Power System Limitations in North Western Victoria and South Western New South Wales

December 2019

Important notice

PURPOSE

AEMO has prepared this document to provide information to National Electricity Market participants about existing and emerging network limits in parts of western Victoria and south-west New South Wales, as at the date of publication.

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VERSION CONTROL

Version	Release date	Changes
1	20/12/2019	First Issue

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1. Issue Overview

1.1 General

The rapid scale and pace of inverter-based renewable generator connections in remote areas of the National Electricity Market (NEM) is resulting in unprecedented technical issues impacting grid performance and operational stability. The nature, extent and causes of these issues are only becoming apparent with the advanced and very detailed modelling capability that is now essential for technical assessments in weak areas of the grid.

The area of the Victorian and NSW power system bounded by Ballarat, Dederang, and Darlington Point (referred to as 'West Murray') has attracted significant investment in grid-scale solar and wind generation, despite being a remote and electrically weak part of the NEM. Put simply, the transmission infrastructure in this part of the network is insufficient to allow access to all the generation that is seeking to connect, and is capable of construction in a matter of months. Transmission infrastructure investments to progressively address these issues have been identified, but will take a number of years to proceed through regulatory approval processes, procurement and construction.

AEMO and network service providers (NSPs) have identified critical stability issues associated with the operation and interaction of inverter-connected generators in West Murray. There may also be some potential adverse stability issues outside this area. Significant small-scale inverter-based generation at the distribution network level may also exacerbate these issues, but these installations generally fall outside the assessment framework applicable to grid-scale generators under the National Electricity Rules.

1.2 Post-fault voltage oscillations

AEMO's large-scale power system stability analysis identified a need to reduce the number of online inverters and output at five solar farms to maintain power system security. Since the associated network constraints were implemented in September 2019, AEMO has been working closely with the solar generators, their equipment supplier and their network service providers (Powercor and TransGrid) on solutions to the complex issues behind post-fault voltage oscillations observed at their connection points.

Until new operating parameters are verified, approved and implemented by the solar plants, AEMO believes the only prudent course is to postpone final approvals for new generators due for commissioning or registration in the impacted area. Where practical, and on a prioritised basis, AEMO will continue to progress studies and address any independent outstanding issues, pending re-establishment of a stable base case on which to conduct final assessments.

1.3 System strength gap

AEMO has also declared a 312 MVA fault level shortfall (generally referred to as a system strength gap) at Red Cliffs Terminal Station in north-west Victoria. This gap accounts for presently operating and commissioning plant that was not required to remediate adverse system strength impacts on connection. AEMO, as Victorian TNSP, will seek system strength services to address this shortfall by 1 January 2021.

This is the third system strength gap identified for the NEM under AEMO's system strength requirements methodology, following South Australia and Tasmania in October 2017 and November 2019, respectively.

2. System strength related stability issues

2.1 Modelling

Power system studies carried out with detailed wide-area models of NSW and Victorian networks developed by AEMO indicate that five operational solar farms in West Murray exhibit sustained oscillations following a single line fault (a credible contingency) under system intact conditions. Depending on the scenario studied, the oscillations could be of constant or varying magnitude. Irrespective of their shape, the magnitude and duration of the oscillations exceed allowable stability limits under the National Electricity Rules and power system stability guidelines, and network standards for quality of supply.

It is clear that some of the stability issues arise when multiple solar farms are online, as each of their responses to the fault interacts with and is exacerbated by the response of the others. Simulation studies confirm that a reduction in the number of online inverters reduces the magnitude of oscillations. A reduction in the total MW output of each solar farm only, while maintaining all inverters online, was not effective.

2.2 Comparison of measured and simulated responses

On 30 November and 1 December 2019, AEMO and related NSPs performed a series of power system switching tests in the West Murray area. The results confirmed the oscillations predicted by the earlier large-scale power system models.

Learnings from these tests indicate that, pending implementation of amended operating parameters for the impacted generators, it may be necessary for a larger number of online inverters to remain disconnected to maintain system security. Presently 50% of the inverters are permitted to remain online.

