage stability:

- Western Power Technical Rules; and
- Reactive Reserve Study Guideline.

The former is an encompassing document that sets out the technical requirements for Western Power and users of the transmission or distribution network. It also documents the technical planning criteria to be applied to the transmission and distribution network.

The Reactive Reserve Study Guideline is a set of instructions interpreting the voltage stability requirements set out by the Technical Rules and how to apply them in power system analysis.

2.1 Technical Rules

The Technical Rules for the South West Interconnected System documents the requirements to be met by Western Power as the Transmission Network Service Provider (TNSP) and users who connect to the transmission or distribution system, such as generating plant or other customers.

For the analysis of the proposed large network augmentation required due to limitations in the transferable power as a result of potential voltage stability, attention is drawn to clause 2.2.11 of the Technical Rules, which defines Western Power's concept of *Long Term Voltage Stability*:

(a) *Long term voltage stability includes consideration of slow dynamic processes in the power system that are characterised by time constants of the order of tens of seconds or minutes.*

(b) *The long term voltage stability criterion is that the voltage at all locations in the power system must be stable and controllable following the most onerous post contingent system state following the occurrence of any event specified in clauses 2.3.7.1(a) and 2.3.7.2 under all credible load conditions and generation patterns.*

Further to the above, clause 2.3.7.3 outlines conditions for which adequate reactive margins must be maintained to meet the criteria outlined in clause 2.2.11. This section of the Rules then details the particular parameters for the modelling and analysis that are used to determine the long term voltage stability and performance of the power system. In summary the key modelling conditions are:

(c) *The Network Service Provider must model the power system for long term stability assessment and transfer limit determination purposes, pursuant to clause 2.3.7.3(b) using the following procedure:*

  (1) For terminal substations in the Perth metropolitan area, 3% of the total installed capacitor banks plus the reactive device that has the largest impact on the power system must be assumed to be out of service; and

  (2) …

  (3) In all situations the Network Service Provider must follow the following additional modelling procedures:

    (A) all loads must be modelled as a constant P & Q loads;

    (B) the load or power transfer to be used in the study must be assumed to be 5% higher than the expected peak load or 5% higher than the maximum expected power transfer into the area. …

    (C) the analysis must demonstrate that a positive reactive power reserve is maintained at major load points and that the power system voltages remain within the normal operating range for this 5% higher load.

    (D) power system conditions must be checked after the outage and both prior to and following tap-changing of transformers.

2.2 Reactive Reserve Study Guideline

The Reactive Reserve Study Guideline is an internal document developed by Western Power based on the Technical Rules. This document applies in particular clause 2.3.7.3, and describes in more detail the procedures for the assessment of voltage stability and adequate reactive margins under credible system contingencies

The Reactive Reserve Study Guideline proposes the development of *V-Q characteristic curves* to quantatively assess the ability of the power system to remain in a stable operating condition following a critical contingency. These curves describe the relationship between the reactive power required at a particular node of the power system in order to obtain particular bus voltages at that location.

Whereas Western Power's Technical Rules set out the operating conditions and requirements, the Guidelines seek to interpret the Rules as they relate to the SWIS, and describe how to apply these operating conditions using power system analysis.

2.3 Western Power's Development of Voltage Stability Margins

As required by the Technical Rules, Western Power has used power flow studies to investigate the need for network augmentations in the Perth metropolitan area.

The studies were carried out using the PSS/E V29 software package. This package is commonly used in Australia and around the world and is more than adequate to handle the modelling requirements for the steady state and long-term voltage stability analysis.

2.4 Network Model

Western Power has used the network model of the SWIS held and developed by the TNSP, including all committed augmentations over the period 2011-2016.

The base forecast demand is in accordance with forecasts made by the Independent Market Operator (IMO) [2].

3. Due Diligence Analysis

3.1 Aim of the Investigation

The due diligence analysis conducted by SKM aims to:

(1) Review the network analysis work carried out by Western Power;

(2) Examine the methodology applied by Western Power to conduct their analysis;

(3) Verify the validity of Western Power's results; and

(4) Determine whether there are alternate options that Western Power has not considered.

3.2 Scope and Methodology

SKM conducted a technical due diligence review of the long-term voltage stability studies undertaken by Western Power. This included the following:

- Identification of study files used for the voltage stability studies;
- Review of Western Power's base case scenarios for each year involving confirmation of generation dispatch, system demand and plant outages;
- Review of automated scripts used by Western Power to determine the controllability of network voltages by calculating the reactive margin available during credible contingencies;
- Review compliance of Western Power's methodology with the Technical Rules and the Reactive Study Guidelines;
- Independently establish base case scenarios to carry out due diligence analysis of the proposed network augmentations;
- Assessment of available reactive margins under proposed augmentations using the independently developed base case scenarios;
- Confirm the validity of the timing of the proposed network augmentation options; and
- Identification of alternative options or means of deferring major augmentations.

3.3 Western Power Study Files

The initial voltage stability studies were conducted by Western Power between October 2006 and May 2007. The power flow study case files used for these investigations were provided to SKM by Western Power and formed the basis of SKM's due diligence review.

Appendix B contains a summary of these files and those used by SKM in this review.

3.4 Review of the Base Case Scenario

The base case scenarios developed by Western Power contain a number of generation dispatch and load assumptions which aim to represent the most severe operating conditions that Western Power expects may be experienced by the network. These assumptions include:

- Future generation development;
- Generation merit order (order of dispatch);
- Status of the Boddington Gold Mine load (largest single load in the network);
- Dispatch and output of the Pinjar generators;
- Output of wind farms located at Emu Downs, Walkaway and Albany.
- Demand forecast.

3.4.1 Future Generation Development

Western Power has indicated that the driving force for this project is the prospect of future generation being concentrated in the south-west region of the state, near known coal deposits. This assumption is due to current limitations in gas supply, and the relative generation costs of coal and gas fired power plant. With new generation in the south-west, coupled with the potential retirement of aging metropolitan plant, this would result in increasing power transfers across the bulk transmission network from the Muja and Collie regions to the metropolitan area, consequently increasing the reactive power demand as the 330kV transmission lines exceed their surge impedance loading[4].

The current IMO Capacity Credit System only provides forward-looking credits for a two year period. Beyond this period no generation arrangements are guaranteed and therefore modelling for the 2011-2016 period requires a number of assumptions about future generation. Western Power has modelled an additional 220 MW of generating plant at

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[4] Above the surge impedance loading of a transmission line the impact of line inductance begins to significantly outstrip the contribution of line capacitance and consequently this leads to greater reactive line losses at higher power transfers.

Bluewaters power station to commence operation by October 2010, and additional 320 MW of base load power generation in the Collie region in both 2013 and 2016. Western Power's assumed generation development forecast is included in Appendix C.

3.4.2 Generation Merit Order

In the regulated electricity market of Western Australia, generation dispatch is at the discretion of the IMO. For the reactive reserve studies Western Power has made a number of assumptions, based on historical evidence, as to the expected 'merit order' for generation within the SWIS. This order of merit is largely determined by the likely cost of generation, with the highest cost generation located at the bottom of this order, indicating that this generator will be dispatched last. Within the SWIS Western Power have assumed dispatch is as follows:

- All non metro generation, including wind farms at Emu Downs, Walkaway and Albany;
- Newgen Power Station (Cockburn 3);
- Cockburn 1;
- Kwinana Power station C generators (assuming A and B station will be retired);
- Pinjar generators.

3.4.3 Pinjar Generation

The Pinjar generators are located to the North of the metropolitan area, and comprise a number of Frame 6 and Frame 9 industrial gas turbines totalling approximately 500 MW generating capacity. As these machines are located close to the load centres of the SWIS, their operating status has a significant impact on the reactive reserves of the power system. However, as these machines are high cost generators, they are last in the merit order of generation dispatched to meet demand. This can result in situations where, subject to demand and generation availability, these machines may not be dispatched and may be shut-down or operating for the purpose of ancillary services only.

3.4.4 Boddington Gold Mine Load

When operations commence, the proposed Boddington Gold Mine will become the largest single load in the SWIS, with a projected demand of 145 MW during the day and 172 MW at night. An interruption to this load could result in Pinjar generation not being dispatched due to its position in the merit order. Furthermore, such an event would result in greater power transfer from the south-west to the metropolitan area as Bluewaters generators transfer their generated power to the metropolitan area rather than to Boddington.

SKM have noted that Western Power network model files have Boddington load represented as the night-time demand under all scenarios. Since the daily summer peak demand in the SWIS network occurs around 6 pm the assumption of 172 MW is considered acceptable. Furthermore, since the basic load model considers the worst case scenario for maximum power transfers across the 330 kV network between the south-west and the metropolitan area, the Boddington load is assumed to be out of service.

While it is quite correct to consider the loss of the largest single load in a power network as a credible contingency, it may be somewhat conservative to assume for this to occur simultaneously with the loss of a major transmission element, as well as the outage of the reactive plant that has the largest impact on the overall reactive margin. However, in accordance with clause 2.2.11 of the Technical Rules, all credible load scenarios must be considered when reviewing the long-term voltage stability of the network and therefore under the Technical Rules and in light of the fact that this outage has a significant impact on power transfers within the network, this configuration will be considered.

3.4.5 Wind Farm Output

In the arguments for network conditions used to simulate the constraints for the North Country region CRA International, as a consultant to Western Power, have stated:

"The Walkaway Wind Farm (WWF), located close to Geraldton was commissioned in 2005 and has notional capacity of 90 MW. However, the wind farms's contribution to peak summer capacity may be significantly lower than this notional capacity, as the power output will be a function of the prevailing winds. Based on data from South Australian wind farm, Western Power estimates that the WWF can provide approximately 5 MW of firm capacity" [3]

In the same report, the above statement was also made about the Emu Downs wind farm located close to Cataby.

Subsequently, Western Power has also stated the firm capacity of the wind farm as 5 MW in their draft submission to the Energy Regulating Authority (ERA) for this proposed North Country reinforcement [4].

For the reinforcement of the metropolitan electricity supply Western Power have assumed that power generated by wind farms in the north and the south of the SWIS will displace metropolitan generation, such as Pinjar. This is reflected in the dispatch of the Walkaway, Emu Downs and Albany wind farms at full rated power.

SKM notes that such renewable energy generation is subject to prevailing winds and therefore not scheduled. Hence, it is possible that the IMO may dispatch generation at Pinjar to cover this variable generation. SKM does not have information regarding these procedures and can not further comment on such operation.

SKM concurs with Western Power's assumptions for the worst case generation dispatch on the basis that clause 2.2.11 of the Technical Rules requires all credible generating scenarios to be considered for long-term voltage stability. Hence, the dispatch of the aforementioned wind farms at rated output can be deemed to be a reasonable assumption while determining the required worst case scenario generation dispatch for the metropolitan reinforcement requirements.

3.4.6 Load Forecast

SKM was advised by Western Power that the loads in the network model zones labelled *Zone 1* and *Zone 2*, and the network losses within these two zones, comprise normal system load as reported by the IMO. The loads modelled in the base case files appear to closely match those of the 2006 IMO forecast, as shown in Table 1.

Table 1: Comparison of Demand Forecasts

MW DEMAND	2011	2012	2013	2014	2015	2016
PSS/E model Zone 1 & 2 including losses	4237	4341	4483	4609	4735	4892
2006 IMO Forecast	4228	4360	4483	4604	4741	4858

However, additional losses under 'Zone 9' of the network models may represent the system bulk transmission losses, which should be included in the zone forecast. This exclusion could indicate that the base case load forecasts had been adjusted, possibly to meet Technical Rule guidelines regarding power transfer safety margins. This issue will be discussed in section 3.7.4.

The 2007 IMO forecast indicates significantly higher loading levels, of the order of 100 MW, and this will result in subsequent changes in the timing of additional generation and network reinforcements. However, for the purposes of this review, the 2006 forecasts as applied in the Western Power study files have been adopted.

3.4.7 Spinning Reserve

The Reactive Study Guidelines require a spinning reserve in the system of 70% of the largest single generator minus the interruptible load of 80 MW. Over the period covered in this study, the largest single generator is expected to be 320 MW, resulting in a total spinning reserve requirement of 145 MW.

Under the Reactive Study Guidelines, the generating plant generally used for spinning reserve are outlined in Table 2.

Table 2: Spinning Reserve

Generator	Number of Units	Maximum Spinning Reserve per Unit (MW)	Total Contribution (MW)
Mungarra	3	17	51
Pinjar Frame 6	6	23	138
Pinjar Frame 9	3	60	180
Kwinana C	2	25	50
Kwinana A/B	4	20	80

SKM notes that with the expected retirement of Kwinana A/B before 2010, and under the scenarios considered where Pinjar generation is not scheduled to run due to merit order placement, the total available spinning reserve is around 100 MW. This is insufficient to meet requirements, and alternative sources may need to be considered or if necessary, Pinjar forced to run in order to provide sufficient reserve.

3.4.8 Summary of Western Power Study Files

In summary, the files provided by Western Power make the following critical assumptions:

- All future generation will come from the south-west region;
- Boddington load is out of service;
- Wind farm generation in the SWIS is operated at rated power;

- Pinjar generation, as the last generator in the merit order, is not actively generating but providing some voltage support[5].

It is assumed that sufficient generation is available from alternate sources to provide the required spinning reserve as described in the Reactive Study Guidelines and other frequency control services without the presence of Pinjar generation under these scenarios.

3.5 Critical Contingencies

To identify the key constraints on the bulk transmission network SKM has reviewed:

- The original Western Power report supporting the proposed augmentation [1];
- The results of the Western Power voltage stability studies carried out for the proposed reinforcement;
- The "Bulk Transmission Network Strategic Directions" document [5]; and
- A number of additional outages.

Under the modelling assumptions proposed by Western Power it was identified that for the majority of scenarios the loss of one of the four 330 kV transmission lines between the south-west generating region and the metropolitan demand centres are generally the most severe contingencies. These are the 330 kV transmission lines between the following substations:

- Muja – Northern Terminal[6];
- Shotts – Southern Terminal;
- Landwehr – Southern Terminal; and
- Kemerton – Kwinana.

[5]The Pinjar Frame 6 gas turbines are equipped with clutches that allow the prime mover to be disengaged from the generator and allow the machine to operate as a synchronous condenser, and for several of the scenarios investigated some of the Pinjar generators are operating as sources of reactive power only.

[6] Depending on the option being considered, this outage is taken to be Muja – SET or ET.

These contingencies have been reviewed in order to validate Western Power study results. However, there are a number of other contingencies that SKM considers significant, such as loss of a Southern Terminal to Guildford 330 kV line.

3.5.1 Outage of Southern Terminal to Guildford Terminal 330kV line

Under system normal conditions, this transmission line carries a significant amount load, in the order of 400 MW, from Southern Terminal to Guildford Terminal and Northern Terminal. An outage on this line causes a large shift in power onto lines feeding the Northern Terminal, and results in a significant reactive shortfall in later years with a number of the proposed augmentations. However, with additional reactive support at Northern Terminal and/or Guildford Terminal, or surrounding zone substations, this can be rectified.

3.5.2 Outage of Northern Terminal 330/132kV Transformer

This outage can be the most severe contingency event for some of the proposed network reinforcement options, as identified in Western Power simulations. For the 2013 scenario this contingency is critical in particular for Option 6. However, as indicated in Western Power's Annual Planning Report [6] this network limitation will require commissioning of a third transformer at the Northern Terminal by 2014. Hence, as augmentations to relieve this contingency have already been proposed, SKM has not further examined this outage during the due diligence process.

3.6 Sensitivity Analysis

Sensitivity analysis was conducted for a number of factors influencing the voltage stability studies, to determine whether Western Power have made appropriate assumptions on system condition for these simulations.

3.6.1 Sensitivity to Swing Bus

Location of the system swing bus during simulation can have a significant impact on the reactive reserve calculations. If it is located too close to the target bus, an artificial level of support would be introduced and distort the results. Western Power has conducted their studies with the swing bus located in the Eastern Goldfields (Bus 55), a large distance from the buses under consideration.

The impact of locating the swing bus at a number of remote points in the SWIS has been considered to determine whether this is an appropriate location;

- Bus 54 – Mungarra generator in the North Country
- Bus 55 – Kalgoorlie generators in the Eastern Goldfields
- Bus 459 – 132kV network bus 'behind' Muja Power Station

The results of this analysis are shown in Figure 2. It can be observed that the difference in reactive margin between each case is minimal. Theoretically, the use of a swing bus behind the Muja generators such as bus 459, could lead to excessively conservative results, as the additional demand placed on the system during the reactive study will be transferred across the 330kV bulk transmission lines, thus increasing the line loading. This is considered unrealistic, as the spinning reserve generation is more likely to come from the metropolitan area and would not increase loading on these transmission lines.

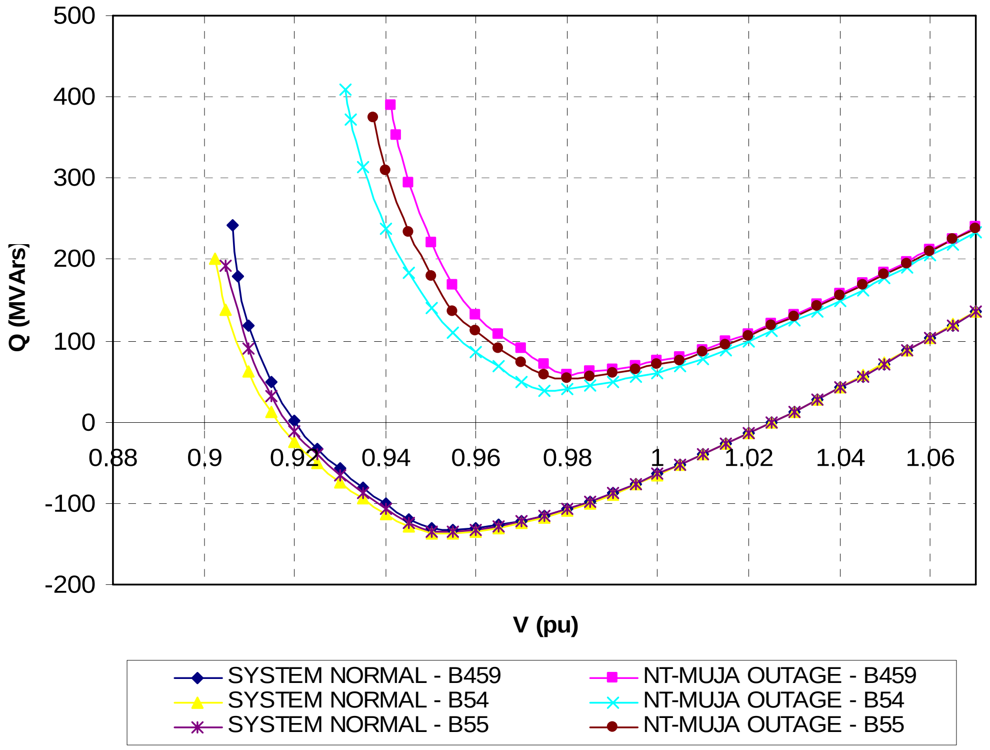

Figure 2: Comparison of reactive margins when considering different swing bus locations for the base case in 2011

3.6.2 Comparison of loading scenarios

This section reviews the difference in reactive margin if it is assumed that the Boddington load is in service, and the load condition is such that the Pinjar generation may be disabled (ie shoulder load period), or if Boddington is out of service and thus peak generation may be considered. To simulate this, the base case scenario with Boddington out of service has been adjusted to assume Boddington is in service, but that metropolitan load is reduced by an equivalent amount to reflect a shoulder-period loading which does not require the operation of the Pinjar generators. The results of this study are shown in Figure 3.

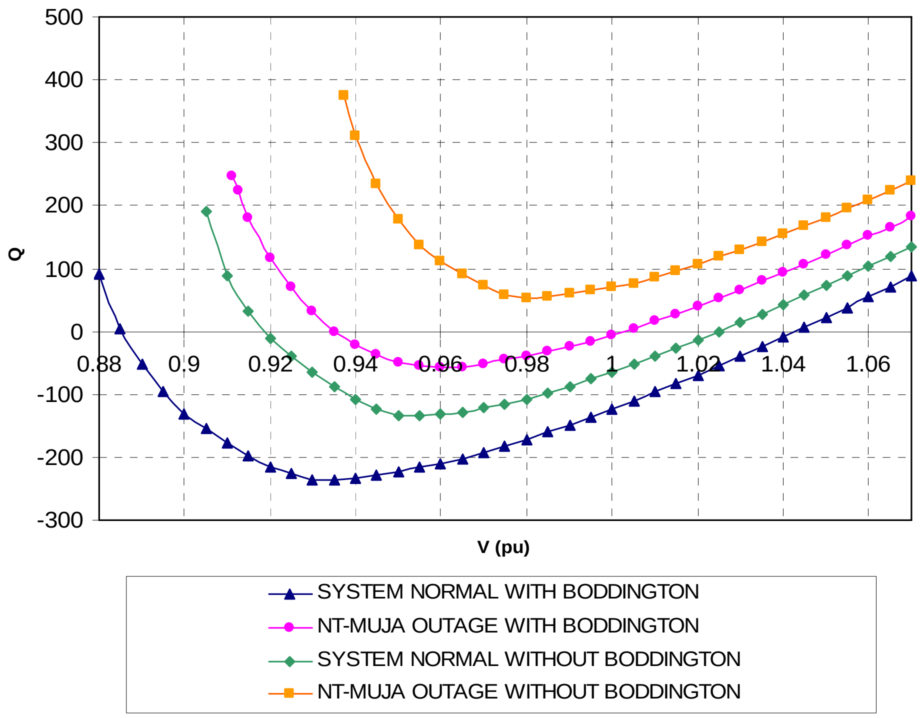

Figure 3: Comparison of reactive margins with and without Boddington load for the base case scenario in 2011

It can be seen from the above graph that with the outage of Boddington load there is a significant reduction in reactive margin within the metropolitan area, under worst-case conditions.

3.7 Compliance with Technical Rules and Reactive Study Guidelines

SKM has reviewed the methodology used by Western Power in their reactive margin studies and their consistency with the Technical Rules and Reactive Study Guidelines.

As outlined in Section 2.1, the Technical Rules require a number of network events and safety margins to be considered for long-term voltage stability studies. The scenarios studied by Western Power for this project therefore need to make certain assumptions of network operating conditions and plant availability.

3.7.1 Load Modelling

Loads have been modelled as constant P and Q loads. This is consistent with the Technical Rules and Reactive Study Guidelines, and is a suitably conservative approach, especially since no detailed information regarding the composition and voltage dependence of the system loads is available.

3.7.2 Capacitor Bank Scaling

Shunt capacitor banks located at the network's terminal stations have been scaled down by 3%, based on historical information and as required by the Technical Rules, to reflect the general availability of shunt capacitors.

It must be noted that the capacitor banks proposed as augmentations in Option 3 were not scaled by the requisite 3% in simulations for this reinforcement strategy.

3.7.3 Coincident Outage of the Southern Terminal SVC

This is consistent with the Reactive Study Guidelines produced by Western Power, but does not strictly adhere to the Technical Rules requirements of having "the generator with the largest impact on reactive reserve *and* the largest reactive device out of service". However, SKM considers this a suitably conservative approach when determining reactive power margins, given the SVC's rating and relative proximity to the metropolitan area.

Analysis has also been conducted to examine the difference between this scenario and the outage of the generator with the largest impact on reactive reserves in the metropolitan area in conjunction with one of the largest capacitor banks.

In 2011 and beyond, the Newgen Cockburn 3 Combined Cycle Gas Turbine (CCGT) – connected to the SWIS at the Kwinana substation – provides the largest amount of reactive power capability within the metropolitan area. This machine has been considered as the generator with the largest impact on reactive margins. In addition, a 90 MVAr switched capacitor bank at the Northern Terminal has been considered as the reactive device out of service.

As illustrated in Figure 4 and Figure 5, the outage of the Static VAr Compensator (SVC) poses a significantly more onerous scenario than the outage of a generator and capacitor bank. This is a result of the lost generation being supplemented by other stand-by generation in the metropolitan area, and thus compensated by the additional reactive support provided by these generators.

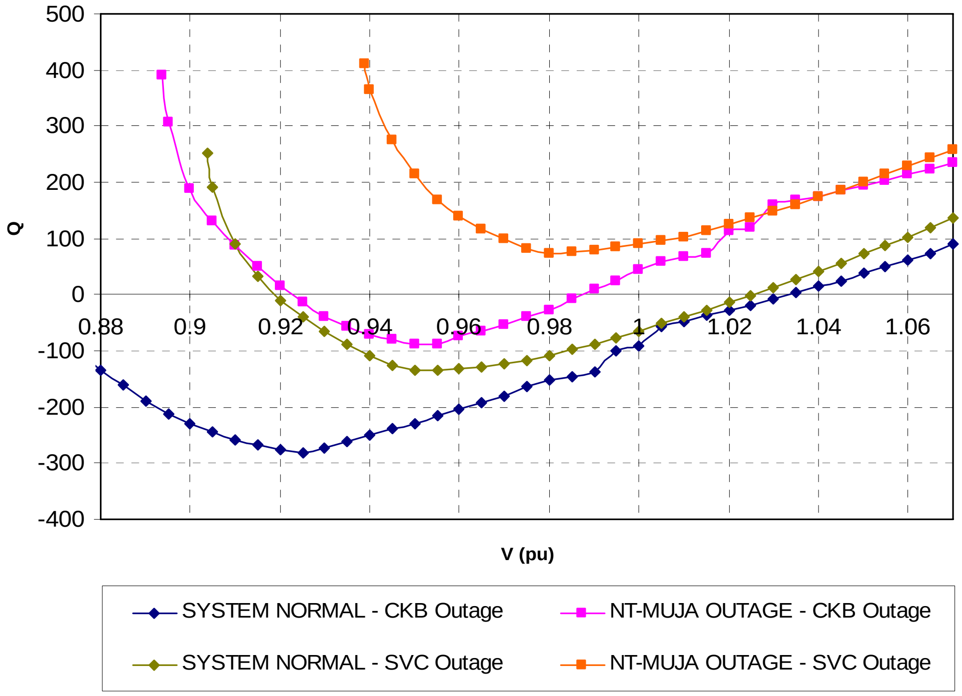

Figure 4: Comparison of reactive margins at Northern terminal for pre-contingent outage of either Southern Terminal SVC or Cockburn 3 generator

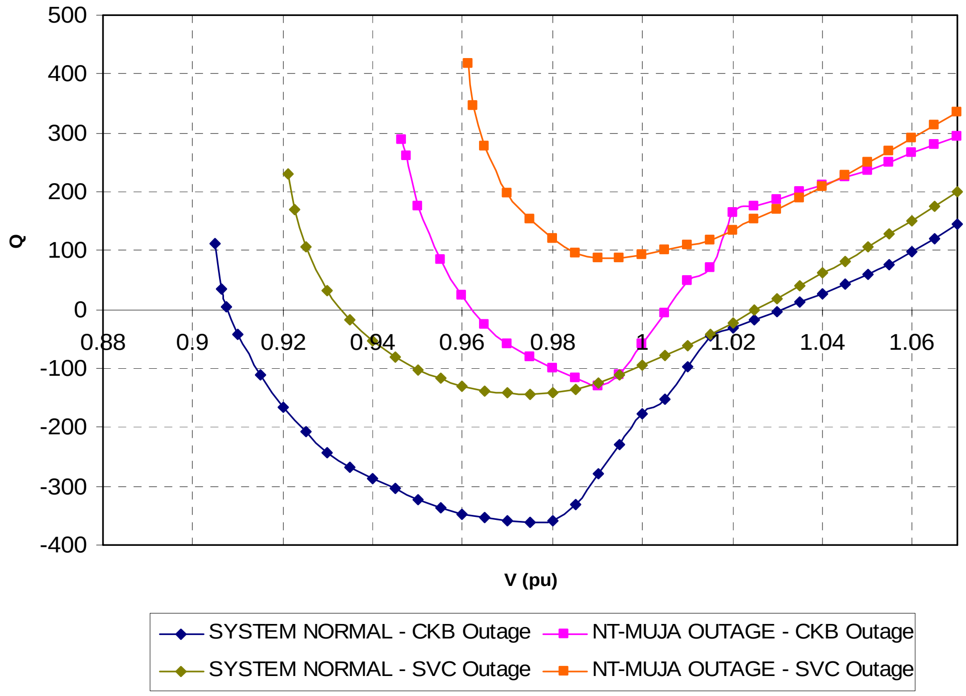

Figure 5: Comparison of reactive margins at Southern Terminal for pre-contingent outage of either Southern Terminal SVC or Cockburn 3 generator

3.7.4 Power Transfer Safety Margin

Western Power appears to have applied the active power transfer safety margin in accordance with clause 2.3.7.3 to the base case scenario files provided to SKM. In the network models provided to SKM the increase in 330 kV power transfers has been achieved through a combination of generation and load scaling.

In the base case reactive study files used by Western Power there appears to have been a safety margin included through a combination of generation scaling at Muja and the scaling of load in the metropolitan area. In the absence of the original pre-scaled files used for these simulations, SKM has attempted to estimate the safety margin applied to these files. This calculation is shown in the following tables, where:

- Table 3 summarises the base case in 2011;
- Table 4 summarises Option 1 in 2013; and
- Table 5 summarises Option 1 in 2016.

Table 3: 2011 load scaling validation - IMO Forecast load 4228 MW

Scenario	System Normal	WP Base Case File for Reactive Studies	V-Q Study File
Zone 1 Load	3730	3860	3980
Zone 2 Load (Includes Boddington)	329.4	329.4	156.9
Losses	169.2	182.7	204
Load total	*4228.6*	*4372.1*	*4340.9*
450-380	431.7	451.8	481.1
350-51040	493.8	515.3	540.9
350-51250	507.6	525.5	546.3
400-51050	495.2	511.2	539.8
Total	1928.3	2003.8	2108.1
% increase in loading:		**3.92%**	**5.21%**

Table 4: 2013 load scaling validation - IMO Forecast load 4483 MW

Scenario	System Normal	WP Base Case File for Reactive Studies	V-Q Study File
Zone 1 Load	3978.1	4078.1	4080
Zone 2 Load (Includes Boddington)	329.4	329.4	156.9
Losses	182.6	192.5	203.8
Load total	*4490.1*	*4600*	*4440.7*
450-380	386.4	406	433.3
350-51040	479.5	500.4	524
350-51250	295.7	311.5	318.2
400-51050	422.4	441.6	467
380-51250	303.4	307.1	326.3
380-51250	303.4	307.1	326.3
Total	2190.8	2273.7	2395.1
% increase in loading:		**3.78%**	**5.34%**

Table 5: 2016 load scaling validation - IMO Forecast load 4858 MW

Scenario	System Normal	WP Base Case File for Reactive Studies	V-Q Study File
Zone 1 Load	4320	4490	4470
Zone 2 Load (Includes Boddington)	329.4	329.4	156.9
Losses	213.8	226.4	237.7
Load total	*4863.2*	*5045.8*	*4864.6*
450-380	420.4	445.1	477.7
350-51040	522	547.1	569.4
350-51250	314.1	332.5	337
400-51050	458.7	480.7	510.7
380-51250	322	326.9	352
380-51250	322	326.9	352
Total	2359.2	2459.2	2598.8
% increase in loading:		**4.24%**	**5.68%**

As shown in the tables above, the safety margin applied appears to be of the order of 4%. It must be noted that the “System Normal” scenario analysed above is an estimate developed by SKM and may not precisely represent the base scenario used by Western Power in undertaking their V-Q analysis. Nevertheless, it is apparent that the development of the V-Q analysis files may not have been conducted in strict adherence to the Reactive Study Guidelines.

Under these guidelines, it is suggested that the credible load and generation pattern be established first, and then scaling of load and generation be applied to obtain the 5% safety margin. Western Power studies were conducted in the reverse order, with scaling of load / generation applied to the base case scenario, and then development of the generation and load scenario, such as Boddington load outage and subsequent generation re-dispatch. SKM has reviewed the impact of this, and determined that it would have a detrimental impact on reactive margin of up to 50 MVAr, as shown in Figure 6.

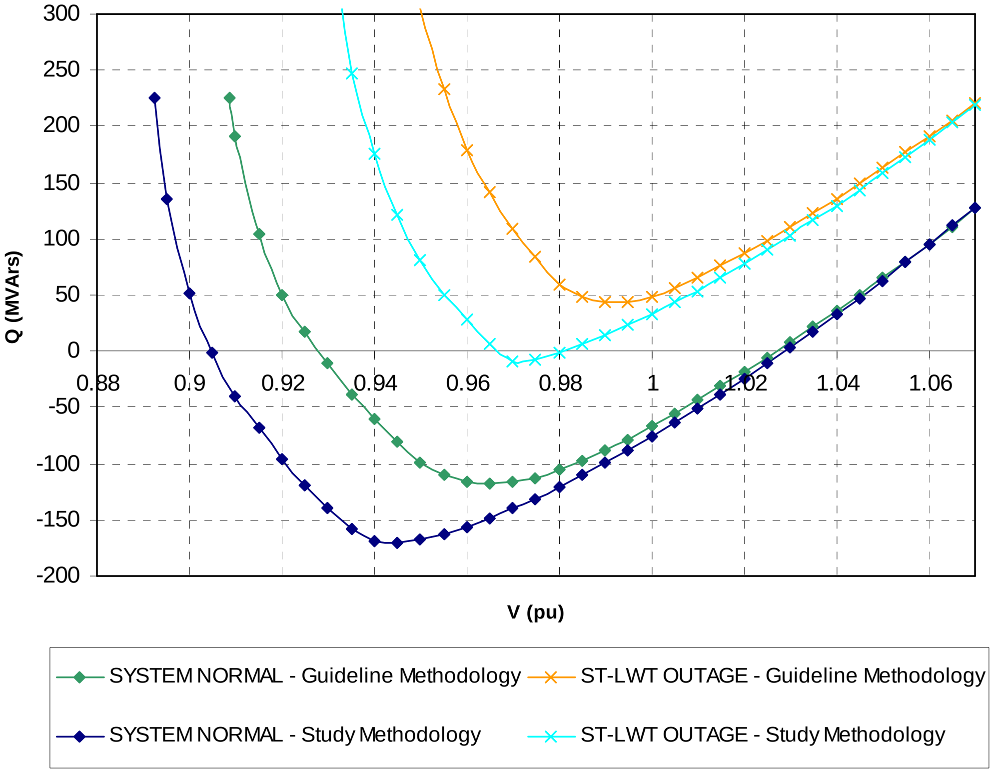

Figure 6: Comparison of methodologies for reactive margins at Northern Terminal under Option 3 in 2011

The largest differences were identified in 2011, and subsequent years indicate less significant changes. SKM believes that a difference in reactive margin of this magnitude could affect the results of these studies, and that the net result would be to advance timings of any proposed augmentation works where the expected reactive margin is low.

Overall, Western Power appears to have conducted their studies in a manner generally compliant with the Technical Rules. However, the methodology used to develop the appropriate extent of load scaling could have an impact on system results, and it is expected that with stricter adherence to the Reactive Study Guidelines, the calculated reactive margins would be less than what is represented in this report.

3.8 Voltage Stability Analysis of Proposed Options

3.8.1 Preparation of Study Cases

SKM conducted these studies using, where available, the files provided by Western Power. For scenarios where network files had not been prepared, SKM have attempted to create simulation scenarios using the same methodology applied by Western Power. This process involved:

(a) Network configuration consistent with the augmentation proposal document:

- The *20xx_BaseOct06.sav* files provided by Western Power were used as the basis for all scenarios considered. By inspection it was apparent that these files have had some form of power transfer safety margin already applied, as outlined in the Technical Rules. Major network augmentations were validated against approved projects in the Annual Planning Report;
- Scripted change files developed by Western Power were used to recreate proposed network augmentations where scenario options did not exist. These were primarily used to develop network models for years 2012, 2014 and 2015 – years for which few or no existing study files were available;
- The base case file generation dispatch included some Pinjar generation but no Cockburn 1 generation. Where necessary, the generation dispatch was adjusted within the metropolitan area to meet merit order guidelines, as outlined in the Reactive Study Guidelines document. These adjustments did not materially impact on the 330 kV bulk transmission power transfers;

(b) Preparation of V-Q scenario files for input into the SKM V-Q analysis program:

- An automation script was developed to construct the V-Q analysis scenarios for each option and contingency. This script configured the appropriate contingency, swing bus and analysis point for each scenario.

The above methodology provided a consistent approach for studying the reactive margin of each option across the study period.

It was assumed across all years considered that the base case files provided by Western Power represented credible load and generation dispatch scenarios, subject to the application of the merit order as outlined above.

SKM has some concern over the distribution of spinning reserve, which was discussed in Section 3.4.7, but this was not considered for the technical validation of the reactive margins.

3.8.2 Initial Scenario – 2011 Base Case

The driving force for this proposed network augmentation is a reactive shortfall in 2011. This shortfall is a result of proposed generation coming on line in the south-west of the SWIS[7].

The reactive margins represented in Figure 7 and Figure 8 confirm that under worst-case operating conditions there would be a reactive short-fall of nearly 100 MVAr.

Additional reactive support in the form of shunt capacitors could be installed around the Southern and Northern terminals to mitigate these outages. For this purpose, as illustrated by the reactive margin shown in Figure 8, 100 MVAr would be sufficient. However, excessive shunt compensation that is required only during system contingencies could result in over-voltages during normal system operation if continuously in service, or if out during system normal operation be too slow to respond to dynamic system processes.

[7] The generator in question is the Bluewaters power station scheduled for commissioning by late 2010.

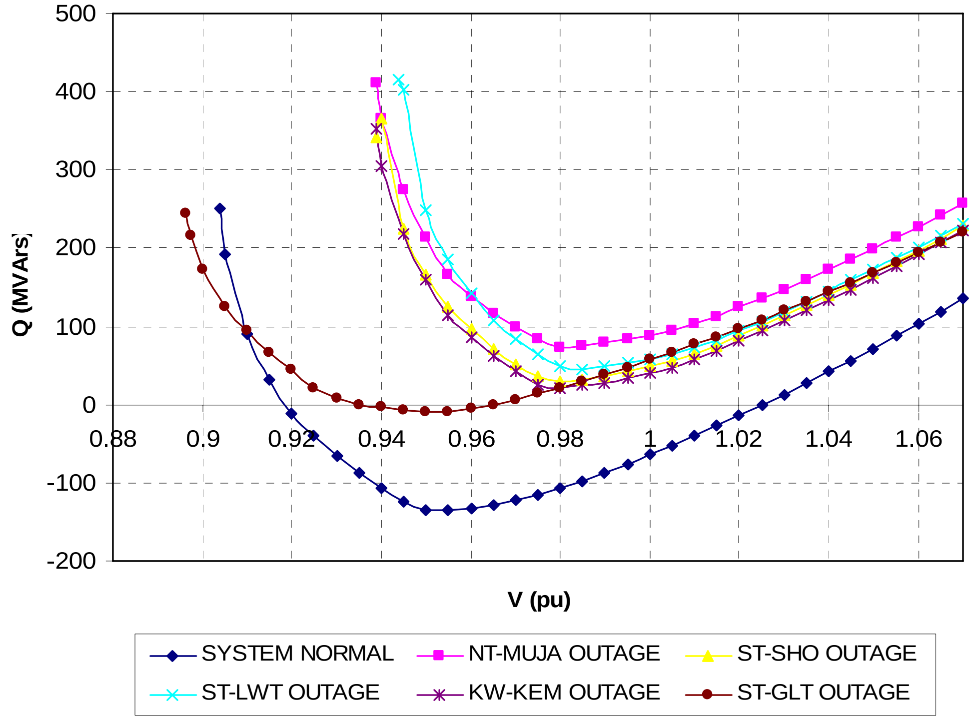

Figure 7: Reactive margins at Northern Terminal for the base case scenario in 2011

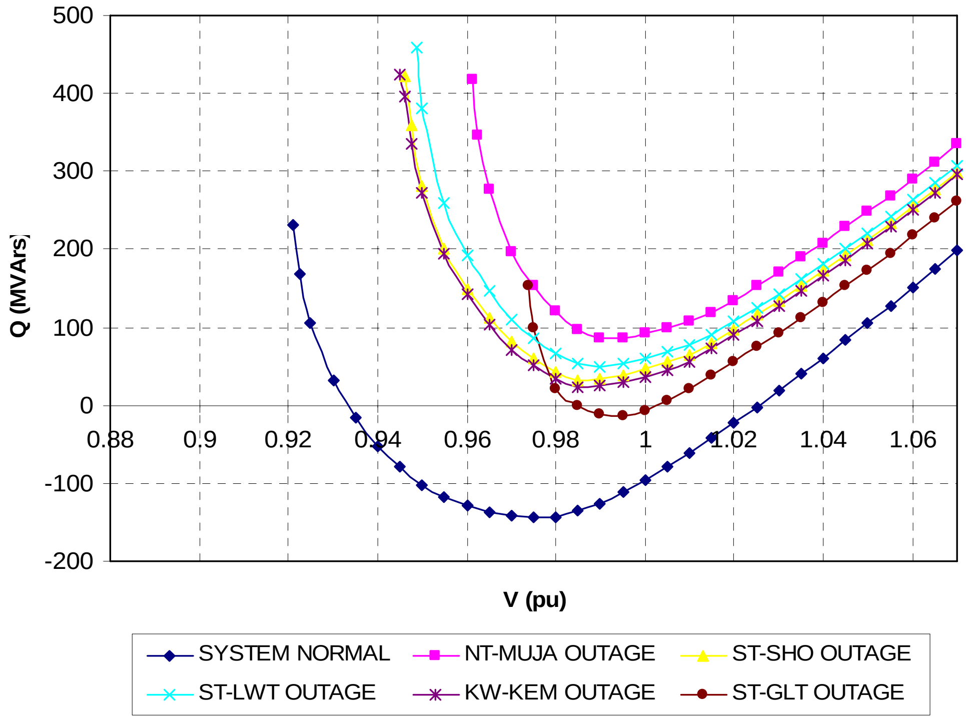

Figure 8: Reactive margins at Southern Terminal for the base case scenario in 2011

3.8.3 Option 1 – Increased transfer through South East Terminal

The reinforcement strategy represented by Option 1 proposes:

- The establishment of the South East Terminal (SET) switchyard in 2011;
- Cutting the newly established SET substation into the KW-NT 91 and MU-NT 91 transmission lines;
- The construction of a double-circuit 330kV transmission line from Landwehr (near the Wagerup Power Station) to the SET in 2011; and
- Creation of a cut-in on the previously described transmission line to the Landwehr Terminal in 2016[8].

