AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

NEM Operational Forecasting and Dispatch Handbook for wind and solar generators

September 2022

A guide to key requirements of semi-scheduled generating units and some non-scheduled intermittent generating units for forecasting and dispatch in the National Electricity Market (NEM)

Important notice

PURPOSE

AEMO has prepared this document to provide general information for grid-scale wind and solar generators about requirements relating to energy forecasting and dispatch in the National Electricity Market, as at the date of publication.

This document or the information in it may be subsequently updated or amended.

DISCLAIMER

This document does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice, specific to your own circumstances, about the application of the National Electricity Law, the National Electricity Rules, or any other relevant laws, procedures or policies. AEMO has made reasonable efforts to ensure the quality of the information in this document but cannot guarantee its accuracy, currency or completeness.

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VERSION CONTROL

Version	Release date	Changes
1.0	11/02/2021	First issue
1.1	15/04/2021	Removed the requirement for participants to submit intermittent generation availability information in the Pre-Production Markets Portal.
1.2	08/12/2021	Updated 'Elements Unavailable' to 'Elements Available' for submitting new plant availability and included API as a new method for submitting plant availability. Clarified generator requirements during transmission network outages in Section 2.4.3.
1.3	19/09/2022	Updated the document to reflect the National Electricity Amendment (Integrating Energy Storage Systems into the NEM) Rule 2021.

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Introduction

The purpose of this handbook is to provide general guidance to semi-scheduled generating units and non-scheduled intermittent generating units with dispatch-related obligations[1], about the requirements and expectations for registration and ongoing participation in central dispatch and related processes in the National Electricity Market (NEM). This handbook provides an overview of:

- Registration requirements from an operational forecasting perspective.
- Integration into the Australian Wind Energy Forecasting System (AWEFS[2])/Australian Solar Energy Forecasting System (ASEFS) forecasting model.
- Ongoing requirements for data inputs for bidding and dispatch, and the potential consequences for generators and participants of inaccurate inputs to the AWEFS/ASEFS forecasting model, and non-compliant behaviour.
- How generators can register and participate in self-forecasting.

This handbook highlights key requirements of relevant parts of the National Electricity Rules (NER), and some formal guidelines, procedures and standards published by AEMO under the NER. The main documents referenced in the handbook are listed for convenience in Appendix B. All intermittent generators are expected to be familiar with the detail of all regulatory instruments that apply to their operation in the NEM. Those instruments apply in precedence to this handbook in the event of inconsistency.

Key AEMO contact emails are provided throughout the handbook and also listed in Appendix B.

Terms defined in the NER are used with the same meanings, and there is a glossary of acronyms at the end of this document.

[1] Obligations may be determined under clause 2.2.3(c) or 3.8.2(e) of the National Electricity Rules

[2] A high-level overview of AWEFS is at: https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/dispatch/policy_and_process/2016/australian-wind-energy-forecasting-system-awefs.pdf

1. Pre-registration

1.1 Operational forecasting as part of NEM registration

Registration as a Generator (or Integrated Resource Provider (IRP)) in the NEM is a prerequisite to connecting, energising and commissioning a generating system, and participating in the wholesale market (by submitting availability and bids, receiving dispatch instructions, and selling the energy output). The path to intermittent generator registration and connection is complex; it involves the provision of extensive information to AEMO and the connecting Network Service Provider (NSP), and often requires iterative studies as part of the assessment process.[3]

As part of the registration process, semi-scheduled generating units and any semi-scheduled generating units in an integrated resource system (and some non-scheduled intermittent generating units[4]) applicants must submit an energy conversion model (ECM) to AEMO for formal assessment. However, AEMO recommends that a draft ECM is submitted to AEMO for review and feedback well ahead of the final registration application. The formal ECM assessment involves verification against both the registration application form and the negotiated generator performance standards (GPS).

1.2 Energy conversion model submission and approval

An ECM is a model that defines how an intermittent input energy source (such as wind or solar radiation) is converted by the generating unit into electrical output.

ECMs are submitted to AEMO at op.forecasting@aemo.com.au for review and approval[5]. The ECM approval process requires at least two weeks and can take up to six weeks due to multiple iterations required to assess and verify the contents in the ECM. AEMO aims to provide feedback to participants within two business days of receiving a new or updated ECM.