NSPs and AEMO may perform further network switching tests to validate updated models, settings changes and generator performance.

2.3 Examples of oscillations

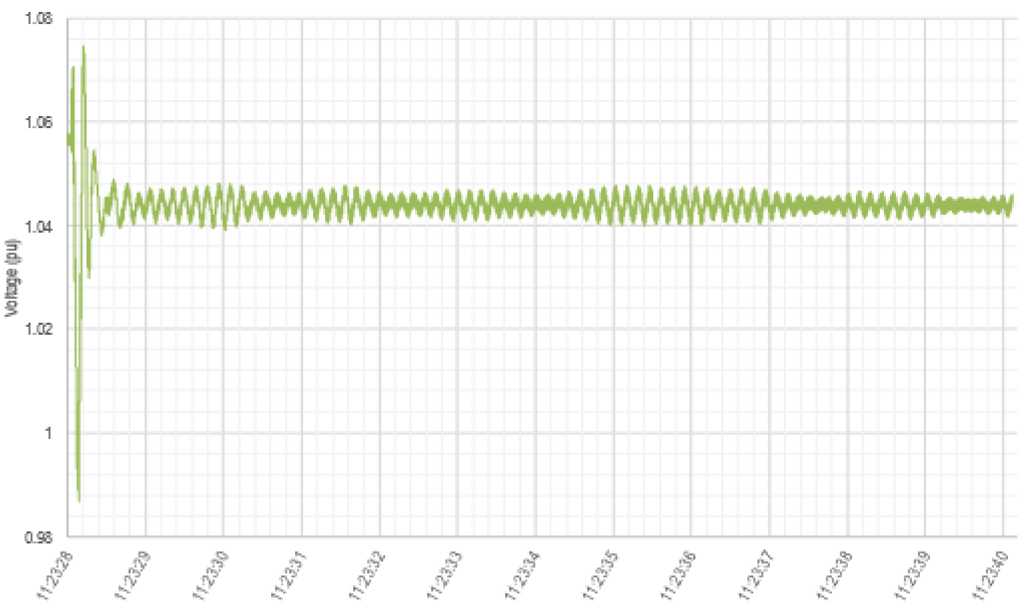

Figure 1 Voltage oscillations observed during testing (site 1)

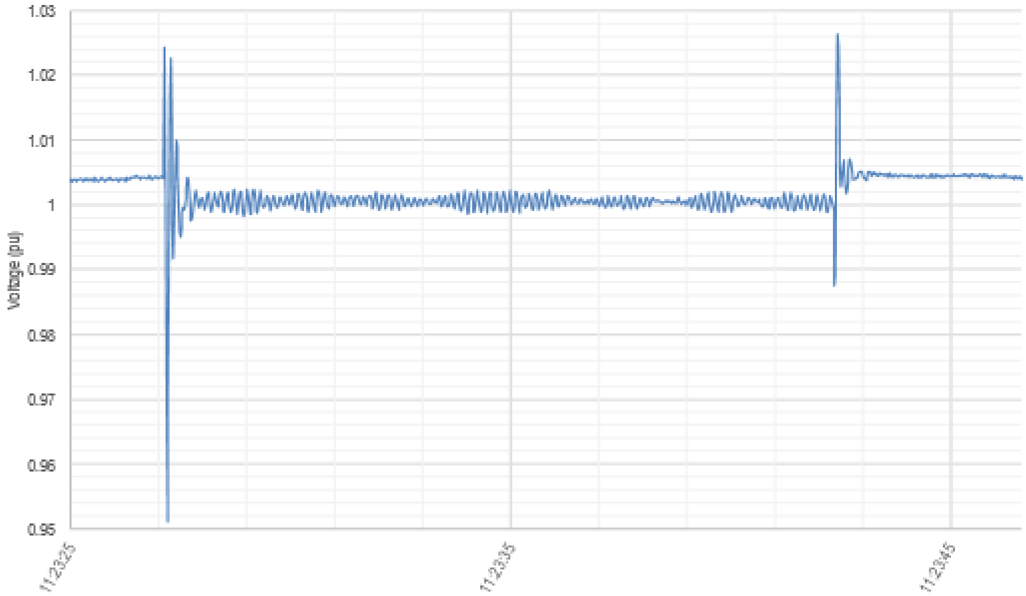

Figure 2 Voltage oscillations observed during testing (site 2)