Figure 9 and Figure 10 indicate that in 2011 the proposed augmentation provides sufficient support to the network to result in a positive reactive margin, when measured at the Northern Terminal bus. As illustrated, the critical contingency is the outage of the Shotts to Southern terminal 330 kV circuit. Loss of this transmission line places additional loading on the remaining 330 kV circuits supplying the Northern Terminal substation, consequently resulting in additional reactive losses.

Further augmentation is required by 2016, as shown in Figure 11. Under this scenario, outages of the Shotts – Southern Terminal and Southern Terminal – Guildford Terminal result in reactive power shortfalls at the Southern and Northern Terminals. The proposed augmentation in 2016 is sufficient to meet reactive reserve requirements, although the reactive margin for the Southern Terminal – Guildford Terminal outage is marginal and may require some additional reactive support on the sub-transmission network.

V-Q analysis for Option 1 over the entire study period is included in Appendix D.

[8] This augmentation is required in 2016 to mitigate an outage of the Shotts Terminal to Southern Terminal line.

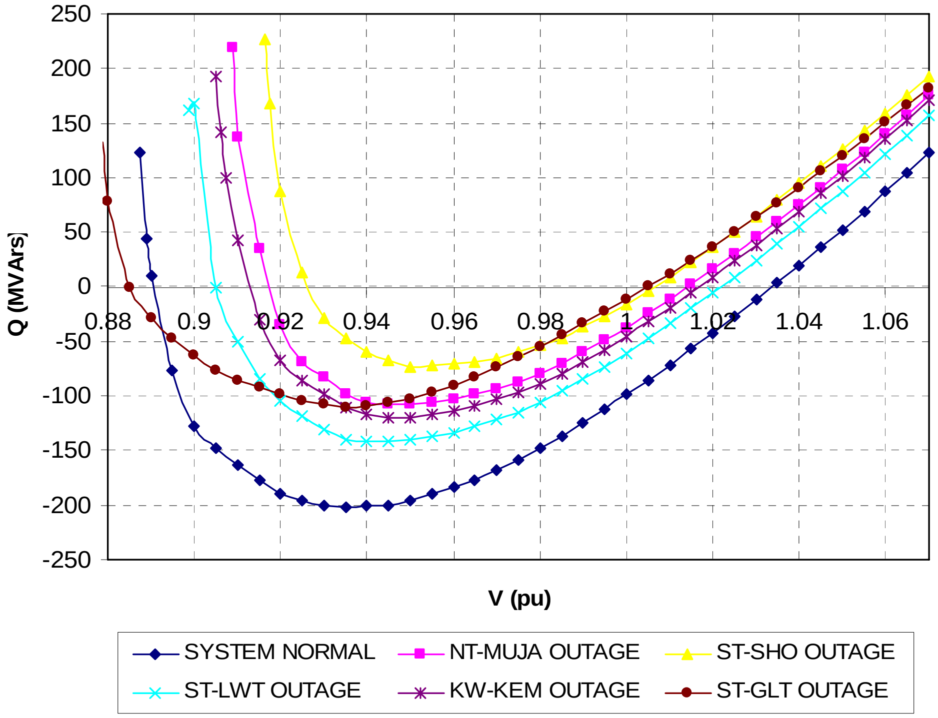

Figure 9: Reactive margin at the Northern Terminal bus for Option 1 in 2011

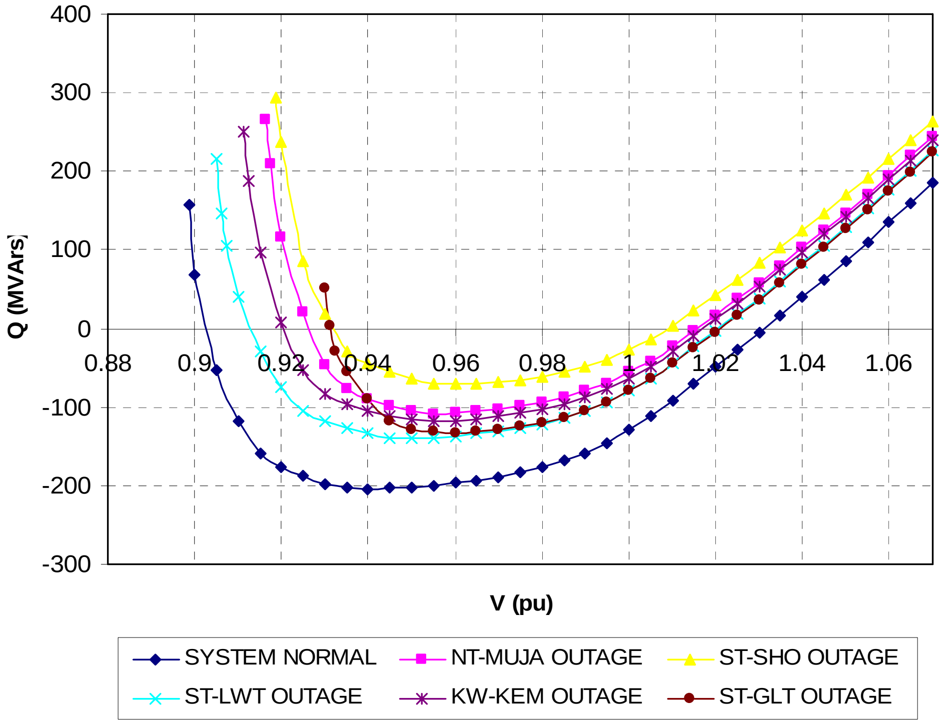

Figure 10: Reactive margin at the Southern Terminal bus for Option 1 in 2011

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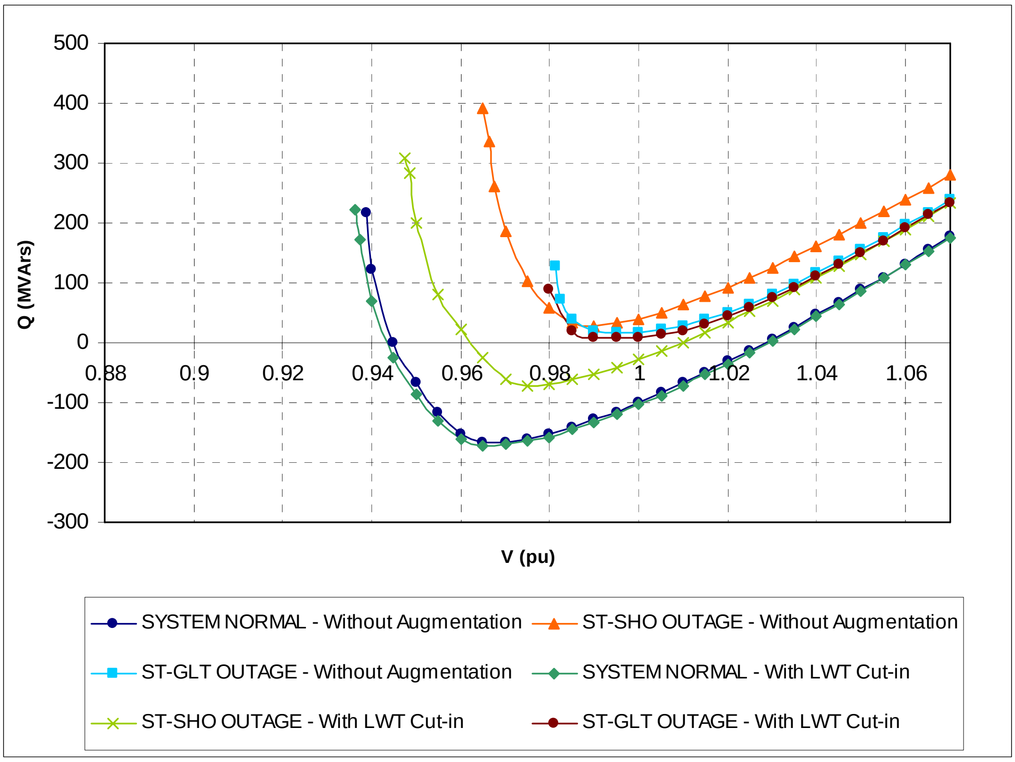

Figure 11: Reactive margin at the Southern Terminal bus for Option 1 in 2016

3.8.4 Option 2 – Deferred Landwehr to South East Terminal lines

Option 2 is a variation of Option 1, with the deferment of new transmission lines achieved by constructing the SET in 2011 in conjunction with the ST – Shotts cut-in to Landwehr Terminal. The transmission lines can then be deferred until 2013.

Option 2 can be summarised as follows:

- The establishment of the South East Terminal (SET) switchyard in 2011;
- Cutting the newly established SET substation into the Shotts to Southern terminal 330 kV transmission line in 2011; and
- The construction of a double-circuit 330kV transmission line from Landwehr (near the Wagerup Power Station) to the SET in 2013.

Figure 12 and Figure 13 indicate that the initial stage of network augmentation under Option 2 provides a marginal solution for the worst credible contingency in 2011. However, as illustrated in Figure 14, additional augmentation, such as the proposed transmission lines from Landwehr to SET, are required by 2013. Without further augmentation outage of the NT – Muja transmission line there will be a significant reactive shortfall and potential voltage instability following this contingency. These results are in agreement with Western Power's findings and support the construction of additional 330 kV transmission lines for the Option 2 reinforcement strategy.

In 2014 and beyond, outages of the Southern Terminal – Guildford Terminal 330kV line cause marginal reactive shortfalls at the Northern and Southern Terminals. A robust and well planned reactive scheduling strategy for the Western Power network should be sufficient to address this issue. Possible locations for additional reactive power include Northern and Southern Terminal. However, SKM also notes that the placement of reactive support solely to support contingency operation may result in unacceptably high network voltages during normal system operation.

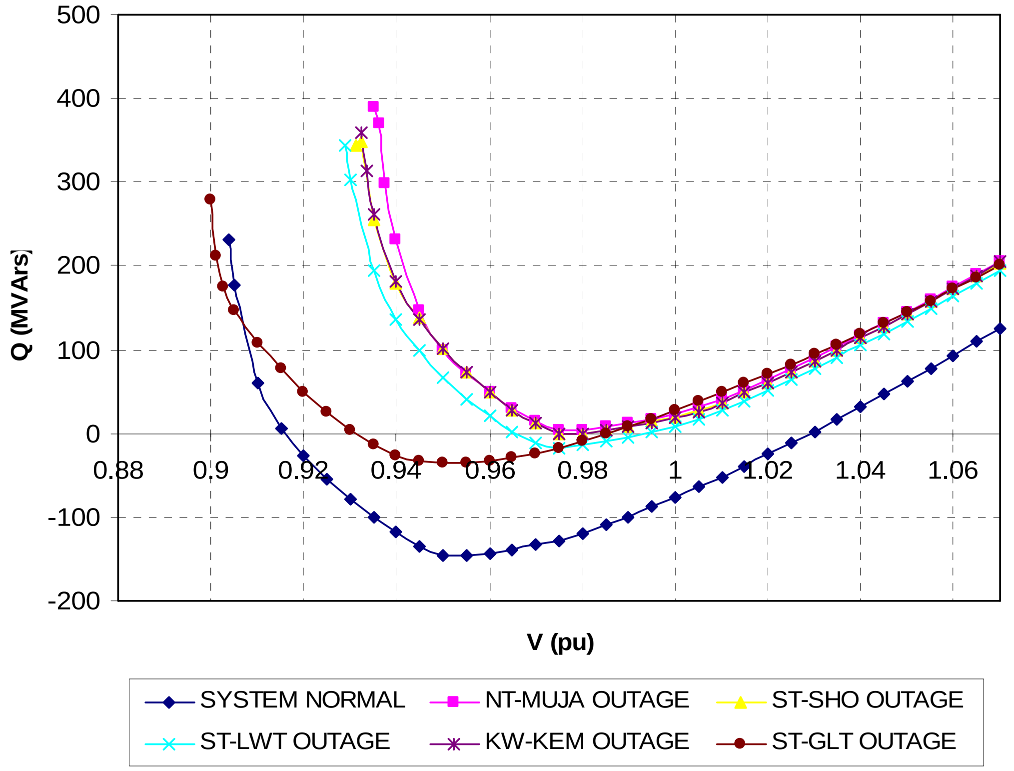

Figure 12: Reactive margin at the Northern Terminal bus for Option 2 in 2011

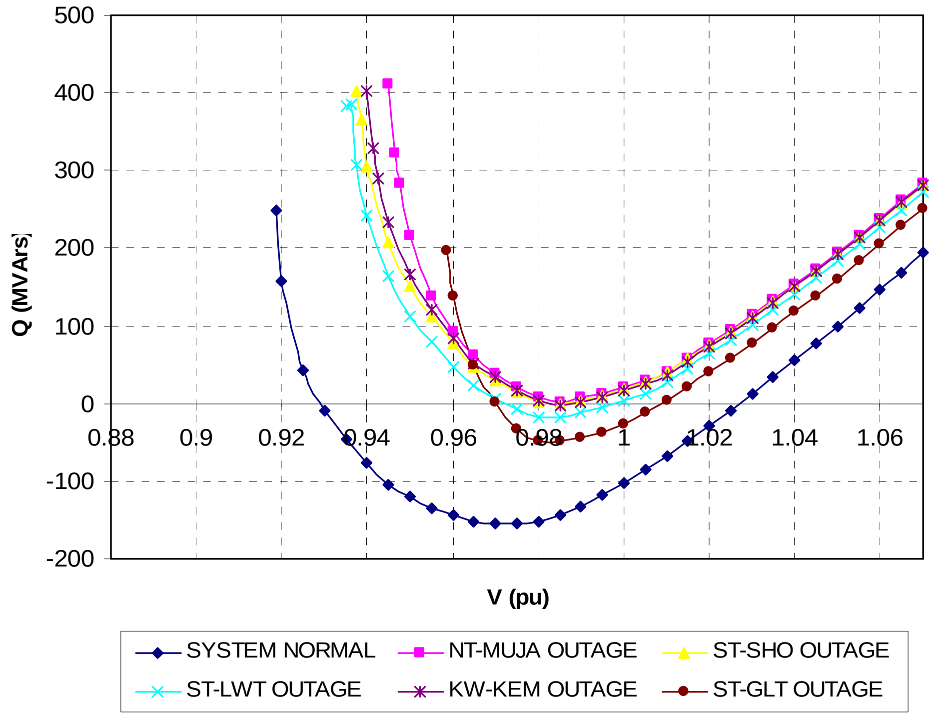

Figure 13: Reactive margin at the Southern Terminal bus for Option 2 in 2011

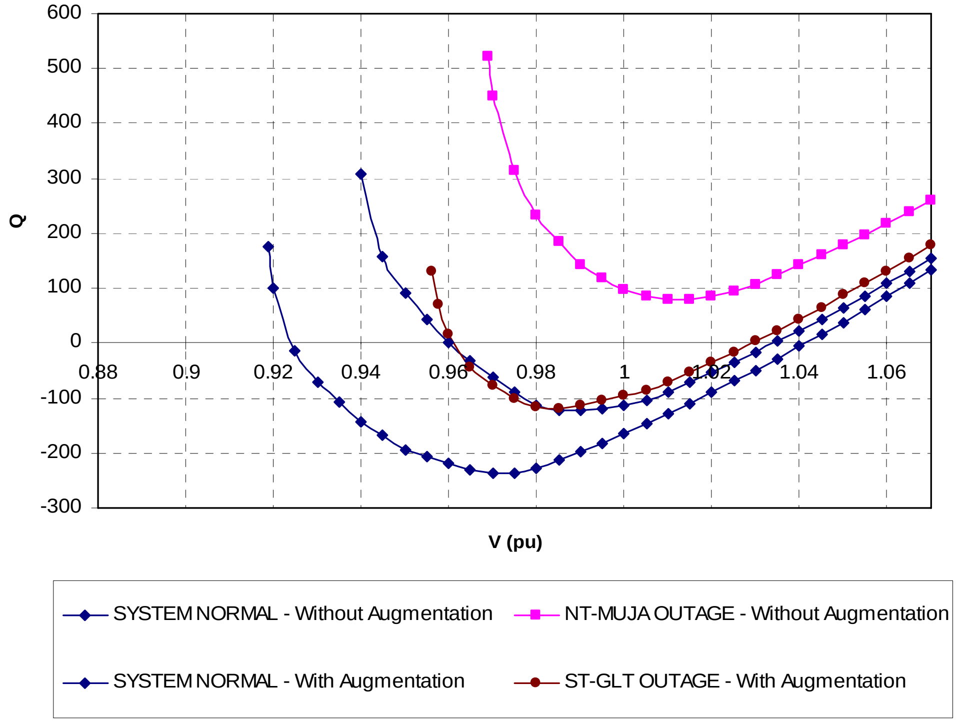

Figure 14: Reactive margin at the Southern Terminal bus for Option 2 in 2013, with and without further augmentation

3.8.5 Option 3 – South East Terminal with additional Reactive Support

Option 3 is also a variation of Option 1 with the deferment of new 330kV transmission line developments achieved by the addition of reactive support at the proposed South East Terminal and at Guildford Terminal.

The reinforcement strategy under Option 3 is summarised as follows:

- Establishment of the South East Terminal (SET) switchyard in 2011;
- Commissioning of additional 330 kV shunt capacitors at SET and Guildford Terminal station in 2011;
- The construction of a double-circuit 330kV transmission line from Landwehr (near the Wagerup Power Station) to the SET in 2013; and
- Cutting the SET substation into the Shotts to Southern terminal 330 kV transmission line in 2016;

V-Q Analysis has indicated that the proposed addition of capacitor banks in 2011 is only just sufficient to provide the necessary reactive margin, as shown in Figure 15 and Figure 16.

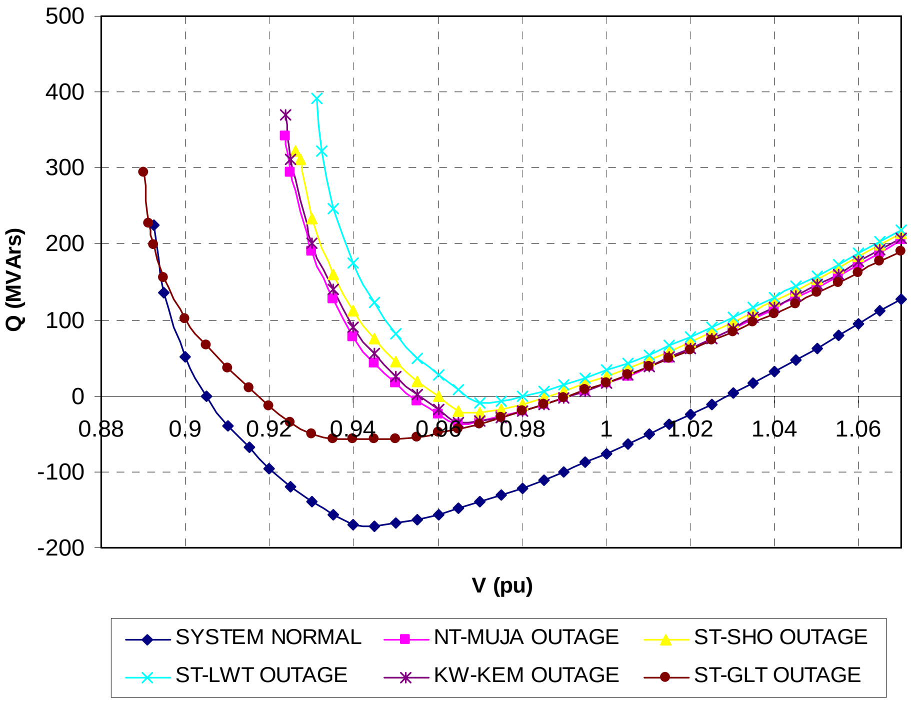

Figure 15: Reactive margin at the Northern Terminal bus for Option 3 in 2011

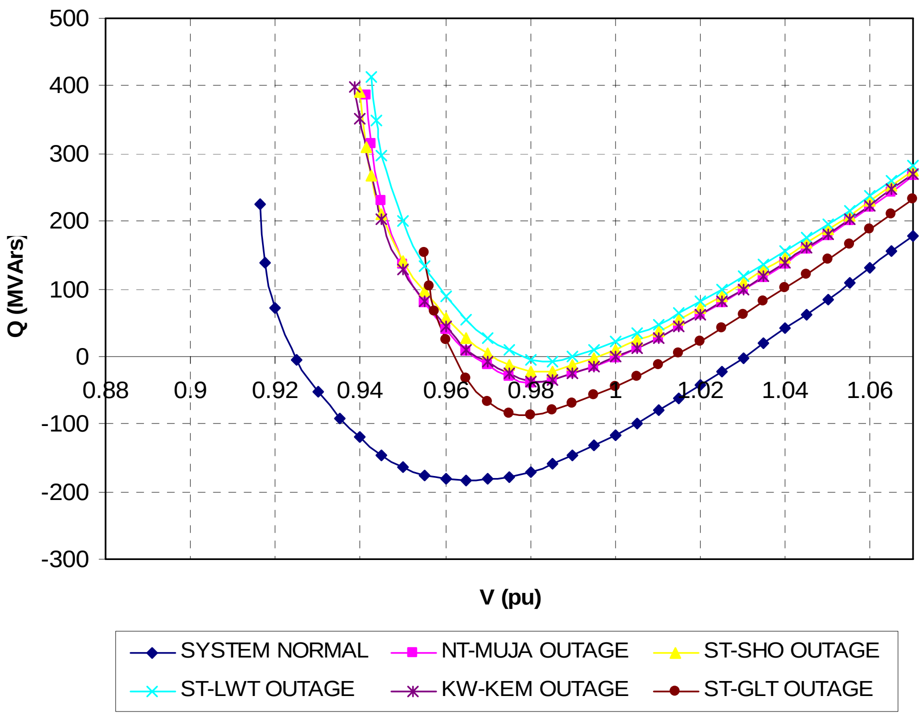

Figure 16: Reactive margin at the Northern Terminal bus for Option 3 in 2011

As these results are marginal, the methodology used to apply the requisite 5% power transfer safety margin may result in this option failing to meet voltage stability criteria. However, minor sub-transmission works could be capable of mitigating this without requiring advancement of the proposed 330 kV augmentations. Such minor works may involve an appropriate reactive scheduling strategy for the SWIS, or the establishment of new zone substations that may lead to lower system losses.

As shown in Figure 17, additional augmentation is required for Option 3 in 2013. The proposed augmentation, construction of the double-circuit transmission lines between Landwehr and SET, appears sufficient to meet reactive shortfalls until 2016. These results are consistent with the findings of Western Power for this option.

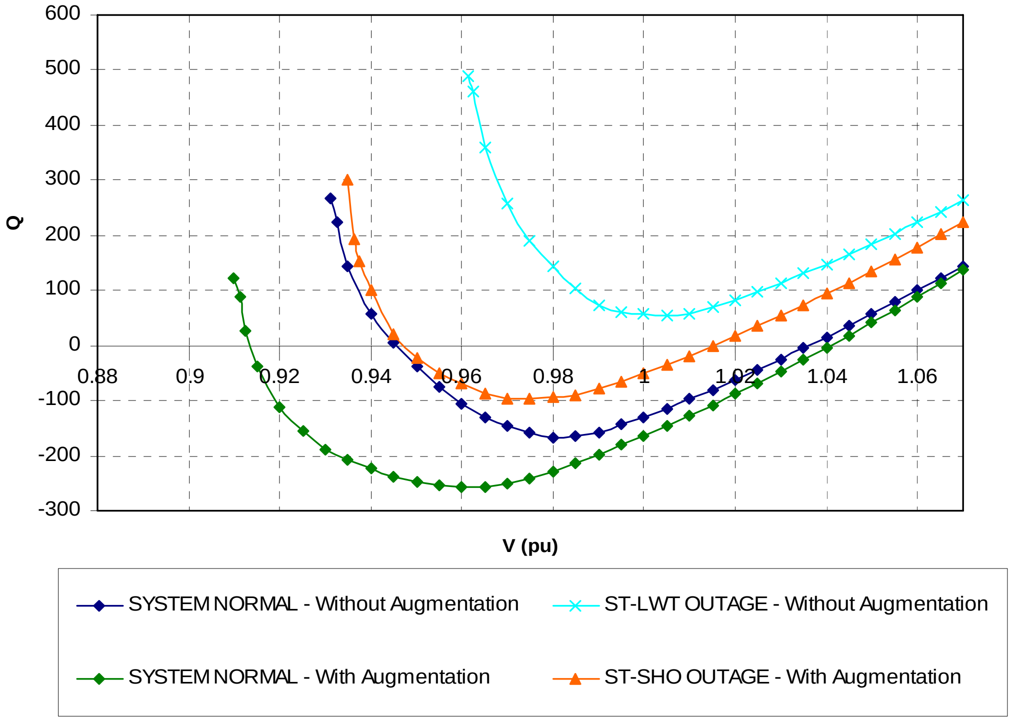

Figure 17: Reactive margin at the Southern Terminal bus for Option 3 in 2013, with and without further augmentation

3.8.6 Option 4 – New SVC at Northern Terminal

Option 4 proposes a series of reinforcement as follows:

- Commission a new +200/-100 MVAr SVC at Northern Terminal substation 132 kV bus;
- Establishment of the SET switchyard to cut into the existing KW-NT 91 and MU-NT 91 330 kV transmission lines in 2013; and
- The construction of a double-circuit 330kV transmission line from Landwehr (near the Wagerup Power Station) to the SET in 2013.

Voltage stability studies conducted by SKM have shown that the initial stage of this reinforcement option is capable of meeting reactive and voltage control requirements in the years 2011-2012. More detailed V-Q data can be found in Appendix D.

Western Power has proposed additional network reinforcement in 2013 by commissioning the SET switching station. However, given the performance of the SVC in the voltage stability studies conducted by SKM, this may not be required until 2014. Shown in Figure 18 is the reactive margin at the Northern terminal in 2013 with and without the proposed augmentation. Similarly, Figure 19 demonstrates the reactive margin measured at Southern Terminal switchyard for the same outages. As illustrated, there is sufficient reactive margin at both the Northern and Southern Terminal buses for all analysed contingencies to defer establishment of the SET switchyard until the following year.

In 2014 augmentations including the SET establishment, the Shotts – ST cut-in and additional reactive support would be necessary to meet the requirements of the Technical Rules. These works, completed in 2014, will – as proposed by Western Power – defer additional transmission augmentations until 2016, when the construction of a new Landwehr to SET double circuit 330 kV transmission line is proposed. Alternatively, the additional reactive support required in 2014 can be addressed by advancing the construction of the 330 kV double circuit between Landwehr and SET.

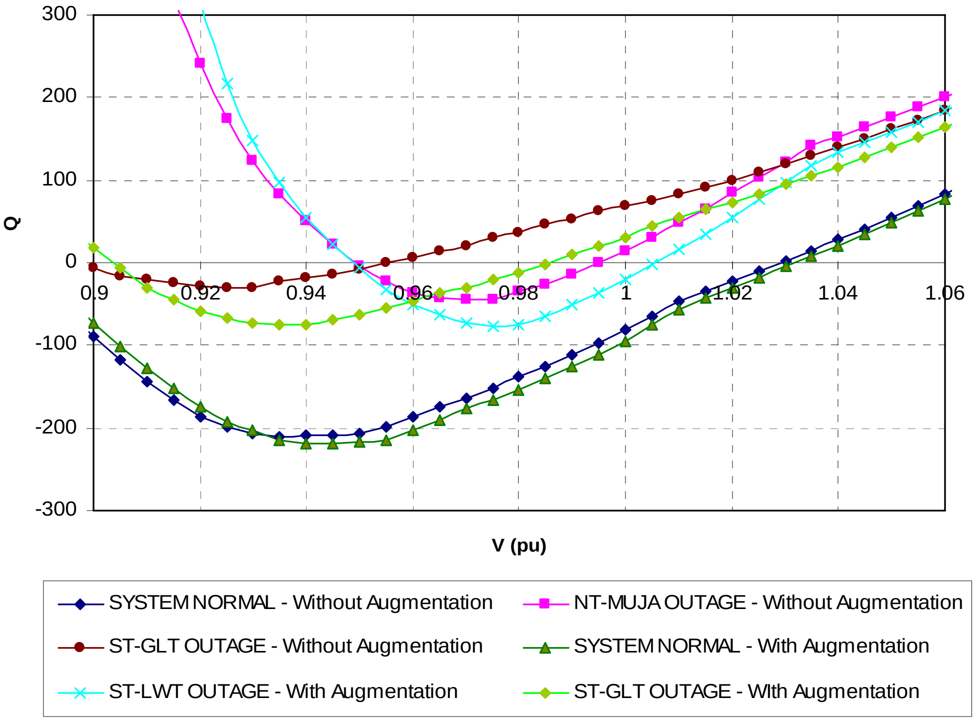

Figure 18: Reactive margin at the Northern Terminal bus for Option 4 in 2013

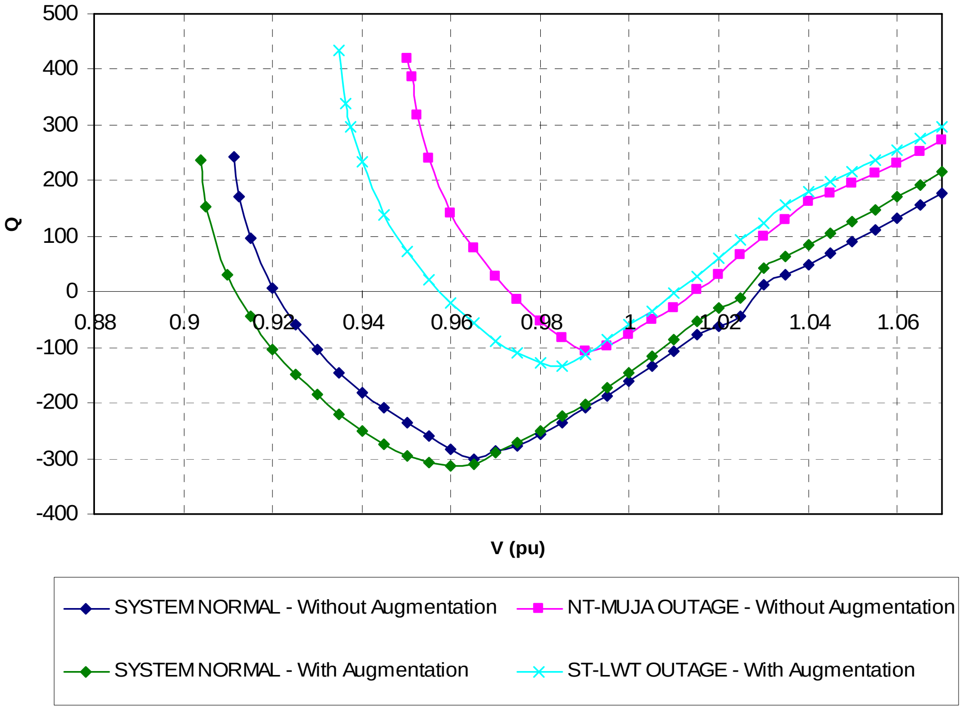

Figure 19: Reactive margin at the Southern Terminal for Option 4 in 2013

Analysis of Option 4 augmentation highlights the relatively minor increase in reactive margin that the establishment of SET switchyard affects. Only combined with further augmentations does this switchyard allow for an increase in the stable power transfer limit.

3.8.7 Option 5 – Series Compensation

This option proposes to defer the construction of new transmission line assets by installing series compensation on all major 330 kV transmission lines in the south-west of the SWIS.

The reinforcement strategy of Option 5 is described by the following activities:

- Install 9 separate series capacitor banks in the 330 kV bulk transmission lines between the south-west region and Perth in 2011;
- Establish a new switchyard at South East terminal to cut into the existing KW-NT 91 and MU-NT 91 transmission lines in 2013;
- Cut the existing Shotts to Oakley Terminal and Southern Terminal 330 kV transmission line into Landwehr Terminal in 2013; and

- The construction of a double-circuit 330kV transmission line from Landwehr (near the Wagerup Power Station) to the SET in 2016.

For the installation of series capacitors to compensate for reactive power losses on major 330kV transmission lines in the SWIS Western Power considered two options:

(a) typical compensation level of 40%; and

(b) maximum compensation level of 70%.

Western Power believes that compensation at the 70% level may result in sub-synchronous resonance issues. For this reason, V-Q analysis has been conducted for the 40% compensation level only. However, to allow thorough assessment of this option the impact of the maximum compensation has been also been briefly assessed by SKM.

The proposed sequence of augmentations outlined by Western Power is sufficient to meet reactive margin requirements for 2011-13 and 2016. However with the 40% compensation level, there are reactive shortfalls in 2014 and 2015, as shown in Figure 20 below.

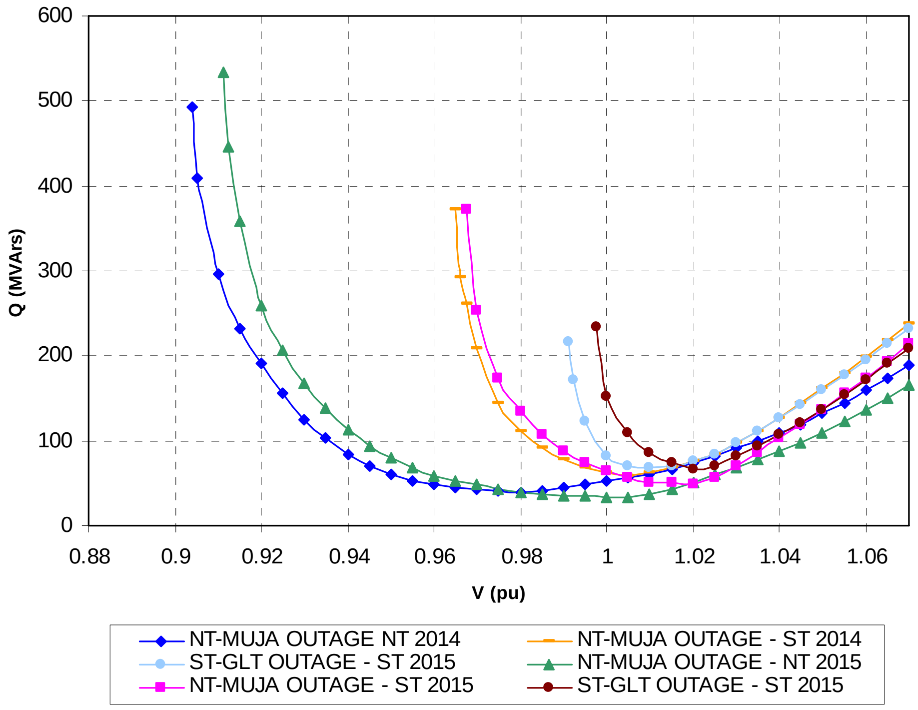

Figure 20: Reactive margin at Northern and Southern Terminal for Option 5 in the years 2014 and 2015 for 40% Series Compensation

Analysis with the maximum of 70% compensation indicates that this should be sufficient to overcome these issues without advancing further 330kV augmentation, as shown in Figure 21. However, as indicated by Western Power, such a high level of compensation may result in sub-synchronous resonance issues. SKM has not conducted any analysis to confirm this point and notes that more detailed analysis would be required to test this.

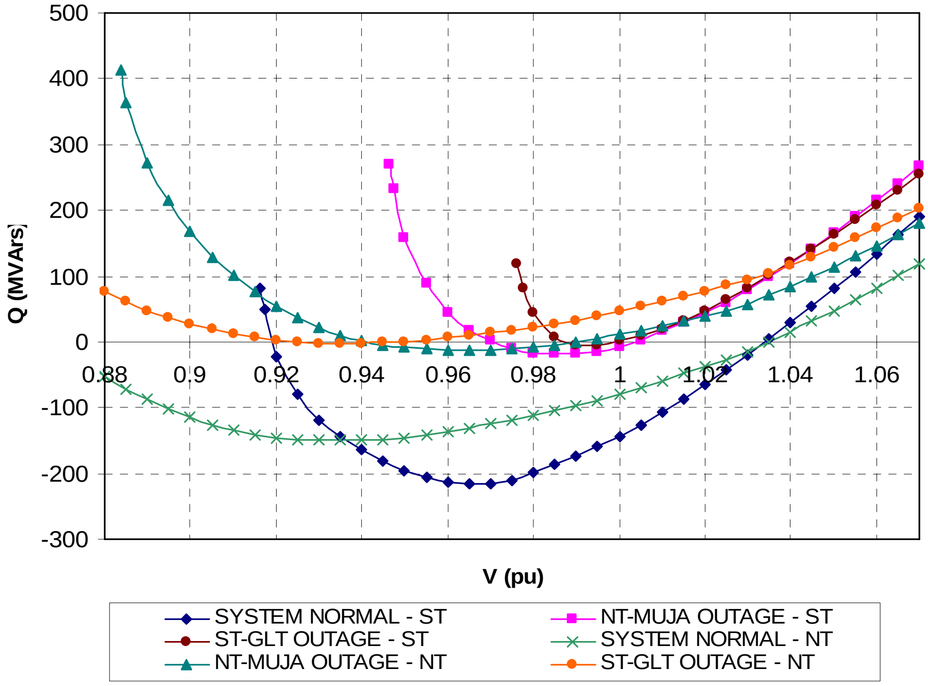

Figure 21: Reactive margin at Northern and Southern Terminal for Option 5 in 2014 for 70% Series Compensation

While there are potentially technical limitations for high levels of series compensation due to sub-synchronous resonance, it needs to be noted this is not the reason that resulted in Western Power expressing preference for Option 6. Indeed, Western Power's economic model indicated that Option 5 was not considered as a result of the high cost of series compensation required for all major 330 kV circuits to make this strategy feasible [1]. Overall the economic ranking of Option 5 was the least favourable of the reinforcement strategies proposed by Western Power.

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3.8.8 Option 6 – Increased Transfer through Eastern Terminal

Option 6 is Western Power's recommended development option. Ideally this reinforcement strategy involves:

- Stringing the second side of the 330kV double circuit transmission line from Shotts Terminal to Wells Terminal in 2011;
- Establishing a new Eastern Terminal switching station, which would cut into the existing KW – NT 91 and MU – NT 91 transmission lines in 2011;
- Construction of a double-circuit transmission line from Wells Terminal to the proposed new switchyard at Eastern Terminal in 2011; and
- Cutting the existing Shotts to Oakley Terminal and Southern Terminal 330 kV transmission line into Landwehr Terminal in 2016.

SKM has established that this development provides a significant amount of reactive support, as shown in Figure 22 and Figure 23 below, and is sufficient to postpone any further augmentation until 2016.

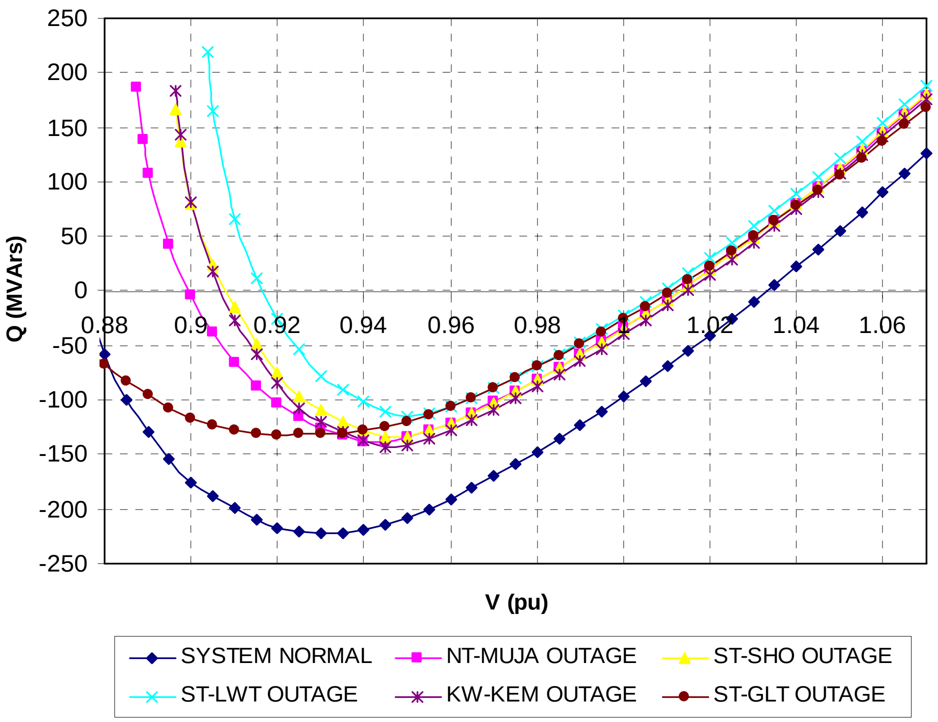

Figure 22: Reactive margin at the Northern Terminal bus for Option 6 in 2011

In 2016, there is a marginal shortfall in reactive margin following an outage of the Southern Terminal – Landwehr Terminal 330kV transmission line or Southern Terminal – Guildford Terminal 330kV transmission line, as shown in Figure 24 below. This could easily be mitigated by additional reactive support from within the metropolitan sub-transmission or distribution networks, and could allow deferment of the proposed 330kV transmission line cut-in for at least one year.

Overall, this option provides a sufficient amount of reactive support to cover all major contingencies analysed over the study period.