The information in the ECM submitted by participants is used by the AWEFS and ASEFS to create the unconstrained intermittent generation forecast (UIGF) in Dispatch, 5-minute Pre-Dispatch, 30-minute pre-dispatch and projected assessment of system adequacy (PDPASA and STPASA) timeframes. The dispatch forecast becomes the semi-scheduled generating unit's availability in dispatch. The pre-dispatch and PASA forecasts are critical for providing accurate forecasts of wind and solar generation used in, respectively, preparing the pre-dispatch price schedules and assessing short term capacity reserves over the next seven days. If the information in the ECM for a generating unit does not reflect its actual design, there is a risk that forecast accuracy (and hence the generator's UIGF) will be impacted. An applicant for registration as a semi-scheduled generating unit must submit an ECM under NER clause 2.2.7(c)(2) and 2.2.7(c1)(3)(ii). Some non-scheduled generating units may also need to submit an ECM under NER clause 2.2.3(c). To avoid delays, AEMO recommends that the first draft of the ECM be submitted to AEMO at least three months **before** applying for registration.

[3] AEMO has published information and guides on:

- Network connections at: https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections/transmission-and-distribution-in-the-nem/stage-3-application
- Generator registration at: https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/registration/register-as-a-generator-in-the-nem

[4] A non-scheduled intermittent generator located in a constrained part of the network may be required to submit an ECM to AEMO.

[5] The current ECM guidelines are at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Solar-and-wind-energy-forecasting.

1.3 SCADA signal list submission and approval

The SCADA signal list is a list of SCADA signals provided by the participant and used by AEMO for operational and forecasting purposes. The list comprises ECM and non-ECM SCADA signals which are reviewed/approved by AEMO.

SCADA signal lists are submitted to AEMO at gridmodellers@aemo.com.au for review and approval, or can be submitted as part of the generator registration application[6].

AEMO may be able to provide preliminary feedback to participants on SCADA requirements prior to ECM approval. However, ECM SCADA signals can only be fully reviewed and approved following ECM approval, because the approved ECM dictates how many SCADA signals are required for forecasting purposes.

Semi-scheduled and non-scheduled generating units must have remote monitoring equipment (that is, SCADA) as per Clause S5.2.6.1 in the NER. ECM SCADA data is a key input to the forecasting model when preparing the dispatch UIGF for a semi-scheduled generating unit and is required by clause 3.7B(c)(3) of the NER.

[6] A guide to ECM SCADA data requirements is at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/Guide-to-Data-Requirements-for-AWEFS-and-ASEFS.pdf.

2. Post-registration

2.1 Provision of ECM SCADA signals

ECM SCADA signals communicate to AEMO the generator's real-time available capacity and on-site weather conditions. A number of these signals are classified as critical ECM SCADA signals, which are key inputs to the forecasting model to produce the dispatch UIGF.

Table 1 describes each critical signal and what it is used for when determining the dispatch UIGF.

Table 1 List of critical ECM SCADA signals for wind and solar farms

Technology type	Critical ECM signal	Description
Wind and Solar	Active Power (Wind: farm and cluster-level Solar: farm-level)	• The total active power measured at the agreed point of dispatch (Point of Connection (POC)). • Used by AWEFS/ASEFS to produce the dispatch UIGF during unconstrained farm operation. This is deemed an active power-based forecast.
	Control System Set-Point (farm-level)	• The Active Power Set-Point applied in the farm's control system to limit (down-regulate) its output. This signal should equal the semi-dispatch level when a semi-dispatch cap is set. • Used by AWEFS/ASEFS to detect if the farm is under constrained or unconstrained operation.
	Local Limit (farm-level)	• The lower of the farm's plant availability and all technical limits on the capacity of its connection assets to export energy. • Used by AWEFS/ASEFS to cap the dispatch UIGF in the dispatch timeframe.
Solar only	Number of Inverters Available (cluster-level)	• The number of inverters connected and available to deliver active power (if sufficient sunlight is available). • Used by ASEFS to produce the dispatch UIGF during constrained operation. This is deemed a weather-based forecast.
	Global Inclined Irradiance (cluster-level)	• The measured irradiance at the same inclination/orientation of the solar panels. This should be calculated as an average of all pyranometer inclined irradiance measurements within each cluster. • Used by ASEFS as an average of all cluster global inclined irradiance measurements to produce the dispatch UIGF during constrained operation. This is deemed a weather-based forecast.
Wind only	Number of Turbines Available (farm and cluster-level)	• The number of turbines connected and available for generation. • Used by AWEFS to produce the dispatch UIGF during constrained operation. This is deemed a weather-based forecast.
	Number of Turbines in Extreme cut-out (farm and cluster-level)	• Number of turbines counted in the Turbines Available signal that are currently in cut-out mode due to extreme high wind speed or extreme wind direction change. • Used by AWEFS to produce the dispatch UIGF during constrained operation. This is deemed a weather-based forecast.
	Wind Speed (farm and cluster-level)	• Single wind speed measurement, which must be representative of wind conditions across the site. This is an average of all turbine nacelle wind speed measurements for farm-level, and an average of cluster turbine nacelle wind speed measurements for cluster-level.