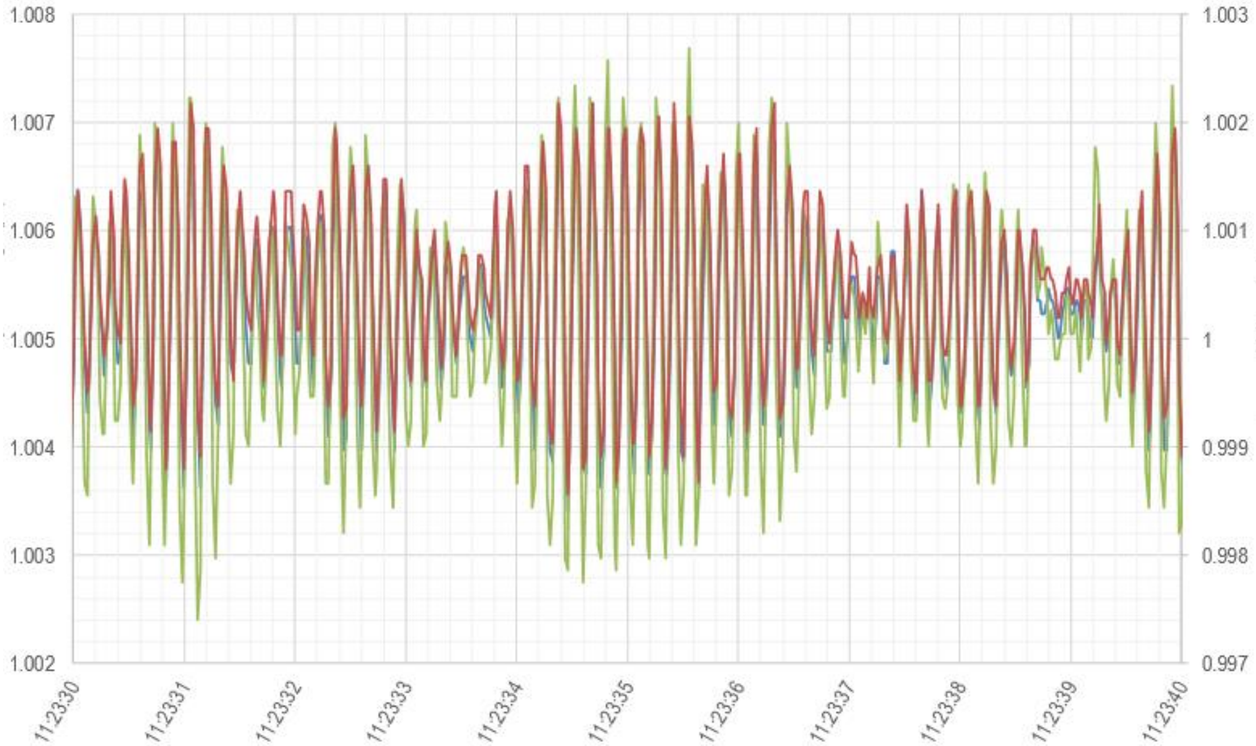

Figure 3 Voltage oscillations observed during testing (various sites)