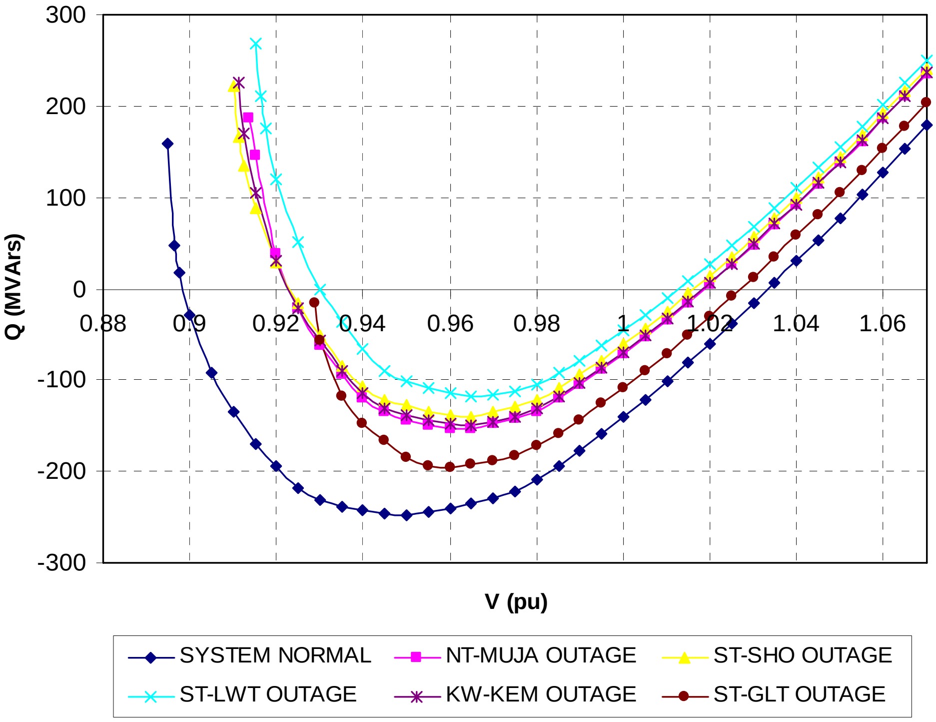

Figure 23: Reactive margin at the Southern Terminal bus for Option 6 in 2011

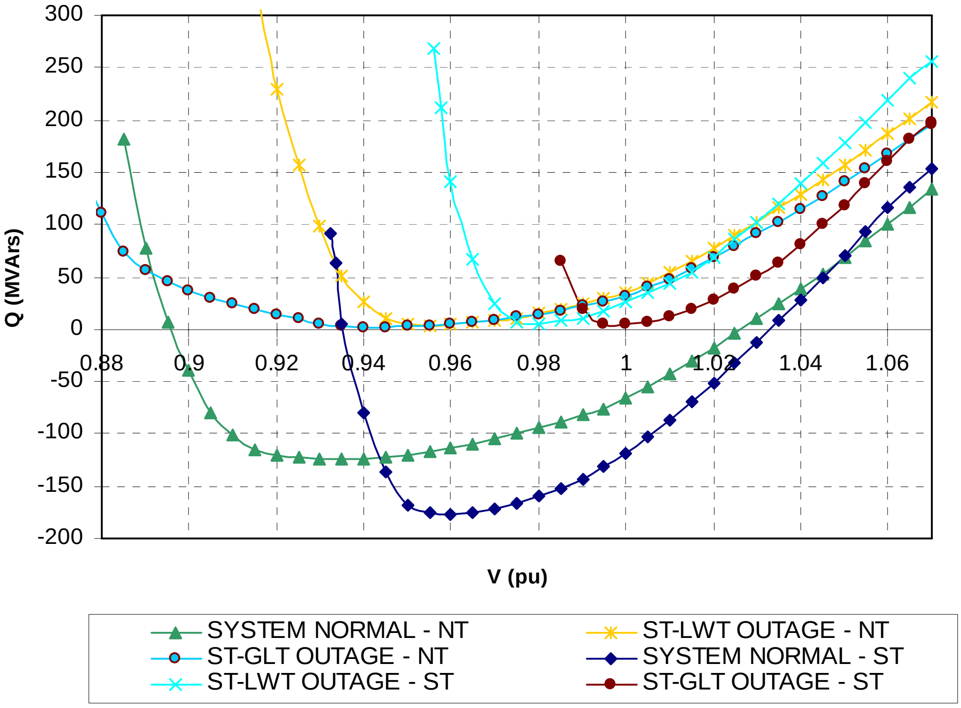

Figure 24: Reactive margin at Northern and Southern Terminals for the worst-case outage for Option 6 in 2016 without additional augmentation

3.8.9 Option 7 – Eastern Terminal deferred by SVC at Northern Terminal

Option 7 is a variation of Option 6 with deferment of the 330kV network augmentations to 2013 achieved by the installation of a SVC at the Northern Terminal 132kV bus. The proposed reinforcement strategy includes the following works:

- Commission a new +200/-100 MVAr SVC at Northern Terminal substation 132 kV bus;
- Establish a new 330 kV Eastern Terminal switching station, which would cut into the existing KW – NT 91 and MU – NT 91 transmission lines in 2013;
- Stringing the second side of the 330kV double circuit transmission line from Shotts Terminal to Wells Terminal in 2013;
- Construction of a double-circuit transmission line from Wells Terminal to the proposed new switchyard at Eastern Terminal in 2013; and

As outlined for Option 4, this SVC is capable of meeting reactive power demands under the most severe contingency events until 2014.

With proposed construction of the Shotts – Wells – Eastern Terminal 330kV transmission lines, the reactive margin is more than sufficient for the remainder of the study period, as shown in Figure 25 and Figure 26 below. It must be noted that as no new generation is modeled to come on-line in the southern region in 2014 and 2015, differences in reactive margin between these years are primarily a result of metropolitan generation dispatch and sub-transmission works.

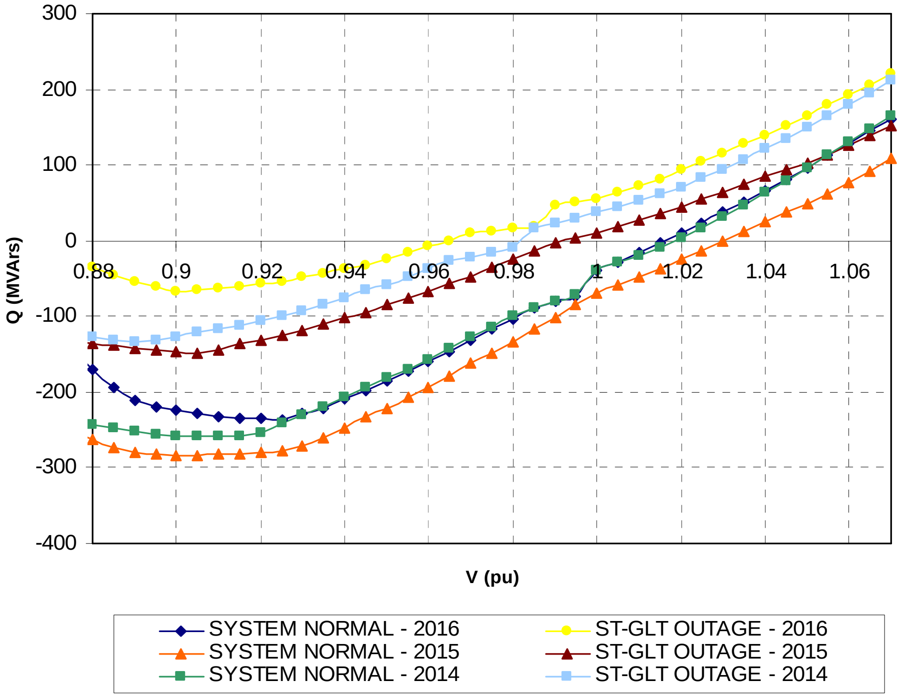

Figure 25: Reactive margin at the Northern Terminal for worst-case contingency under Option 7; 2014-2016

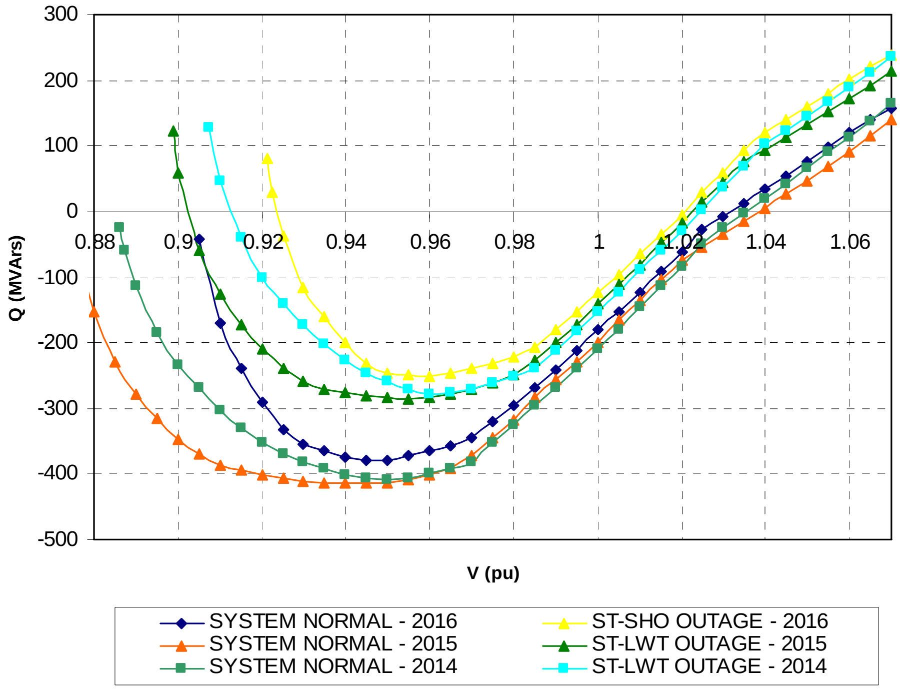

Figure 26: Reactive margin at the Southern Terminal for worst-case contingency under Option 7; 2014-2016

3.8.10 Option 8 – Establishment of 500 kV Transmission

Option 8 proposes the establishment of a 500 kV transmission line to support the requirement for increased transmission capacity. Western Power has noted that this option is technically inferior to the other reinforcement strategies and not pursued this augmentation further.

SKM also considers this strategy to be the least favourable of the options propose for the following reasons:

- Sharing of line loading between a 500 kV and a parallel 330 kV network can be unbalanced unless generation can inject directly into the 500 kV network. Hence the asset would not be fully utilised;
- The capacity of a 500 kV circuit is generally more than twice that of a 330 kV line and thus by far exceeds the requirements for the SWIS, as it is primarily voltage stability that threatens the secure operation of the network for additional generation in the south east of the state;

- The establishment of 500 kV substations and the construction of a 500 kV double circuit transmission line are very capital intensive and are unlikely to rank favourable against similar 330 kV network augmentations; and
- While line charging attributed to 500 kV transmission lines is significant and would therefore increase reactive margins, the loss of one of these 500 kV transmission lines would deprive the network of this reactive support, as well as increasing loading on existing lines and further reducing network voltages, thus requiring additional reactive power to support the network during such contingencies.

As a consequence SKM has not conducted further analysis on the feasibility of this option.

3.9 Alternative Options

A high-level review of the network configuration and potential for augmentation has not indicated that any further network augmentations are likely to provide similar levels of support. Given the relative geographical location of the metropolitan load centres and the south-east generation region of the SWIS, it is unlikely that other transmission options exist that could facilitate higher network transfers. It is expected that more detailed analysis would be required to allow adequate analysis of potential long-term strategies for the SWIS, a task made more difficult by the relatively short notice of generator commitments under the IMO’s 2 year contract scheme.

It could however be possible to defer major 330 kV augmentation by contracting network support from the Pinjar generation. As this generation is expected to be the last generator in the “merit order” for dispatch, the development of the worst-case scenarios in this simulation assume that this generation is not running. It may however be possible to contract generation from these units in order to provide reactive support from within the metropolitan area. This could potentially allow the deferment of additional augmentation until 2013, as shown in Figure 27.

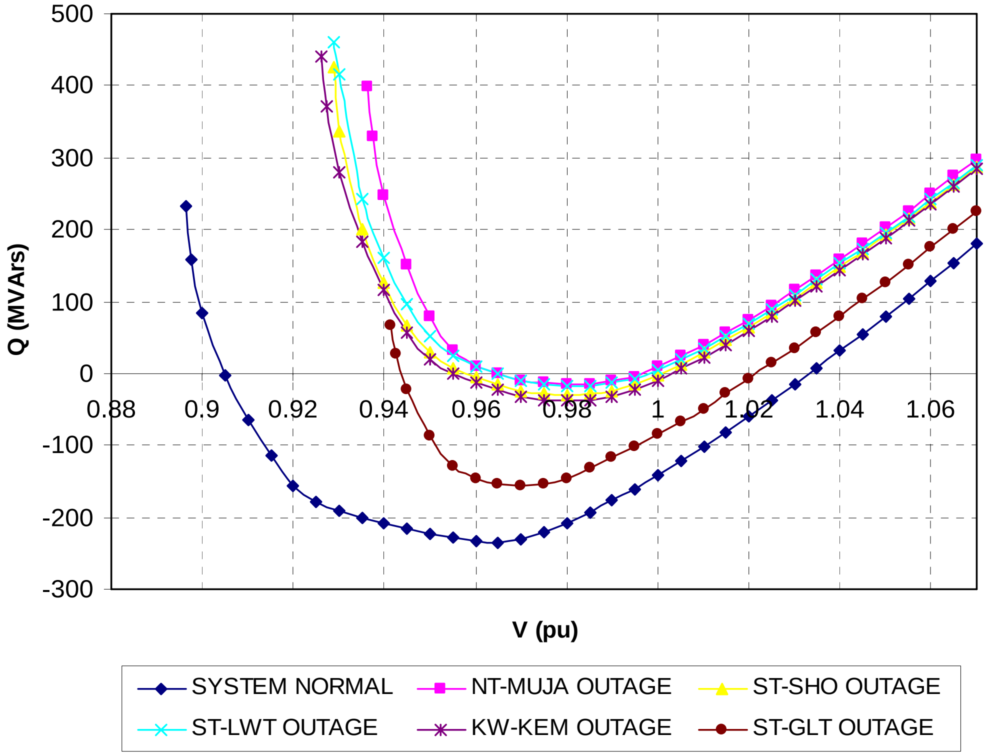

Figure 27: Reactive Margin in 2013 without 330kV augmentation but Pinjar generation in service

The Pinjar generators are Frame 6 and Frame 9 gas turbines. Given their respective operating costs and the likelihood that generation in the south west would need to be constrained to accommodate the operation of these generators, a detailed cost analysis would be required to determine whether this is in fact a viable option for deferment of major augmentation.

SKM

4. Discussion of Results

4.1 Methodology

(1) Spinning reserve requirements after the potential retirement of Kwinana A/B:

Under the scenarios put forward by Western Power, where Pinjar generation is not dispatched due to demand and the historical generator merit order, the necessary spinning reserve capability recommended by the Reactive Study Guidelines is not met. Alternate sources of spinning reserve should be identified in order to meet system stability requirements, otherwise Pinjar generators may be forced to operate in order to provide the required margin.

(2) Load-scaling:

SKM was unable to categorically identify the magnitude or methodology behind the load-scaling applied to the system reactive study models, as specified by the Technical Rules. Analysis has indicated that some scaling was applied. However, the methodology used may not have been in strict accordance with the Reactive Study Guidelines. It is expected that with strict application of the guidelines, the reactive margins outlined in this report would be reduced. This may affect the timing or feasibility of some options.

(3) Network operating conditions:

The network operating conditions proposed as the worst-case situation for which the network is to remain stable includes the following major assumptions:

- Peak demand for 1 in 10 year hot summer;
- Boddington load out of service;
- Wind farm generation throughout the SWIS at maximum;
- Outage of the Southern Terminal SVC;
- Increased loading on 330 kV transmission lines between south west and metropolitan regions of the SWIS by 5% above 1 in 10 peak summer demand;
- Availability of terminal station shunt capacitor banks of 97%; and
- Unplanned outage of a major 330kV element.

While the probability of occurrence of all the above events at time of peak or near-peak demand is likely to be low, SKM acknowledges the obligation of the TNSP to ensure a continued secure transfer of power during all possible generation and load conditions. Furthermore, while possibly not being a highly probable network condition, the above does reflect a scenario that may occur under extreme conditions, thus addressing the requirements of the Technical Rules.

4.2 Verification of Results & Conclusions

- Based on the scenarios put forward, there is a clear need for additional augmentation in 2011, as outlined by Western Power.
- For the majority of options, SKM agrees with the proposed timings put forward by Western Power. In some cases, additional deferment may be possible, but given the increase in load forecast and application of the 5% safety margin required by the Technical Rules, this deferment may not be prudent.
- Analysis of the Southern Terminal – Guildford Terminal circuit outage should be considered as it becomes the most severe contingency in later years. This however, could be mitigated by potentially already planned sub-transmission works in and around Guildford Terminal and may not require major 330kV augmentation to secure.
- Western Power's preferred option is construction of Eastern Terminal and a double-circuit 330kV transmission line from Wells Terminal to Eastern Terminal. Technical analysis indicates that this option achieves acceptable reactive margins across the study period.

  Technically deferment of this option is possible with the installation of an SVC at the Northern Terminal switchyard, and SKM believes this may be a technically sound alternative that would allow a grace period in which to better identify future generation patterns and demand forecasts.

  However, SKM recognises that the 2 year deferment of the proposed network augmentation by installation of the SVC may not be economically viable, as the cost of installing the SVC is significant.
- Option 1 and its variants could meet the requirements for long-term voltage stability over the study period. However in some cases additional reactive scheduling would be required to ensure the timings proposed by Western Power meet the voltage stability requirements outlined in the Technical Rules.
- Option 5 is capable of postponing major 330kV augmentation until 2013. Even so this strategy would require significant augmentations in 2013 and beyond to meet voltage stability requirements. Furthermore, there is some concern expressed by Western Power over sub-synchronous resonance issues within the network which may be exacerbated by series compensation that would require complex analysis in order to identify any potential risks to existing or future generators. Due to these concerns this option is not considered optimal.

However, while there are potentially technical limitations for high levels of series compensation due to sub-synchronous resonance, it needs to be noted this is not the reason that resulted in Western Power expressing preference for Option 6. Indeed, Western Power's economic model indicated that Option 5 was not considered as a result of the high cost of series compensation required for all major 330 kV circuits to make this strategy feasible [1]. Overall the economic ranking of Option 5 was the least favourable of the reinforcement strategies proposed by Western Power.

4.3 Further Considerations

- The IMO Statement of Opportunities released in 2007 indicates a forecast demand approximately 100 MW higher than the 2006 edition. As these studies were conducted using the 2006 forecast demand, it is clear that any works proposed here may need to be advanced in order compensate. More detailed studies would allow confirmation of advancement required, but it is expected that additional reinforcement may be needed up to a year earlier than outlined in this report.
- Additional generation in the north could defer the need for additional 330 kV reinforcement between the South-west and the metropolitan area. However, with the relatively short lead-time for generator capacity credit distribution compared to construction of major transmission projects, it would be imprudent to rely on hypothetical generation distribution to defer major reliability works.
- A network support agreement with Pinjar generators, or other generation in the northern area, could postpone major augmentation works. As demonstrated, contracting of network support services from Pinjar could defer construction of additional 330kV augmentations by up to 2 years, depending on cost considerations. This may allow a grace period to clarify future generation patterns and network constraints.

4.4 Summary

The technical analysis conducted indicates that given the available information on proposed generation and expected generation development patterns, additional augmentation is required by 2011 at the latest. Whilst a number of relatively minor reinforcements exist for deferment of the proposed augmentation, considering the potential for a significant proportion of base-load generation to be constructed south of the metropolitan area it is expected that major 330 kV augmentation would be required in the near future to support growing demand in the metro area.

The establishment of an Eastern Terminal switching station appears to present the most suitable option. While a deferment of major augmentations through the installation of a SVC may be a possible alternative the economic viability of this has not been investigated. Indeed, Western Power has indicated that the capital cost of the SVC may exceed the saving due to delayed transmission augmentations. Furthermore, given the increase in demand indicated by the latest forecast it is more likely that the augmentations described by Option 6 will be required earlier rather than allow them to be deferred.

5. References

[1] Western Power report "Proposed major Augmentation to the Electricity Network – 330 kV Transmission Line to support Electricity load in the Perth metropolitan Area", May 2007.

[2] IMO report "Statement of Opportunities Report – The South West Interconnected System", July 2006.

[3] CRA International report "Reinforcement Options for the North Country Region – Public Version", Final Report V2, March 2007.

[4] Western Power Report "Submission to the Economic Regulation Authority: Major Augmentation Proposal – 330 kV Transmission Line and Associated Works in the Mid-West Region Western Australia", August 2007.

[5] Western Power Document "Bulk Transmission Network Strategic Direction 2007-2026", July 2007.

[6] Western Power Document "Annual Planning Report 2007".

Appendix A – Analysis of Voltage Stability

Measuring Voltage Stability

The V-Q[9] curve is a plot of reactive power versus voltage, at constant power and provides information about the voltage region where instability can occur. More importantly, the V-Q curve provides an insight into the relative amount of reactive power that is available at a particular point of the network, ie. how much reactive power can be provided by the power system at the point of interest and whether additional reactive power is required to maintain system stability following a network outage.

Using power flow calculations a V-Q curve for a particular bus in a power system can obtained by determining the reactive power required to achieve a desired voltage at the bus under consideration. The reactive power required to achieve the voltage is generated using a fictitious reactive supply (i.e. Static VAr Compensator) at the test bus. If the reactive power is now plotted at various levels of bus voltage then the resulting curve is referred to as a V-Q curve. Figure 28 shows an example of what typical V-Q curves can look like for two different power systems.

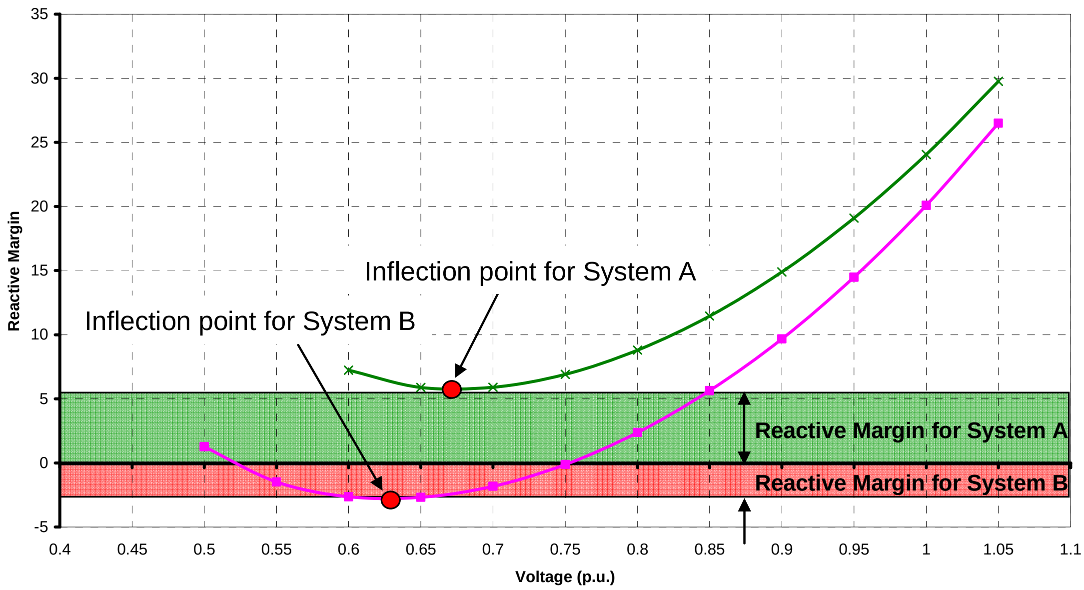

Figure 28: Example of V-Q curves for two systems following a contingency

[9] Sometimes referred to as a Q-V curve, the V-Q and Q-V curve are essentially the same, except that a V-Q terminology stresses that voltage rather than reactive power is the independent variable. Q-V curves are developed by scheduling reactive power rather than voltage.

As illustrated in Figure 28, the bottom of the V-Q curve (also referred to as the point of bifurcation), where the derivative dQ/dV is equal to zero, represents the inflection point of the V-Q curve. The V-Q curve at this point defines the minimum reactive power requirement for stable system operation. A positive value indicates that additional reactive power is required to achieve stability, while the negative margin indicates that the system at this point of the network is capable of providing additional reactive power. Beyond the point of stability the injection of further reactive power will actually result in a decrease in network voltage. Generally voltage collapse has already occurred at this point resulting in total or partial black out of the network.

SKM

Appendix B – Power Flow File Listings

FILENAME	OPTION STUDY
2011-PJR-bod+KWtx.sav	
2011-PJR-bod+lwtcut-SETOct06.sav	
2011-PJR-bod+lwtcutOct06.sav	
2011-PJR-bod+SETLWT+cltOct06.sav	
2011-PJR-bod+SETLWT+lwtcutOct06.sav	
2011-PJR-bod+SETLWT+WDTOct06.sav	
2011-PJR-bod+SETLWTOct06.sav	
2011-PJR-bod+SVC-setOct06.sav	
2011-PJR-bod+SVCOct06.sav	
2011-PJR-bod-KPP-SETOct06.sav	
2011-PJR-bod-SET+SVCOct06.sav	
2011-PJR-bod-SET-svcOct06.sav	
2011-PJR-bod-SETOct06.sav	
2011-PJR-bod-svc+500kV.sav	OPTION 8
2011-PJR-bod-svc+GLTcapDec06.sav	
2011-PJR-bod-svc+GLTSETcapsDec06.sav	OPTION 3
2011-PJR-bod-svc+lwtcutDec06.sav	OPTION 2
2011-PJR-bod-svc+LWTSETDec06.sav	OPTION 1
2011-PJR-bod-svc+SeriescompFeb07.sav	
2011-PJR-bod-svc-SET+ET+capsDec06.sav	
2011-PJR-bod-svc-SET+ETDec06.sav	OPTION 6
2011-PJR-bod-svc-SET+NTSVCFeb07.sav	OPTION 4 and OPTION 7
2011-PJR-bod-svc-SET+SeriescompFeb07.sav	
2011-PJR-bod-svc-SETDec06.sav	
2011-PJR-bod-svc-SETSeriesCapBanks40Feb07.sav	
2011-PJR-bod-svc-SETSeriesCapBanksFeb07.sav	OPTION 5
2011-PJR-bod-svcDec06.sav	
2011-PJR-bod.sav	
2011-PJR-bodOct06.sav	
2011-PJR-svc-SET+ETFeb07.sav	
2011-PJR.sav	
2011-PJROct06.sav	
2011-SET+KWTx-PJR.sav	
2011-SET-PJR-bod+KWtx.sav	
2011-SET-PJR-bod.sav	
2011-SET-PJR.sav	
2011-SETLWT+LWTcutin+KWtx-PJR.sav	
2011-SETLWT+LWTcutin+KWtx.sav	
2011-SETLWT+LWTcutin.sav	
2011-SETLWT-PJR.sav	
2011-SETLWT.sav	
2011_Base.sav	BASE CASE

2011_BaseOct06.sav	BASE CASE

FILENAME	OPTION STUDY
2012-PJR+KWtx-bod.sav	
2012-PJR+KWtx-SETLWT-bod.sav	
2012-PJR+KWtx-SETLWT.sav	
2012-PJR+LWTcutOct06.sav	
2012-PJR-bod+LWTcutOct06.sav	
2012-PJR-bod-SETOct06.sav	
2012-PJR-bod-svc+LWTcutFeb07.sav	OPTION 2
2012-PJR-bod-svcFeb07.sav	OPTION 1
2012-PJR-bodOct06.sav	
2012-PJR.sav	
2012-PJROct06.sav	
2012-pjrSVC-bodOct06.sav	
2012-pjrSVCOct06.sav	
2012_Base.sav	
2012_BaseLWTcutOct06.sav	
2012_BaseOct06.sav	BASE CASE
2012_BaseSVCOct06.sav	

FILENAME	OPTION STUDY
2013+KWTx-pjr-bod.sav	
2013+KWTx-pjr.sav	
2013-PJR-bod-SETLWTOct06.sav	
2013-PJR-bod-svc+500kV.sav	OPTION 8
2013-PJR-bod-svc+CAPS-LWTSETFeb07.sav	OPTION 3 WITHOUT AUGMENTATION
2013-PJR-bod-svc+ETFeb07.sav	OPTION 6
2013-PJR-bod-svc+LWTCUT-SETLWTFeb07.sav	OPTION 2 WITHOUT AUGMENTATION
2013-PJR-bod-svc+NTSVC+SETFeb07.sav	OPTION 4
2013-PJR-bod-svc+NTSVCFeb07.sav	
2013-PJR-bod-svc+SET+LWTcut+SeriesCap40Feb07.sav	
2013-PJR-bod-svc+SET+SeriesCap40Feb07.sav	
2013-PJR-bod-svc-SET+LWTcut+SeriesCap40Feb07.sav	OPTION 5
2013-PJR-bod-svc-SET+LWTcut+SeriesCap70Feb07.sav	
2013-PJR-bod-svc-SET+SeriesCap40Feb07.sav	
2013-PJR-bod-svc-SET+SeriesCap70Feb07.sav	
2013-PJR-bod-svcFeb07.sav	OPTION 1
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2013-PJROct06.sav	
2013_Base.sav	
2013_BaseOCT06.sav	
2013_CLT+KWTx.sav	

2013_EPTx.sav
2013_KNL2.sav
2013_KWTx-bod.sav
2013_KWTx.sav
2013_LWT+KW+CLT-pjr.sav
2013_LWT+KW-pjr.sav
2013_LWT+KW.sav
2013_LWTcutin.sav
2013_NTTx.sav
2013_SETTx.sav

FILENAME	OPTION STUDY
2014-PJR-bod+GLTHOct06.sav	
2014-PJR-BOD.sav	
2014-PJR-bodOct06.sav	
2014-PJR.sav	
2014-PJROct06.sav	
2014_base.sav	BASE CASE
2014_baseOct06.sav	BASE CASE
2014_LWT+KW-PJR-ckb3.sav	
2014_LWT+KW-PJR.sav	
2014_LWT+KW.sav	

FILENAME	OPTION STUDY
2015+LWTKEM+KW-PJR.sav	
2015-PJR-bodOct06.sav	
2015-PJROct06.sav	
2015_BaseOct06.sav	BASE CASE
2015_LWT+KW+CLT+NT-PJR.sav	
2015_LWT+KW+CLT-PJR.sav	
2015_LWT+KW+NT-PJR.sav	
2015_LWT+KW-PJR.sav	
2015_LWT+KW.sav	

FILENAME	OPTION STUDY
2016-PJR-bod+HopeOct06.sav	
2016-PJR-bod+LWTcutOct06.sav	
2016-PJR-bod+NTOct06.sav	
2016-PJR-bod+NTTx+LWTcutOct06.sav	
2016-PJR-bod+SHOcutOct06.sav	
2016-PJR-bod-svc+ET-SETFeb07.sav	OPTION 6
2016-PJR-bod-svc+LWTCut+SERIESCAPS40Feb07.sav	OPTION 5
2016-PJR-bod-svc+LWTCut+SERIESCAPS70Feb07.sav	
2016-PJR-bod-svc+LWTCutFeb07.sav	OPTION 1 / OPTION 2
2016-PJR-bod-svc+NTSVC+LWTcutFeb07.sav	
2016-PJR-bod-svc+NTSVC+LWTSETFeb07.sav	OPTION 4

2016-PJR-bod-svc+NTSVCFeb07.sav
2016-PJR-bod-svc+SETLWT+LWTCut+SERIESCAPS40Feb07.sav
2016-PJR-bod-svcFeb07.sav
2016-PJR-bodOct06.sav
2016-PJR-svc+ET-SETFeb07.sav
2016-PJR.sav
2016-PJROct06.sav
2016_Base.sav
2016_BaseOct06.sav BASE CASE

Appendix C – Future Generation Developments

The following table outlines the proposed or estimated generation developments assumed in the study files provided by Western Power:

Study Year	Modelled Generators	Total MW Supply
2010/11	Bluewaters 3 Project L	540 MW
2011/12	None	-
2012/13	Collie Power Station	320 MW
2013/14	None	-
2014/15	None	-
2015/16	Collie Power Station	320 MW

The following table outlines the expected reserve generation margins under system normal and the worst-case scenario proposed by Western Power.

Study Year	Forecast Demand (MW)	Forecast Generation (MW)	Reserve Margin (MW)	Margin under study scenarios[10] (MW)	Spinning Reserve Requirement (MW)
2010/11	4228	4808	580	420 MW	145 MW
2011/12	4360	4808	448	290 MW	145 MW
2012/13	4483	5128	645	490 MW	145 MW
2013/14	4604	5128	524	365 MW	145 MW
2014/15	4741	5128	387	230 MW	145 MW
2015/16	4858	5448	590	430 MW	145 MW

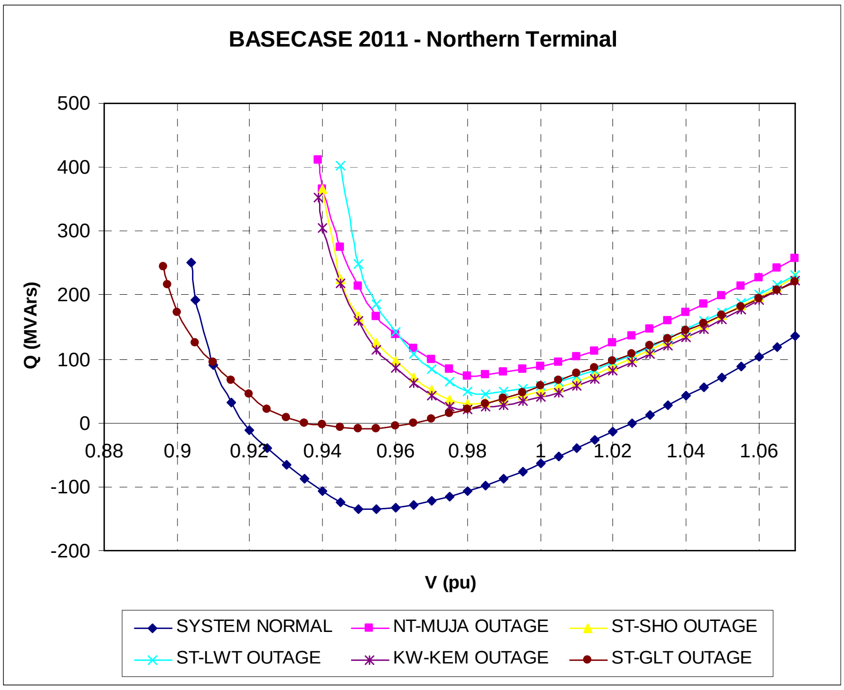
The calculation used to derive the study scenario margin is as follows:

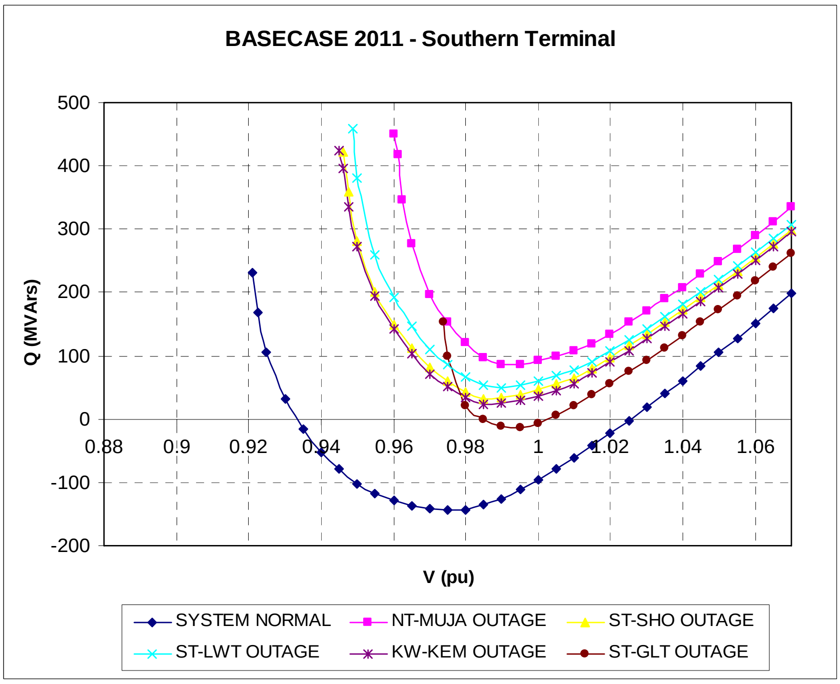
Study Margin = Reserve Margin – Pinjar Generation + Windfarm output + Boddington Load

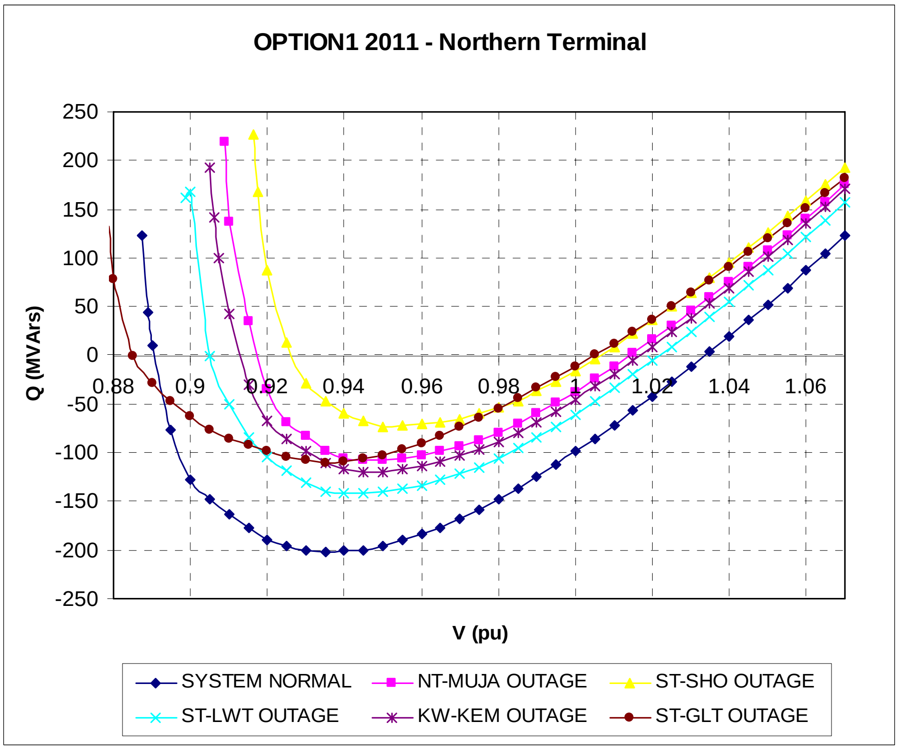
[10] This margin is a calculation of Reserve Margin + windfarm output + Boddington load – Pinjar Generation

