SA ENERGY TRANSFORMATION RIT-T

Special Protection Scheme

22 May 2019

Revision Record

Date	Version	Description	Author	Checked By	Approved By
17 May 2019	1.0	Report submitted to the AER	V Dayal	T Fretwell S Appleby R Korte	R Korte
22 May 2019	1.1	Minor clarifications following feedback from the AER	V Dayal	H Klingenberg	R Korte

Contents

This page is intentionally blank

1. Introduction

ElectraNet published the SA Energy Transformation (SAET) Regulatory Investment Test for Transmission (RIT-T) Project Assessment Conclusions Report (PACR) on 13 February 2019.

The key finding of the PACR is that a new 330 kV interconnector between Robertstown in South Australia and Wagga Wagga via Buronga in New South Wales, with an added link from Buronga to Red Cliffs in north west Victoria, would deliver substantial economic benefits to customers and the broader Australian economy as soon as it can be implemented.

On 15 February the Australian Energy Regulator (AER) received a dispute notice from the South Australian Council of Social Service (SACOSS) contending that the PACR provides little detail about the operation of the Special Protection Scheme (SPS) proposed to detect and manage system security risks associated with the loss of the Heywood interconnector and/or the proposed new South Australia to New South Wales interconnector (Project EnergyConnect).

SACOSS is concerned that the modelled market benefits are based on combined interconnector capacities that are not achievable if the SPS does not work as intended.

The purpose of this report is to provide a high level overview of the concept level design of the SPS and how this has been developed, and thereby provide greater assurance to the AER and other stakeholders that the proposed SPS can operate as intended and support realisation of the forecast market benefits of Project EnergyConnect.

2. Need for a Special Protection Scheme (SPS)

Project EnergyConnect would result in two parallel high capacity AC interconnectors from South Australia with the other being the existing Heywood interconnector between South Australia and Victoria.

This introduces the risk that, for a non-credible loss of either of the two double circuit interconnectors under high power transfer conditions, the other interconnector could overload, cause instability and result in separation of South Australia from the NEM and a potential widespread loss of supply.

The loss of a double circuit interconnector is a very low probability event and is considered to be a non-credible contingency under the National Electricity Rules.

However, consistent with good electricity industry practice prudent measures are planned to mitigate the risk and impact of this high impact low probability event occurring.

The SPS is designed to achieve this objective.

3. Design basis for new interconnector

The technical system design objective for all interconnector options considered in the SA Energy Transformation RIT-T was to ensure that for a non-credible loss of either of the two double circuit interconnectors (existing or proposed), the remaining interconnector will remain connected and keep the system securely connected to the NEM.

Typically, power systems and power transfer capability are planned for credible contingency events (N-1) and operated to the corresponding limits. In the case of the proposed new interconnector, the combined nominal transfer capability of the new interconnector and Heywood interconnector for credible contingencies is +/-1550 MW, as shown in the table below.

Considering the system security objective to protect against the non-credible loss of either of the double circuit interconnectors reduces this combined transfer capability.

Interconnector	Nominal Limit	Nominal Combined Limit	Applied Combined Limit in the PACR
Heywood	+/- 750 MW	**+/- 1550 MW**	**+1300/-1450 MW**
Proposed SA to NSW	+/- 800 MW		

+ Import into SA; - Export from SA

This means that the available combined capability of the two interconnectors has been reduced by 250 MW for import into South Australia and 100 MW for export from South Australia to manage system security.

On detection of loss of either of the double circuit interconnectors, the following actions will be taken to keep system parameters (primarily rotor angles and voltages) within limits:

- While importing into South Australia, battery systems will be rapidly discharged and targeted load shedding initiated, as required, to balance supply and demand
- While exporting from South Australia, generation plant will be rapidly tripped as required to balance supply and demand

The following maximum quantities of battery action and load shedding support the combined interconnector transfer capability set out above and in the RIT-T modelling.

Direction	Load/Generation shed limit	BESS discharge capability
Import into SA	400 MW load	100 MW
Export from SA	500 MW generation	Not applicable

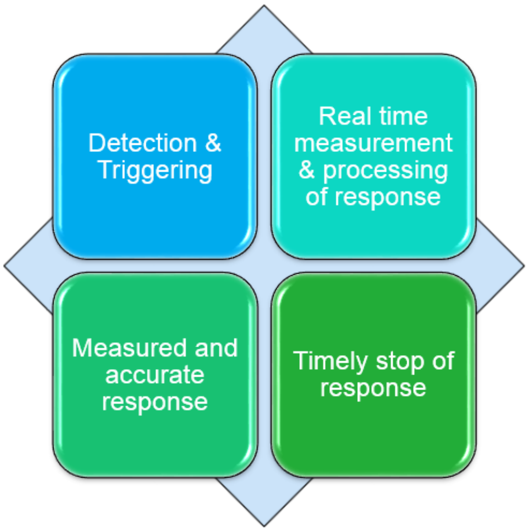
Further studies to be undertaken during the detailed design of the SPS will consider the availability of additional BESS, which would reduce the amount of load shedding required.

4. Design concepts and feasibility studies

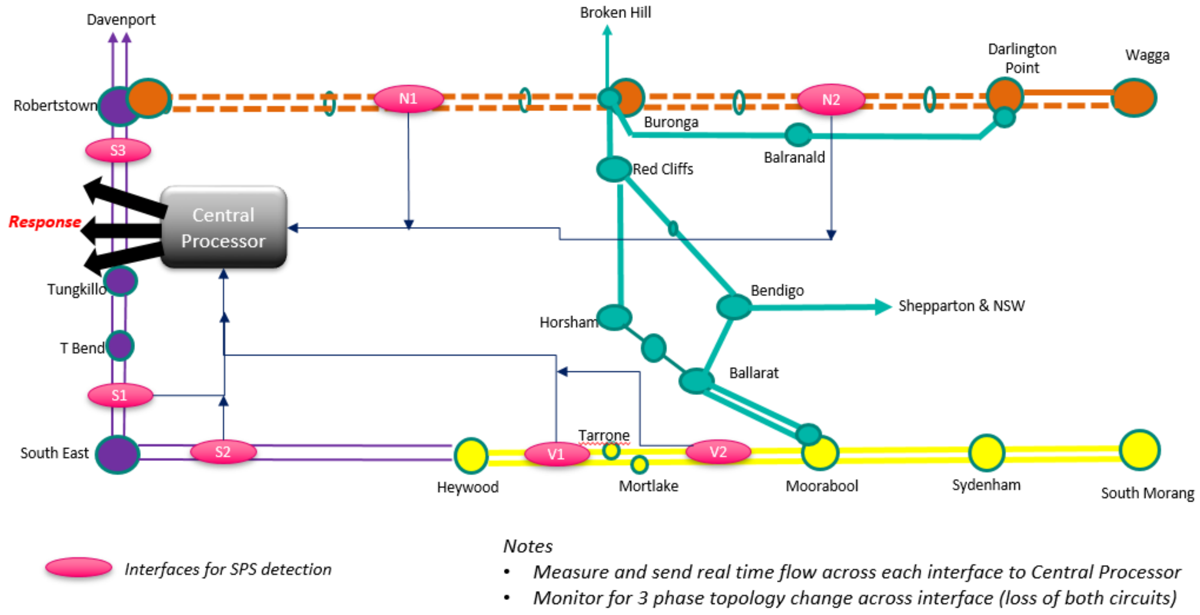
ElectraNet developed design concepts and performed feasibility studies for the SPS as described in the following sections.

4.1 Design concept

The design of the SPS is based on the following broad aspects, which are described further below.

