



Department of
**Energy and Economic
Diversification**

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System security and reliability modelling methodology

Appendix F



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1. System security modelling methodology

1.1. Overview

For a relatively small islanded power system like the SWIS, it is crucial that system security is adequately modelled to ensure that the FESO model yields a power system that is practically operable and secure. The following system security elements are considered in the FESO:

- **Frequency co-optimised essential system services (FCESS):** the current five market services: regulation raise/lower reserve, contingency raise/lower reserve and RoCoF control service.
- **Network constraints:** representing the thermal and non-thermal limits of the transmission network.
- **System strength:** a subset of non-thermal limits that is represented in the FESO as the ability of the power system to maintain fault levels above a minimum threshold at each system strength node.

1.2. Approach

Frequency co-optimised essential system services

FCESS are co-optimised with energy in the dispatch modelling (PLEXOS ST Plan). Regulation Raise, Regulation Lower, Contingency Reserve Raise and Contingency Reserve Lower are each represented using the native PLEXOS Reserve class, with accredited facilities assigned to each Reserve. The model will optimise the trade-off between energy dispatch and FCESS enablement for each facility's capacity and must hold sufficient raise and lower capability to meet each FCESS requirement for a certain duration in every interval.

Regulation Raise and Regulation Lower

The Regulation Raise and Regulation Lower requirements are applied as minimum provision values set by season and time of day, informed by historical requirements. Existing facilities are assigned a maximum response in line with their current FCESS accreditation, while committed and candidate facilities are assigned a response based on AEMO's Frequency Co-optimised Essential System Services Accreditation WEM Procedure.

To meet the Regulation Raise requirement, the model must dispatch accredited facilities with enough headroom to cover the minimum provision. To meet the Regulation Lower requirement, accredited facilities must be dispatched at a level from which they can reduce output (or increase charging, in the case of storage) by the required amount.

Contingency Reserve Raise

The Contingency Reserve Raise requirement is applied as a minimum provision value set at the highest output of any single facility for each interval. Existing facilities are assigned a maximum response in line with their current accreditation and committed and candidate facilities are assigned a response based on AEMO's Frequency Co-optimised Essential System Services Accreditation WEM Procedure. The model must hold sufficient headroom across accredited

facilities to meet the requirement at all times. No single facility may be enabled for more than AEMO's Maximum Contingency Reserve Block Size, currently 65 MW.

Contingency Reserve Lower

The Contingency Reserve Lower requirement is applied as a minimum provision set as the size of the largest load in the SWIS. Existing facilities are assigned a maximum response in line with their current accreditation and committed and candidate facilities are assigned a response based on AEMO's Frequency Co-optimised Essential System Services Accreditation WEM Procedure. The model must hold sufficient capability across accredited facilities to reduce injection or increase withdrawal to meet the Contingency Reserve Lower requirement in every interval, subject to the same 65 MW Maximum Contingency Reserve Block Size.

RoCoF Control Service and inertia

The RoCoF Control Service is not modelled explicitly in the dispatch modelling. Instead, system inertia will be calculated from the dispatch modelling outcomes and assessed as a post-modelling check. Where shortfalls are identified, the capacity expansion modelling (PLEXOS LT Plan) will be rerun with adjusted assumptions and iterated with the dispatch modelling until inertia outcomes are acceptable. For the purposes of this assessment, it is assumed that grid-forming BESS will provide virtual inertia.

Network thermal constraints

Network thermal constraint equations are applied in the dispatch modelling (PLEXOS ST Plan) to model the impact of N-1 thermal congestion in the transmission network. It is noted that only a subset of thermal constraint equations will be applied to the model, representing the parts of the transmission network that are most likely to be congested.

Thermal constraint equations will be developed using a full network representation of the SWIS in PowerFactory and are formulated as open loop constraints that is consistent with the approach AEMO uses for pre-dispatch and MT/LT PASA constraint equations. The process for creating and applying thermal constraint equations is as broadly follows:

1. Based on the outcomes of the capacity expansion modelling (i.e. new entrant generation / storage build and network augmentations), develop a representative PowerFactory model for relevant future system states.
2. Build network thermal constraint equations based on this representative PowerFactory model supported by automated tooling similar to that used by AEMO for developing pre-dispatch and MT/LT PASA constraints.
3. Filter the constraint set to only include constraints that have material binding impacts.

Network non-thermal constraints

Non-thermal constraints such as transient stability, voltage stability and oscillatory stability constraints are modelled when considered relevant under System Normal conditions. The existing set of non-thermal constraint equations published by AEMO in the Congestion Information Resource Operational Constraints Library¹ is used as a basis for the modelling of non-thermal constraints in FESO.

¹ See <https://www.aemo.com.au/energy-systems/electricity/wholesale-electricity-market-wem/system-operations/congestion-information-resource/constraints-library/operational-constraints-library>

Future non-thermal constraints are developed on a case-by-case basis from an assessment of the capacity expansion modelling outcomes, i.e. evaluating whether stability issues may arise from new network augmentations and generation build outcomes. Where stability risks are considered likely, non-thermal constraint equations are developed using a representative PowerFactory model with generic dynamic models for new entrant facilities.