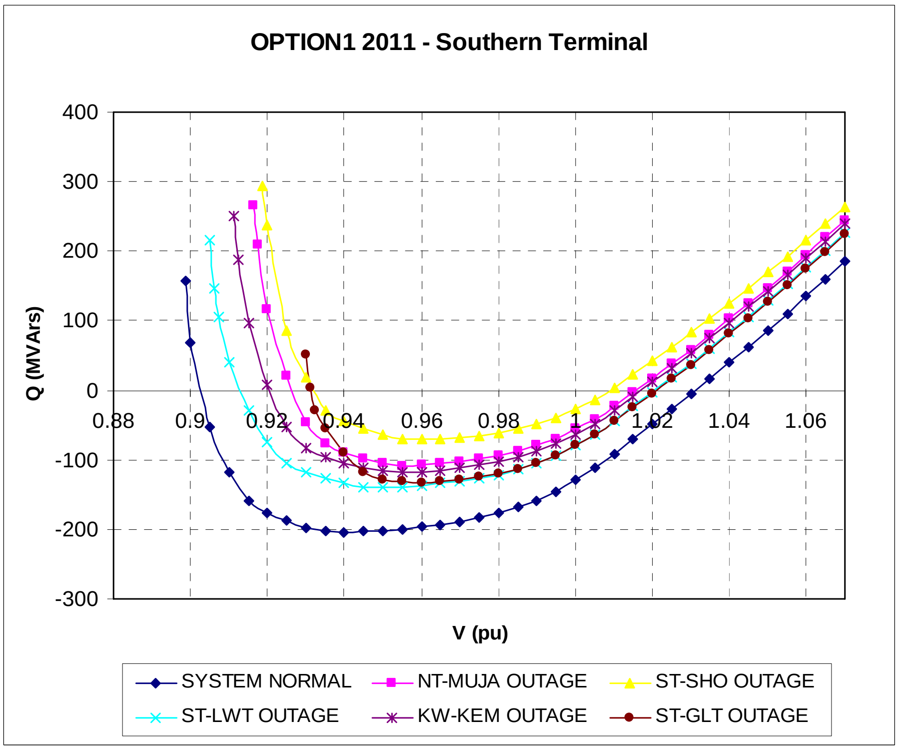
Appendix D – Summary of Results

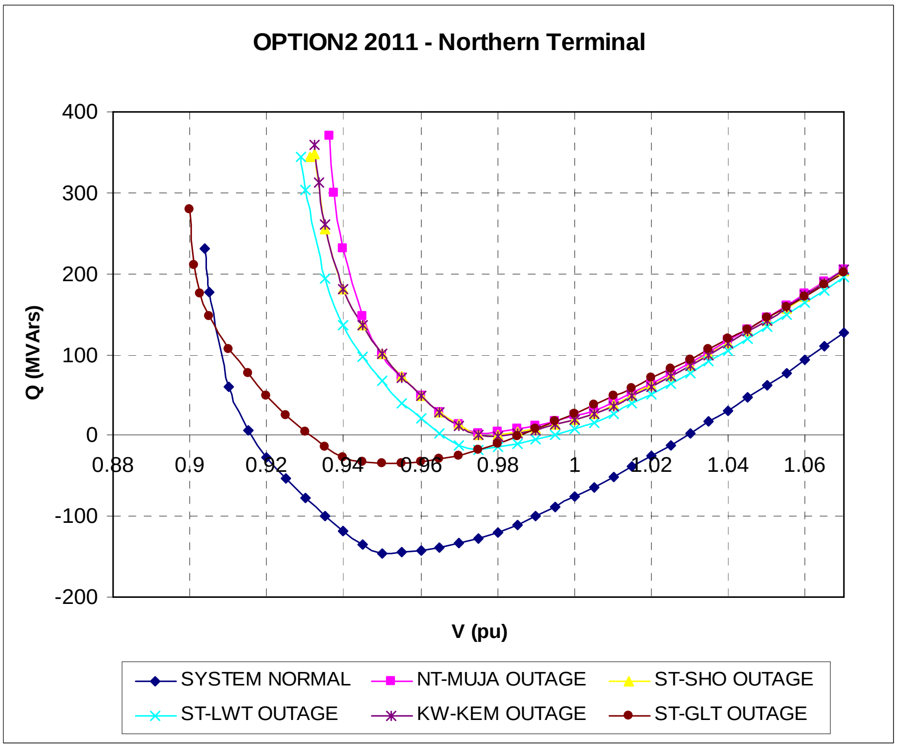
2011 V-Q Analysis

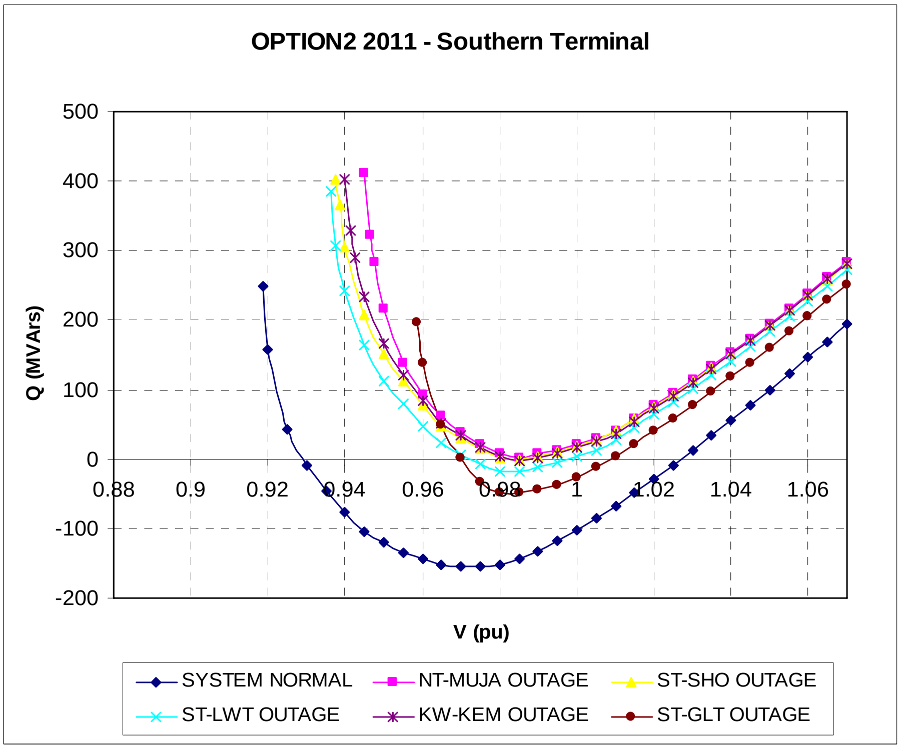


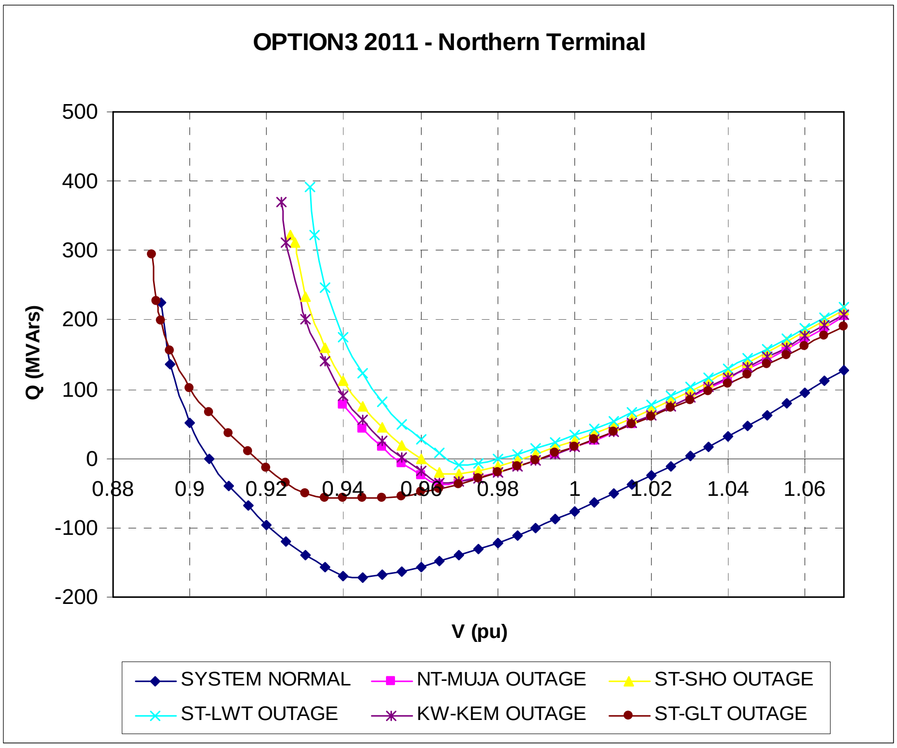


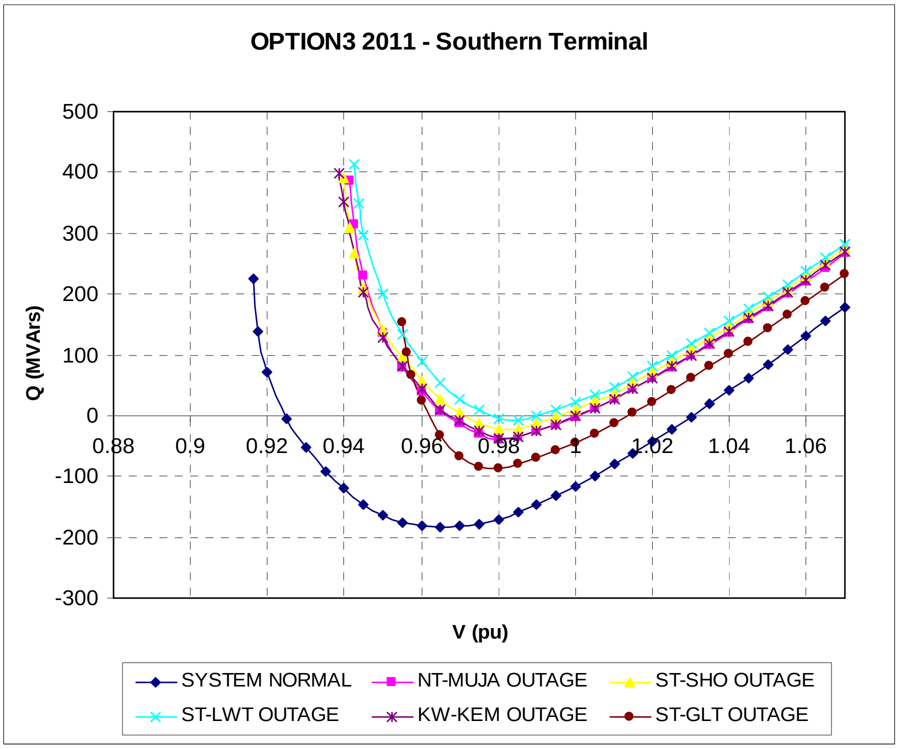

OPTION1 2011 - Northern Terminal
250
200
150
100
50
0
-50
-100
-150
-200
-250
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

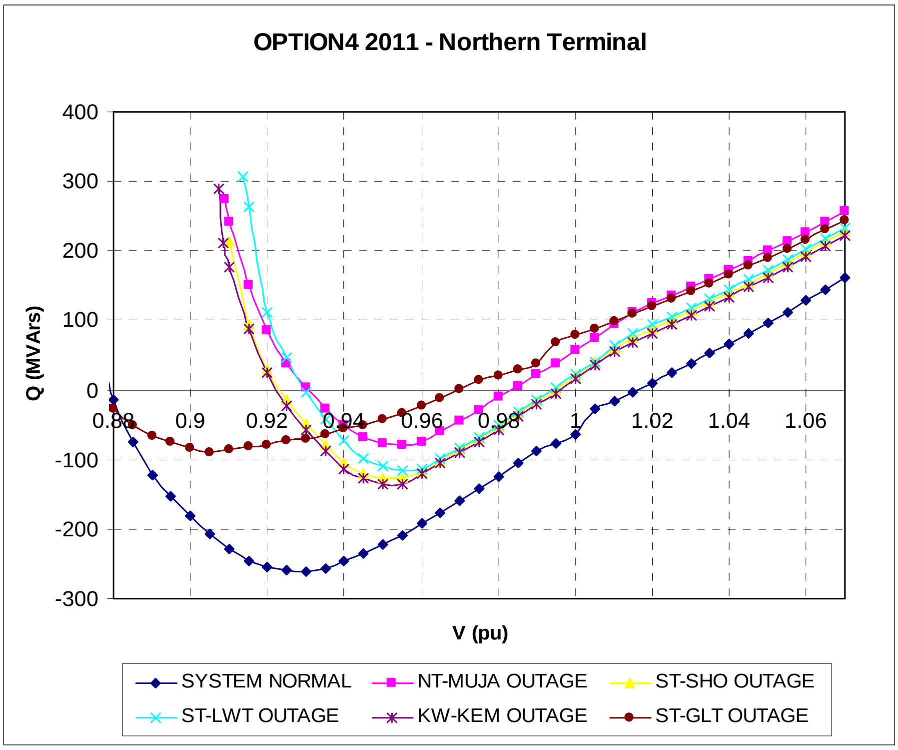

OPTION1 2011 - Southern Terminal
400
300
200
100
0
-100
-200
-300
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

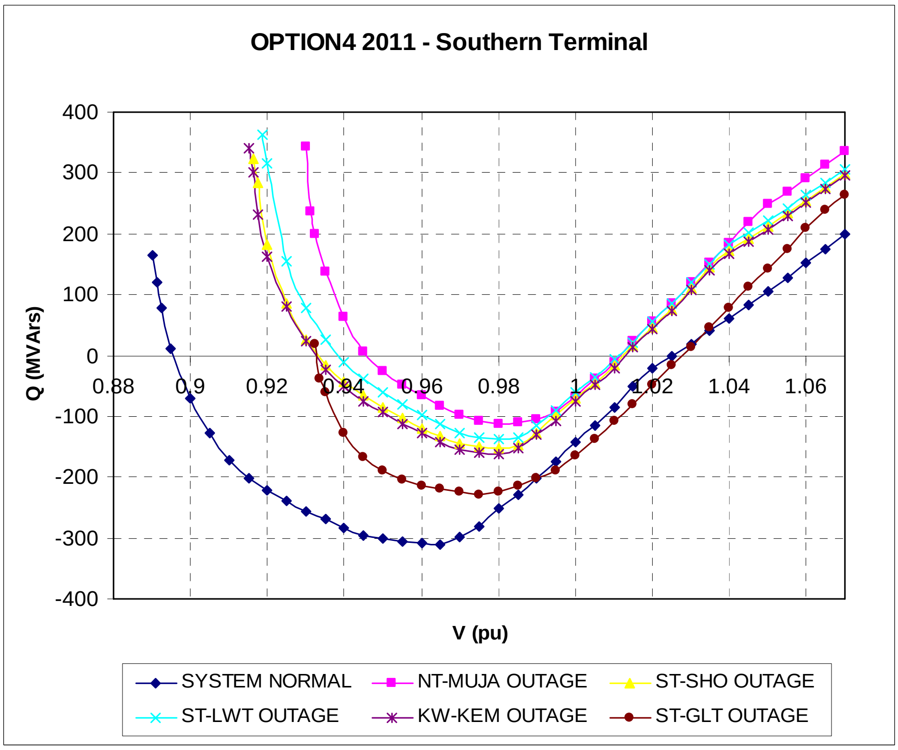

OPTION2 2011 - Northern Terminal
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

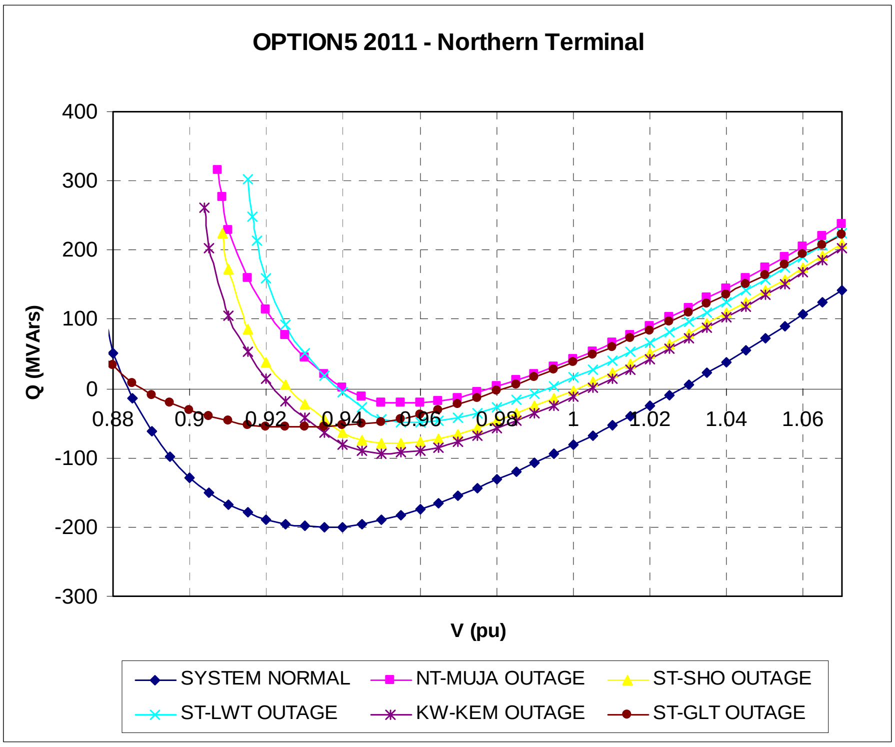

OPTION2 2011 - Southern Terminal
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

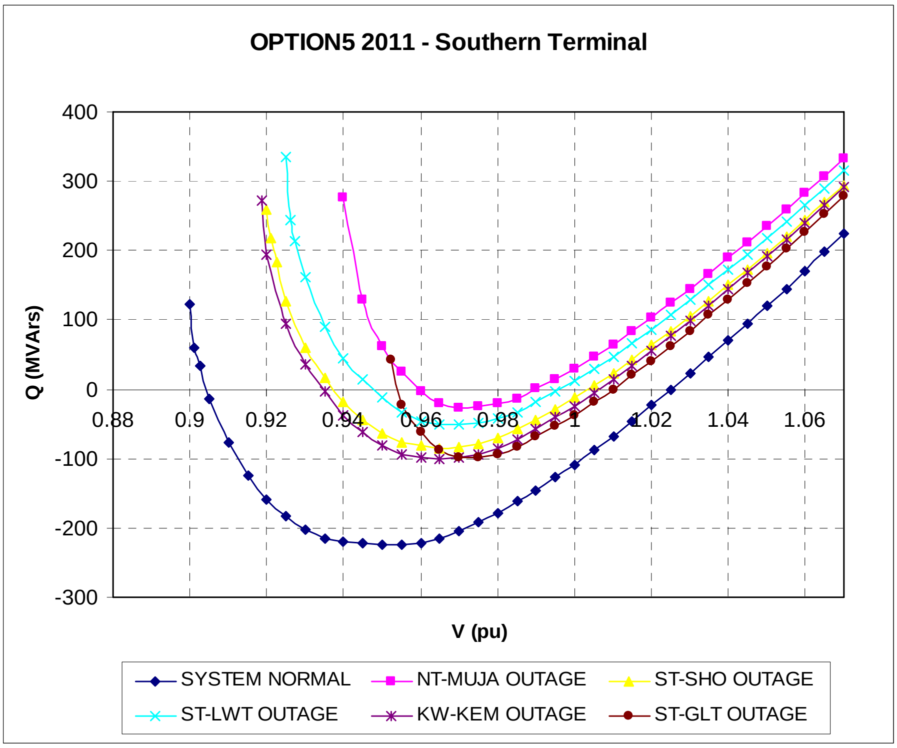

OPTION3 2011 - Northern Terminal
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

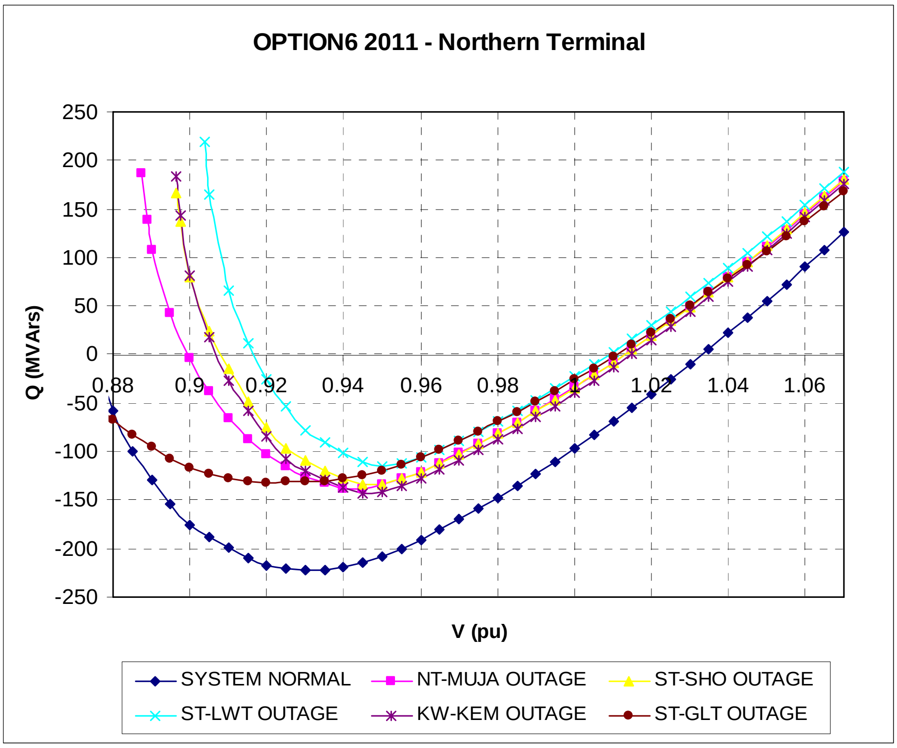

OPTION3 2011 - Southern Terminal
500
400
300
200
100
0
-100
-200
-300
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION4 2011 - Northern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

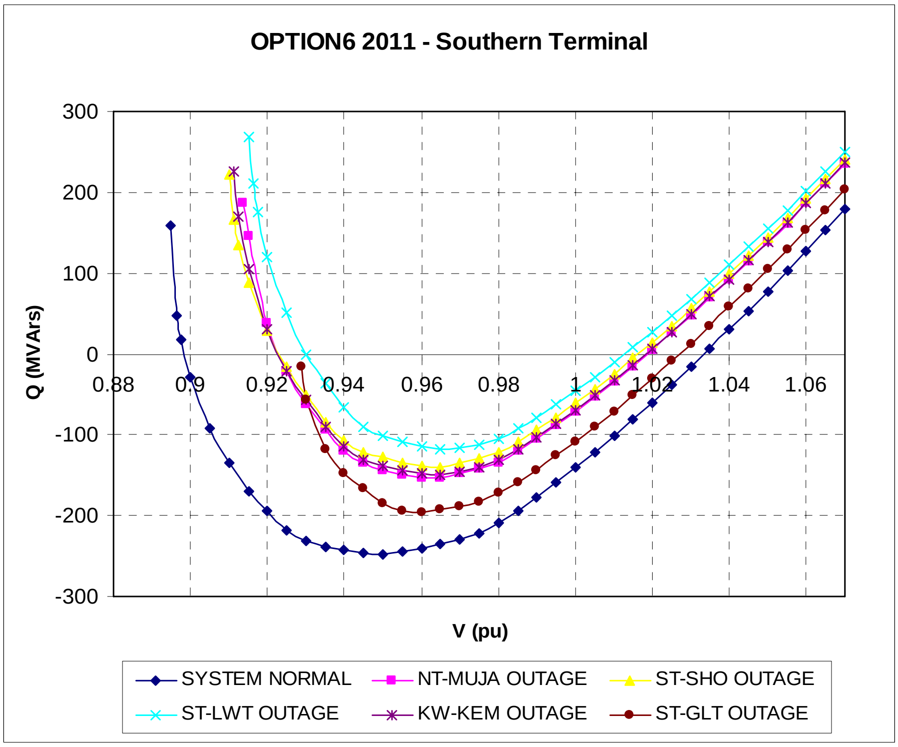

OPTION4 2011 - Southern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION5 2011 - Northern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

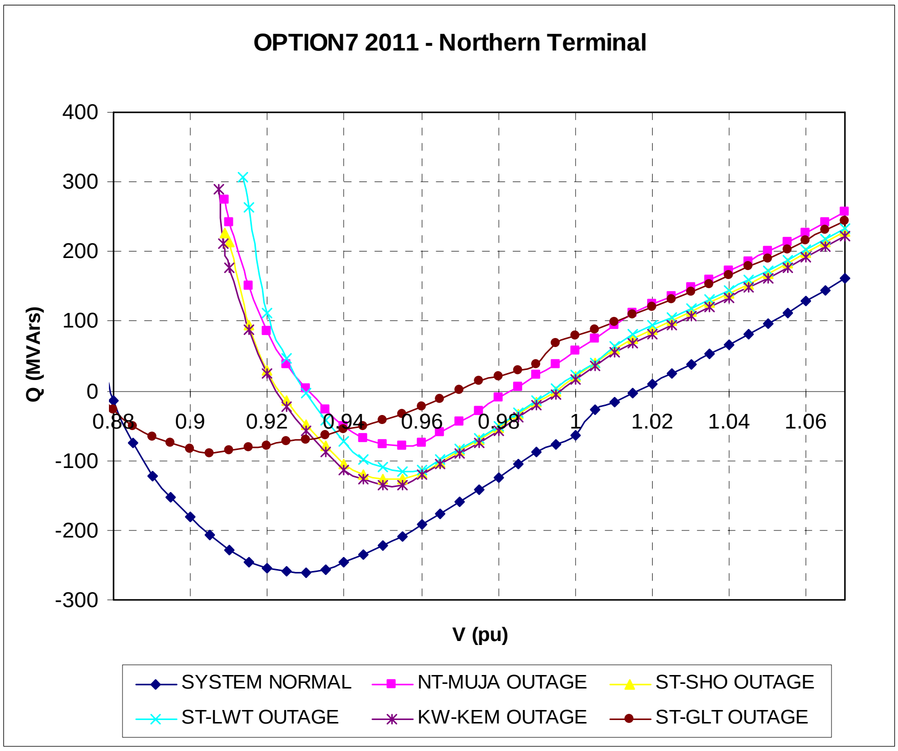

OPTION5 2011 - Southern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

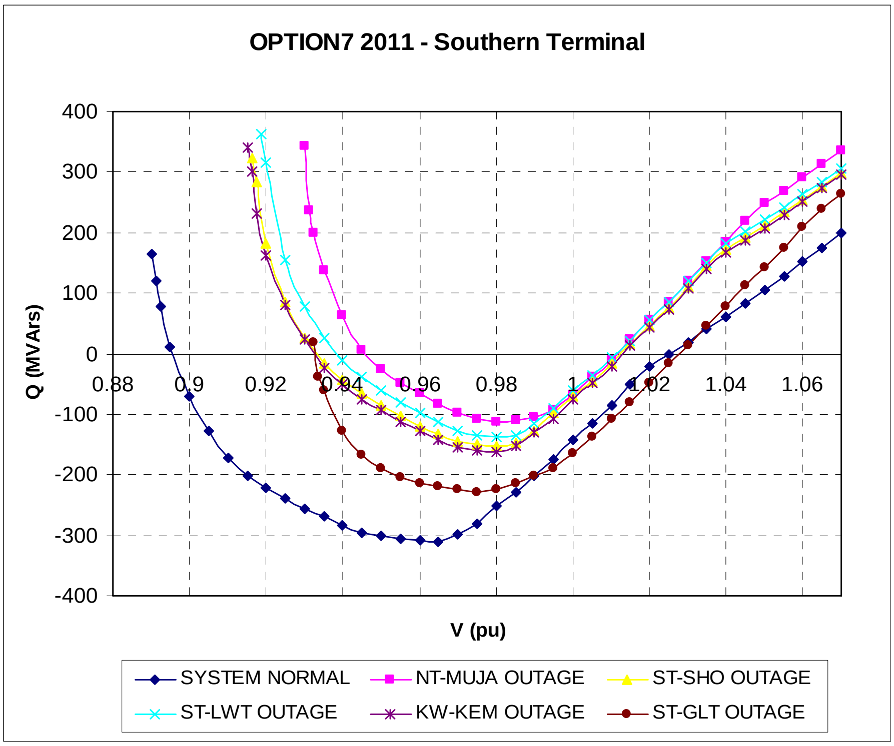


OPTION6 2011 - Northern Terminal
Q (MVArs)
V (pu)
250
200
150
100
50
0
-50
-100
-150
-200
-250
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

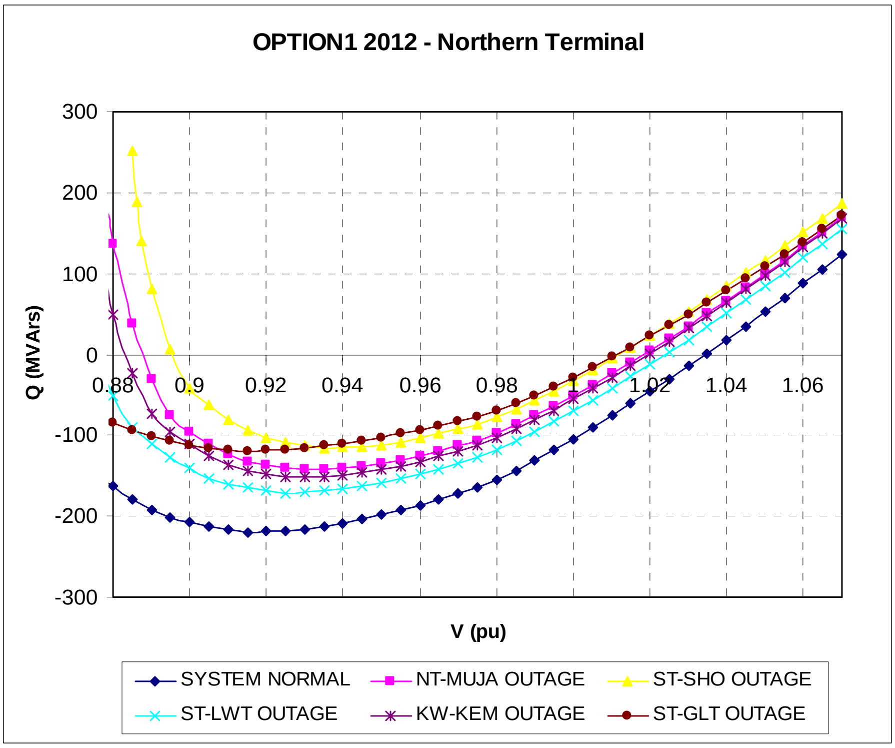


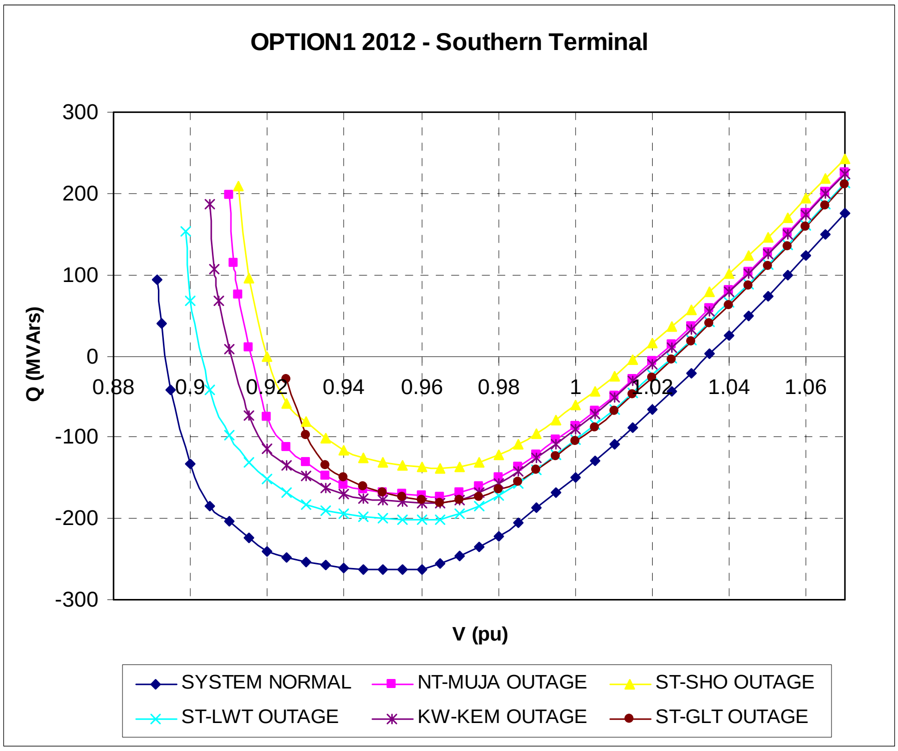
OPTION6 2011 - Southern Terminal
Q (MVArs)
V (pu)
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION7 2011 - Northern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

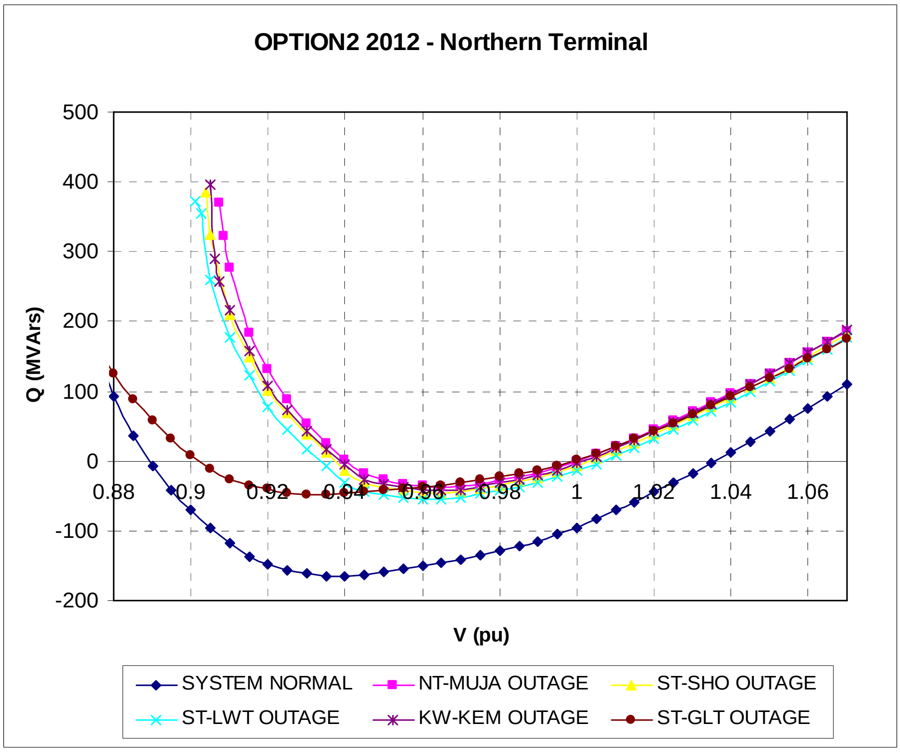

OPTION7 2011 - Southern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
-400
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

2012 V-Q Analysis

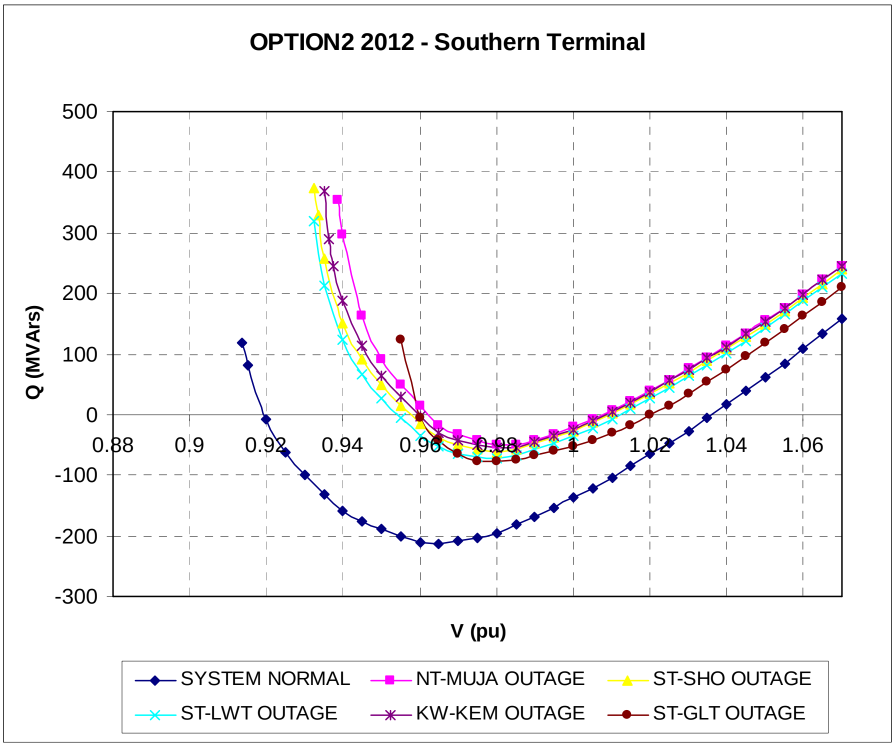




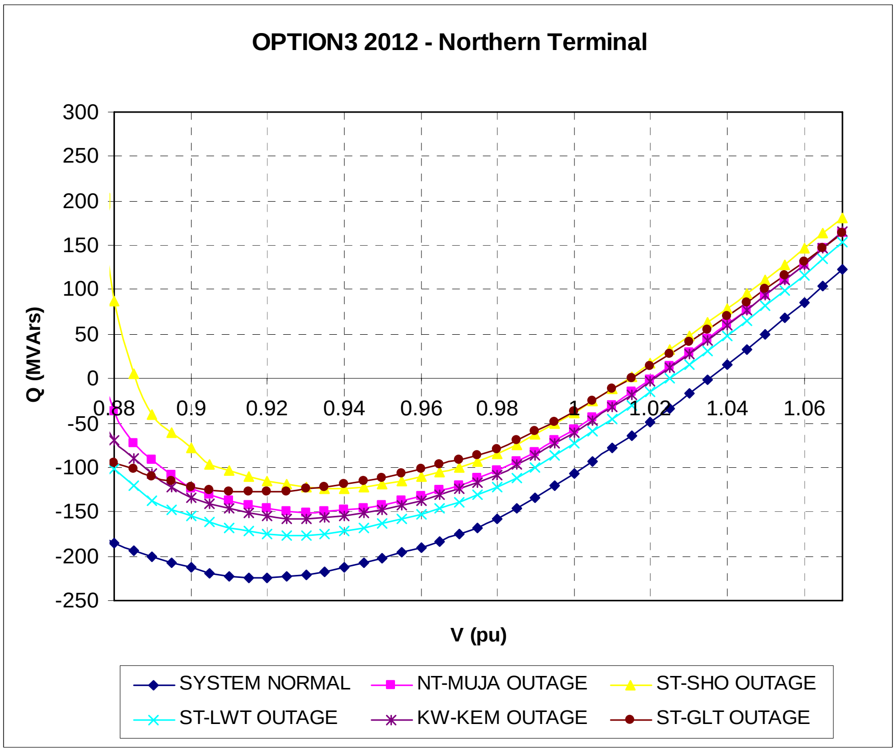
SKM

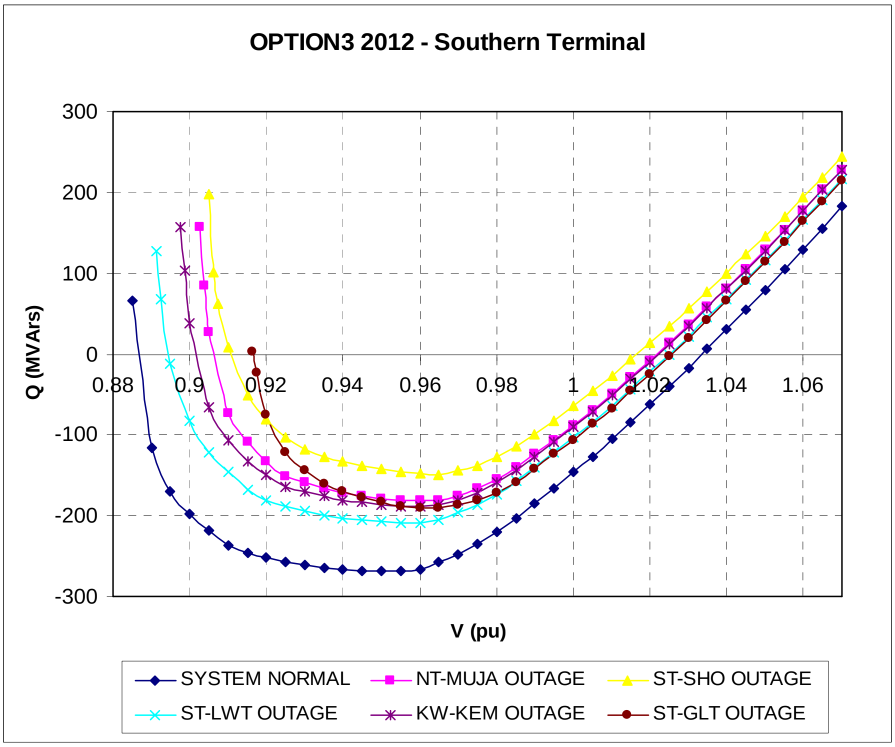


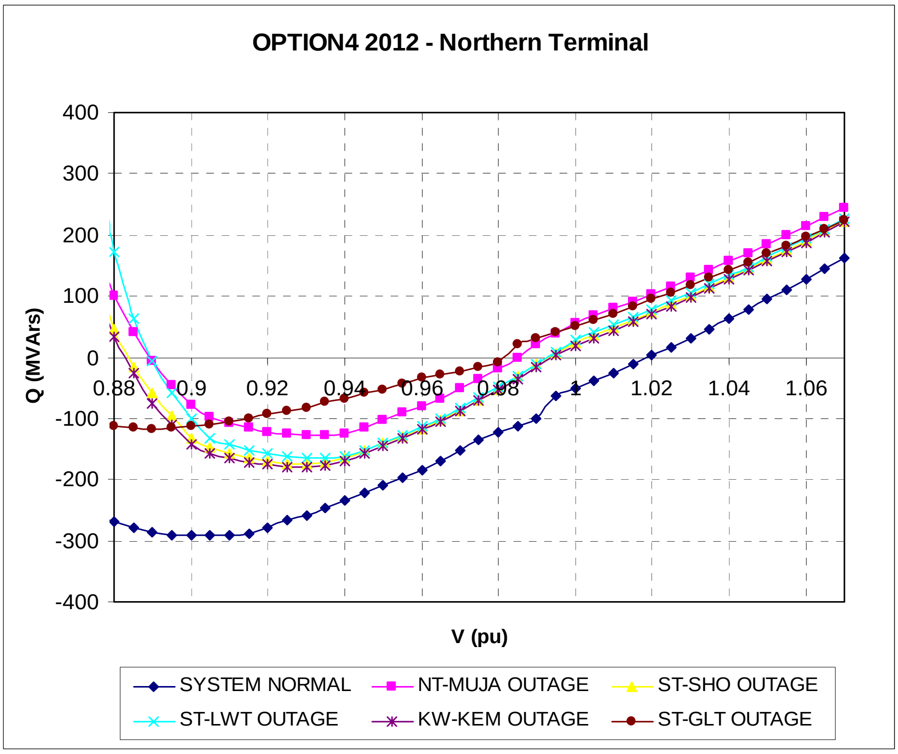
OPTION2 2012 - Northern Terminal
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