Technology type	Critical ECM signal	Description
		• Used by AWEFS to produce the dispatch UIGF during constrained operation. This is deemed a weather-based forecast.

If SCADA is bad quality, not working as expected, not configured correctly, or doesn't represent actual farm conditions, the forecast accuracy will be impacted. This will result in discrepancies between the generator's dispatch target and actual output, which ultimately leads to an increased need for regulation frequency control ancillary services (FCAS) in the NEM. When ECM SCADA signals are correctly configured, most of the SCADA issues that AEMO observe are typically the result of a failure between the measurement device and farm's SCADA interface. Participants must rectify these SCADA issues within the reliability requirements outlined in AEMO's Standard for Power System Data Communications[7] as per Clause 4.11.1 in the NER. Refer to AEMO's Communication System Failure Guidelines[8] for further information.

If participants fail to manage this, it can result in higher 'causer pays' factors for the participant's portfolio, which can potentially have a significant financial impact on the participant[9].

AEMO is responsible for determining a UIGF of what the semi-scheduled generator could theoretically generate, not what it will generate (which is based on the dispatch instruction from central dispatch). The UIGF does not consider on-site limits on that capability, such as turbine/inverter unavailability, plant outages, and limits, unless these are submitted to AEMO via the central dispatch processes provided for in the NER, and described in this document.

It is the participant's responsibility to ensure:

- The dispatch UIGF reflects the plant technical capability using the relevant ECM SCADA signals.
- The dispatch offer reflects commercial intentions.

ECM SCADA signals should be configured and working as early as possible following registration to allow the development and implementation of the forecasting model (see Section 2.3).

2.2 Electricity Market Management System (EMMS) Portal

The Electricity Market Management System (EMMS) is the NEM wholesale system determining the cost of energy. The EMMS Portal ('Markets Portal') provides such functions as ancillary services, dispatch information, market information, NEM reports, submission of bids, submission of intermittent generation availability information, settlements and prudentials, and trading facilities.

The Markets Portal is provided via two environments:

- A Pre-Production environment, which allows participants to test their IT systems and interact with AEMO's systems. This is a testing environment and does not influence outcomes in the NEM.
- A Production environment, which allows participants to interact directly with AEMO's market systems to participate in the NEM. This is a real environment which influences outcomes in the NEM.

Participants will be granted access to the EMMS Pre-Production environment[10] some weeks or months prior to registration, to allow them to test their IT systems and interaction with AEMO's systems.

[7] At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Network_Connections/Transmission-and-Distribution/AEMO-Standard-for-Power-System-Data-Communications.pdfv

[8] At https://www.aemo.com.au/-/media/files/electricity/nem/network_connections/stage-6/communication-system-failure-guidelines.pdf

[9] Information on the calculation of causer pays factors and AEMO's Regulation FCAS Contribution Factor Procedure available at: https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/ancillary-services-causer-pays-contribution-factors

[10] At https://portal.preprod.nemnet.net.au/.

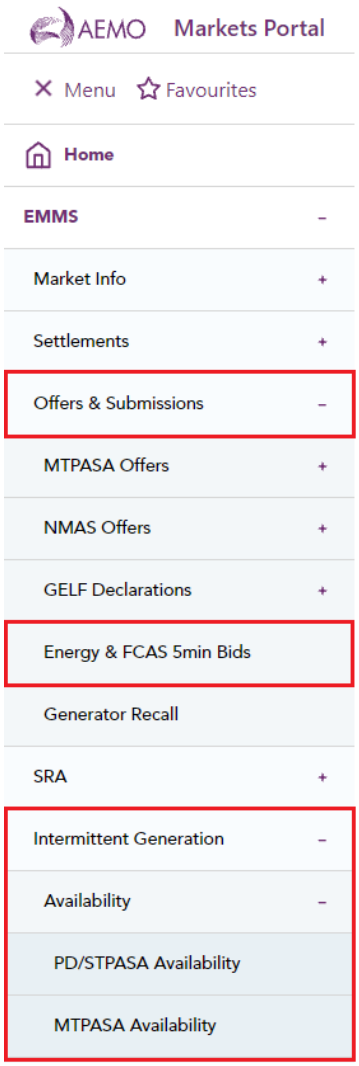
Participants applying to register a new generator under an existing Participant ID will already have access to the EMMS Production environment[11], and will be required to perform the actions outlined in the section below from at least the day prior to the registration effective date.