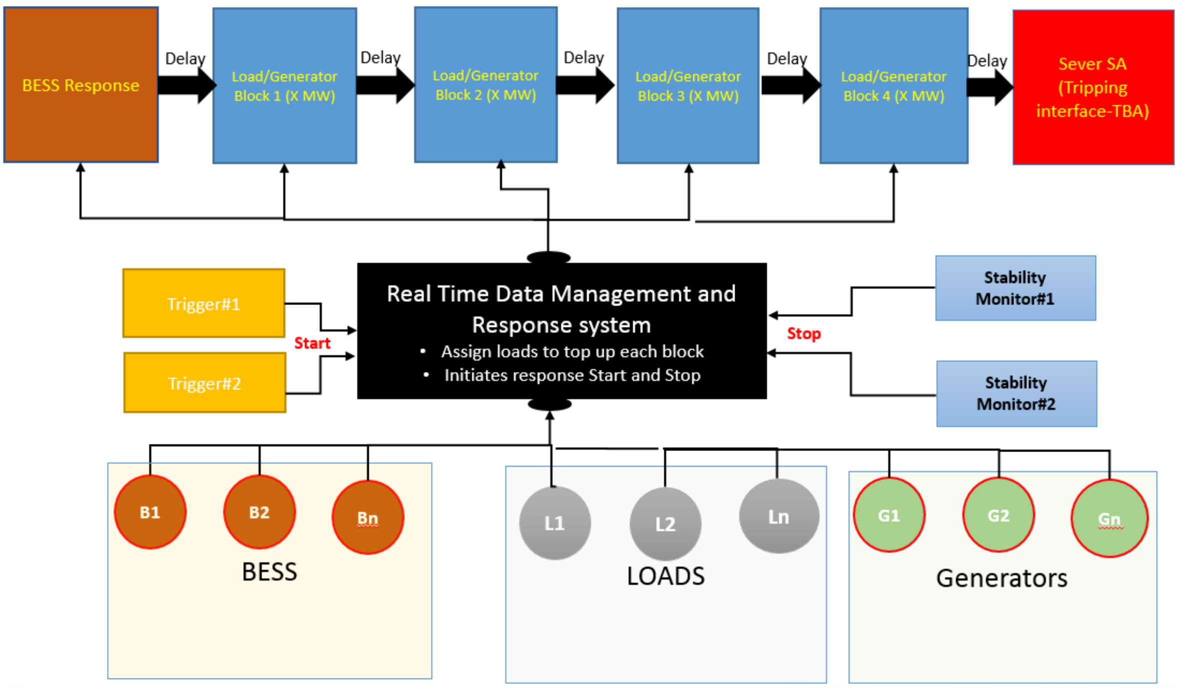


The following figure illustrates the broad design concepts and scope of the SPS, including the sections of the two interconnector corridors that need to be monitored for detecting the loss of interconnection.



The sections are those that have double circuit transmission lines with common failure modes (e.g. collapse of a tower). The detection of loss of the transmission line section and the amount of power lost is sent to a central processor as shown, for processing and response.

The figure below shows the design concept of the scheme for action on receiving signals indicating loss of an interconnector. A key principle is to trigger the BESS first and trigger the load shedding as required.



The real time data management and response system has the following functions:

- Collect real time data of the response elements – loads, generators and BESS;
- In real time, assign adequate response elements for each BESS and load block (block sizes will be optimised during detailed design);
- Scan for event detection trigger including the extent of response required for the event;
- On start trigger, send signals to ensure adequate response is obtained to rebalance supply and demand and manage system security; and
- On stop trigger, send stop signals to BESS and any further signals for additional generation or load tripping.

4.1.1 Detection and triggering mechanisms

A number of event detection methods will be considered and the most optimal and reliable trigger will be implemented. These triggers methods include:

- Topology based – detect breaker status and measured active power flow across open sections;
- Interface flow – detect the opening of circuits by measuring the active power flow rapidly changing to zero (ensuring that zero dispatch of the interconnector is blocked);
- Inter-regional angle deviation – use a synchro-phasor based triggering mechanism which detects loss of interconnection by measuring angle deviation changes between two or multiple regions; and
- Combinations of the above.

4.1.2 Response portfolio and selection criteria

An absolute minimum of 1300 MW of South Australian system demand is required to import 1300 MW from the two interconnectors (with zero generation in SA). There is also a near linear relationship between the level of combined interconnector transfers and the extent of SPS response required.

For example, if interconnector transfer is 1000 MW import into South Australia, then 200 MW of load shedding would be required to supplement 100 MW of BESS response, for loss of the Heywood interconnector. For combined transfer limits of 800 MW or less, no action will be required from the SPS.

Some of the included connection points may not provide sufficient load shedding response depending on time of day due to significant embedded solar PV generation. Therefore, the SPS will have a diverse portfolio of response elements available at all times.

Again, the frequency of events that would lead to SPS action is very rare with:

Probability of SPS action = (Probability of loss of double circuit interconnection
x Probability that the transfer during that time is high enough to require SPS action)

Key criteria for development of the response portfolio include:

- A sufficient sized portfolio based on historical and forecast load and generation data;
- Individual load block size;
- Effectiveness – certain locations in the system can be more effective as they can also reduce system losses and better manage system parameters;
- Availability of a reliable and high speed communication system from the detection point;
- Avoiding sensitive and critical loads;
- Ease of disconnection and restoration (e.g. 30 minutes to 1 hour restoration time is preferred);
- Generator portfolio will be based on generators that would typically be operating during high export conditions; and
- BESS participation will be based on factors such as size, reserved capacity and its location in relation to the intact interconnector.

Details of the actual loads, generators and BESS that will participate in the response portfolio will be developed during the detailed design of the SPS.

However, at this stage, sufficient BESS and load shedding capability has been identified to meet the minimum requirements of the scheme.

4.1.3 Response time

Feasibility studies have used an SPS response time of 370 ms from fault inception.

This response time will be optimised during detailed design and implementation of the SPS.

The response time is dependent on a number of factors, including:

- Maximum response time allowable to maintain system stability;
- Detection time;
- Hardware processing delays; and
- Communication propagation delays.

The availability of reliable high speed communications from the central processor to both the detection and response locations will be considered in the design of the SPS to provide the fastest response practically possible.

The end-to-end communication latency for ElectraNet's communication network is currently no more than 30 ms.

4.2 Feasibility studies

The SPS objective is that for a non-credible loss of either the existing Heywood or new interconnector, the remaining interconnector will continue to operate with the South Australian power system connected to the NEM and in a secure operating state.

Feasibility studies have been undertaken that test whether this objective is achieved with the power system starting from a secure operating state. That is, the already non-credible loss of a double circuit interconnector is assumed not to be preceded by any other event.

4.2.1 Study methodology

The study methodology included making up to 400 MW of load and 100 MW of BESS injection available to respond to the double circuit loss of an interconnector under maximum combined import to South Australia.

Up to 500 MW of generation tripping was made available for loss of an interconnector while exporting from South Australia.

An SPS response time of 370 ms was used in the studies for load/ generation shedding and the BESS response to be completed following loss of an interconnector (fault inception) and includes a total fault clearing time of 120 ms.

Studies were undertaken using PSS/E power system simulation software for a range of system operating conditions.

Transient and voltage stability were assessed for the non-credible loss of either interconnector. All technical parameters such as voltages, frequency and machine angles were checked to ensure that the post SPS action power system remains stable and secure.

4.2.2 Study results

Study outcomes are shown below for the non-credible loss of one of the double circuit interconnectors under a range of system operating conditions, both importing and exporting power from South Australia.