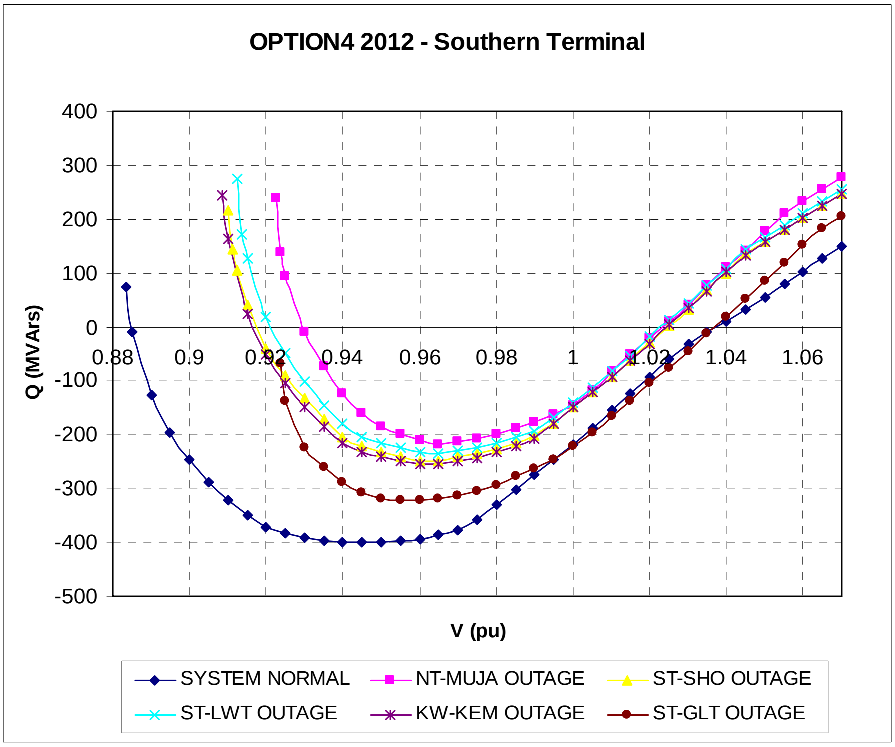


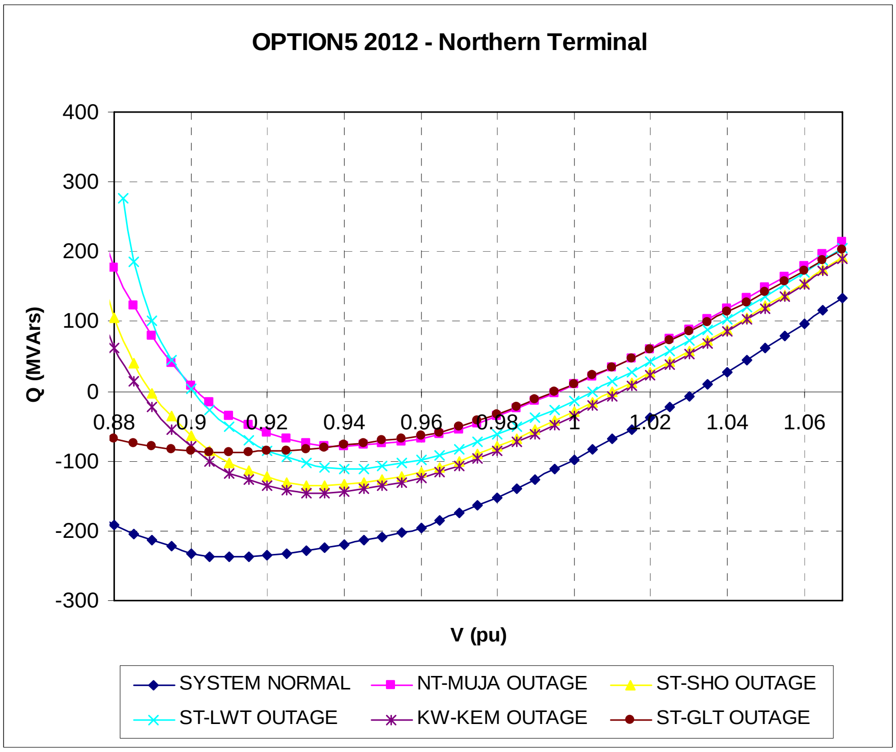
OPTION2 2012 - Southern Terminal
500
400
300
200
100
0
-100
-200
-300
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

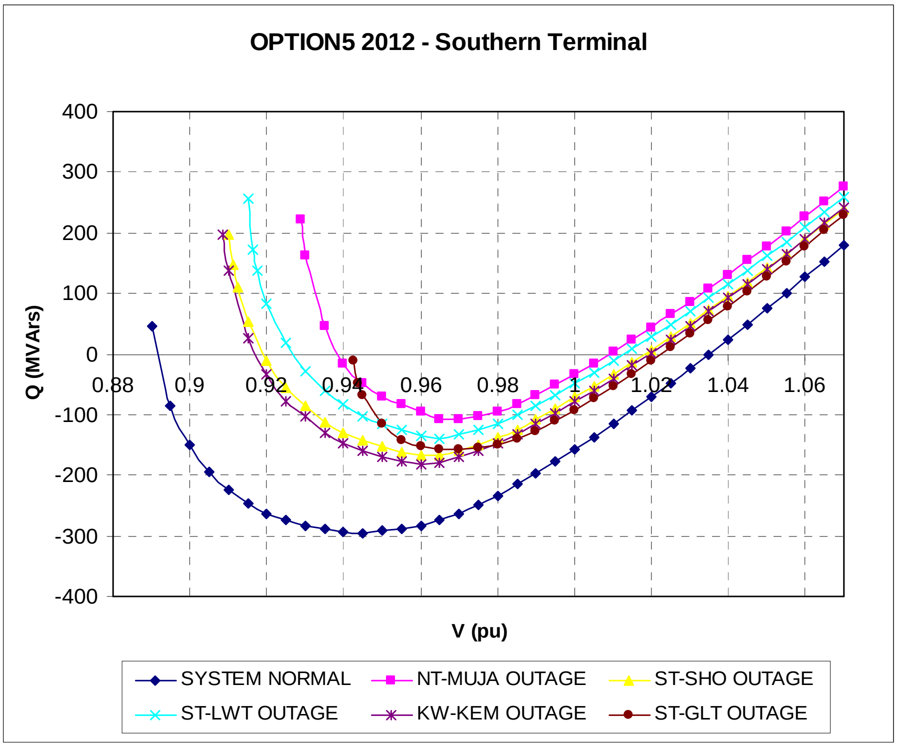

OPTION3 2012 - Northern Terminal
Q (MVArs)
V (pu)
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

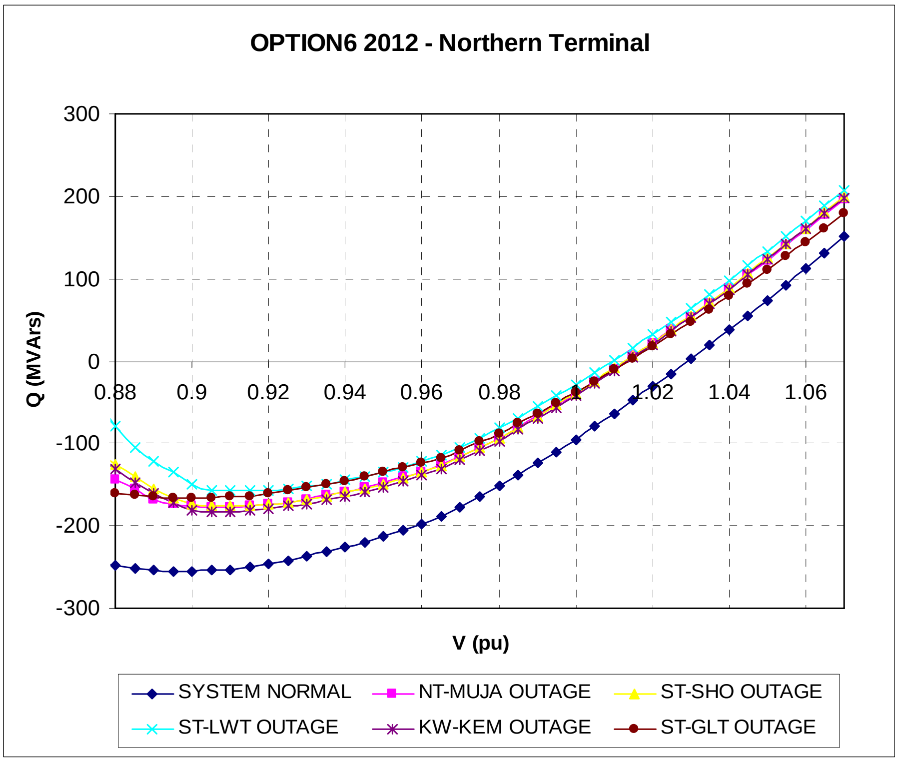

OPTION3 2012 - Southern Terminal
Q (MVArs)
V (pu)
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

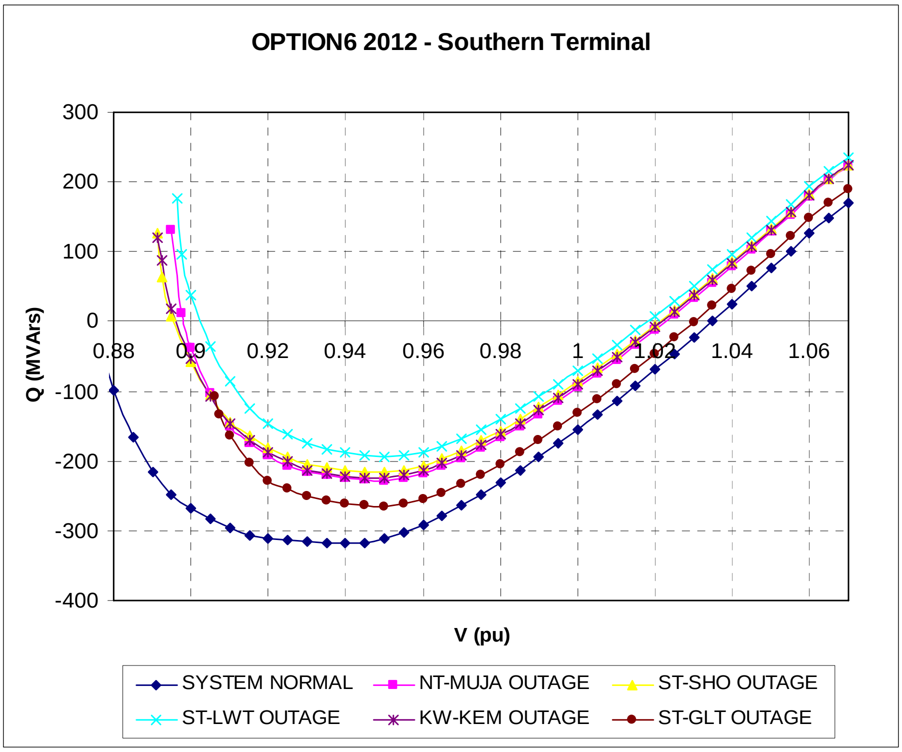

OPTION4 2012 - Northern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
-400
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

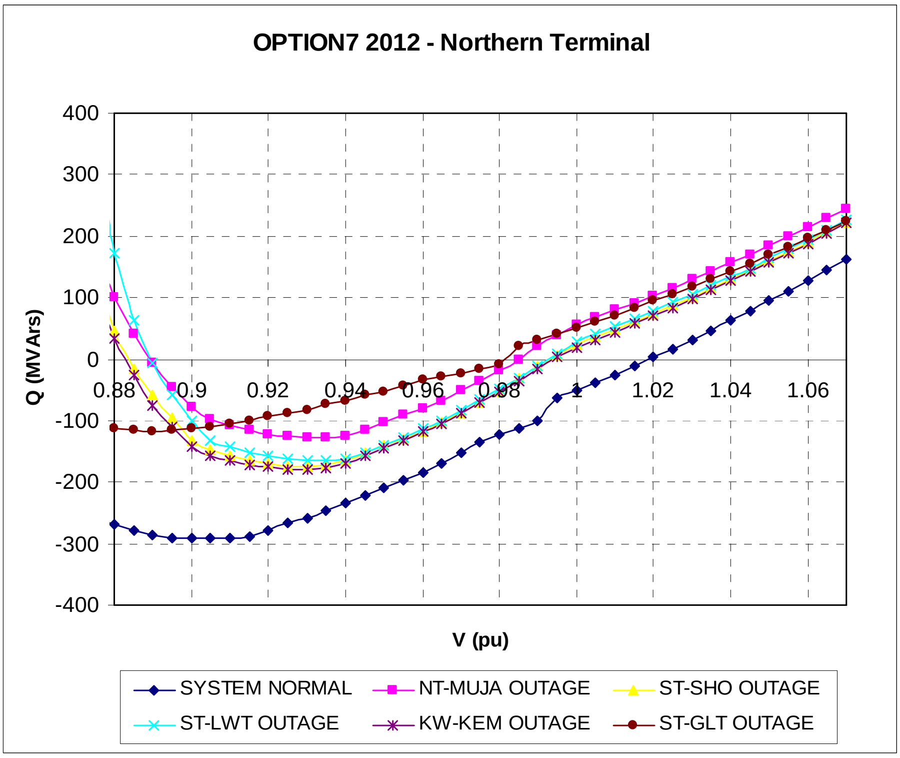

OPTION4 2012 - Southern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
-400
-500
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

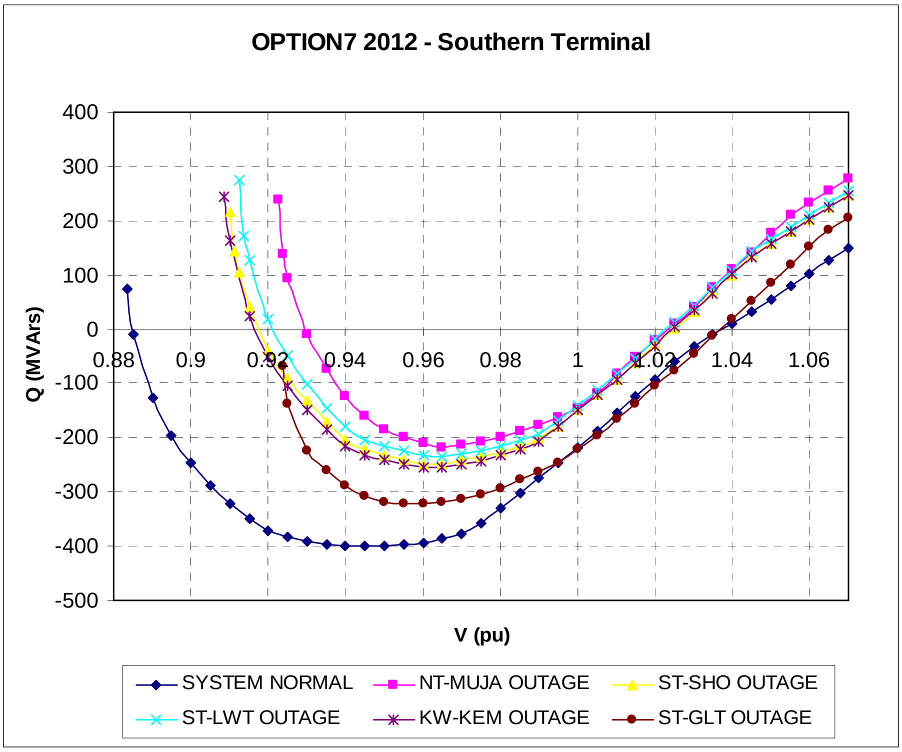

OPTION5 2012 - Northern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION5 2012 - Southern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
-400
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

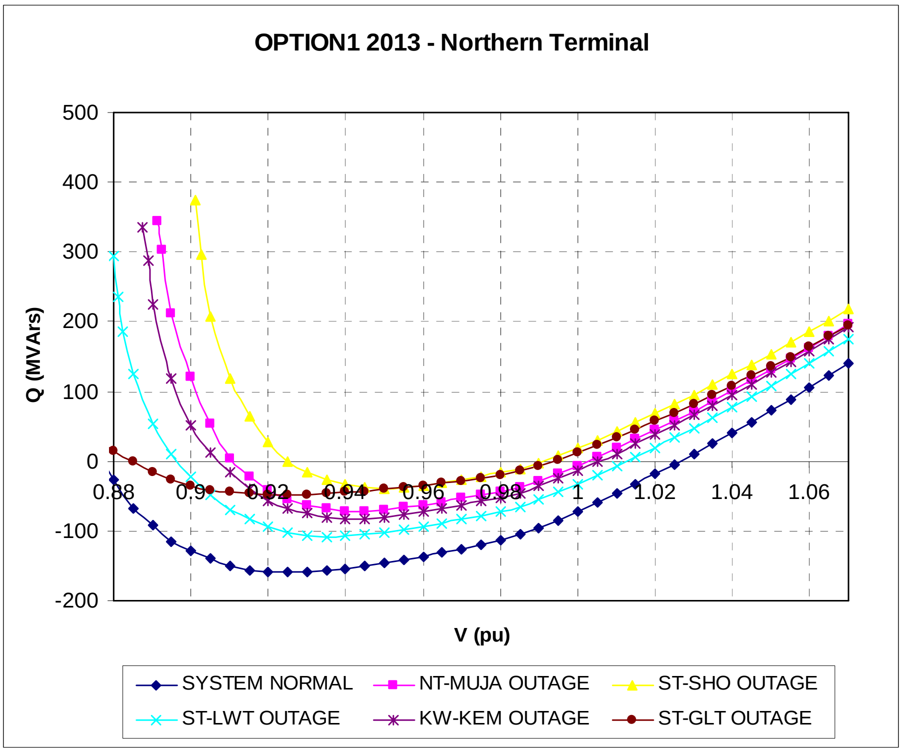

OPTION6 2012 - Northern Terminal
Q (MVArs)
V (pu)
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

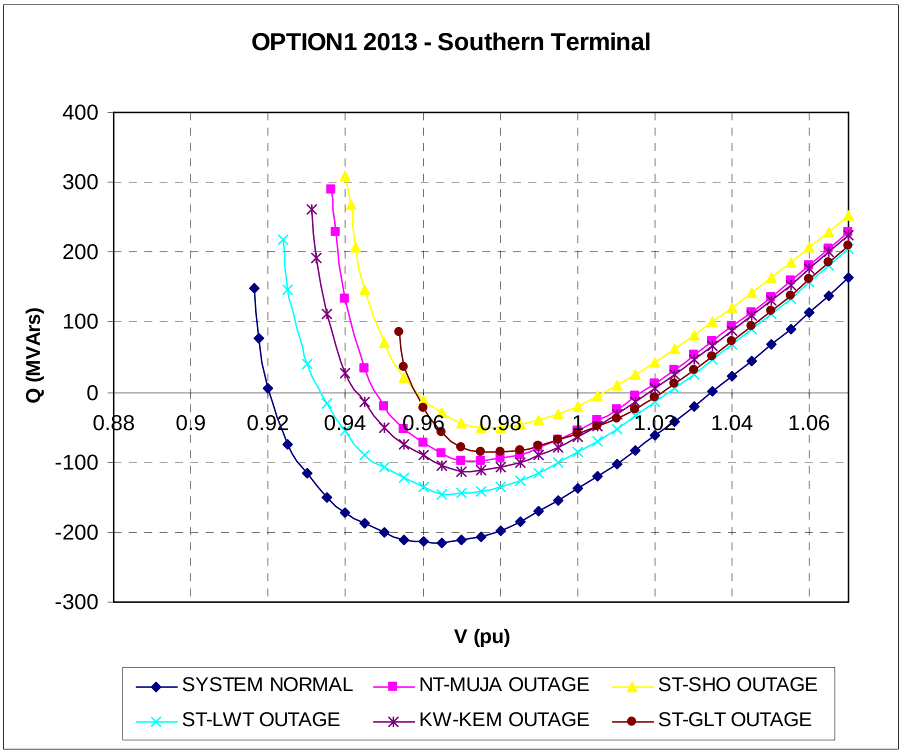

OPTION6 2012 - Southern Terminal
Q (MVArs)
V (pu)
300
200
100
0
-100
-200
-300
-400
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

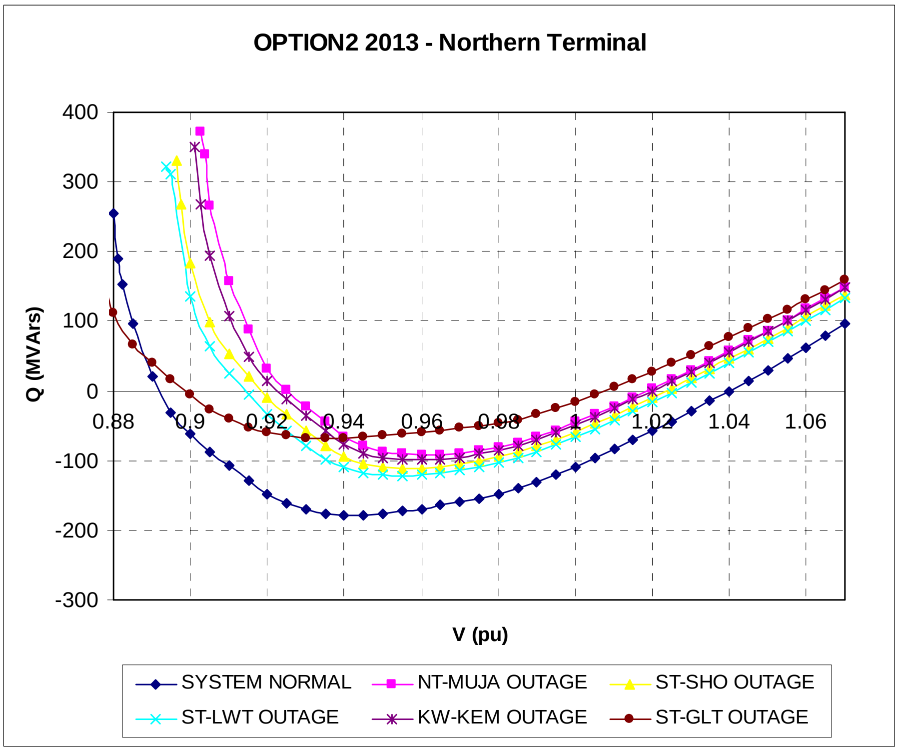

OPTION7 2012 - Northern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
-400
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

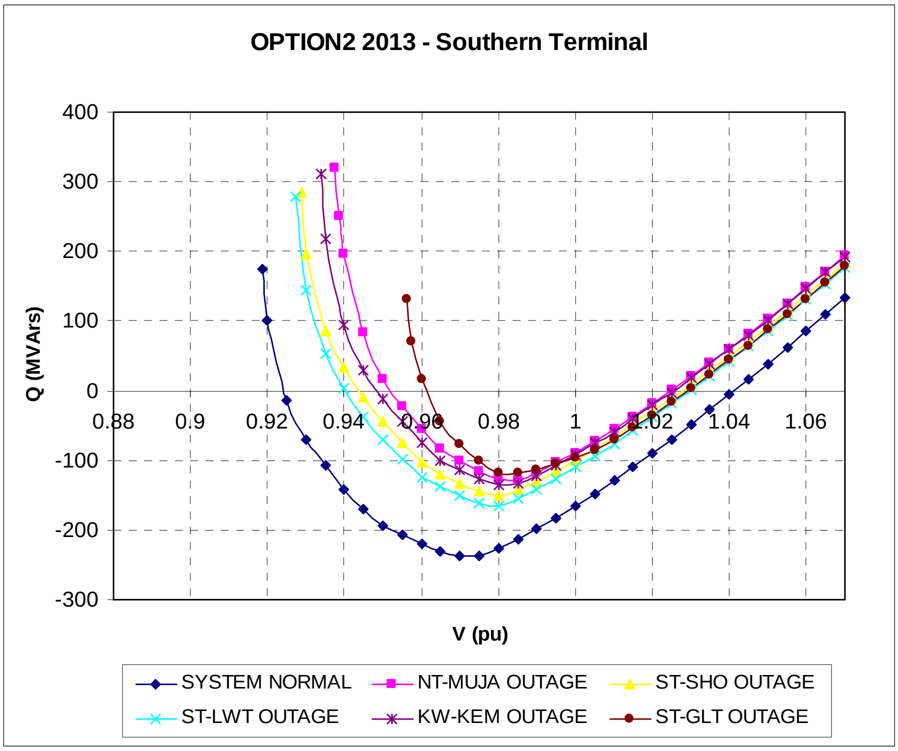

OPTION7 2012 - Southern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
-400
-500
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

2013 V-Q Analysis






OPTION2 2013 - Northern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION2 2013 - Southern Terminal
Q (MVArs)
V (pu)
400
300
200
100
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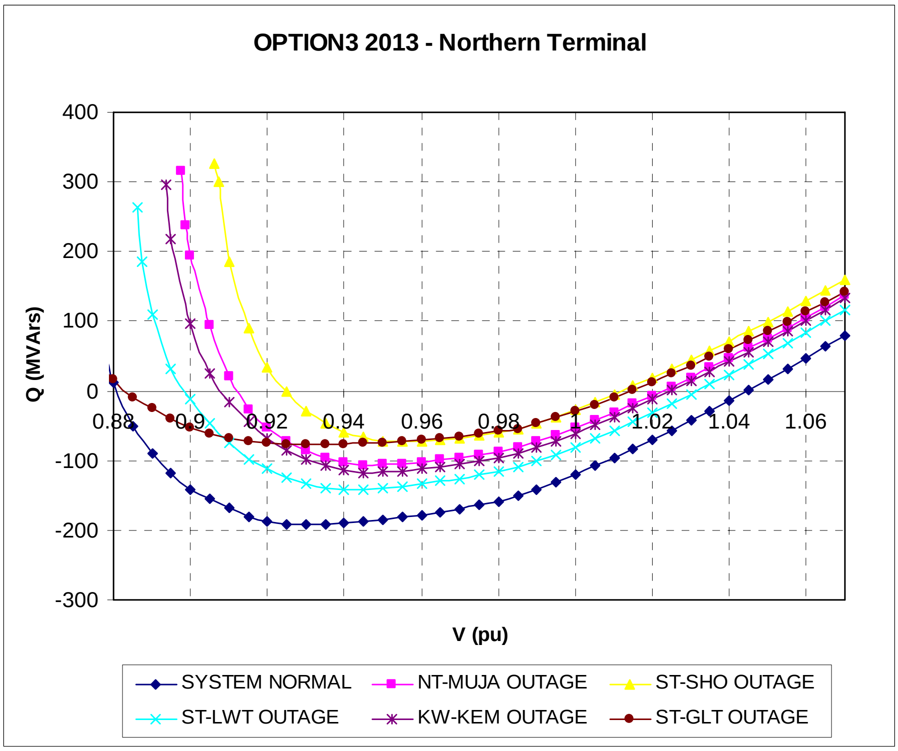
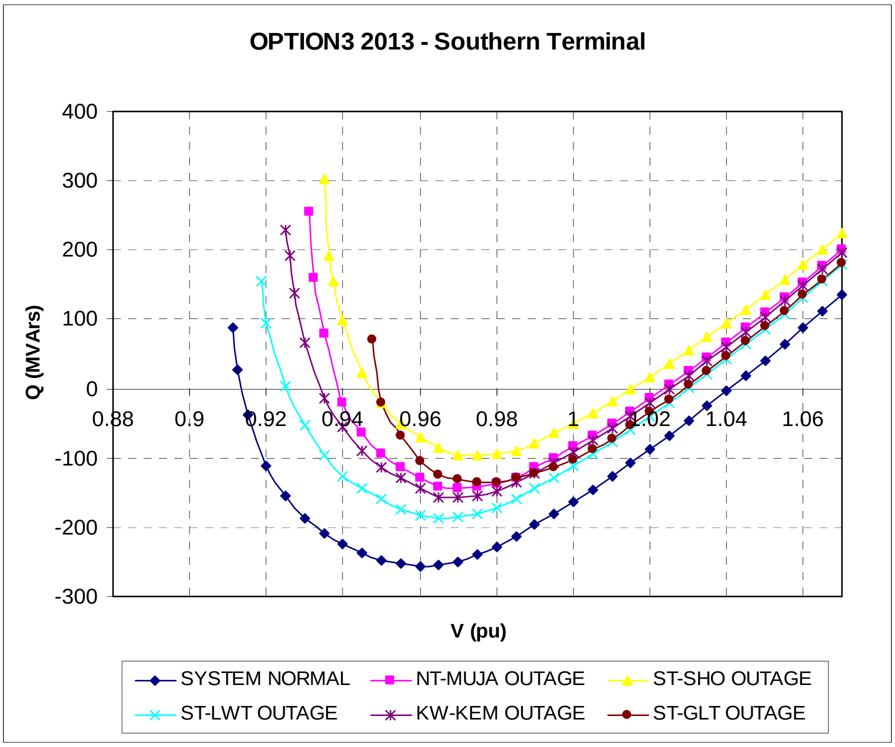
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION3 2013 - Northern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION3 2013 - Southern Terminal
Q (MVArs)
V (pu)
400
300
200
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-200
-300
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0.9
0.92
0.94
0.96
0.98
1
1.02
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SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
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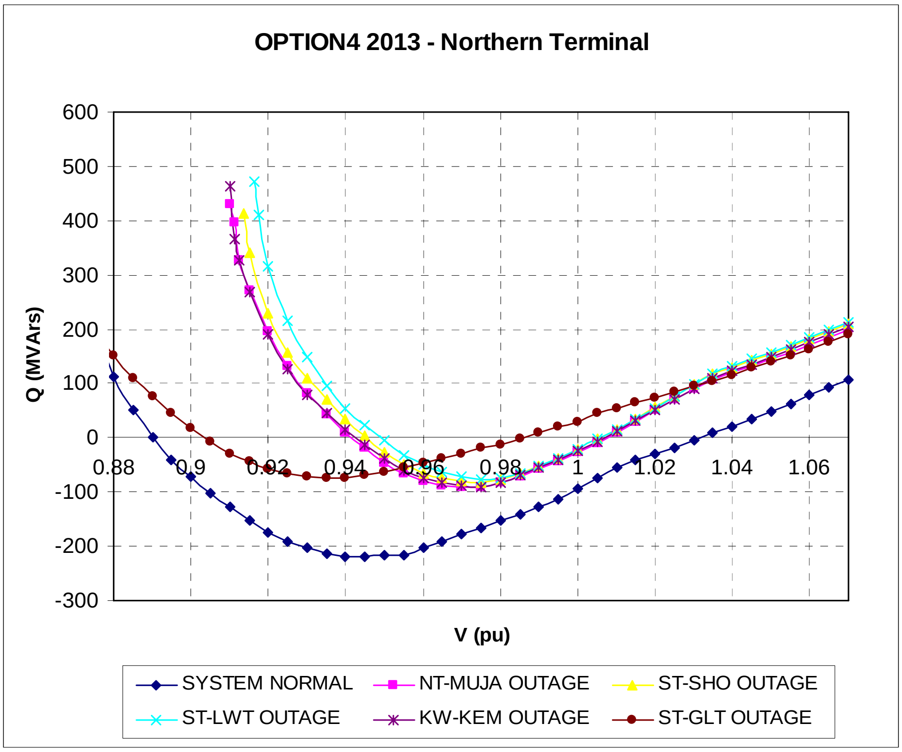
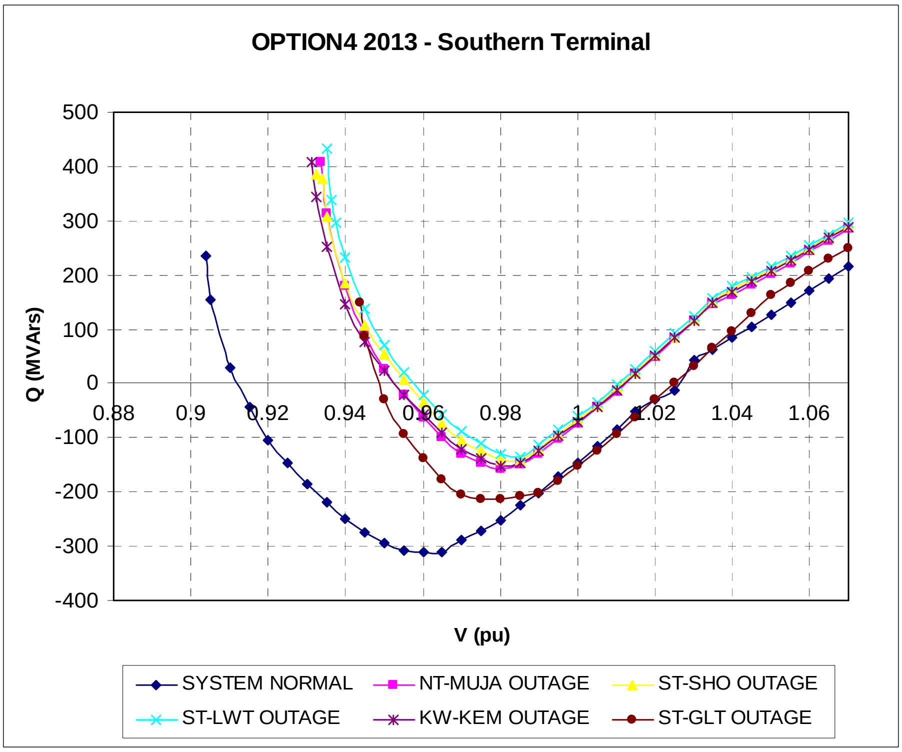
KW-KEM OUTAGE
ST-GLT OUTAGE

SKM



OPTION4 2013 - Northern Terminal
Q (MVArs)
V (pu)
600
500
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE



OPTION4 2013 - Southern Terminal
Q (MVArs)
V (pu)
500
400
300
200
100
0
-100
-200
-300
-400
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
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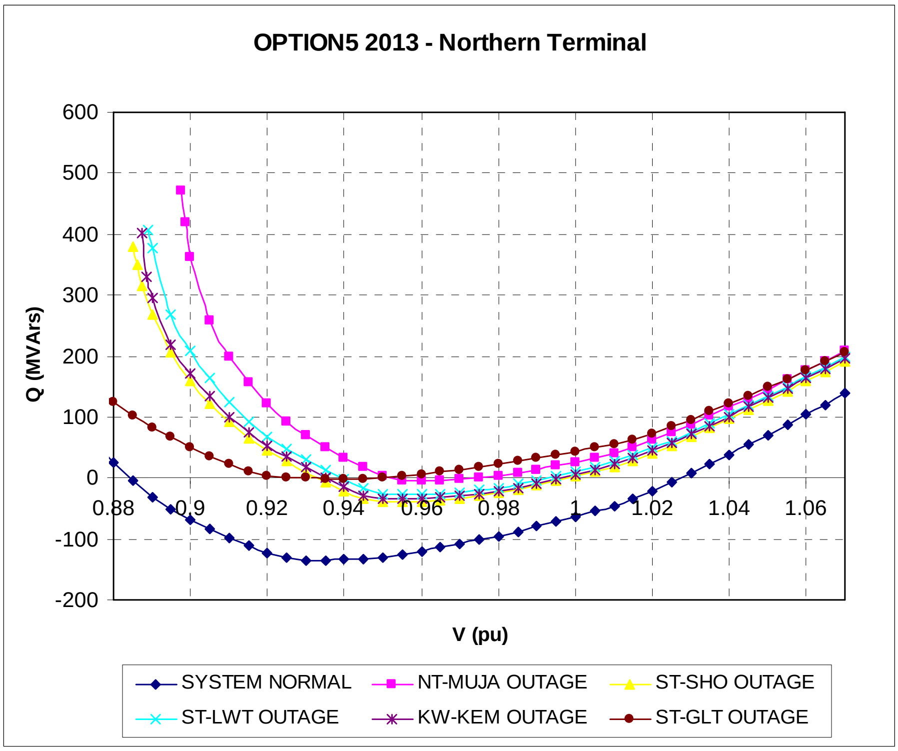
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION5 2013 - Northern Terminal
600
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
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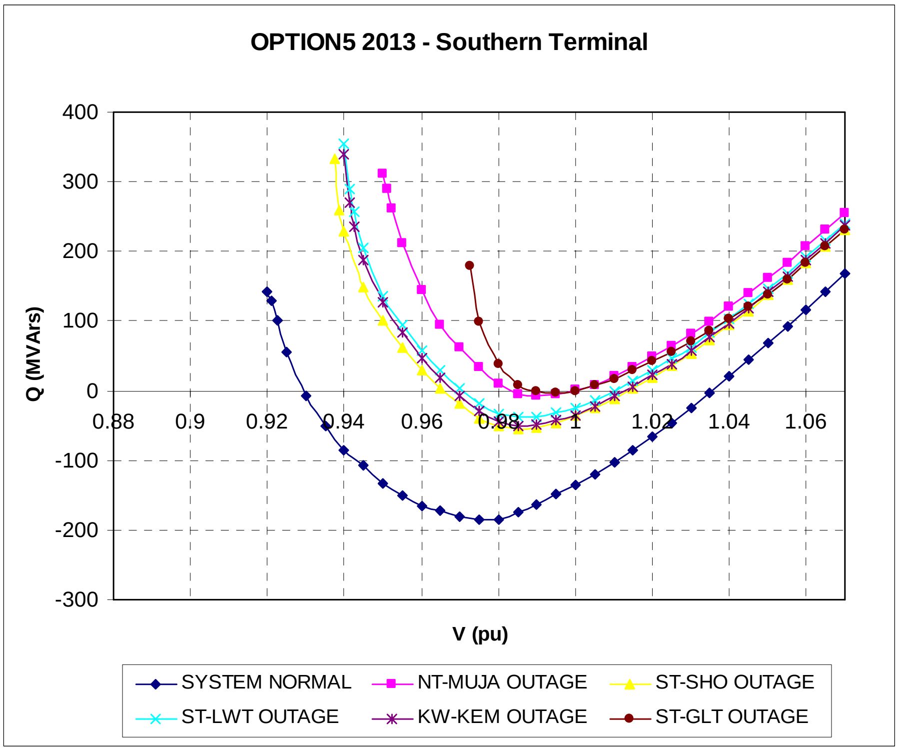
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION5 2013 - Southern Terminal
400
300
200
100
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-100
-200
-300
Q (MVArs)
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0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
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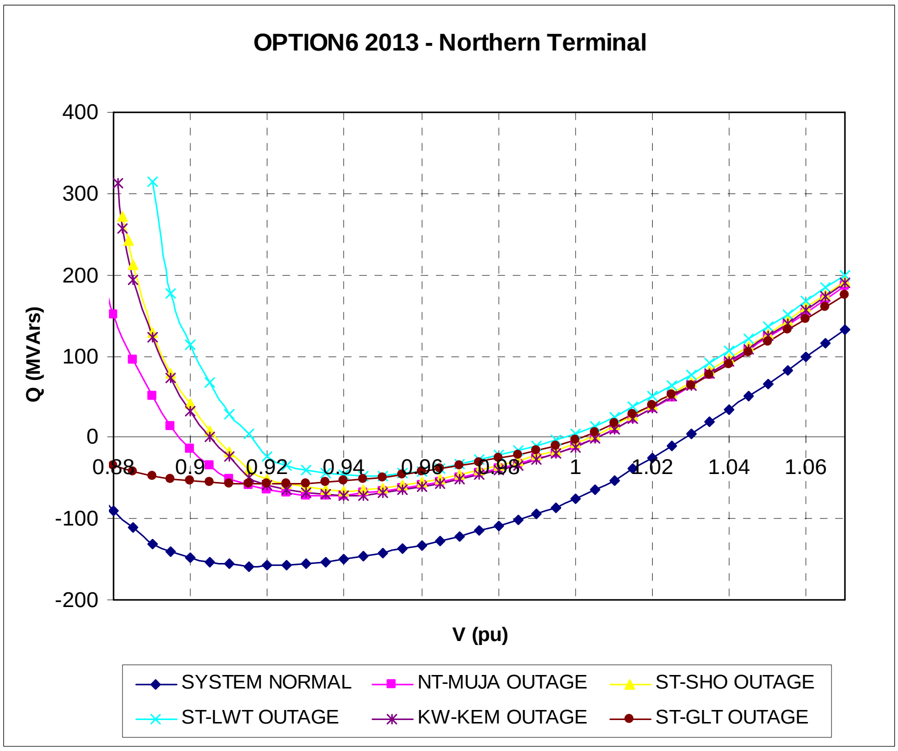
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION6 2013 - Northern Terminal
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
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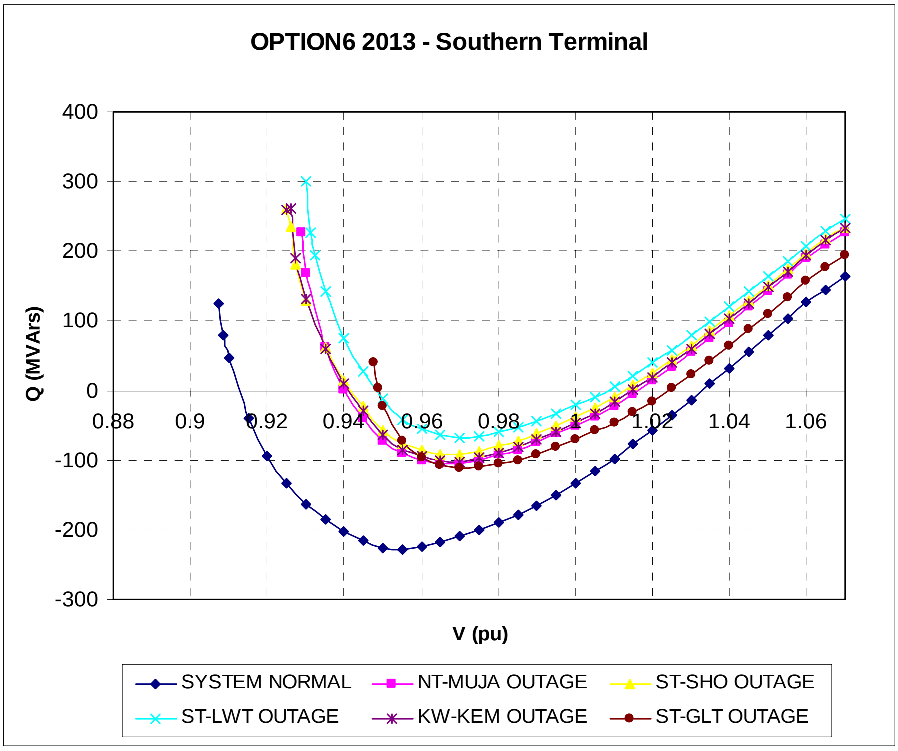
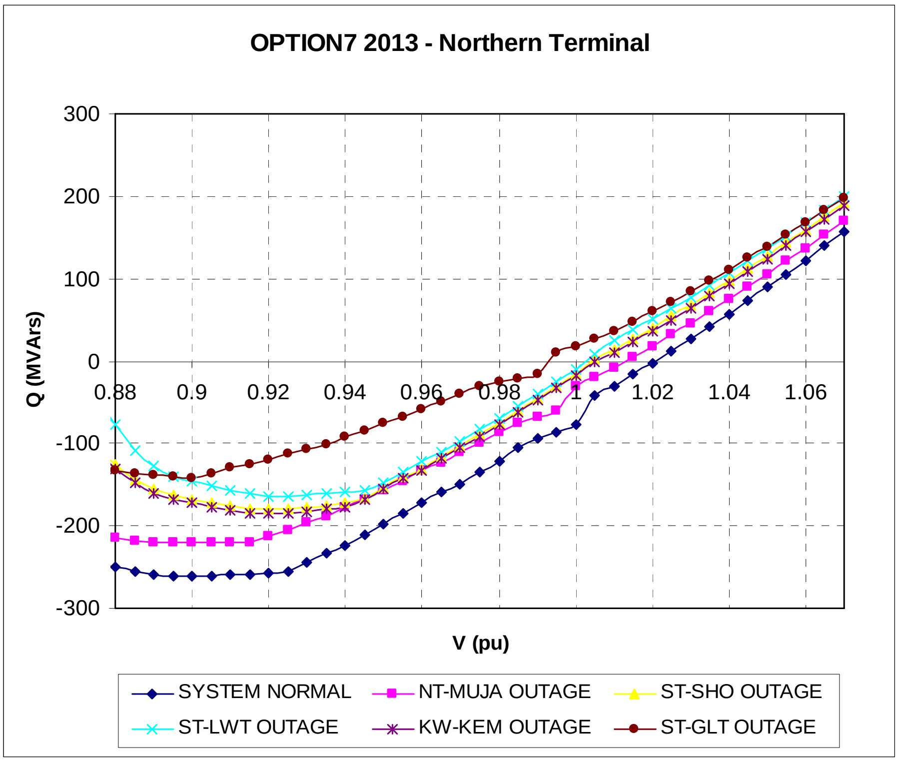
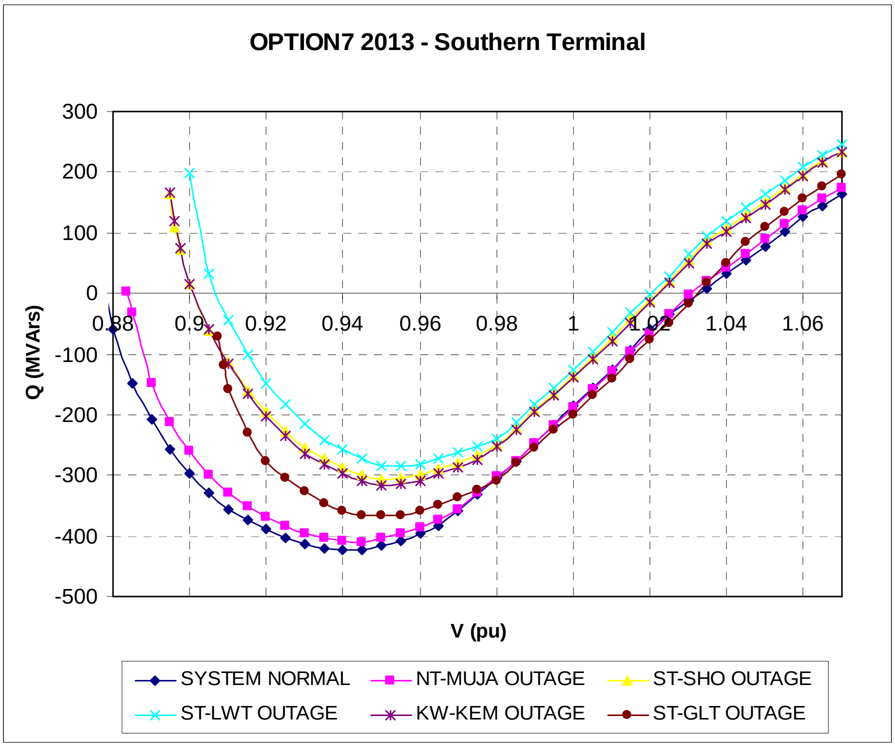
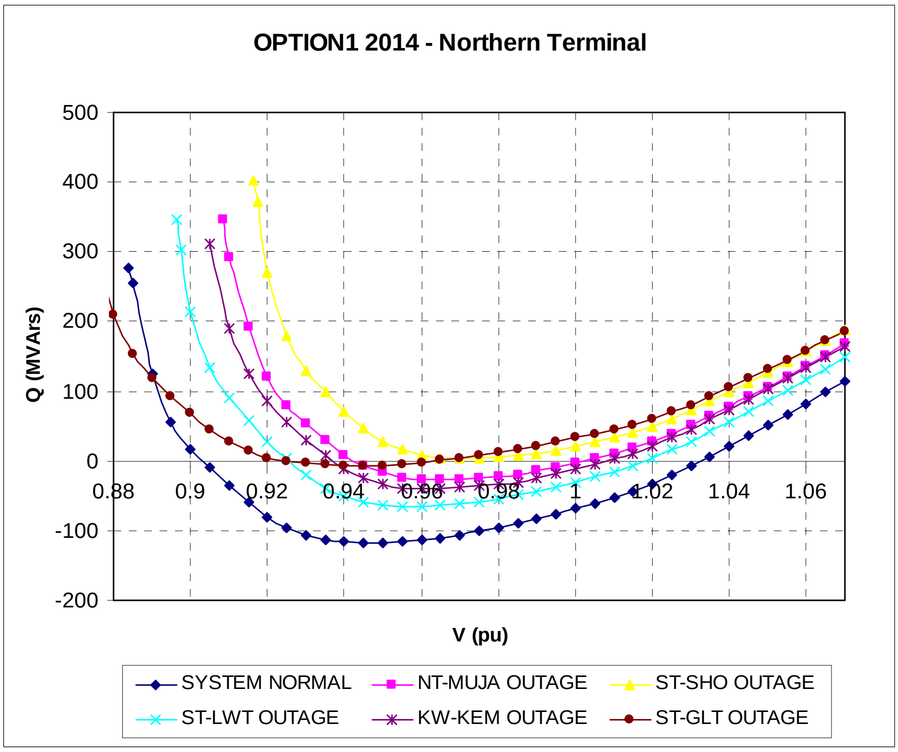
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