System strength

System strength will be assessed via a set of minimum fault level constraints in the dispatch (PLEXOS ST) modelling component and not incorporated directly in the capacity expansion (LT) modelling. The objective of the system strength assessment is to provide an estimate of the approximate value of addressing system strength issues by examining the counterfactual cost difference between i) an unconstrained dispatch without system strength constraints, and ii) a constrained dispatch with system strength constraints considered.

Minimum three-phase synchronous fault levels are determined for a set of key system strength nodes in the SWIS. The minimum fault level constraints for the dispatch model are formulated as follows:

$$c_1 G_{1t,commit} + c_2 G_{2t,commit} + \dots + c_k G_{kt,commit} \geq \text{Fault Level}_{min,n}$$

where $G_{i,commit}$ is the commitment of synchronous generator i for interval t (binary 1 or 0)

c_i is the fault level contribution of the i -th generator to node n (in MVA)

$\text{Fault Level}_{min,n}$ is the minimum fault level for system strength node n (in MVA)

The capability for grid-forming inverters to provide protection quality fault current is still currently being explored². In the near term, it is expected that only synchronous machines can meet the minimum fault level requirements. However, after a period of time (e.g. from 2035 onward), the model will allow grid-forming BESS to contribute to the minimum fault level requirements.

2. Reliability modelling methodology

2.1. Overview

An essential component of any long-term system planning exercise is ensuring the future electricity system is reliable and robust, with sufficient generation to meet demand under a variety of conditions. In the WEM, the reliability standard is defined in the ESM rules, which is a Planning Criterion that the SWIS must satisfy in every Capacity Year across three limbs:

- **Limb A – capacity adequacy:** sufficient capacity to meet the forecast 10% probability of exceedance (POE) peak demand, plus allowances for Intermittent Loads, Regulation Raise, a reserve margin, and the ESR Duration Requirement uplift;
- **Limb B – energy adequacy:** expected unserved energy (USE) of less than 0.0002% of forecast annual unscheduled operational consumption; and
- **Limb C – flexibility:** sufficient supply flexibility to meet the highest forecast Four-Hour Demand Increase (FHDI), plus a reserve margin.

² A trial is currently underway in the NEM: <https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/transition-planning/transitional-services---type-2-services/grid-forming-inverter-protection-quality-fault-current-trial>

Limb A is addressed through the long term capacity expansion modelling as a target that must be met by the build path, while Limb B will be assessed using detailed dispatch modelling as outlined in the approach section below. The current proposed approach does not separately assess Limb C, because it has not historically determined the Reserve Capacity Target. This treatment will be confirmed as the methodology is finalised. Overall, the FESO must demonstrate that the capacity mix and network development pathway emerging from the long-term and short-term modelling for each scenario can deliver against the Planning Criterion over the 24-year planning horizon.

2.2. Approach

A single pass of the capacity expansion and dispatch models is not sufficient for determining whether the reliability standard is met because they assess only one realisation of the future. Therefore, multiple situations must be tested to ensure that the capacity mix is resilient to various shocks. These may include a combination of high demand with low renewable output or plant outage events.

To test different future realisations, we will fix the long-term capacity expansion development pathway and test the short-term dispatch model with multiple weather reference years and synthetic outage traces. The former model is built around a single synthetic weather reference year constructed to include various weather conditions the SWIS may need to operate through, for example, a cold snap with low wind output. The long-term model will build to a standard that ensures the system is robust enough to handle these events. Appendix C has more information on the synthetic weather reference year methodology. On the other hand, the short term dispatch model will test whether the build path with the synthetic weather reference year can handle actual historical weather years, i.e., if the weather in 2040 looked like the weather in 2011 or 2015, can the future system reliably operate?

Unlike the ESOO, the FESO determines whether the investment pathway can meet the reliability standard over a much longer time horizon. Hence, testing reliability over tens of weather reference years, combined with a small number of outage traces, is sufficient for the long-term study. Additionally, forced outages of individual large thermal units usually drive an ESOO-style risk event, but their influence on system reliability diminishes over the medium to long term when the coal fleet retires. As the system transitions, weather is more likely to drive reliability events, such as a sustained VRE drought coinciding with high demand and depleted storage.

Where a scenario fails a limb, the shortfall is first characterised quantitatively by assessing the magnitude (MW), energy (MWh), duration, season and location. Operational mitigations available within the dispatch model are tested, including storage duration and dispatch settings, demand-side archetypes, maintenance rescheduling and network augmentation timing.

Where the shortfall cannot be resolved operationally, additional reserve margins and stricter system security constraints will be developed and implemented into the long-term capacity expansion model. The capacity expansion model is then re-run to produce a revised development pathway, which is passed back through the short-term reliability stages and re-tested against the same weather year and outage trace combinations.

2.3. Outputs

The reliability assessment answers whether the development pathway meets the reliability standard, in which years and under which conditions it does not, and what drives any shortfall. Results are produced for every combination of scenario, sensitivity and case study, for each modelled year of the 24-year horizon. Its principal outputs are:

- **Planning Criterion compliance** – pass or fail against Limbs A and B by year, with the margin or shortfall quantified;
- **Expected unserved energy** – including its magnitude, how and why it occurs.
- **Load shedding by region** – disaggregated by zone and split between voluntary curtailment (DSP) and involuntary shedding.