The charts on the following pages include:

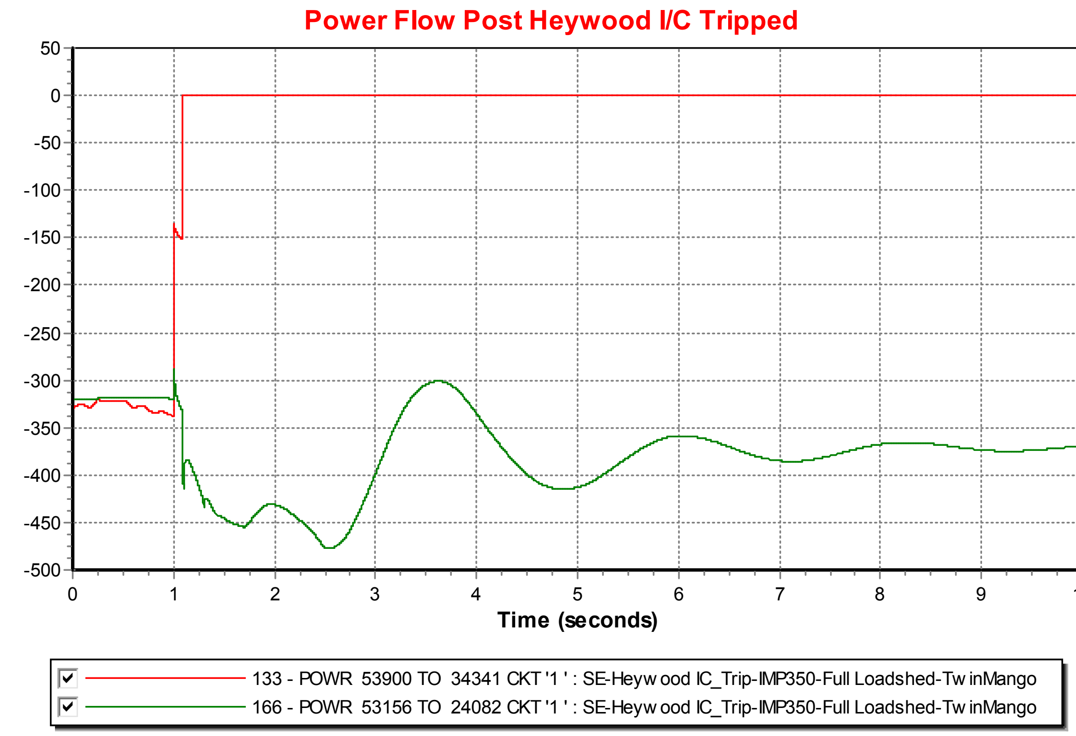
- A description of the case with level of SA demand, level of combined import and the amount of load shed, in the title
- The subtitle shows which interconnector was tripped (with the flow on this interconnector going to 0)
- The trajectory of power flow on the remaining interconnector shows slow oscillations and settling (indicating that the system is stable and secure)
- The second chart on the page shows voltage trajectories at key nodes on the interconnector corridor showing that it has settled to acceptable levels

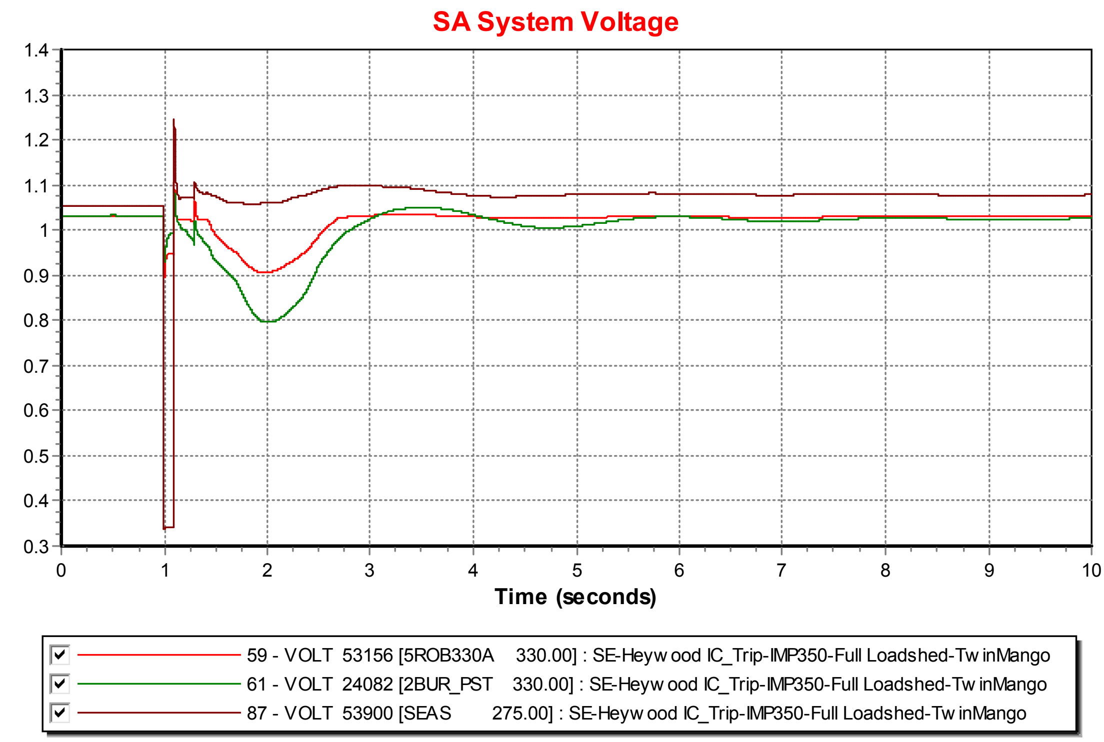
All plots shown indicate that the system is stable and secure following SPS action responding to a trip of either the Heywood or new interconnector.

Chart notes:

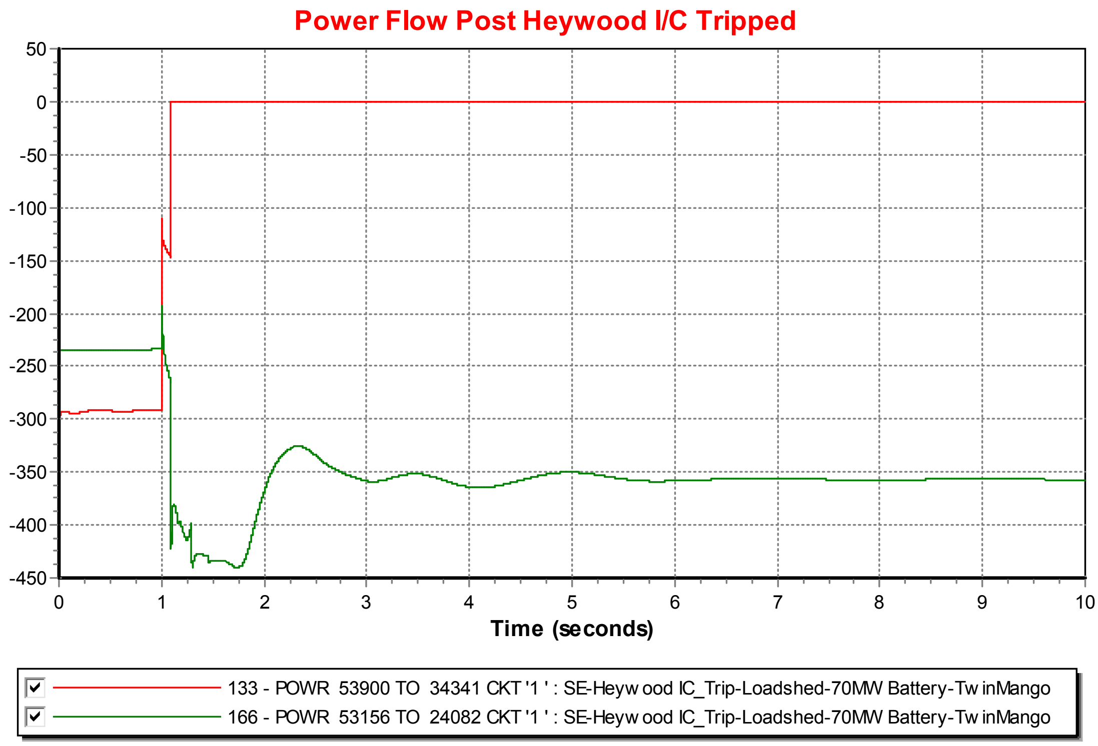
- The power flow chart Y-axis units are MW and indicate the flow on each circuit of the interconnector - this value needs to be doubled to give total flow across the interconnector corridor.
- The system voltage chart Y-axis units are “per unit”; i.e. 1 per unit is 330 kV for 330 kV equipment.