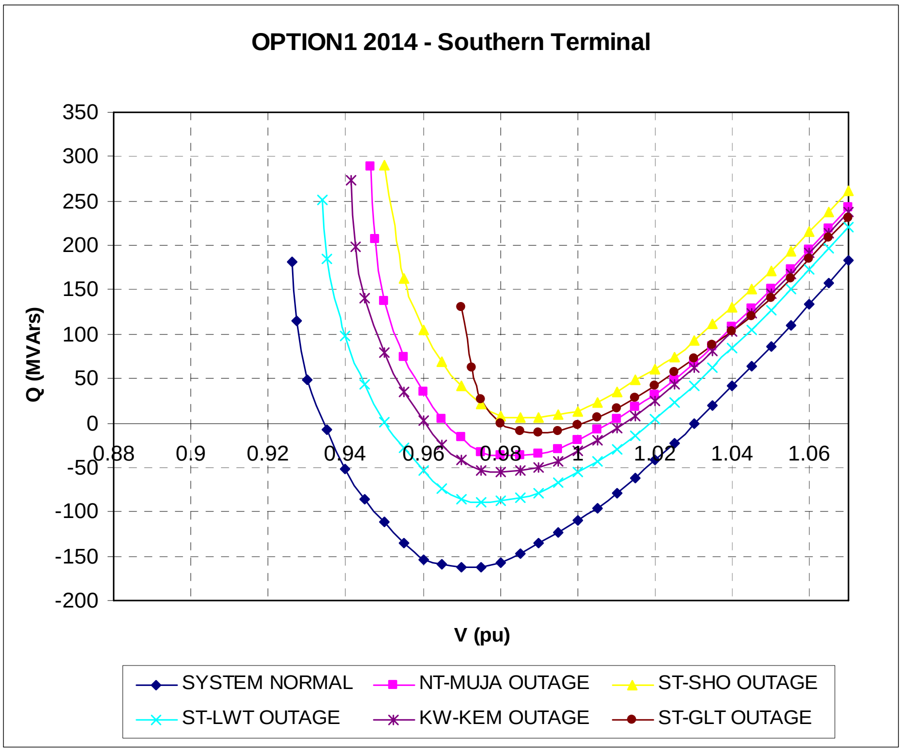

OPTION6 2013 - Southern Terminal
400
300
200
100
0
-100
-200
-300
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

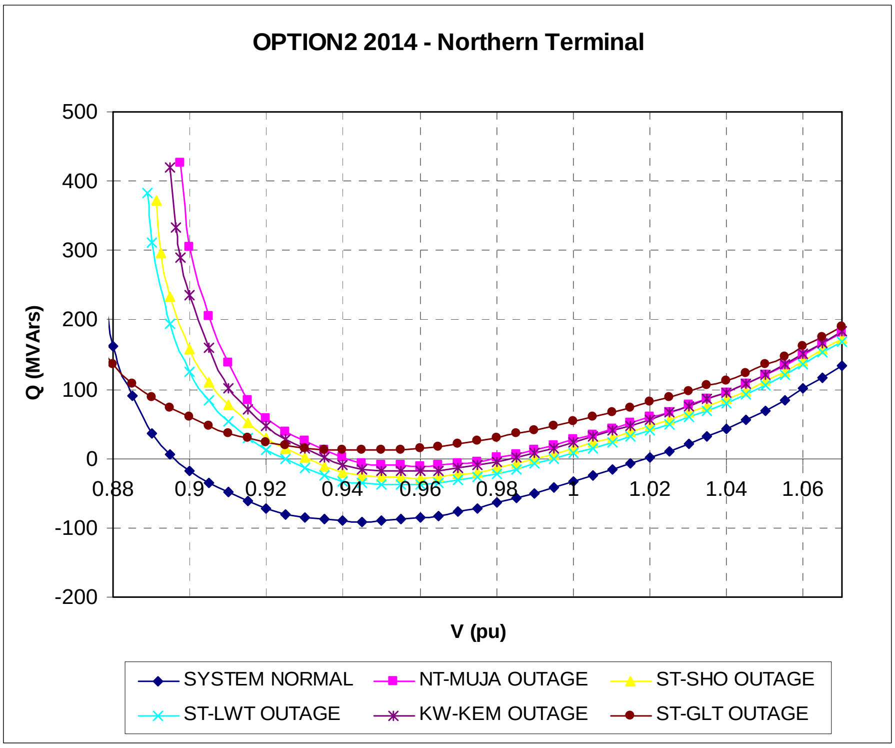

OPTION7 2013 - Northern Terminal
Q (MVArs)
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION7 2013 - Southern Terminal
Q (MVArs)
300
200
100
0
-100
-200
-300
-400
-500
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

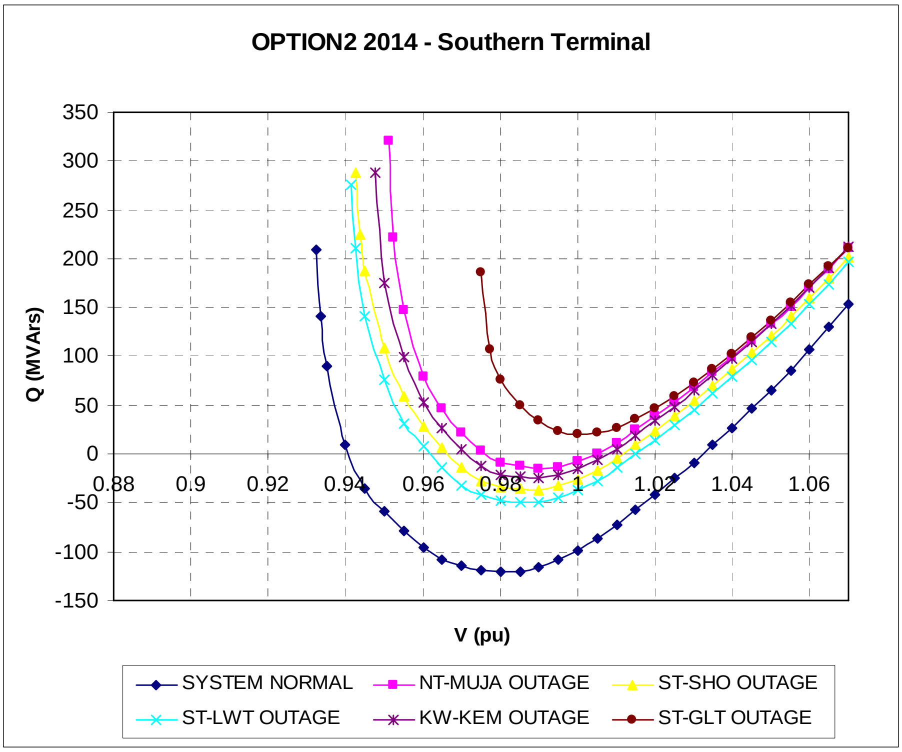
2014 V-Q Analysis



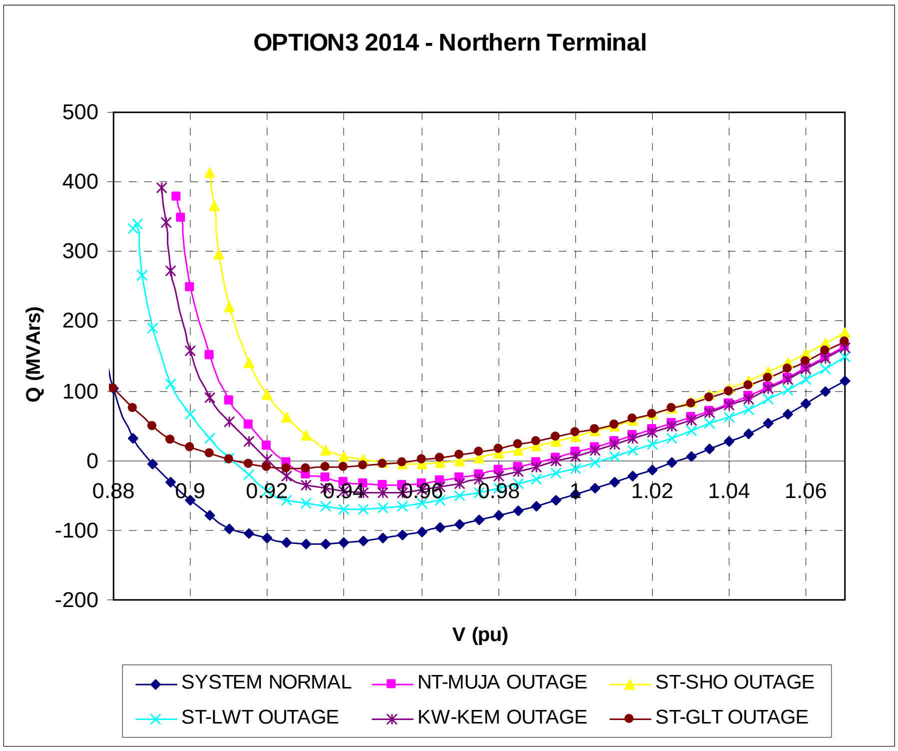


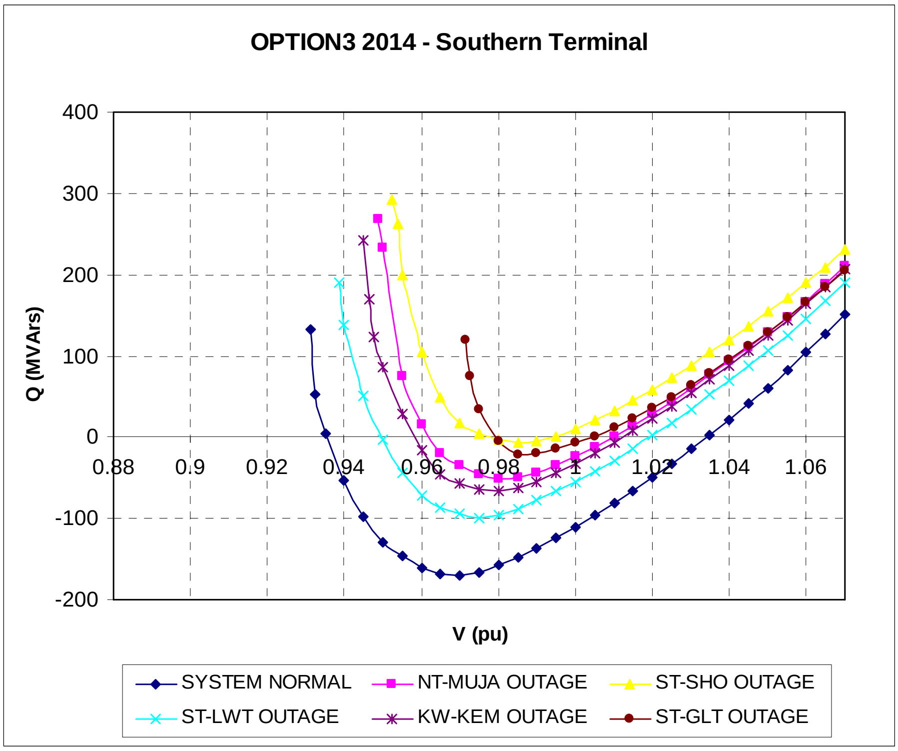


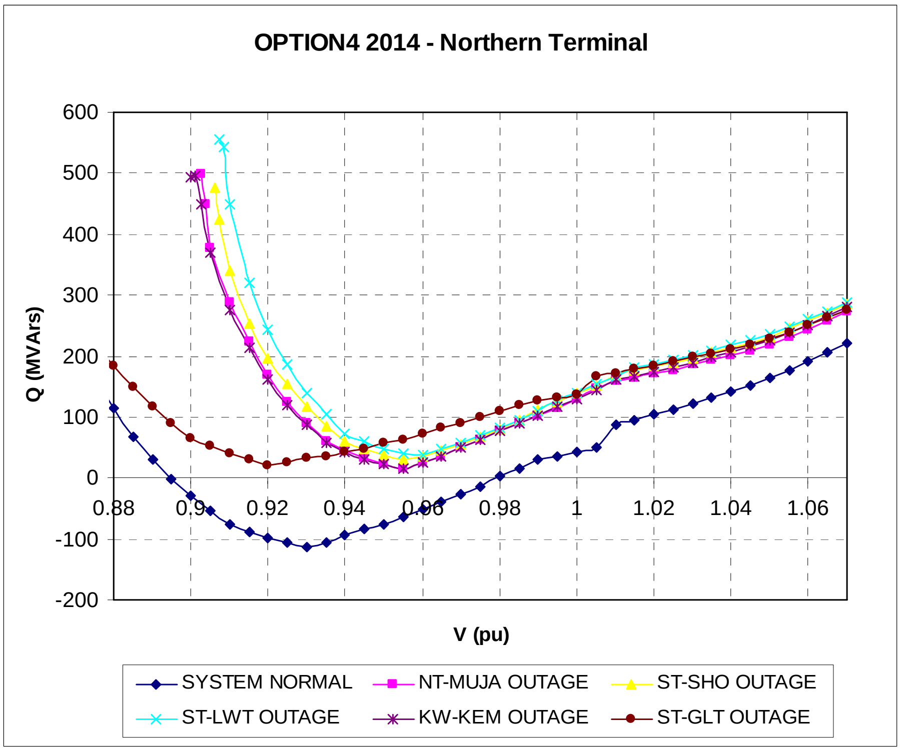
OPTION2 2014 - Northern Terminal
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

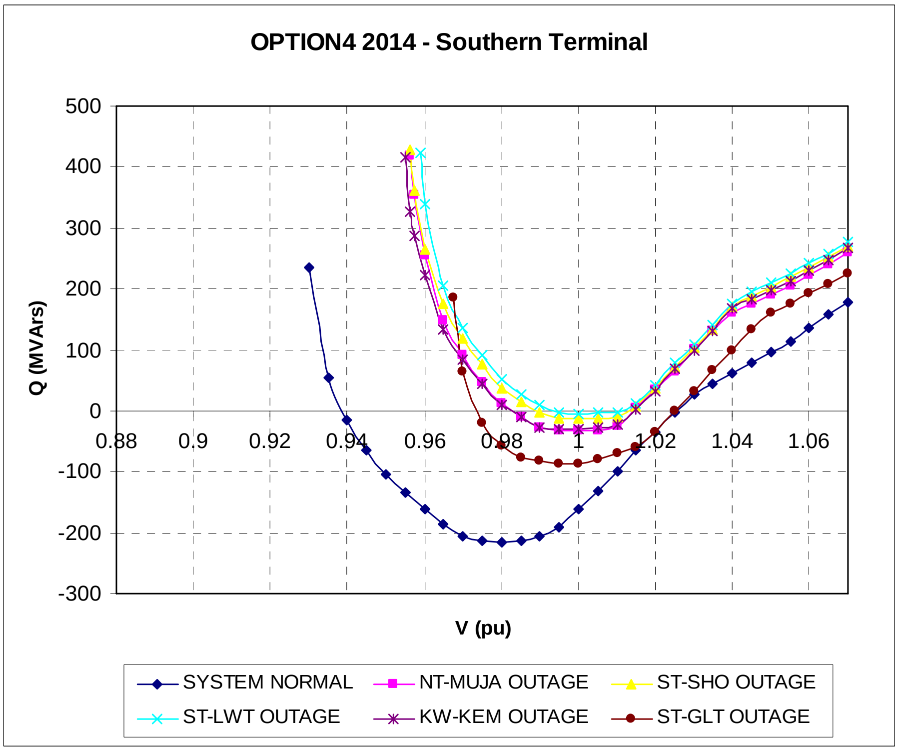


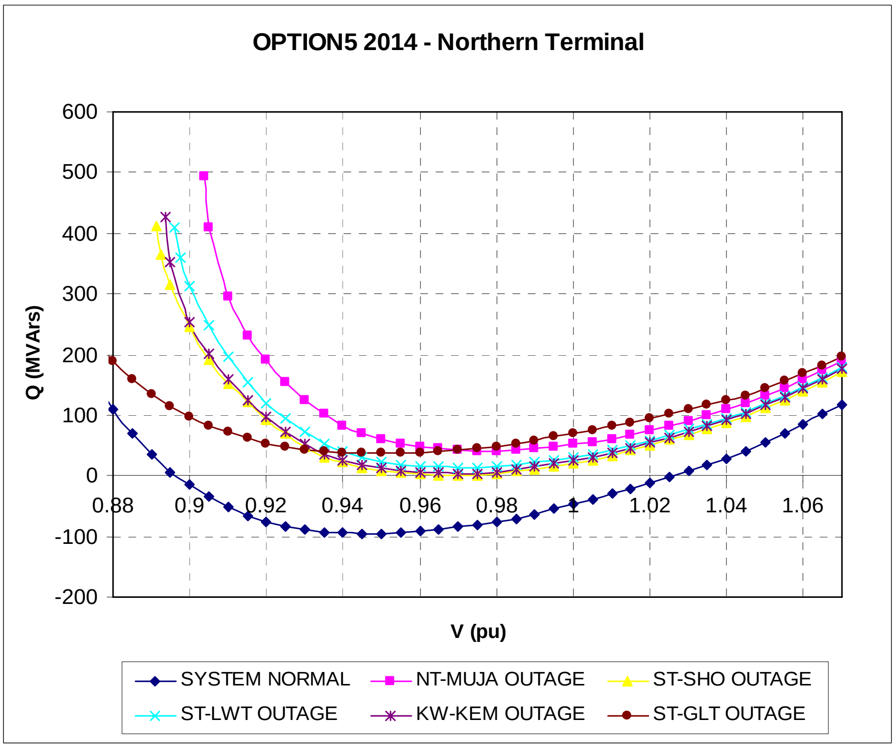
OPTION2 2014 - Southern Terminal
350
300
250
200
150
100
50
0
-50
-100
-150
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION3 2014 - Northern Terminal
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

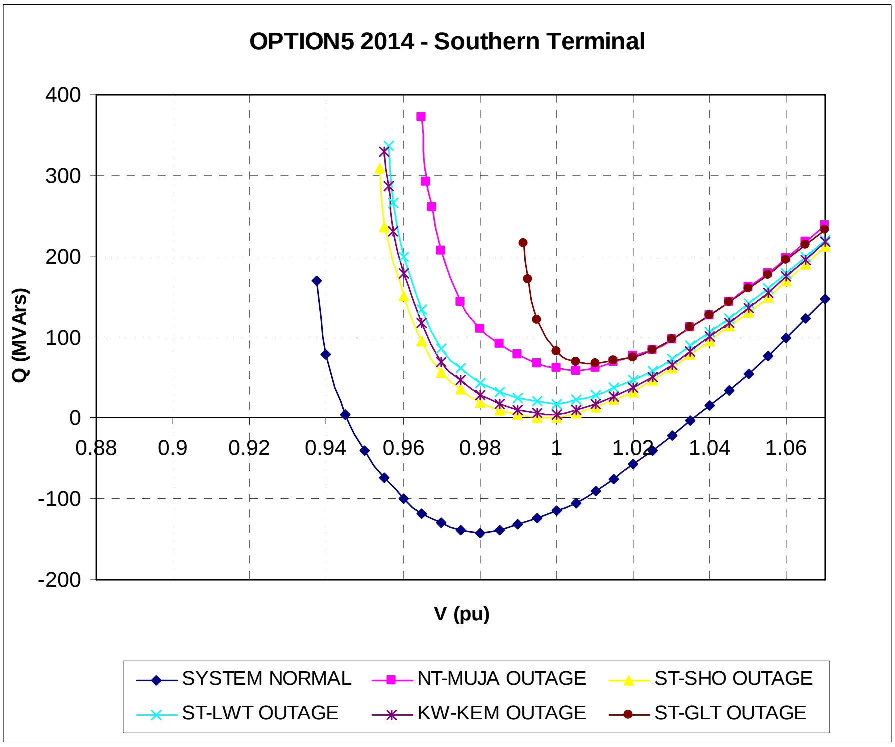

OPTION3 2014 - Southern Terminal
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION4 2014 - Northern Terminal
Q (MVArs)
V (pu)
600
500
400
300
200
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

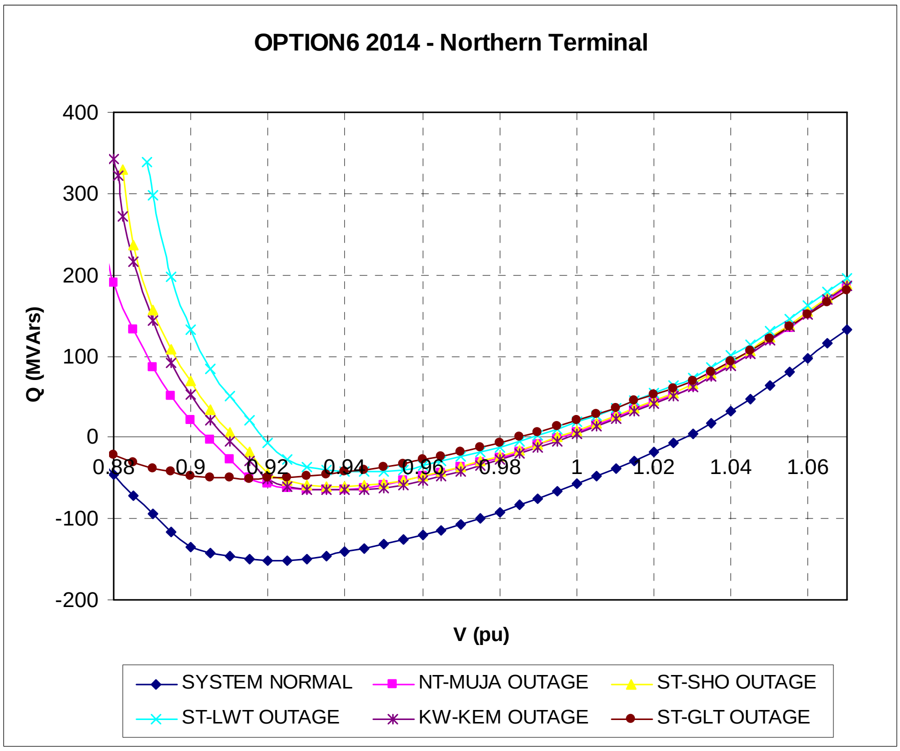

OPTION4 2014 - Southern Terminal
Q (MVArs)
V (pu)
500
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

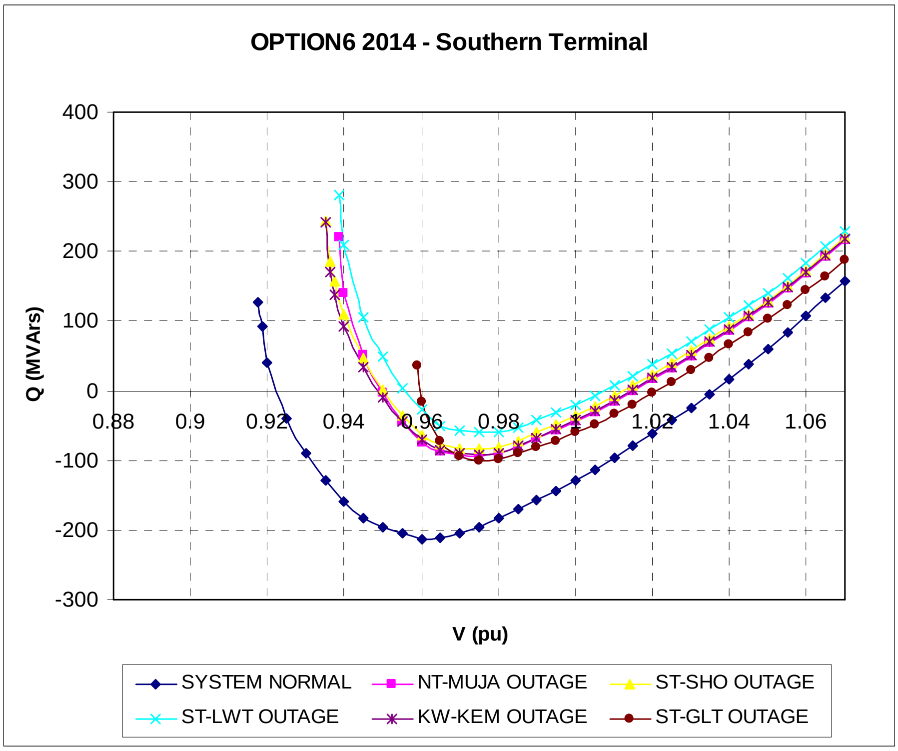


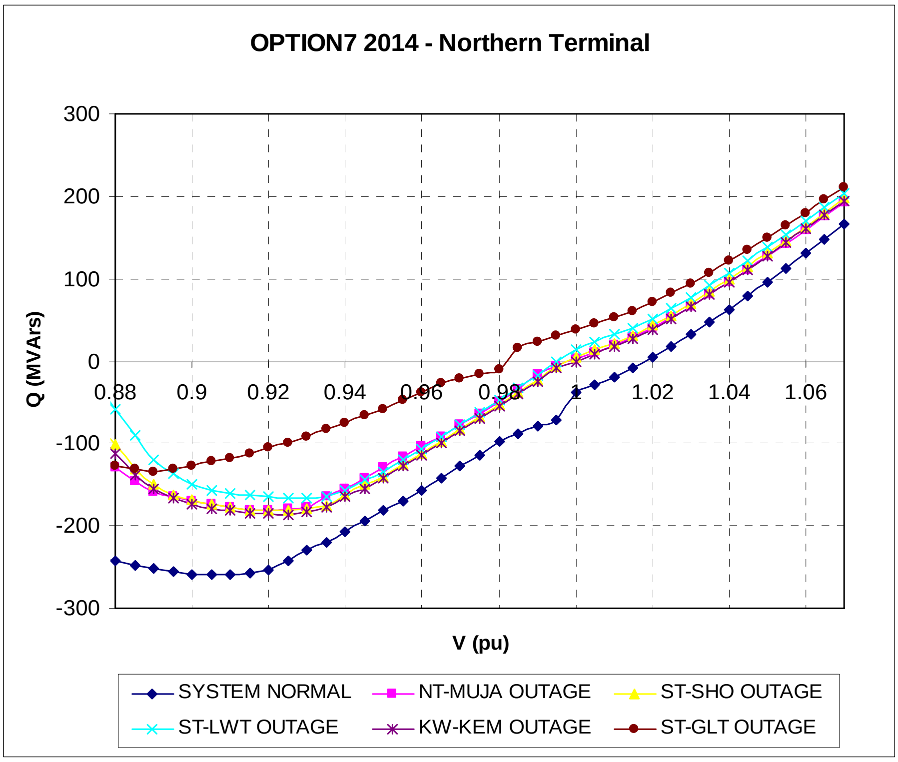
OPTION5 2014 - Northern Terminal
Q (MVArs)
V (pu)
600
500
400
300
200
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

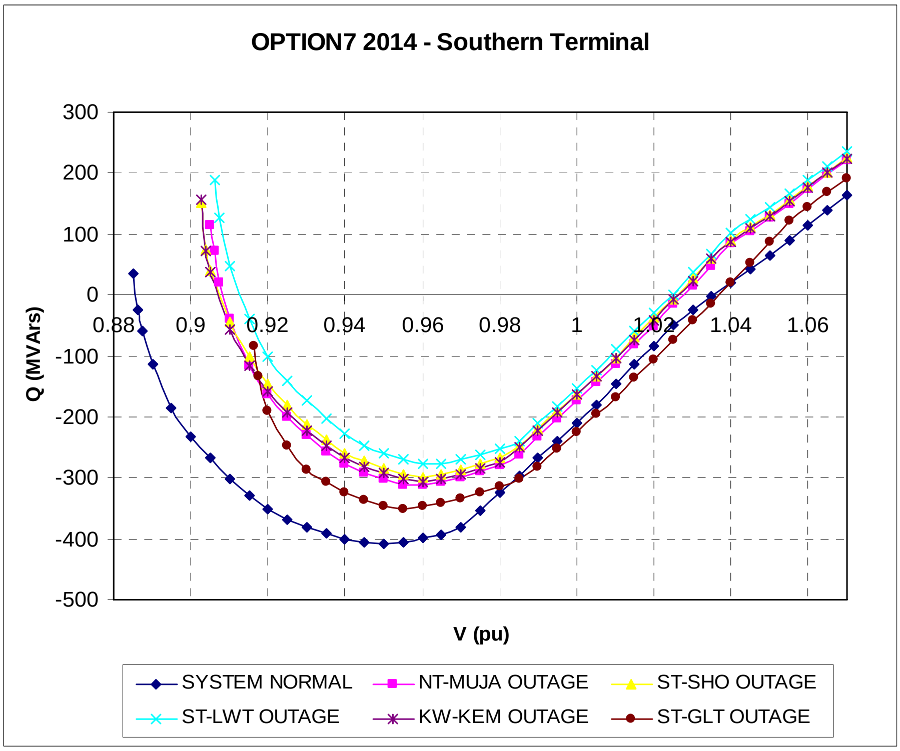


OPTION5 2014 - Southern Terminal
Q (MVArs)
V (pu)
400
300
200
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

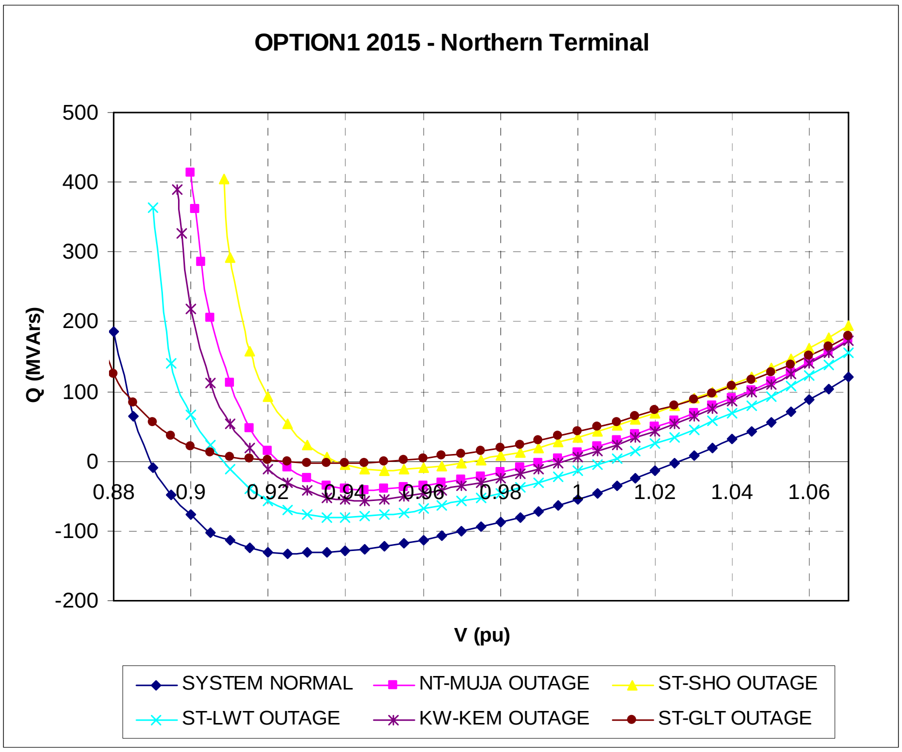

OPTION6 2014 - Northern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

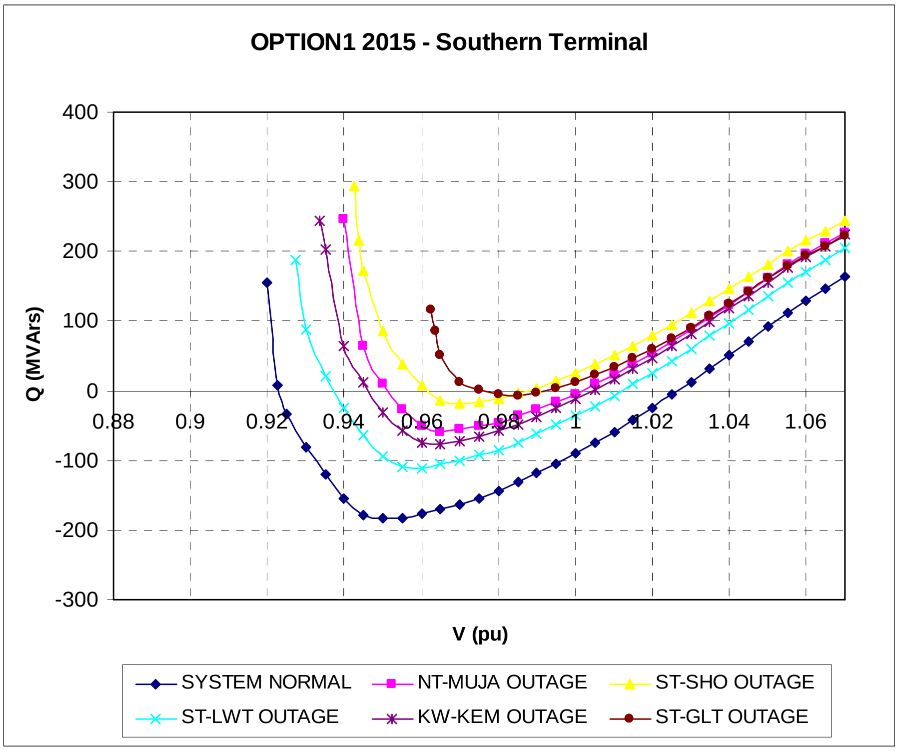

OPTION6 2014 - Southern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

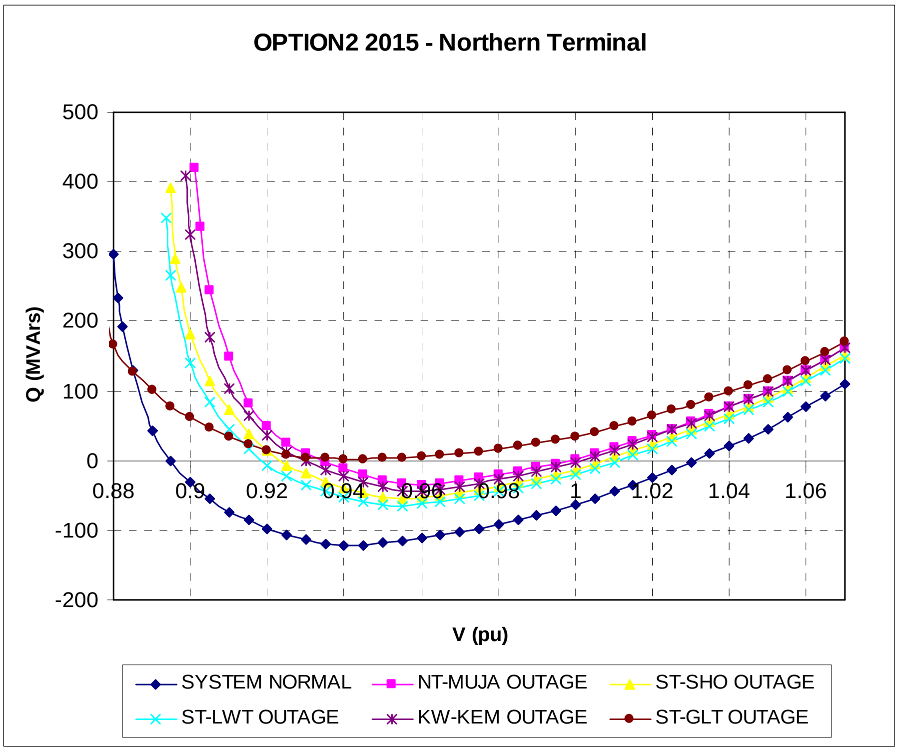

OPTION7 2014 - Northern Terminal
Q (MVArs)
V (pu)
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