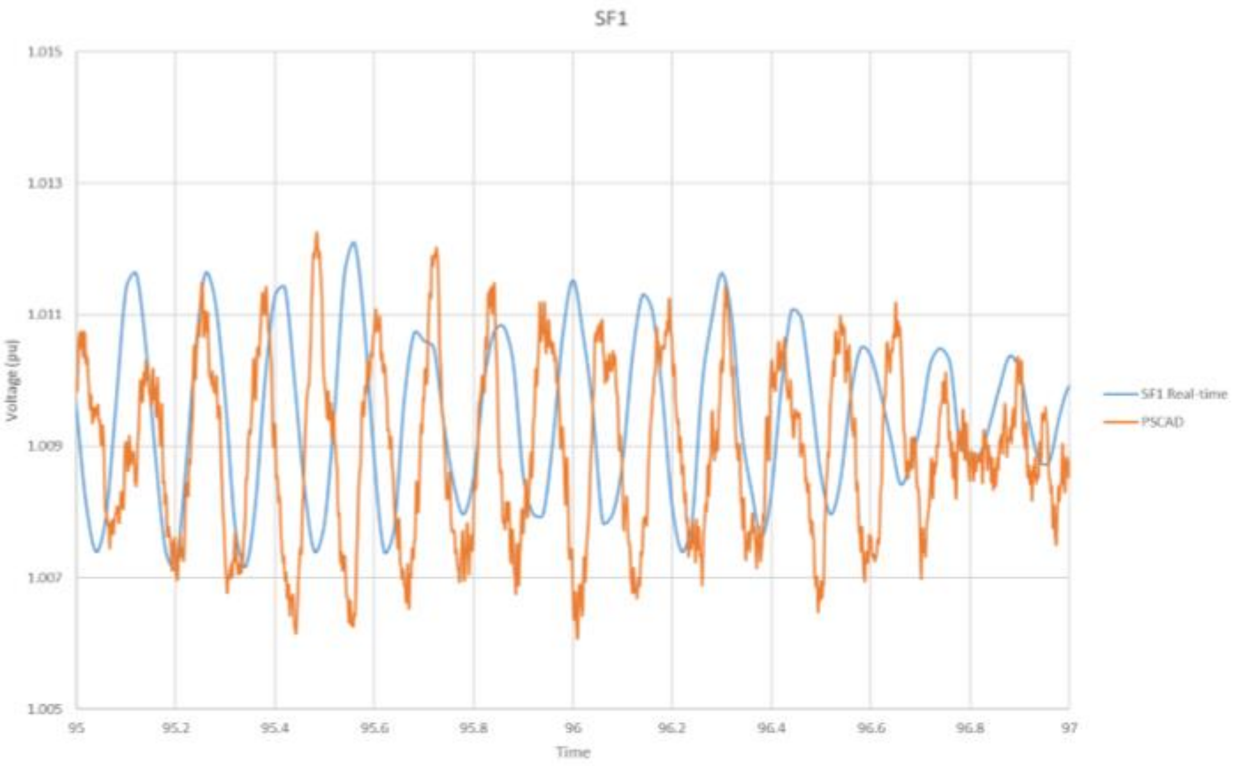

Figure 4 Voltage oscillations – comparison of the model predictions (PSCAD) and actual test results (SF1 real time)

3. Remediation

3.1 Currently – constraining operational generation

Power system security is currently being managed by network constraints that limit the generation of five solar farms in the area. These constraints limit the output and online inverters of these solar farms to a level that minimizes the occurrence of oscillations should an initiating fault occur.

3.2 Short Term – tuning of constrained solar plant

The five solar generators are working with AEMO, Powercor and TransGrid to adjust the performance of their systems to the low system strength environment.

Once these changes have been verified, approved and implemented these solar plants should be able to increase the amount they can generate without compromising power system security. AEMO now expects these changes to be made and tested in early 2020.

3.3 Medium Term – system strength gap remediation

AEMO has declared a system strength gap requiring an additional 312 MVA of three-phase fault current at the Red Cliffs terminal station.

AEMO, as Victorian TNSP, will seek system strength services to address this shortfall by 1 January 2021, but this timeframe cannot be guaranteed.

Reducing or closing the system strength gap will allow inverter-based generation in the West Murray area to increase generation without breaching oscillatory stability limits, but thermal limits will continue to apply. Note this will only address an existing gap – it does not remove or reduce the requirement for new or modified generation to remediate the adverse system strength impact of their connection.

3.4 Long Term – Western Victoria augmentation

To completely remove limitations in the West Murray region, significant network augmentation is required. Currently there are two major projects expected to be delivered for the region within the next five years:

- Western Victoria Renewable Integration Project
- Project EnergyConnect.