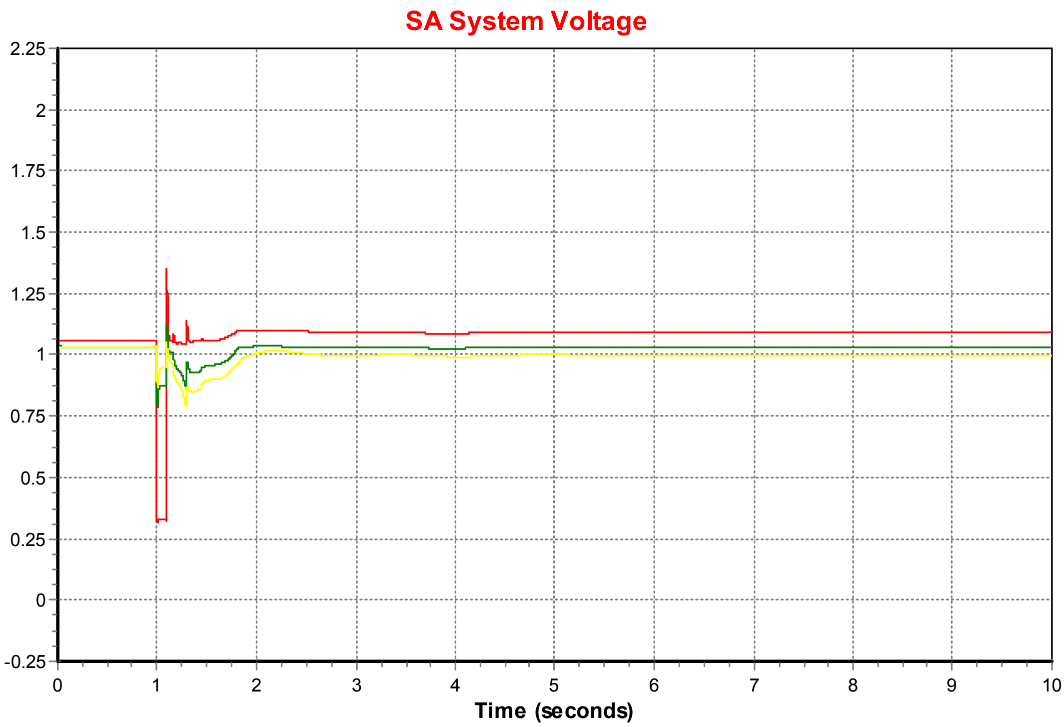
Case 1 - 2800 Demand combined import of 1300 MW with 350 MW load shed



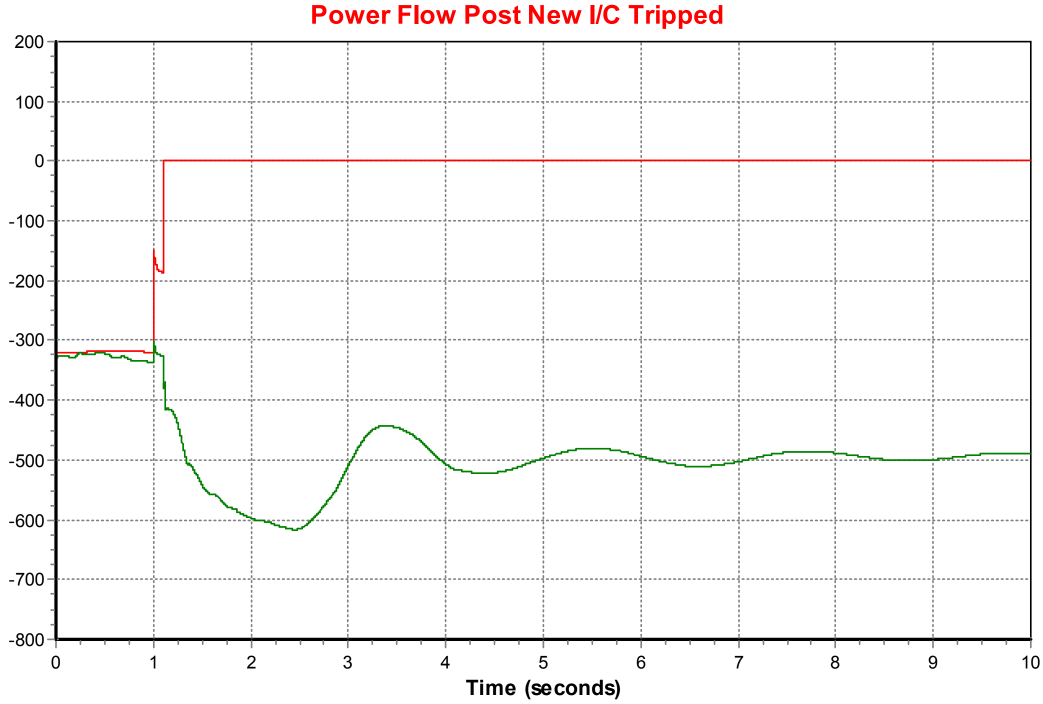


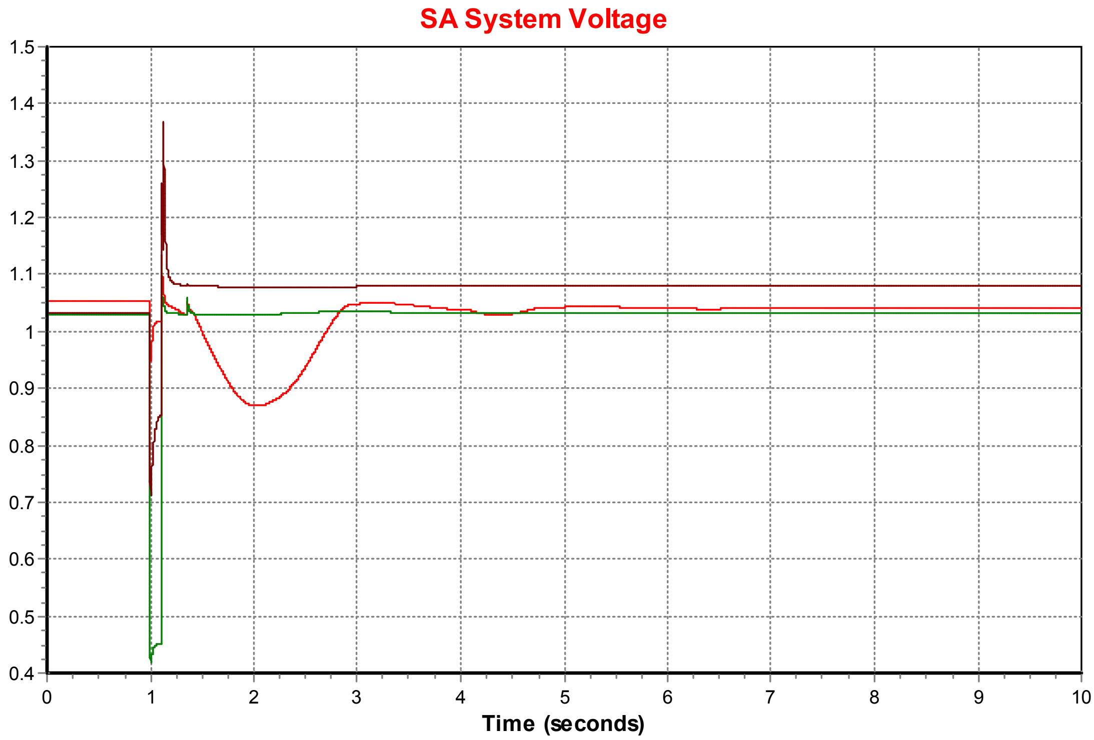
Case 2 - 1500 demand combined import of 1100 MW with 350 MW load shed