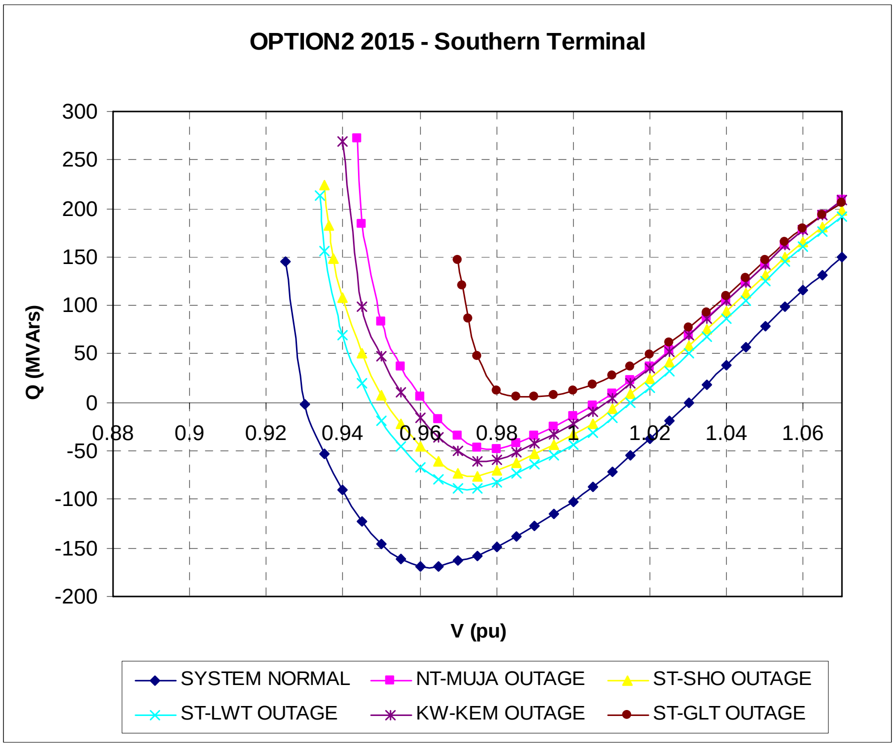

OPTION7 2014 - Southern Terminal
Q (MVArs)
V (pu)
300
200
100
0
-100
-200
-300
-400
-500
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

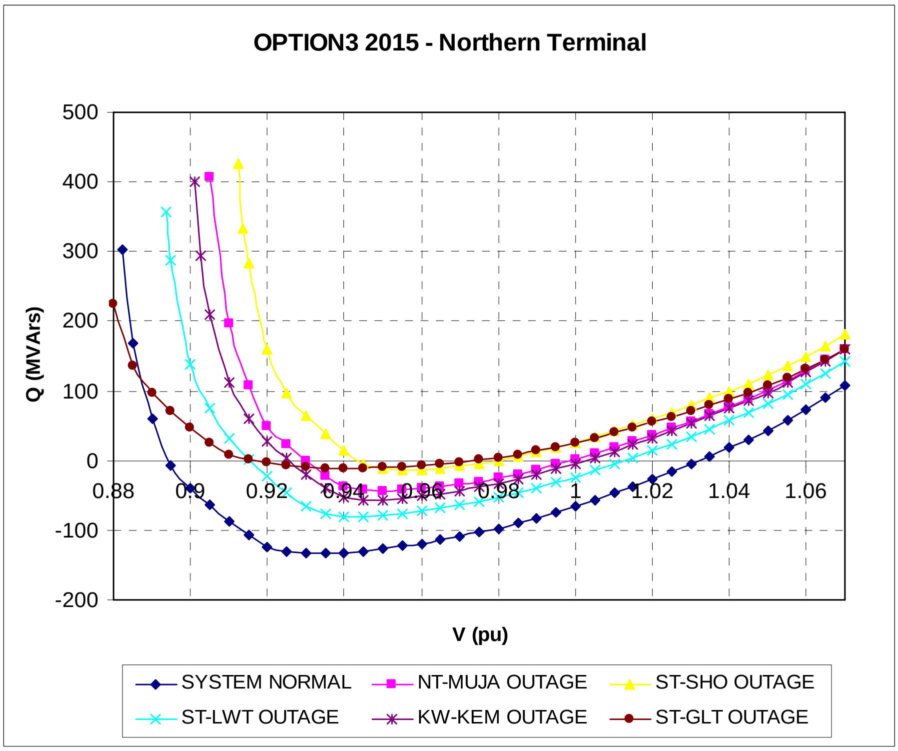
2015 V-Q Analysis

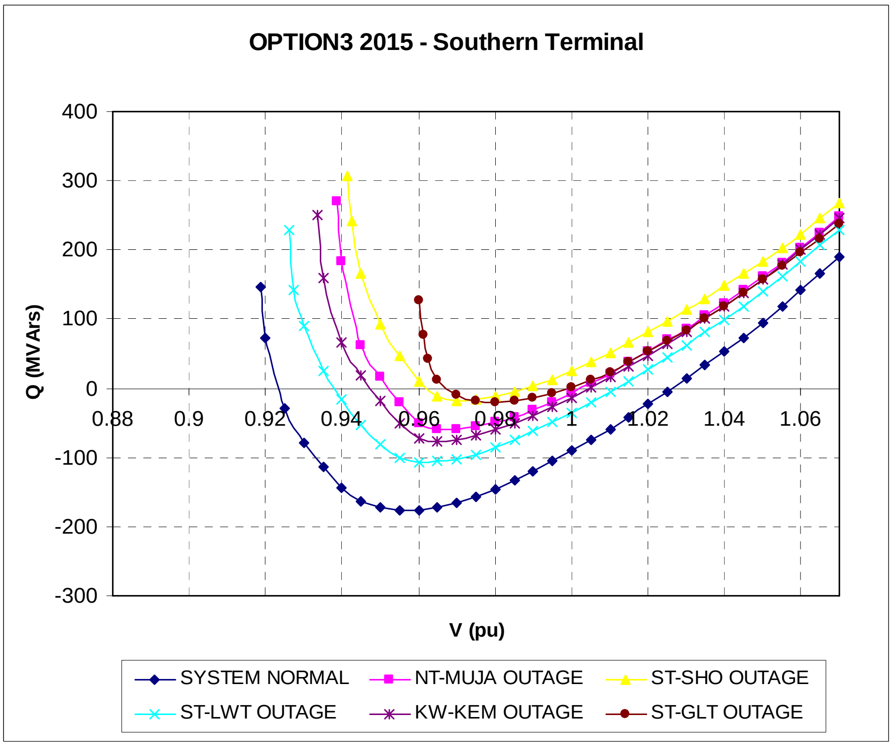





OPTION2 2015 - Northern Terminal
Q (MVArs)
500
400
300
200
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION2 2015 - Southern Terminal
Q (MVArs)
300
250
200
150
100
50
0
-50
-100
-150
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION3 2015 - Northern Terminal
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION3 2015 - Southern Terminal
400
300
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0
-100
-200
-300
Q (MVArs)
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0.9
0.92
0.94
0.96
0.98
1
1.02
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V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
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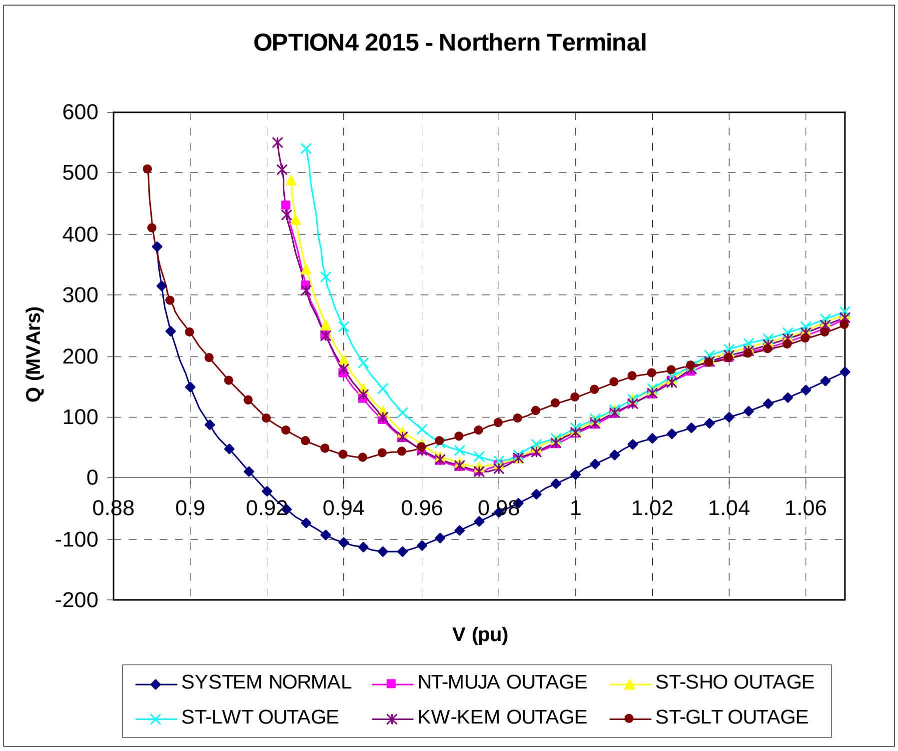
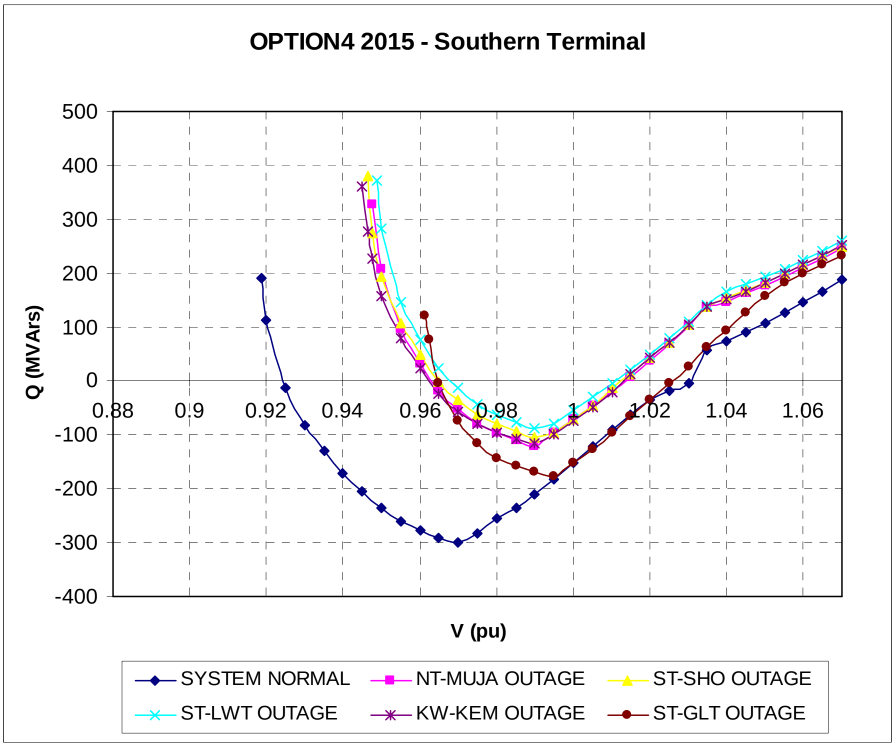
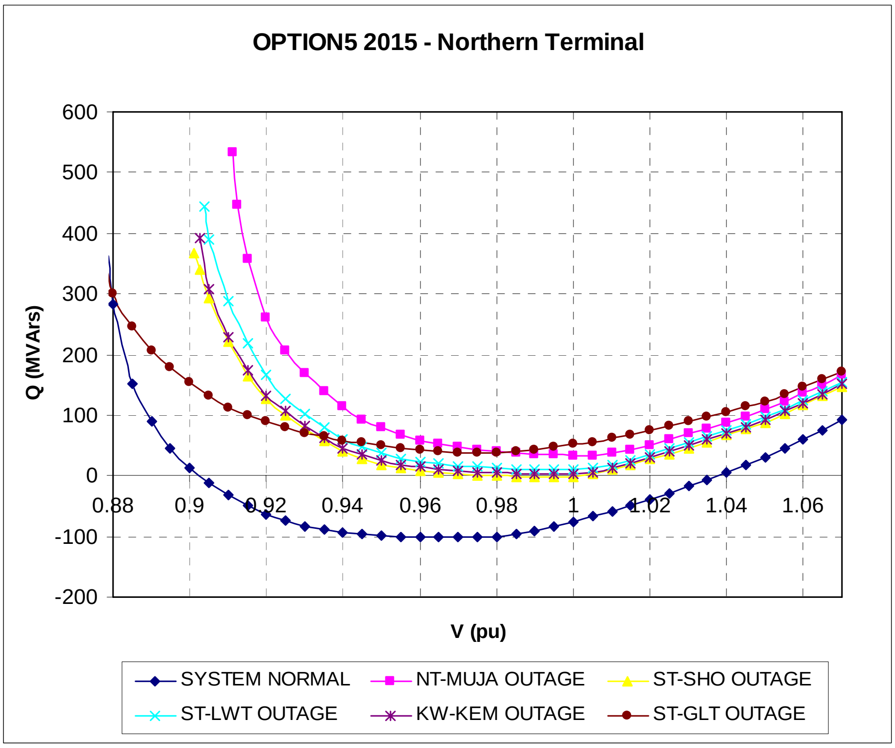
ST-GLT OUTAGE


OPTION4 2015 - Northern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION4 2015 - Southern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION5 2015 - Northern Terminal
Q (MVArs)
600
500
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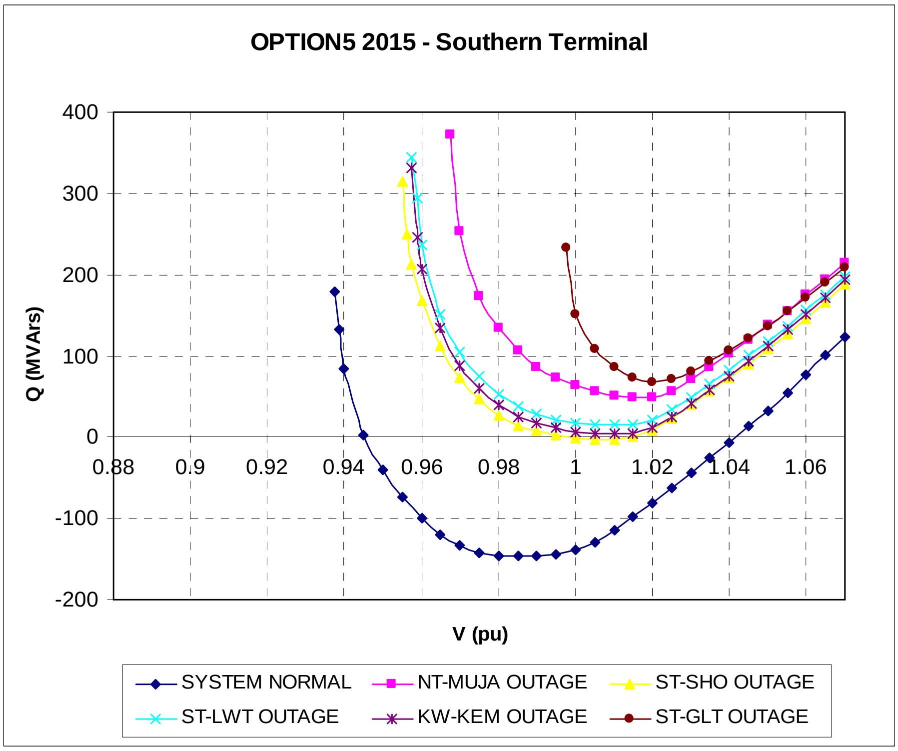
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION5 2015 - Southern Terminal
Q (MVArs)
400
300
200
100
0
-100
-200
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0.9
0.92
0.94
0.96
0.98
1
1.02
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V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
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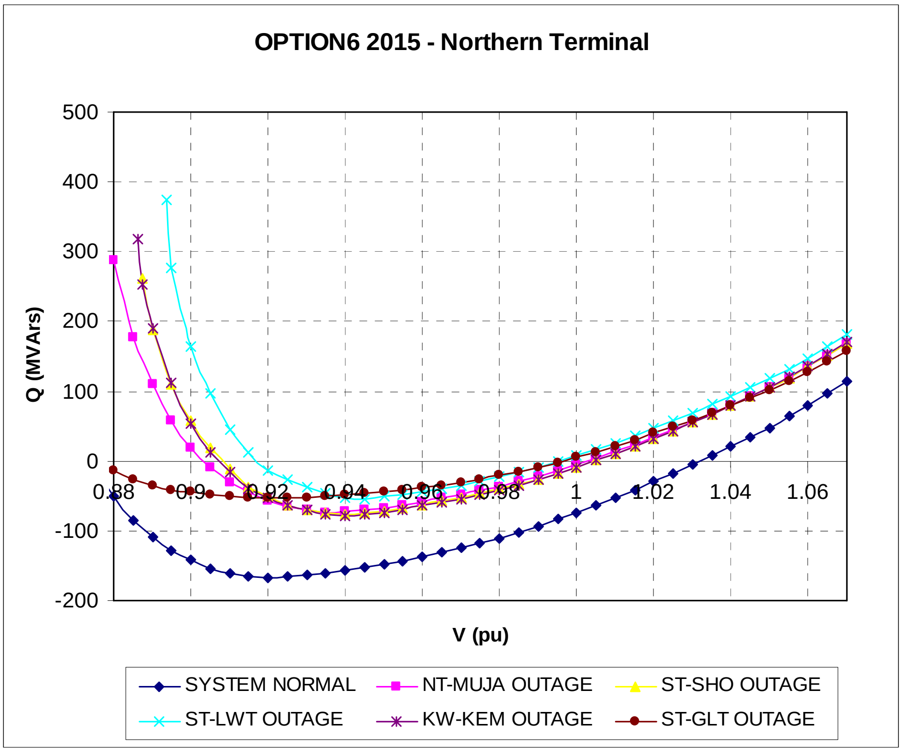
ST-GLT OUTAGE


OPTION6 2015 - Northern Terminal
Q (MVArs)
500
400
300
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100
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-200
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0.9
0.92
0.94
0.96
0.98
1
1.02
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V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
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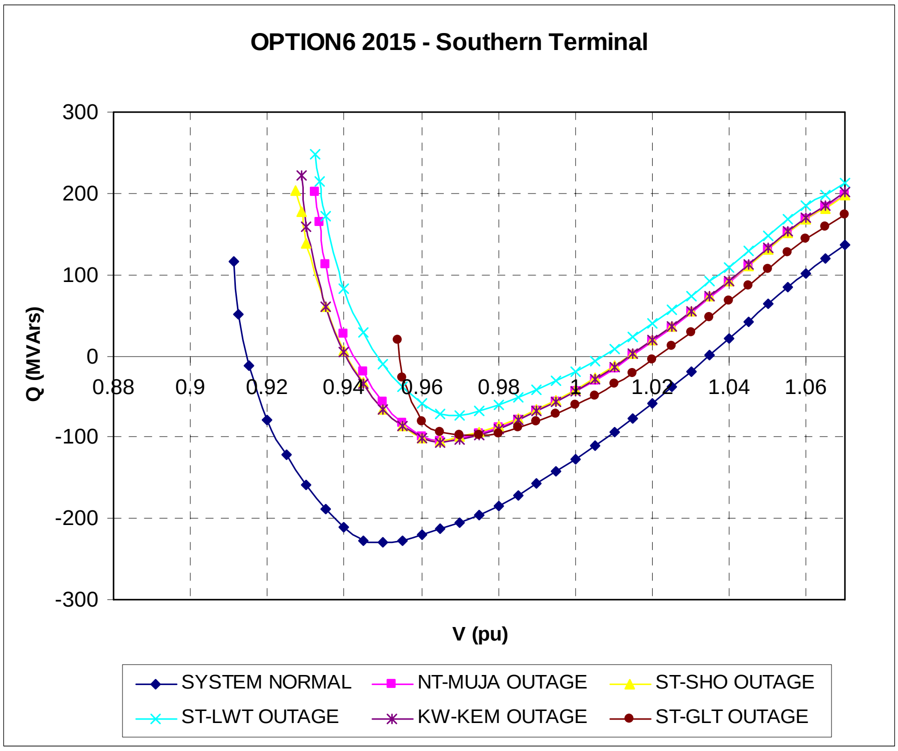
ST-GLT OUTAGE


OPTION6 2015 - Southern Terminal
Q (MVArs)
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-100
-200
-300
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0.92
0.94
0.96
0.98
1
1.02
1.04
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V (pu)
SYSTEM NORMAL
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ST-LWT OUTAGE
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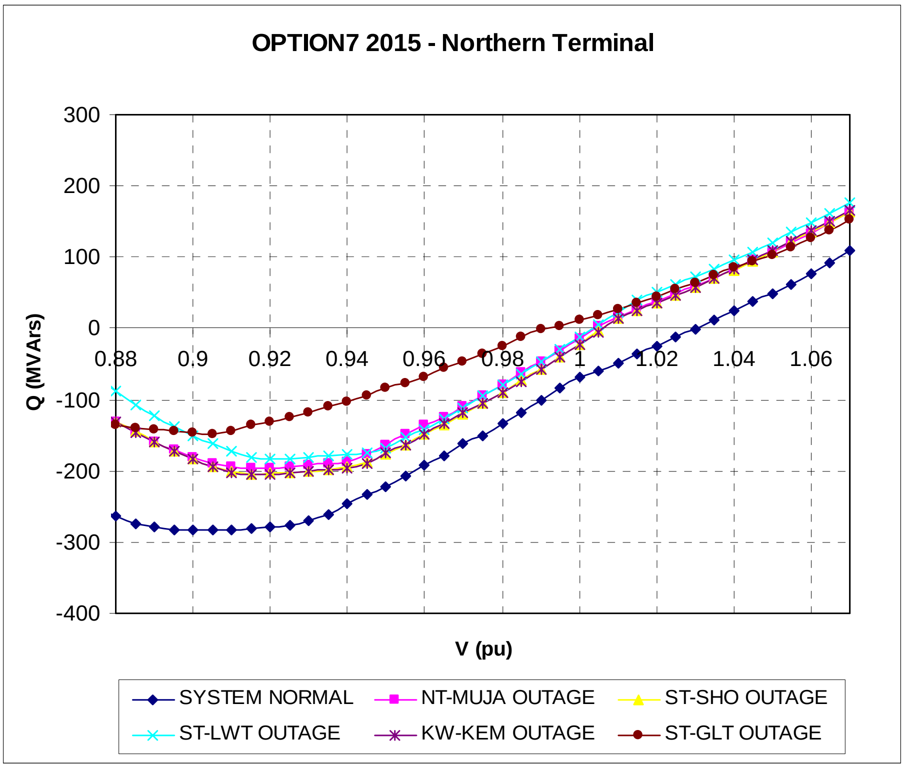
ST-GLT OUTAGE


OPTION7 2015 - Northern Terminal
300
200
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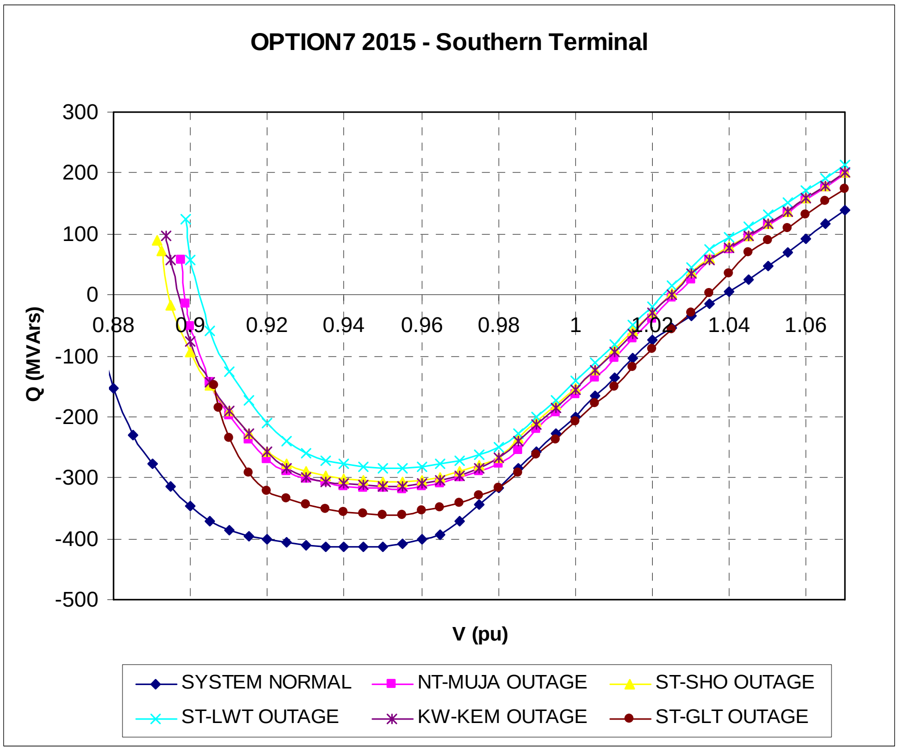
0.96
0.98
1
1.02
1.04
1.06
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION7 2015 - Southern Terminal
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-400
-500
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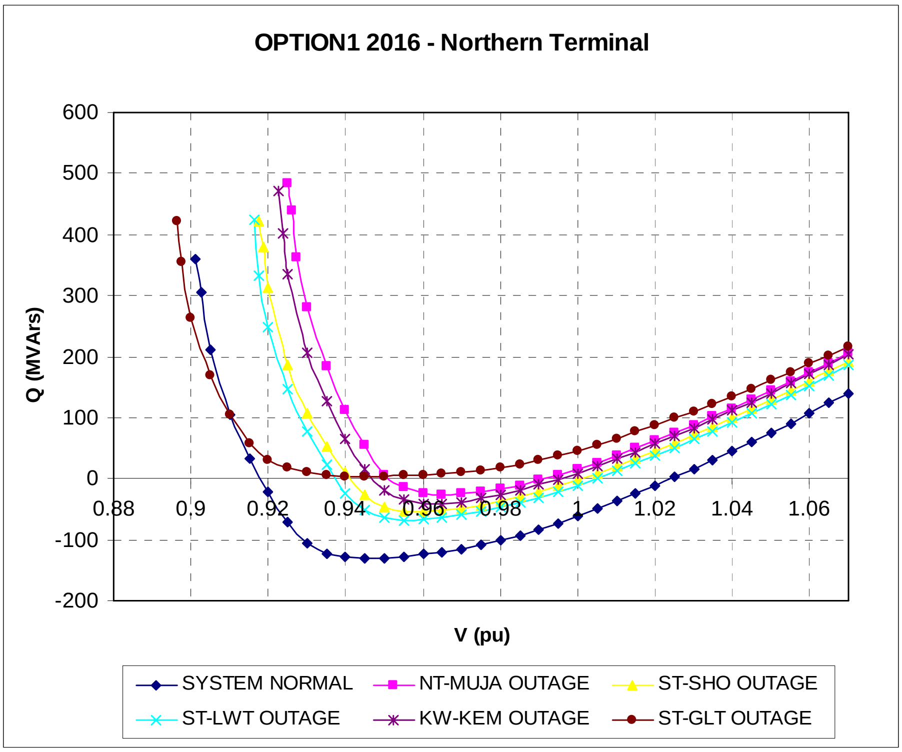
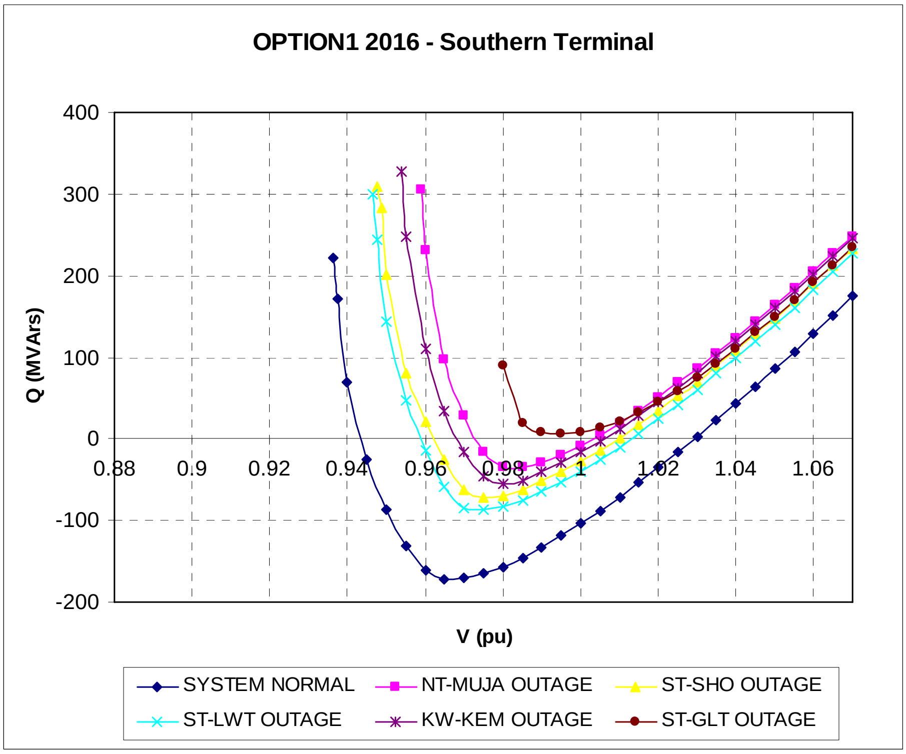
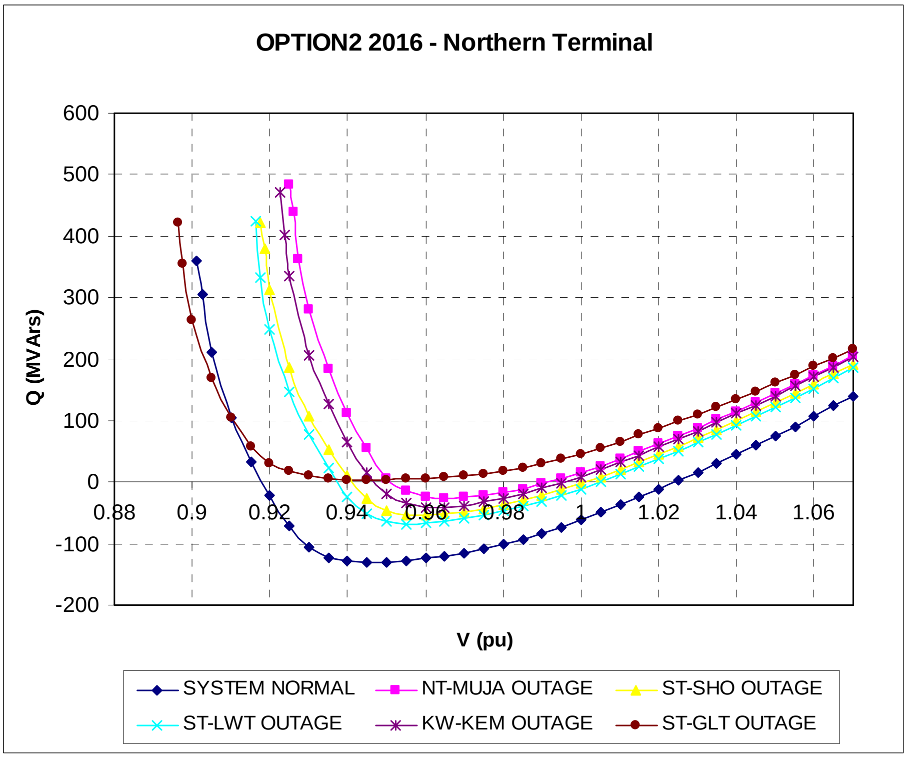
0.94
0.96
0.98
1
1.02
1.04
1.06
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

2016 V-Q Analysis






OPTION2 2016 - Northern Terminal
600
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
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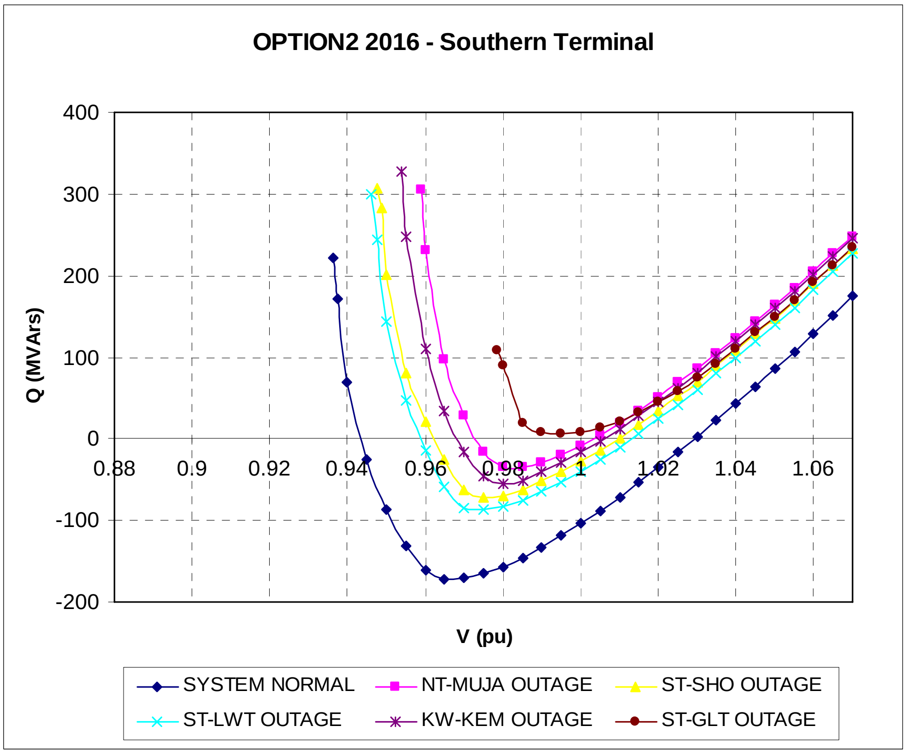
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION2 2016 - Southern Terminal
400
300
200
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-100
-200
Q (MVArs)
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0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
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V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
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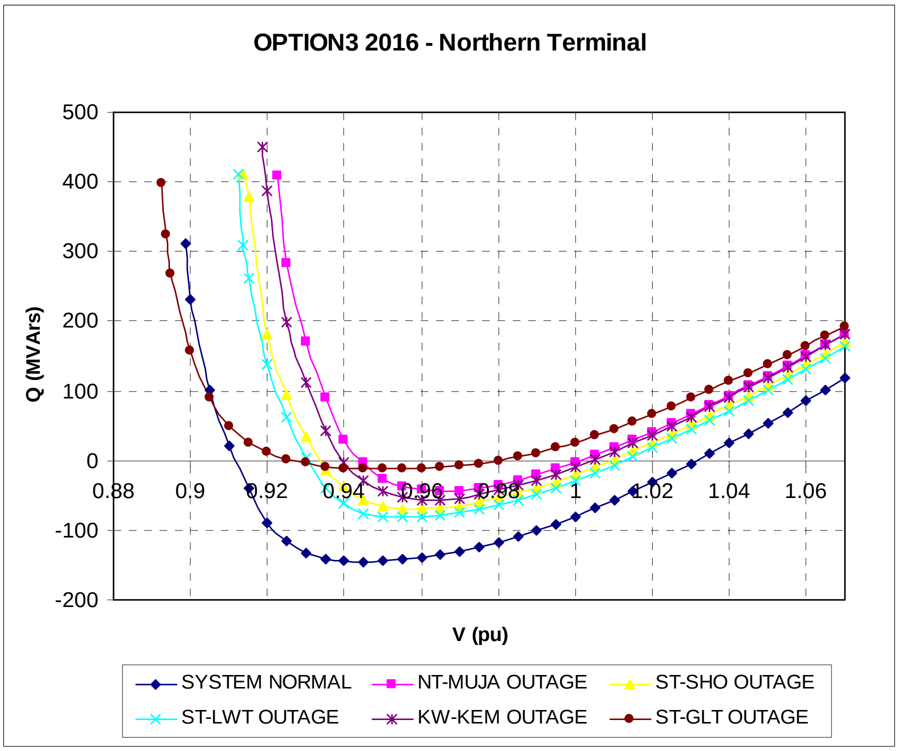
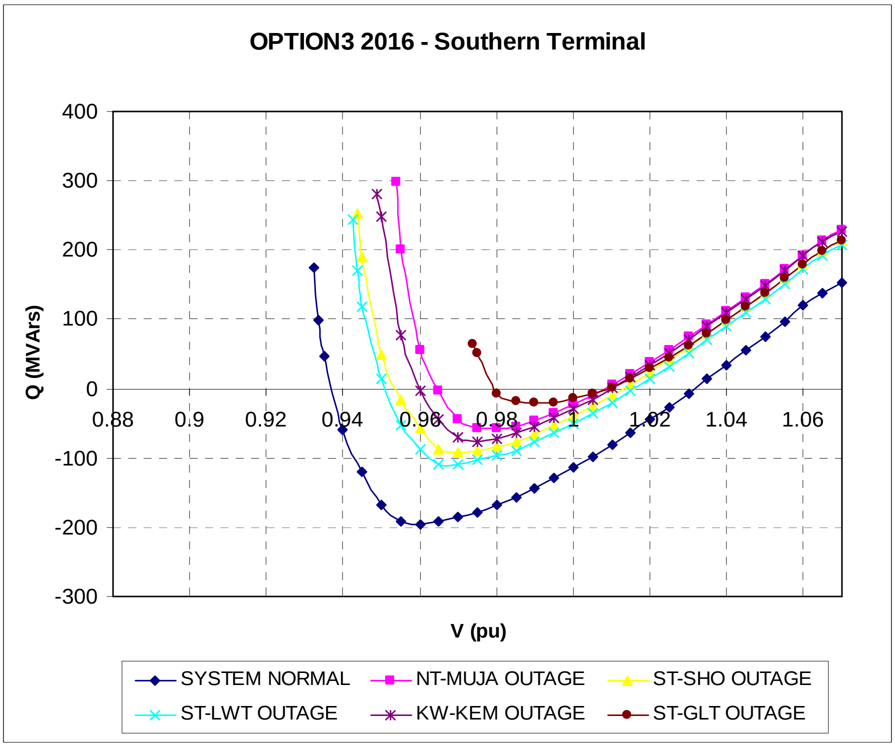
ST-GLT OUTAGE