AEMO's draft 2020 Integrated System Plan also identifies a VNI West link as a priority transmission project: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2019-Integrated-System-Plan.

Each of these will have different levels of impact in terms of relieving constraints in the West Murray area. For example, the Western Victoria Renewable Integration Project will not relieve constraints in the remote parts of the area.

4. Other emerging constraints

In addition to system strength limitations, generation in the West Murray area will also be subject to a number of other power system limitations. Two limitations that are emerging in the immediate term relate to thermal and voltage stability.

4.1 Thermal limits

Studies indicate that the amount of generation in the area is leading to a situation where flows on several power lines in the area may reach their thermal limits under many dispatch scenarios. Constraints have already been invoked to manage power system security in these circumstances and these are expected to start binding in early 2020 with the commissioning of existing committed generation.

The thermal limits are as follows:

- Ballarat to Waubra 220 kV line for trip of either Murra Warra to Kiamal (V>V_NIL_6) or Kiamal to Red Cliffs (V>V_NIL_8). This line has a temperature-based rating and will limit semi-scheduled generation connected to this line to approximately 620 MW at 20°C.
- Darlington Point 220/330 kV transformers (220 to 330 kV direction of flow) of trip of the parallel transformer (N>>N-NIL_DPTX_2). This constraint equation includes generators in south-west NSW and north-west Victoria and will bind during daylight hours on most days.
- Buronga to Red Cliffs 220 kV line on no trips (N>>V-NIL_0X1). This constraint equation includes generators in south-west NSW and north-west Victoria and will bind during daylight hours and at times of high wind.

4.2 Voltage stability limits

AEMO has completed preliminary studies for voltage stability limitations in north west Victoria for loss of the Ballarat – Ararat 220 kV line. Initial results indicate that for greater than 600 MW of generation tripped there are power system security issues. Further work is ongoing to refine, and potentially lift, these limits where possible, but initial constraint equations will be implemented before the end of December 2019.

- AEMO's online tools have now been modified to monitor this condition
- A constraint of 600 MW will be placed on generation connected between Horsham and Ballarat prior to Christmas 2019
- A revised NSW to Victoria voltage collapse limit will be implemented in mid-January 2020 which will include the trip of these generators
- Further work to refine the 600 MW value is planned to be completed by early February 2020.

TransGrid is currently investigating a voltage collapse limit for loss of the Darlington Point to Wagga (63) 330 kV line in NSW.

4.3 Next steps

- AEMO will continue to work closely with the solar generators, their equipment supplier and their network service providers on solutions to the complex issues compromising power system security.
- When the new operating parameters are verified, approved and implemented by the solar plants, restoring network stability, AEMO will be able to progress, on a prioritised basis, projects that are in or commencing commissioning, or committed.
- New stability constraints, in addition to existing thermal constraints, are being implemented and will continue to be investigated in early 2020.

This is very much a dynamic situation, impacted by changes in small-scale inverter connected equipment as well as larger scale generation and network changes. Other issues and constraints are being studied and further updates will be provided as the need for further changes becomes apparent.

5. Further generator connections are not feasible without significant investment

The acute issues faced in the West Murray region have already resulted in network constraints impacting several generators in order to manage system security, with commissioning of other plant delayed until assessment studies can be progressed with known and stable base case quantities.

Even if performance standards have been, or can be, agreed under the National Electricity Rules for new grid-scale projects, it is unlikely that those performance standards could feasibly be achieved under all relevant system conditions, meaning generator registration requirements could not be met.

Generators may also identify the need for plant modification in order to meet performance standards on an ongoing basis.

While equipment and system modifications may alleviate constraints on operational plant, proponents looking to connect into the West Murray network should consider that there are currently around 1,200 MW of committed (pre-commissioning) inverter-based generation projects and about 3,000 MW in the application phase. The currently identified maximum thermal network limit for the West Murray region is 1,700 MW.

Thermal and stability limits mean it will not be possible for many of these projects to connect or generate at full output ahead of significant investment in network infrastructure.