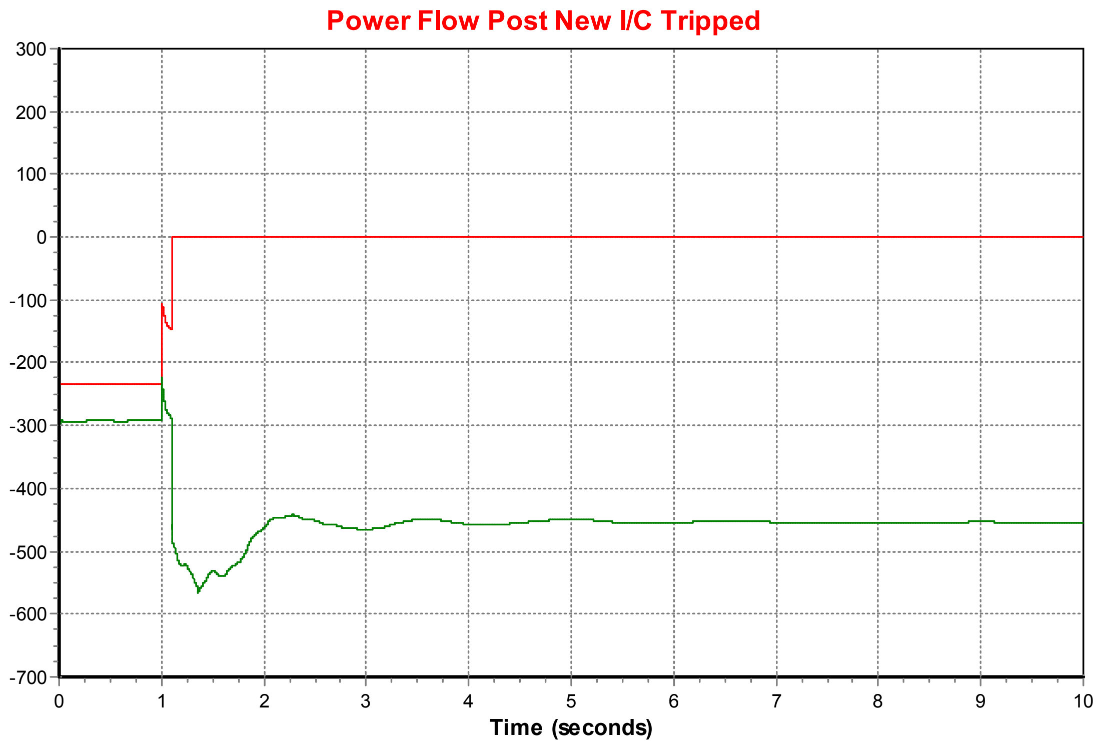


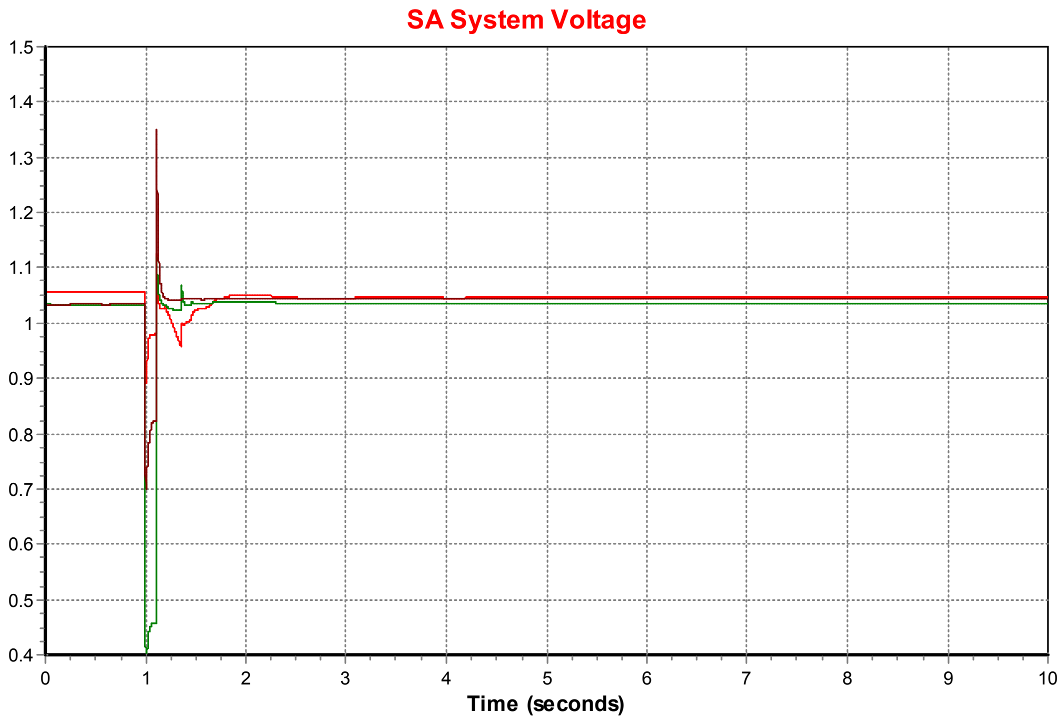
Case 3 - 2800 demand combined import of 1300 MW with 350 MW load shed