OPTION3 2016 - Northern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE



OPTION3 2016 - Southern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
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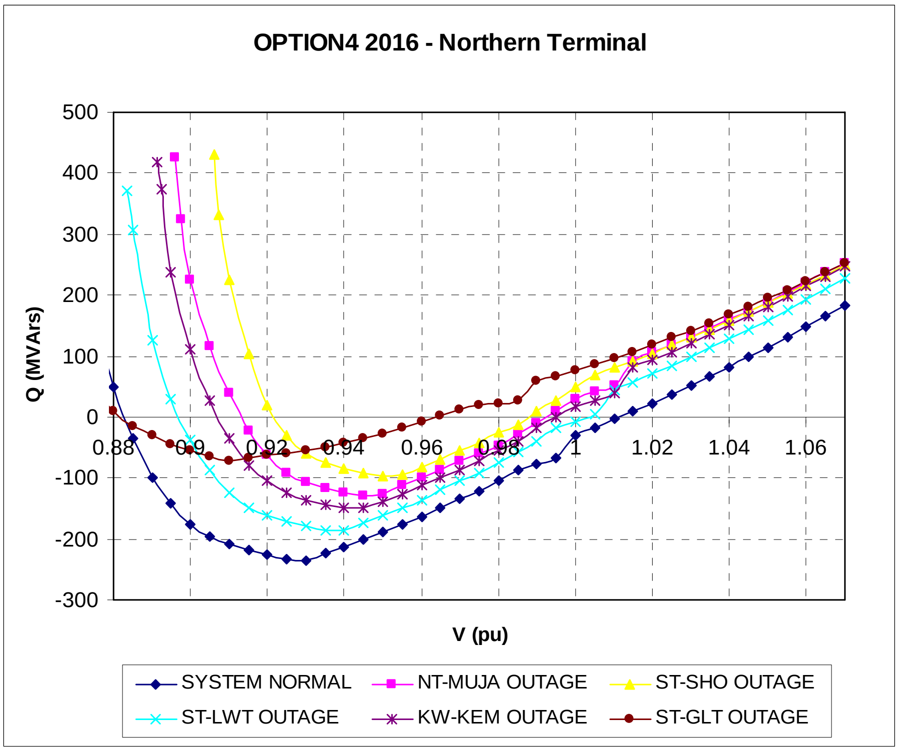
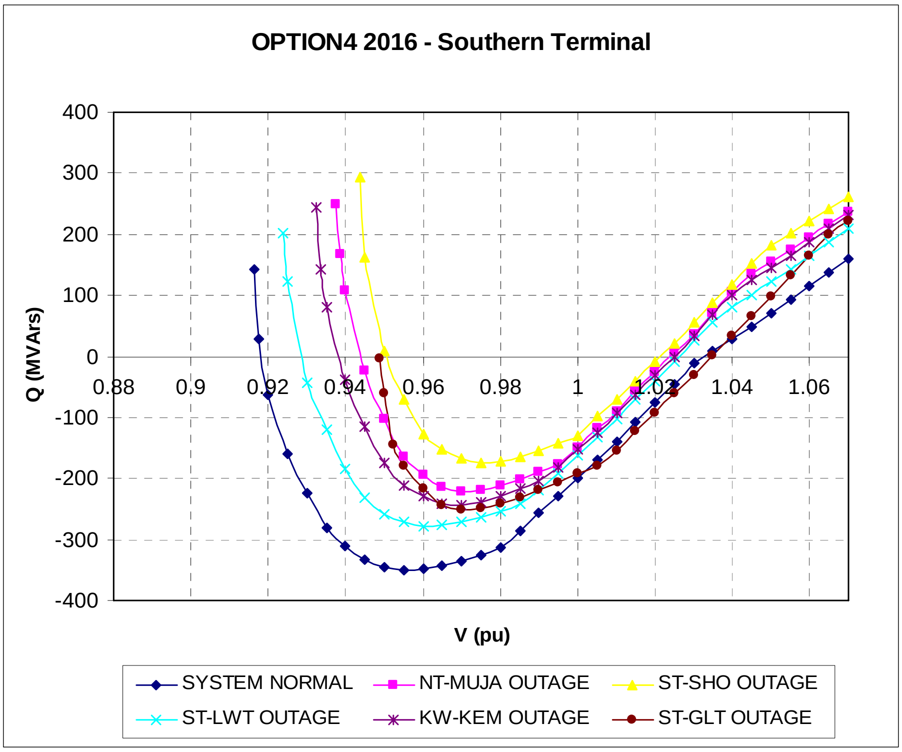
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION4 2016 - Northern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION4 2016 - Southern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
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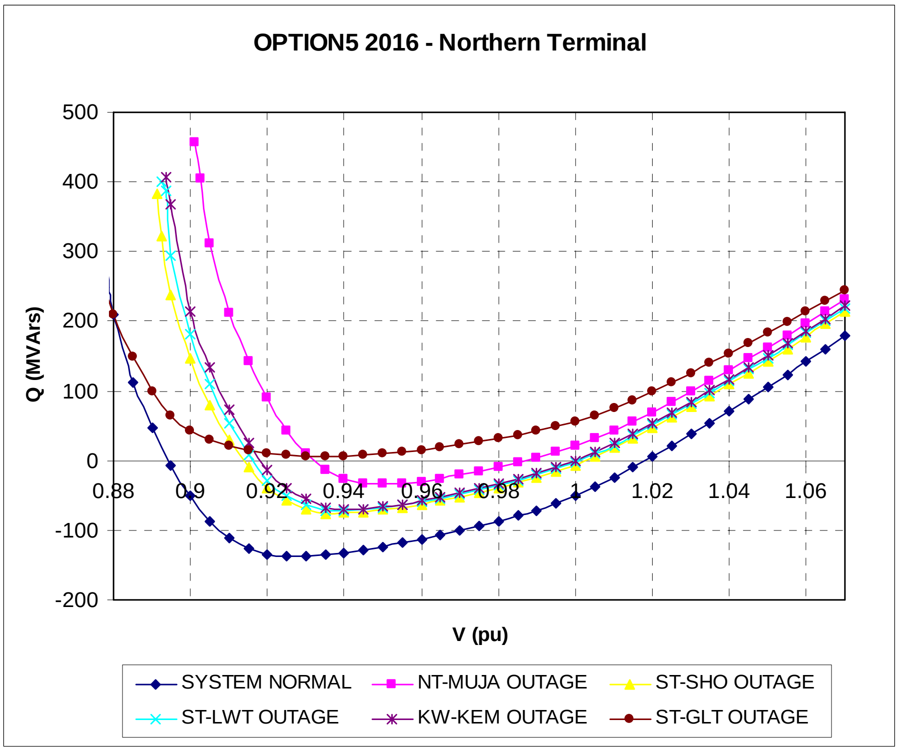
OPTION5 2016 - Northern Terminal
500
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-100
-200
Q (MVArs)
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0.9
0.92
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0.98
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1.02
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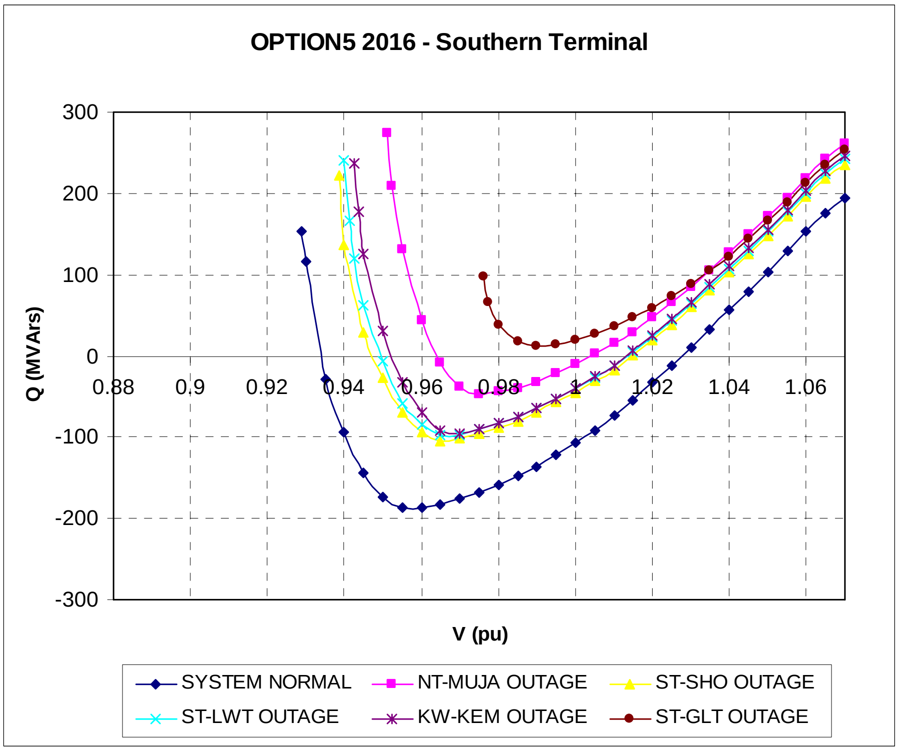
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


OPTION5 2016 - Southern Terminal
300
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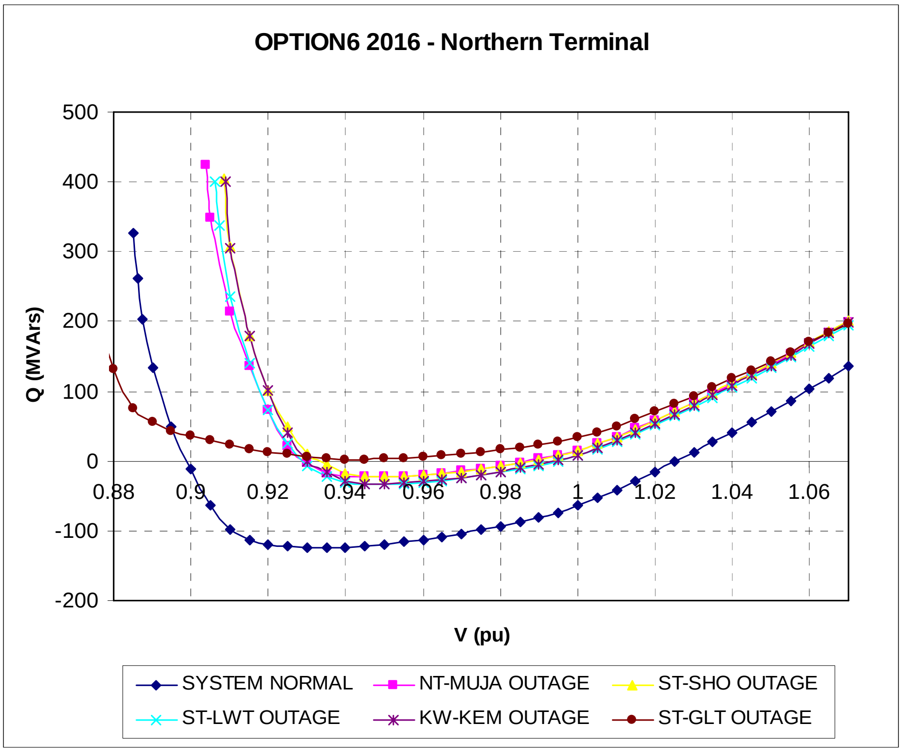
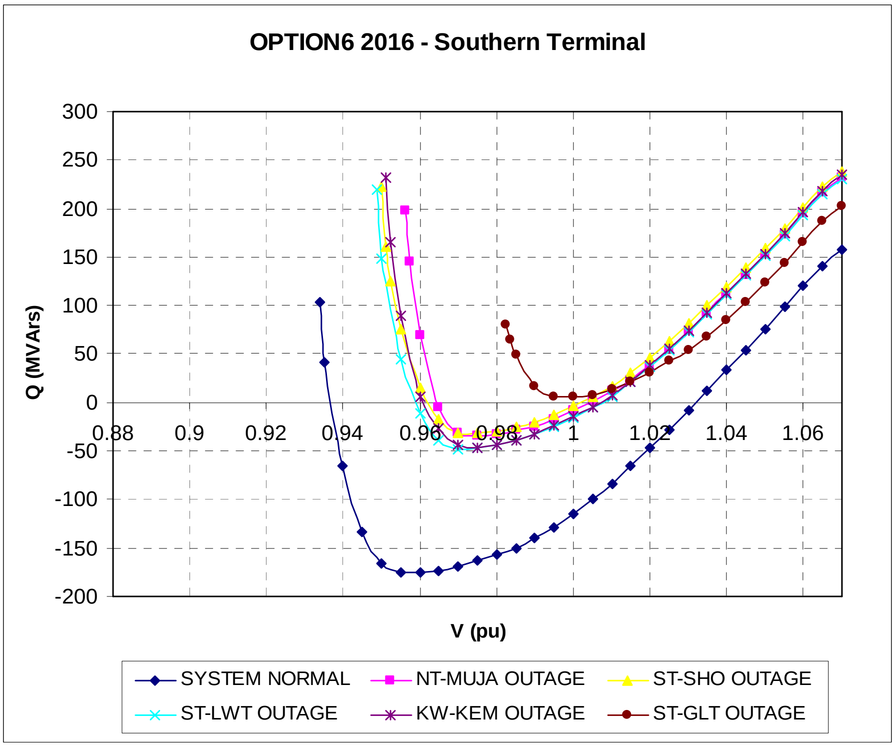
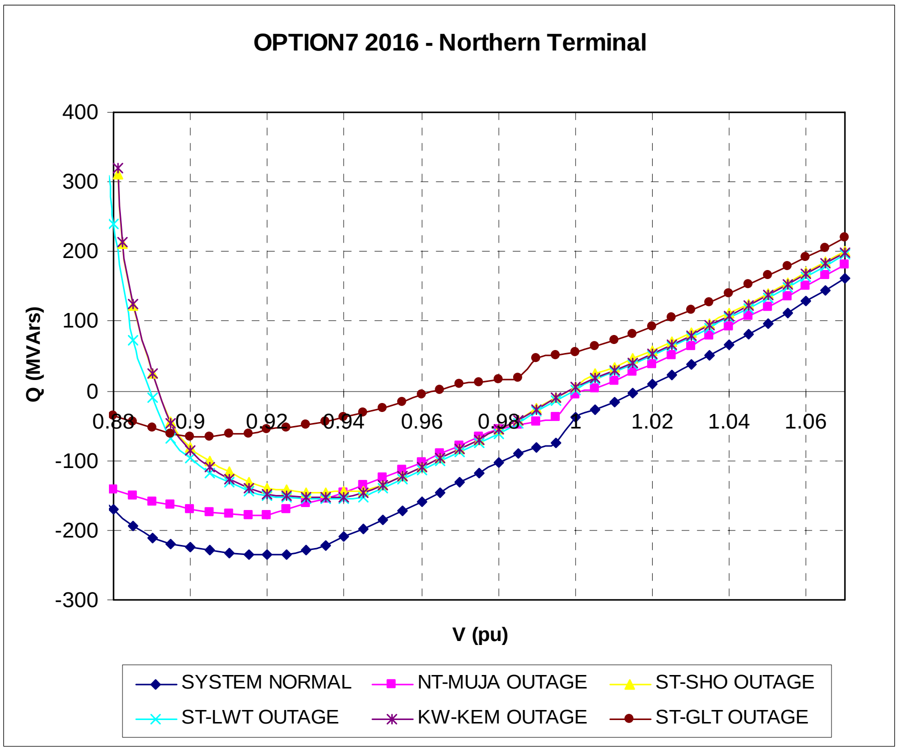
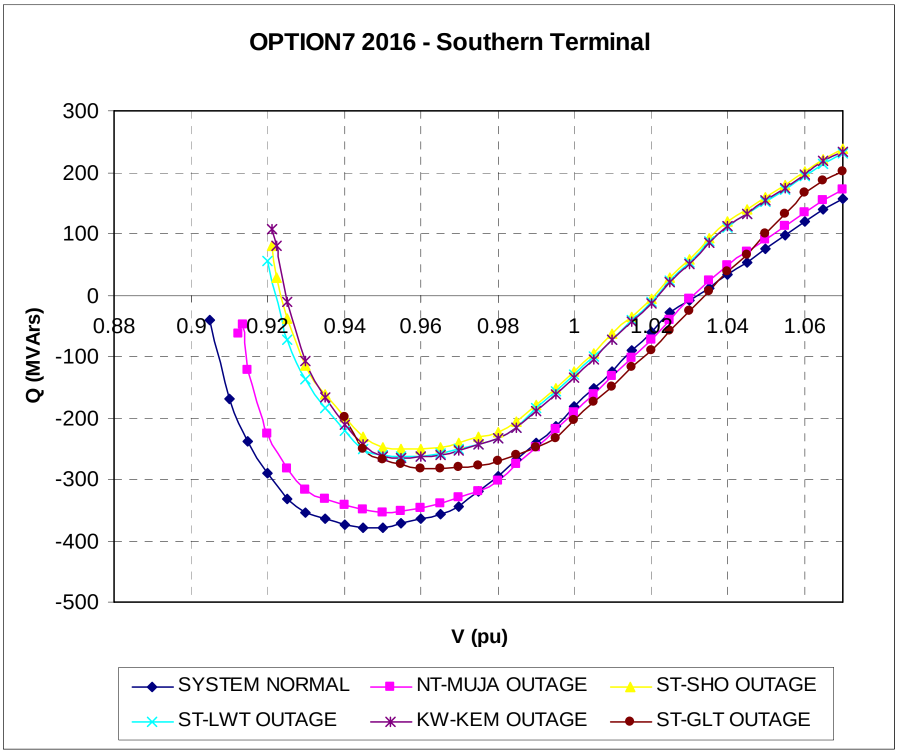
-100
-200
-300
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

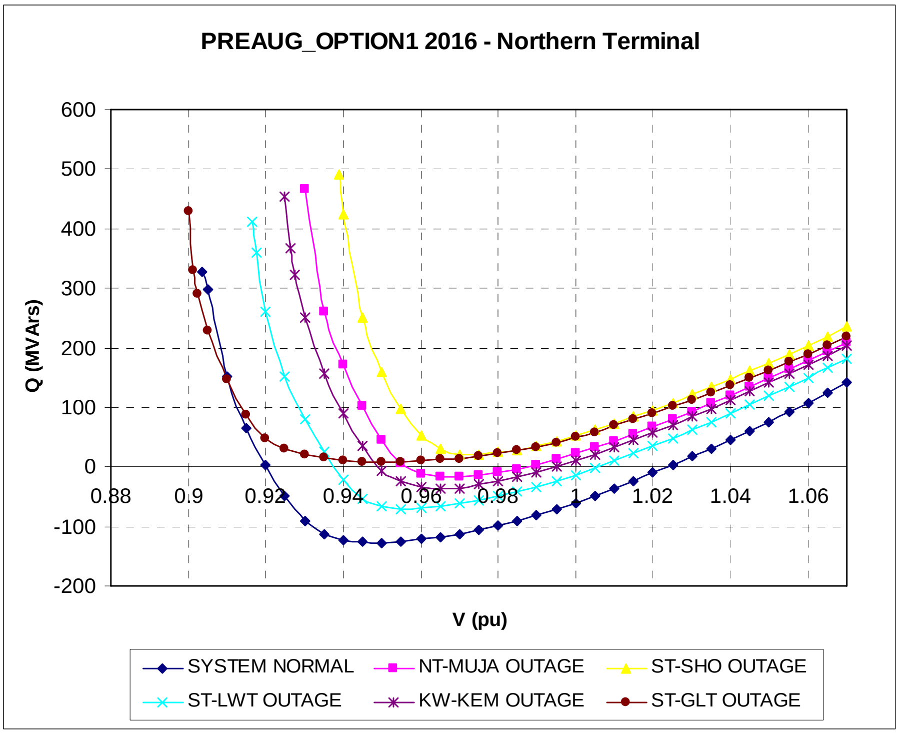

OPTION6 2016 - Northern Terminal
500
400
300
200
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

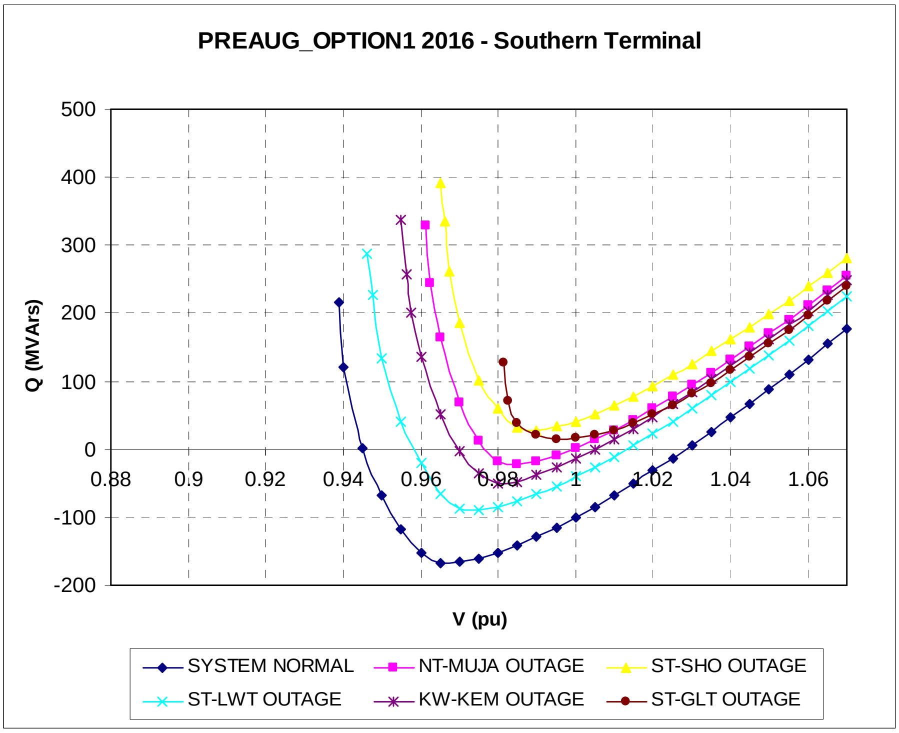

OPTION6 2016 - Southern Terminal
300
250
200
150
100
50
0
-50
-100
-150
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

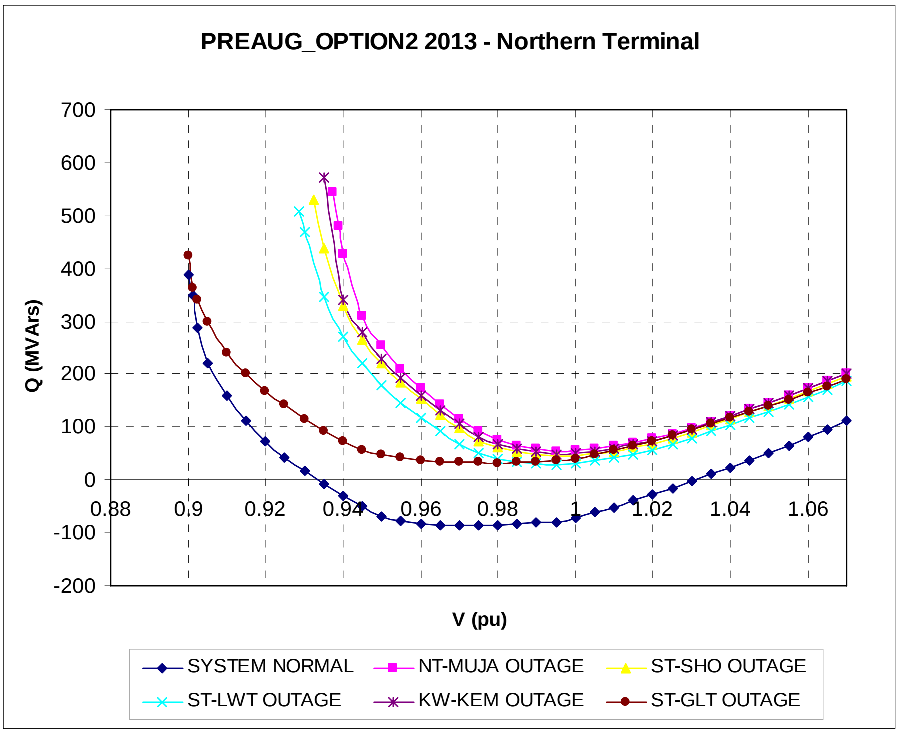

OPTION7 2016 - Northern Terminal
400
300
200
100
0
-100
-200
-300
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

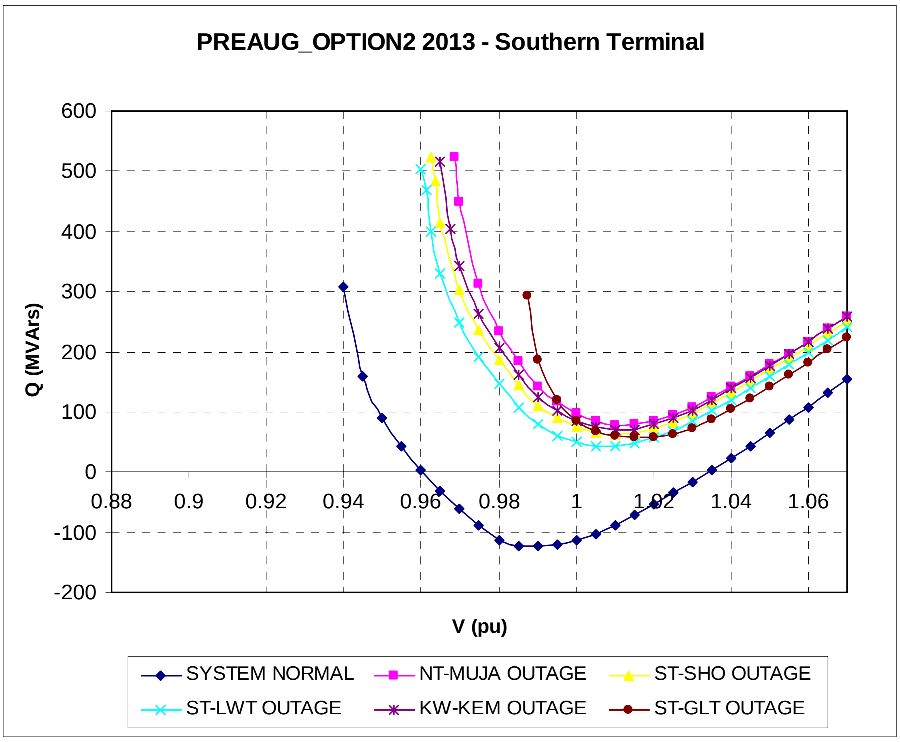

OPTION7 2016 - Southern Terminal
300
200
100
0
-100
-200
-300
-400
-500
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

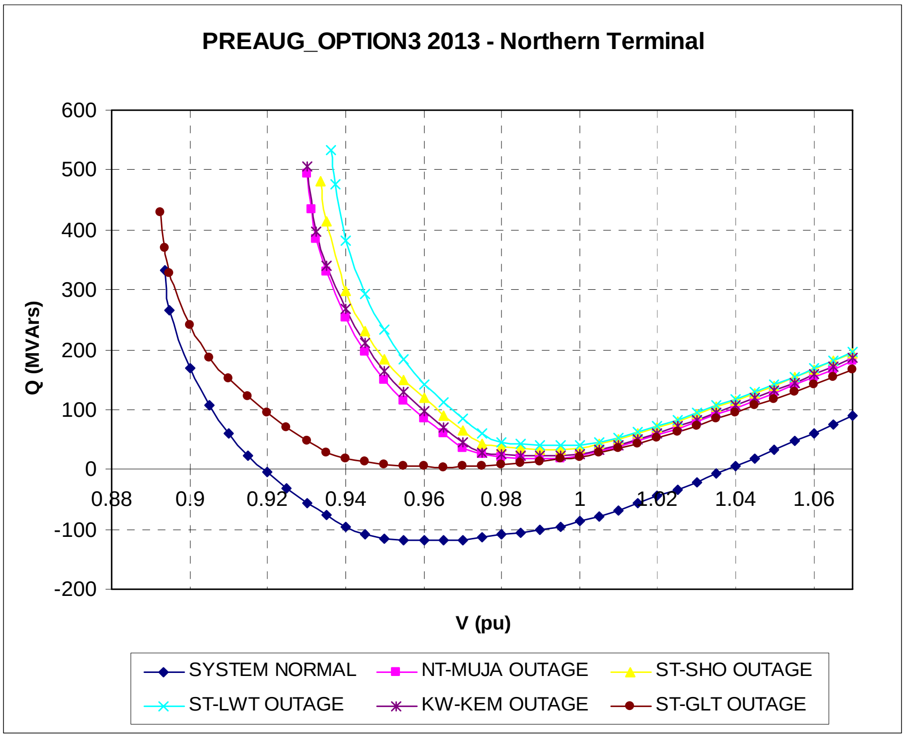
Pre-Augmentation Studies



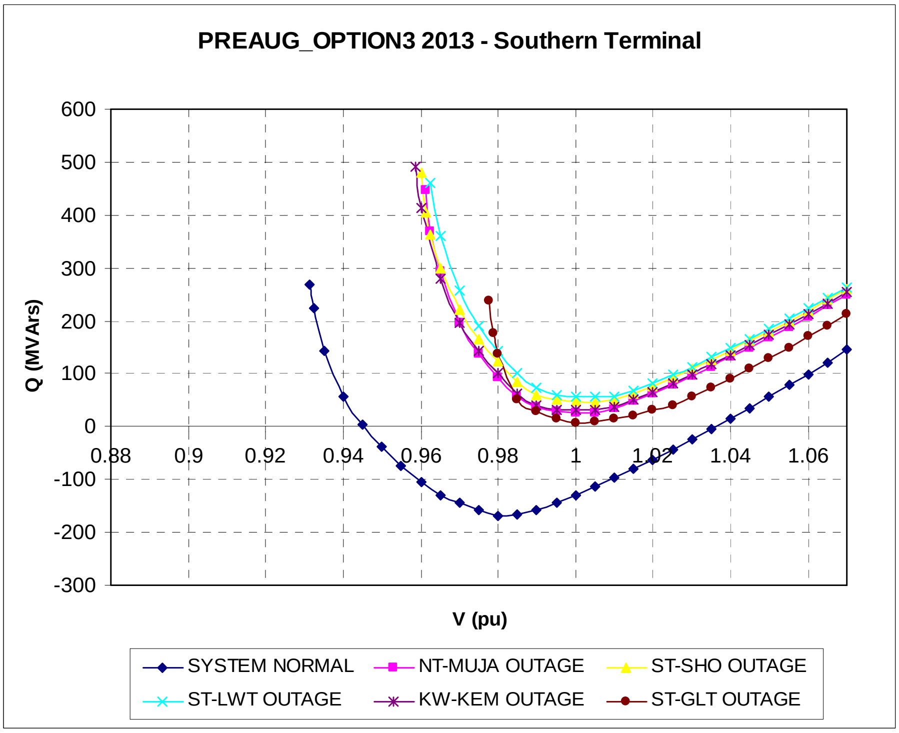



PREAUG_OPTION2 2013 - Northern Terminal
Q (MVArs)
V (pu)
700
600
500
400
300
200
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

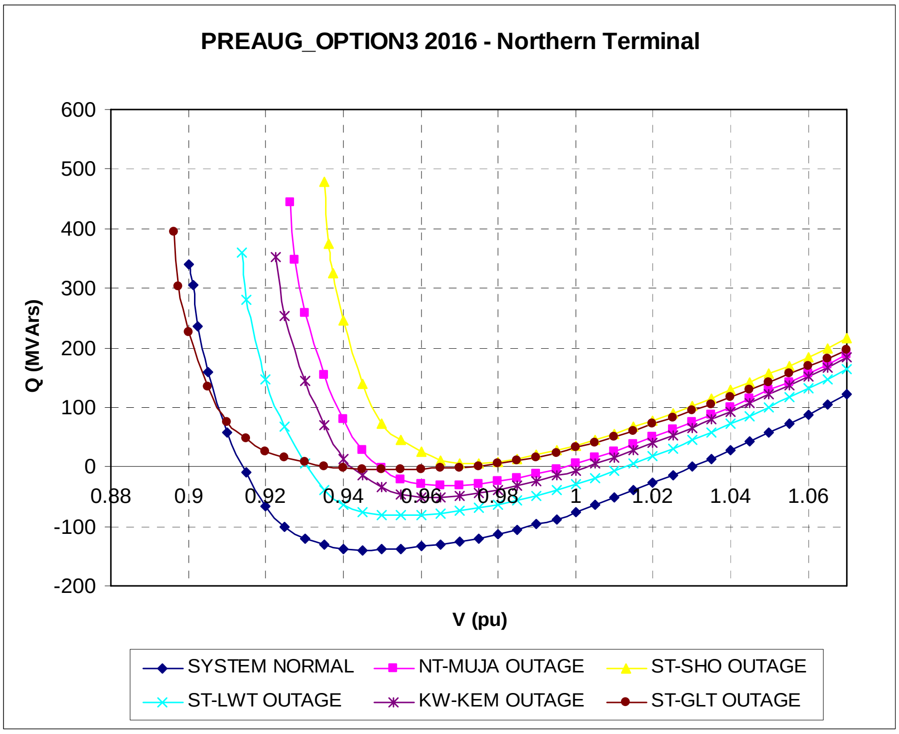

PREAUG_OPTION2 2013 - Southern Terminal
Q (MVArs)
V (pu)
600
500
400
300
200
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

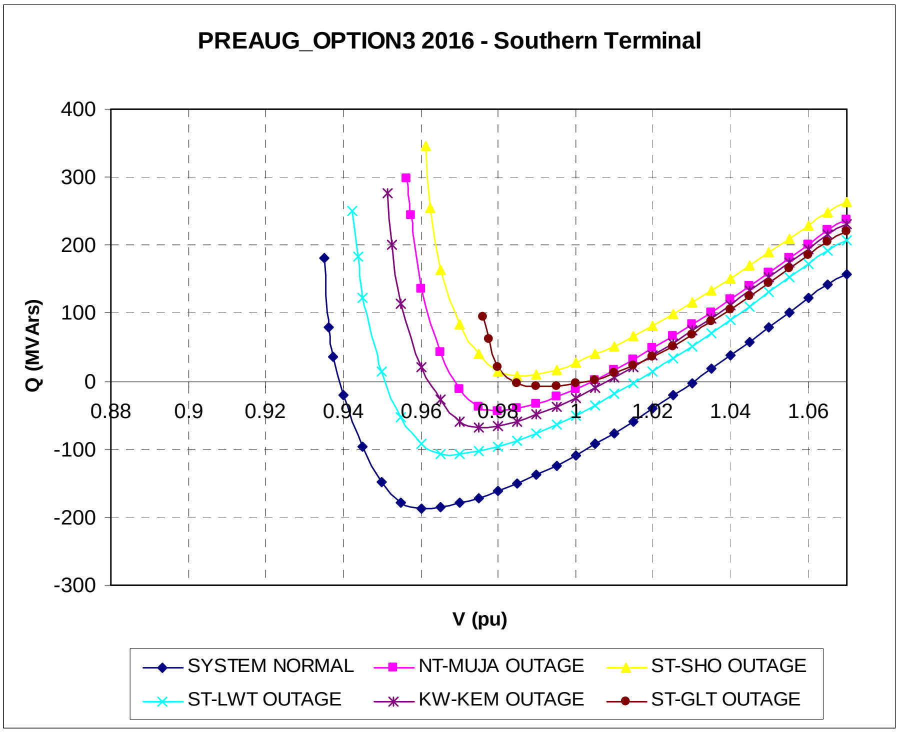


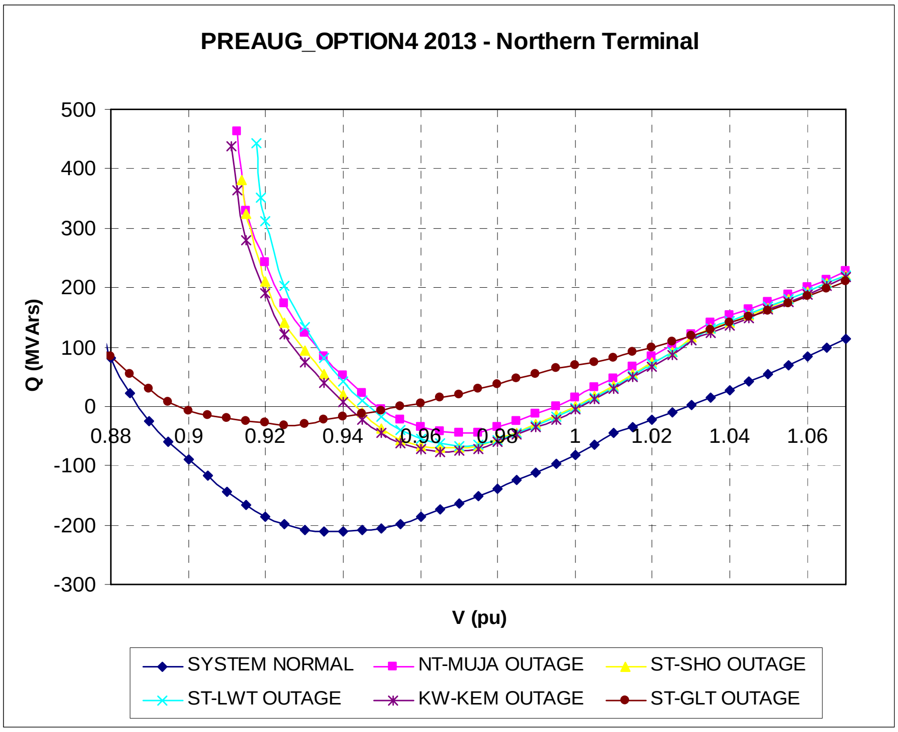
PREAUG_OPTION3 2013 - Northern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

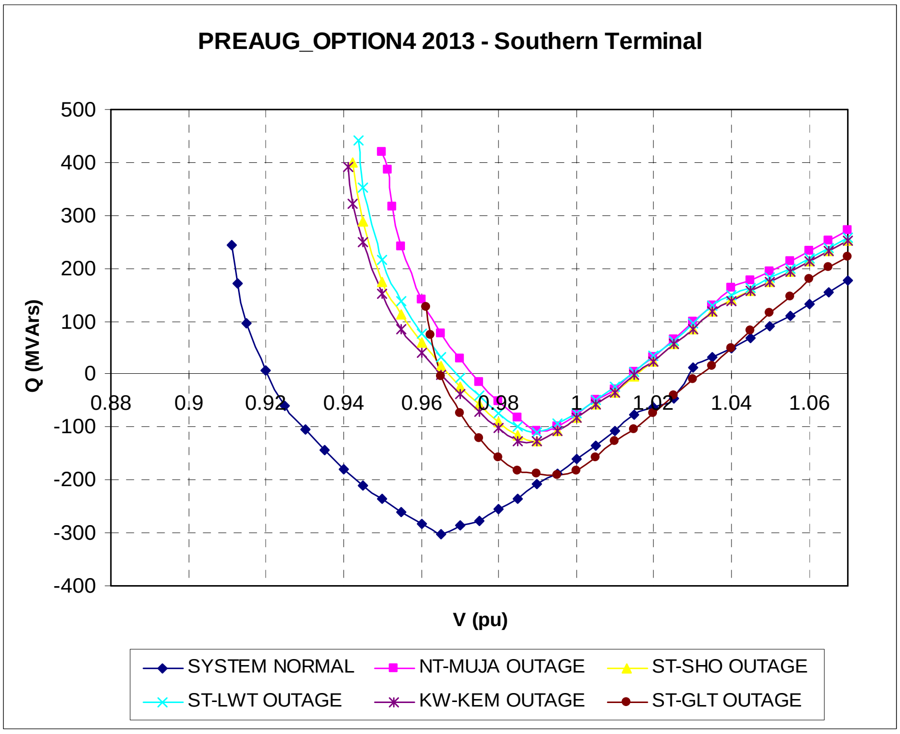


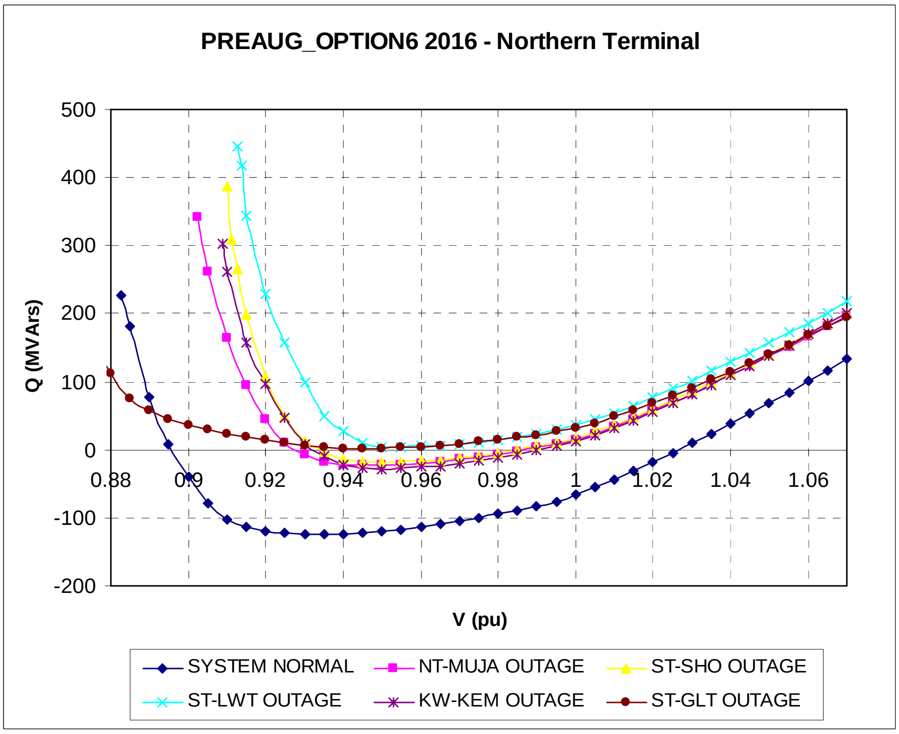
PREAUG_OPTION3 2013 - Southern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE

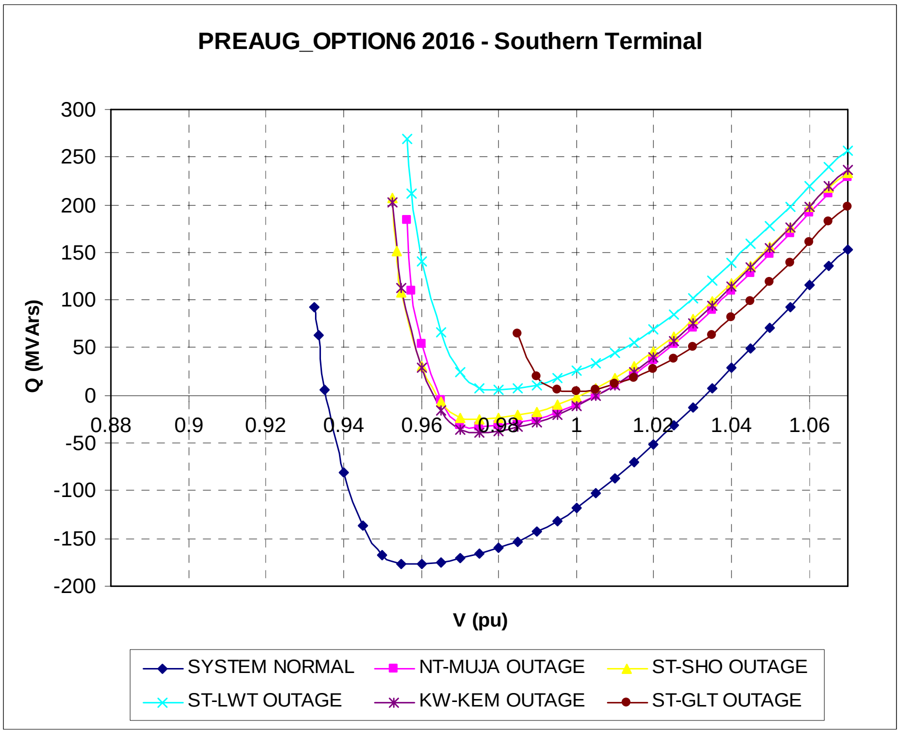

PREAUG_OPTION3 2016 - Northern Terminal
600
500
400
300
200
100
0
-100
-200
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


PREAUG_OPTION3 2016 - Southern Terminal
400
300
200
100
0
-100
-200
-300
Q (MVArs)
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


PREAUG_OPTION4 2013 - Northern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


PREAUG_OPTION4 2013 - Southern Terminal
Q (MVArs)
V (pu)
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


PREAUG_OPTION6 2016 - Northern Terminal
Q (MVArs)
V (pu)
500
400
300
200
100
0
-100
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE


PREAUG_OPTION6 2016 - Southern Terminal
Q (MVArs)
V (pu)
300
250
200
150
100
50
0
-50
-100
-150
-200
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
SYSTEM NORMAL
NT-MUJA OUTAGE
ST-SHO OUTAGE
ST-LWT OUTAGE
KW-KEM OUTAGE
ST-GLT OUTAGE