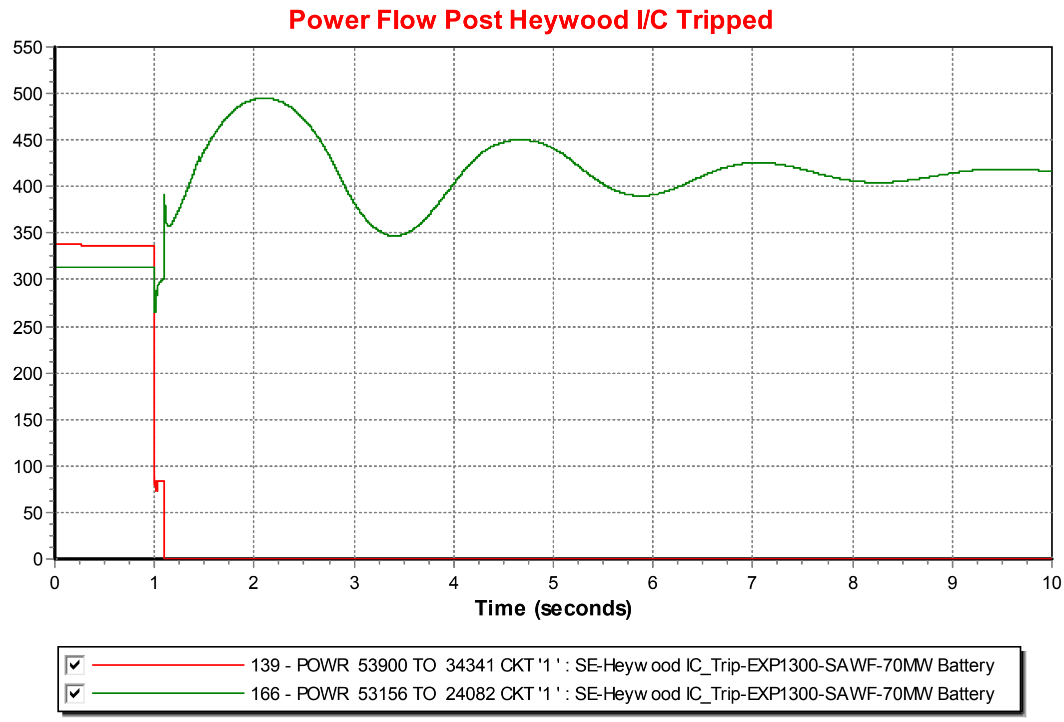


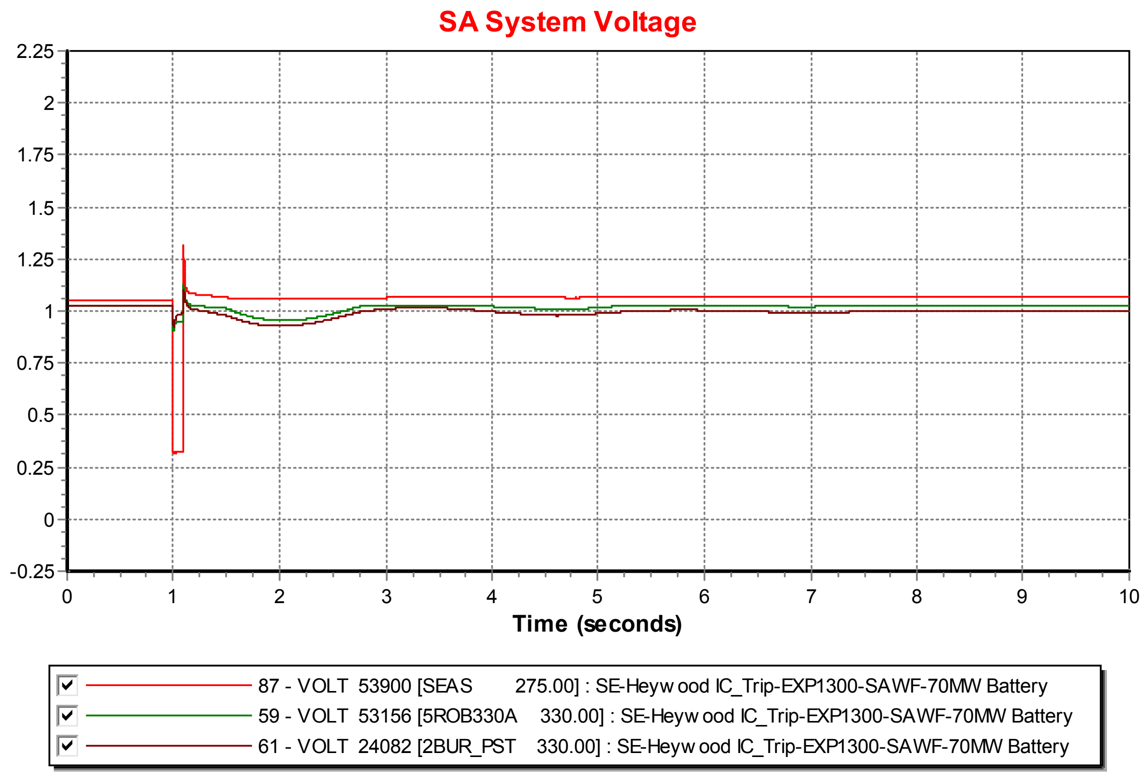
Case 4 - 1500 demand combined import 1100 MW with 350 MW load shed



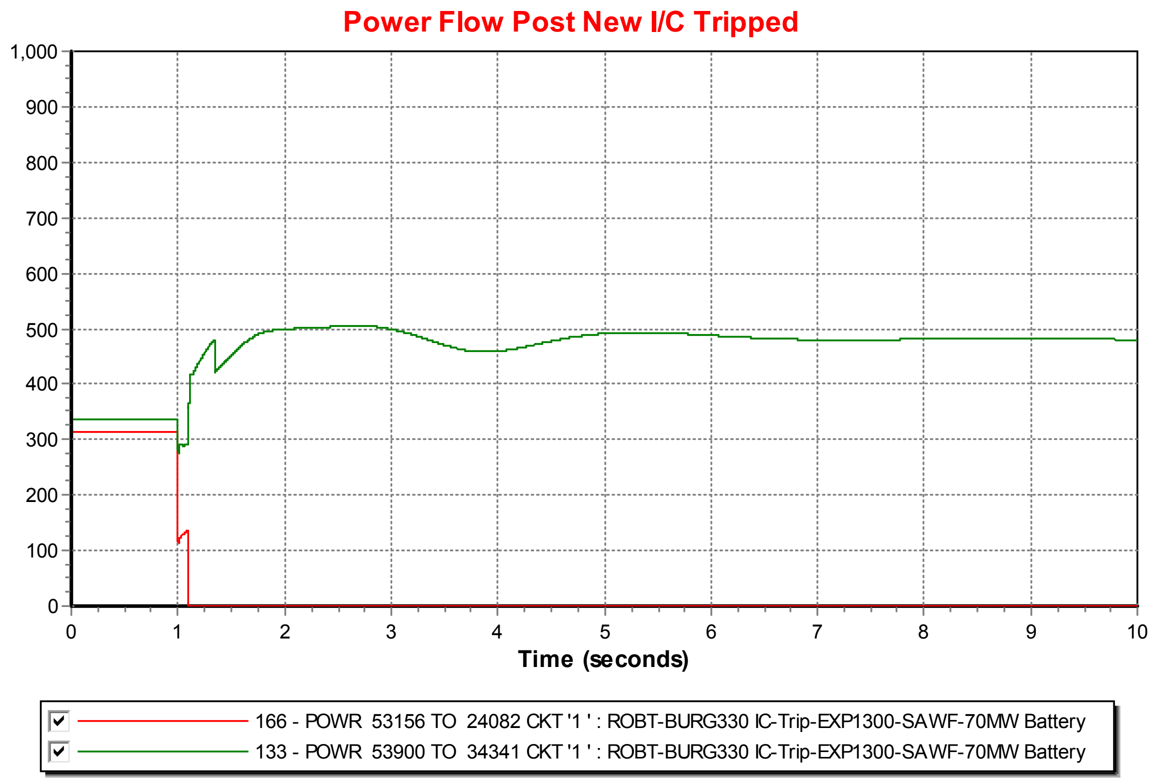


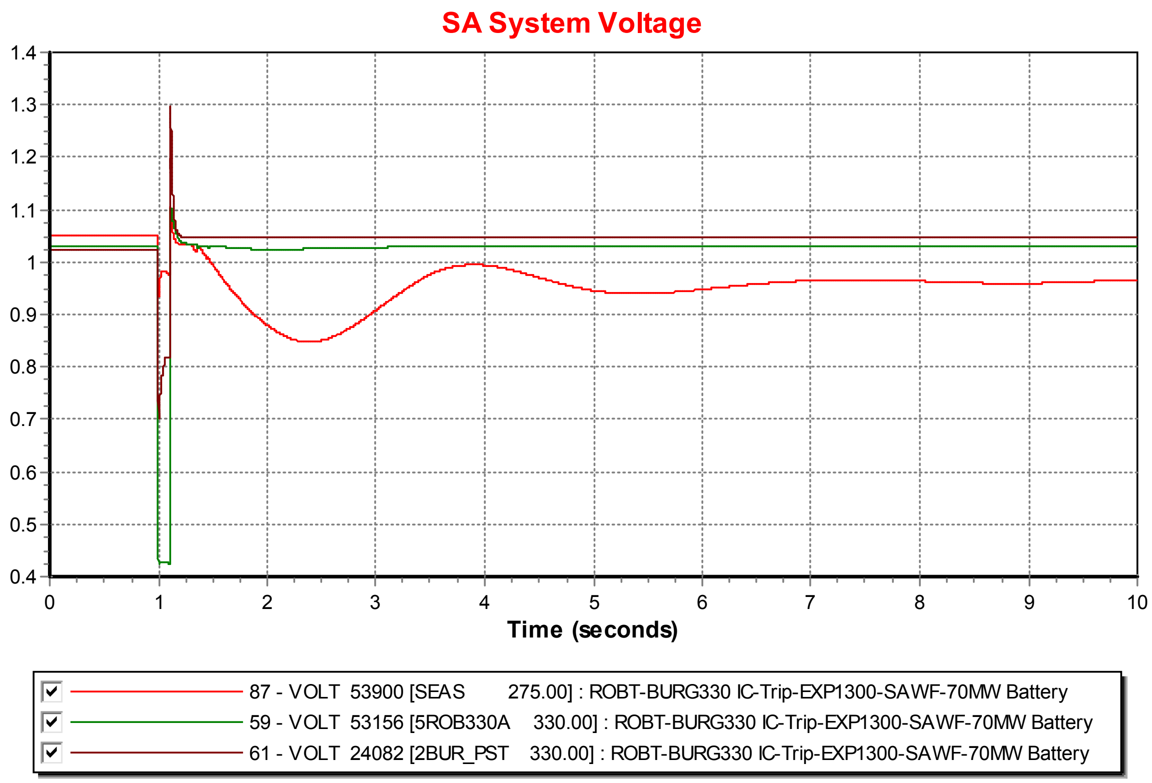
Case 5 - 500 demand combined export of 1300 tripping ~400 MW Wind Generators





Case 6 - 1500 demand combined export of 1300 MW tripping ~400 MW Wind Generators





4.3 Robustness and Reliability

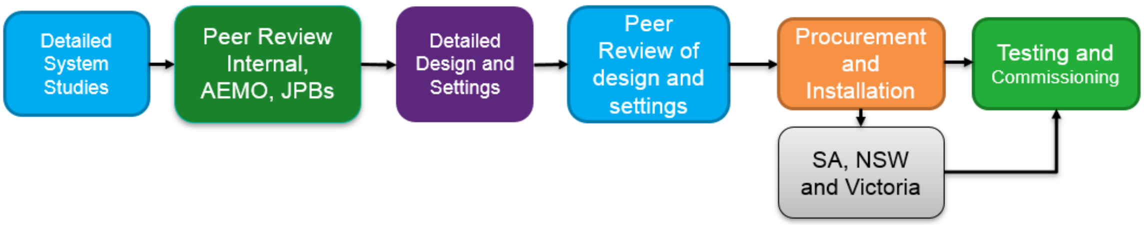
The following design principles will be applied to ensure robust performance of the SPS:

- To provide a high level of dependability the SPS shall comprise of redundant, substation hardened hardware platforms – no single failure shall prevent the SPS from operating when it is required to do so;
- To provide a high level of security the SPS shall comprise of two independent detection devices, configured in a two-out-of-two detection logic – no single failure shall cause the SPS to operate when it is not required to do so;
- The SPS shall communicate over redundant and diverse communication paths, which will be continuously monitored;
- The hardware deployed in the SPS will incorporate a high level of supervisory and diagnostic functions to provide a remote indication of any failure;
- In the event of an outage of the SPS for maintenance or other reasons, the combined interconnector limits would be reduced accordingly;
- The SPS will initiate an appropriate response based on the amount of MW lost due to loss of an interconnector;
- Real time measurement and processing of loads and batteries in the response portfolio will ensure that adequate and timely response is always available – response from batteries will be prioritised over load shedding and load shedding will be pre-selected based on how much load needs to be shed at the time; and
- The SPS will be designed to operate for all foreseeable prevailing network conditions including during network outages along the interconnector corridors and will be capable of expansion to include additional resources (e.g. new BESS) as they become available.

4.4 Detailed design and implementation

Based on the preliminary concepts and design principles, detailed design will be undertaken following regulatory approval of the new interconnector.

The figure below illustrates the tranches of work that will be required:



To avoid the risk of failure of any specific trigger mechanism, multiple trigger (and response) methods will be assessed simultaneously and the most optimal solution chosen.

It is expected that an independent expert consultant will be involved in peer review of the scheme during the development phase.

4.5 Stakeholder engagement

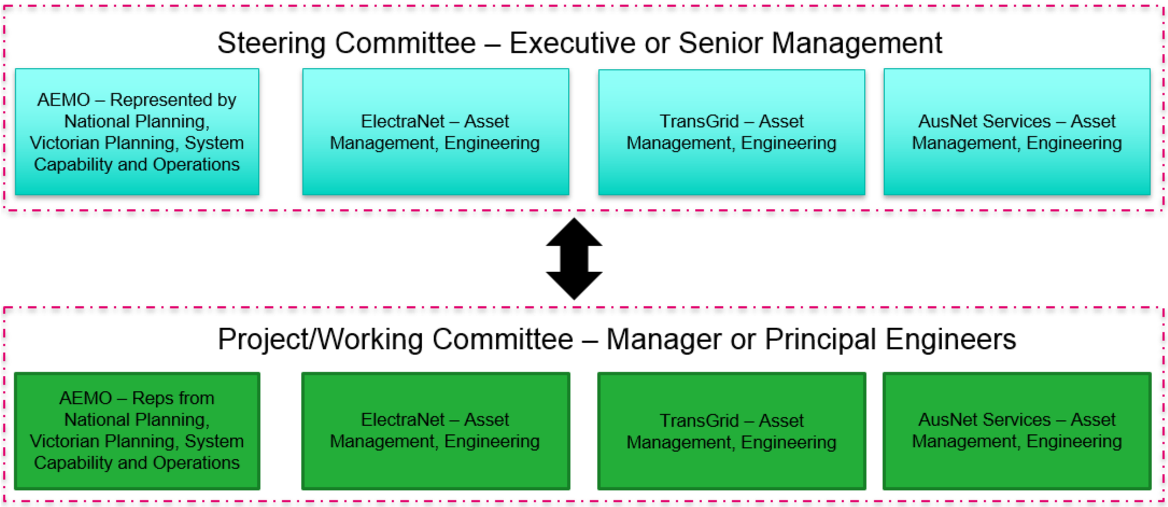
To date the SPS design principles and high level concept design have been developed in consultation with AEMO and TransGrid.

ElectraNet has also engaged with the Office of the Technical Regulator (OTR) and SA Power Networks in developing the System Integrity Protection Scheme (SIPS) that is currently operational in South Australia and will form the basis for developing the SPS load and its response portfolio.

Detailed design of the SPS will include further appropriate engagement with the relevant stakeholders, including AEMO, TransGrid, AusNet Services, OTR, SA government and SA Power Networks to ensure that the SPS is effectively designed and implemented and that the assumed interconnector transfer capacity is operationally released to the market following its commissioning.

4.6 Governance and approval framework

ElectraNet proposes the following indicative governance and approval framework involving all relevant stakeholders for the project, to ensure that the project is progressed with the approval of stakeholders at various stages of its development and commissioning.



4.7 Implementation timeframe

Based on recent experience, ElectraNet is confident that the SPS can be developed, designed and implemented in less than 30 months, well ahead of the proposed commissioning date for the interconnector.

5. ElectraNet experience with Special Protection Schemes

The following section describes ElectraNet's experience in developing and implementing special protection schemes and also provides guidance on how the learnings from this will be leveraged in developing the SPS.

5.1 System Integrity Protection Scheme (SIPS)

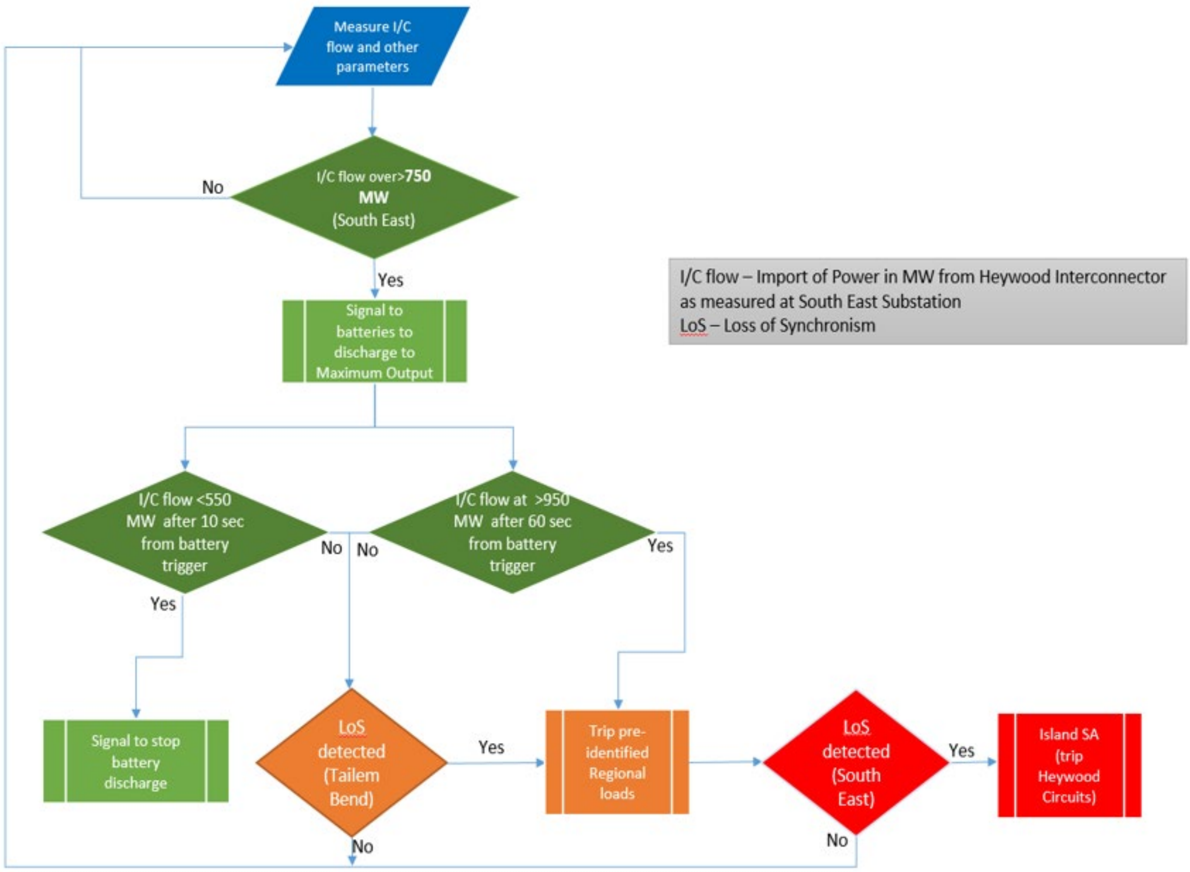
Following the South Australia system black event in September 2016 and AEMO's recommendations that followed, ElectraNet in consultation with AEMO developed a SIPS that is designed to detect multiple generation loss in South Australia and respond appropriately to prevent separation of the South Australian power system from the NEM.

The SIPS was commissioned in December 2017 (with the BESS component of the scheme commissioned in December 2018).

5.1.1 Design basis

The SIPS is based on first triggering BESS response followed by load shedding as required. For certain events, load shedding can be avoided as BESS response is sufficient.

The design of the SIPS is shown schematically in the following figure.



ElectraNet
electranet.com.au

Note: The trigger for battery response and load shedding are independent. “<550 MW” was selected as a stable system state threshold for sending a battery stop response signal, allowing for a 10 second settling time. “>950 MW” is an additional last resort trigger for load shedding, which will only trigger if the LoS trigger does not trigger earlier. It is an extra layer of protection in case the LoS trigger for load shedding is either delayed or does not operate for any reason, noting that at 950 MW transfer immediate action would be required to protect the system based on historical operating experience. It’s important to understand that the initiation of the LoS trigger is also dependent on the nature of the event (e.g. amount of generation lost, delay between multiple events).

5.1.2 Load shedding portfolio

A SIPS requirement for about 200 MW of load shedding to be available was assessed based on available power system data.

A load selection process (described previously) was developed to identify the loads that are suitable for the SPS. The final loads that were selected included nine transmission connected loads in regional South Australia which can provide a response in the range of 170 to 250 MW.

The SIPS does not have load selectivity capability and therefore all the loads are hardwired to trip at the same time, on receiving a signal from the SIPS. However, as discussed earlier, the interconnector SPS will allow for load selectivity to provide a more proportionate response to system events.

5.1.3 Operating times

The SIPS is based on obtaining the maximum BESS response in about 500 ms from detection and load shedding in under 100 ms from detection. The BESS total response time is longer due to the inherent characteristics of the BESS controllers.

However, the BESS trigger is significantly earlier than the load shedding trigger and therefore despite the longer response time, BESS action is typically completed before the load shedding trigger is initiated. This provides the desired discrimination between BESS and load response, which means where possible load shedding will be avoided due to sufficient response coming from the BESS.

5.1.4 Engagement with stakeholders

There was significant stakeholder engagement undertaken in developing and implementing the SIPS, including with:

- AEMO – Consultation during development, study and settings and in developing the Emergency Frequency Control Scheme (EFCS) Setting Schedule;
- SA Power Networks and ElectraNet planners and operators – Load selection criteria and historical data review; and
- OTR and SA government – approval of load shedding schedule.

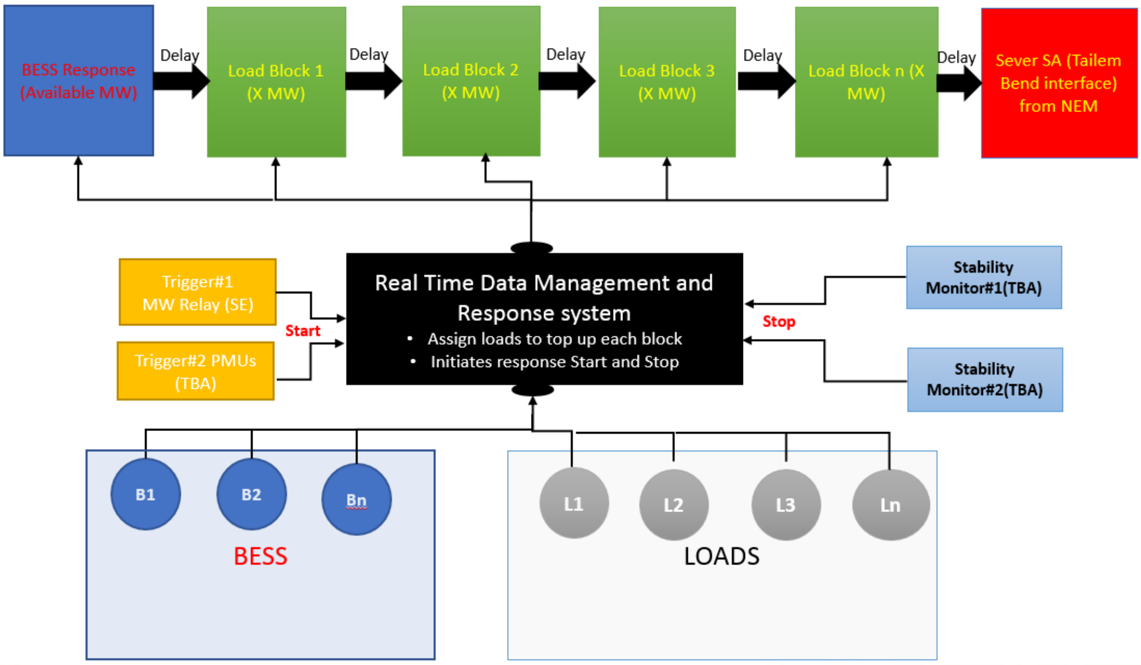
5.2 Wide Area Protection Scheme (WAPS)

AEMO, in its Power System Frequency Risk Review (PSFRR) June 2018, recommended that an augmentation to the SIPS be considered to further improve its performance.

In response, ElectraNet is developing a Wide Area Protection Scheme (WAPS) in consultation with AEMO and this is discussed in the following subsections.

5.2.1 Development and design concepts

Based on areas for improvement identified, ElectraNet has developed the indicative WAPS concept shown below.



Due to the real-time monitoring and pre-processing of response information, when an event occurs, rapid and appropriate response will ensure that the system returns to a new secure state to avoid the risk of interconnector tripping.

This scheme will utilise the available communication network and dedicated hardware to detect and process the response.

The WAPS project is subject to further development during detailed design.

ElectraNet
electranet.com.au

5.2.2 Detection and Triggering

In consultation with AEMO, ElectraNet is trialling the use of synchro-phasors or Phasor Measurement Units (PMUs) as a means to trigger the WAPS.

In relation to this, ElectraNet is implementing a pilot PMU project to understand the applicability of the technology for the WAPS and for a future interconnector related SPS.

This is a potential improvement opportunity in the operation of the scheme and, as discussed earlier, the use of synchro-phasors is only one of many different detection methods which will be considered for implementation of the SPS.

6. Conclusion

ElectraNet is confident – based on the work undertaken so far and our recent experience in implementing a similar special protection scheme in South Australia – that the SPS can be successfully implemented to ensure assumed interconnector transfer capacities and forecast market benefits can be achieved for the proposed South Australia to New South Wales interconnector.

ElectraNet