Participants applying to register a new generator under a new Participant ID will be granted access to the EMMS Production environment on the registration effective date, and will be required to perform the below actions from the registration effective date.

Participants should use the same credentials to access the EMMS Pre-Production Portal and the EMMS Production Portal.

2.2.1 Participant actions required

The participant actions outlined below are required from at least the day before effective registration (for those with an existing Participant ID), or from the day of effective registration (for those with a new Participant ID). Section 2.4 includes some more specific examples of conditions that require updated information, and how to communicate these to AEMO.



Update bids

AEMO implements a default energy bid as part of the registration process; the default bid is the farm's registered Maximum Capacity allocated in Price Band 10 priced at $256 per megawatt hour [MWh]. Participants are expected to submit a bid to ensure their default bid matches their requirements otherwise there is a risk the generator will not be dispatched. Energy bids can be updated in the 'Offers & Submissions' tab under the 'EMMS' tab in the Production Markets Portal, via API, or in the participant file server via FTP.

Update intermittent generation availability[12]

AEMO implements a default intermittent generation availability entry as part of the registration process; the default availability is a 0 megawatts (MW) generation capacity and none of the elements (turbines/inverters) in each cluster are available. Participants are expected to submit an availability entry to ensure their default availability matches their requirements. The availability can be updated by updating the 'Upper MW Limit' and 'Elements Available' columns in the PD/STPASA Availability and MTPASA Availability tabs in the Production Markets Portal or via API. These fields should only be used to reflect changes in availability due to technical limitations, and must not be used to reflect changes in commercial availability which should be submitted via energy bids as above.

Participants must update this section when there is an expected or actual change in plant availability due to events including, but not limited to:

- An unplanned or planned outage of the semi-scheduled generator or its elements.
- Environmental conditions such as forecast high ambient temperatures causing possible de-rating effects on turbines, modules, and inverters, in addition to forecast high wind speeds causing possible de-rating or cut-out effects on turbines.

[11] At https://portal.prod.nemnet.net.au/.

[12] A guide on intermittent generators submitting availability via the Markets Portal is at https://www.aemo.com.au/-/media/files/market-it-systems/guide-to-intermittent-generation.pdf. A guide on submitting availability via API can be found in the 'Intermittent Generation Availability API' document via https://dev.aemo.com.au/. More information on the MMS Data Model is available at https://aemo.com.au/energy-systems/market-it-systems/electricity-system-guides/ (under 'Wholesale IT systems software'), including the MMS Data Model Report and MMS Data Model Table to File to Report Relationships workbook (both found at https://visualisations.aemo.com.au/aemo/di-help/Content/Data_Model/MMS_Data_Model.htm) that identifies the intermittent forecasting files available for subscription.

- GPS requirements, operational arrangements between the generator and NSP/AEMO, and changes in commissioning hold point levels.
- Transformer outages or provision of reactive power.
- Changes in the number of elements connected and available to generate.

The intermittent generation availability excludes limits on the transmission and distribution network that are managed by AEMO through the central dispatch process (for example, via constraints). Participants must liaise with the NSP to determine whether these limits have been communicated to and managed by AEMO through the central dispatch process to ensure appropriate action is taken thereafter (see Section 2.4.3 for further information).

The intermittent generation availability information entered in the Production Markets Portal (or submitted via API) is used to produce the UIGF in the pre-dispatch, PDPASA and STPASA timeframes. For the dispatch timeframe, participants must reflect their availability via their ECM SCADA signals, such as SCADA Local Limit and SCADA Turbines/Inverters Available. If these signals do not reflect the actual availability or are unavailable, participants can withdraw band capacity in their energy bid to achieve the desired dispatch outcome. As a last resort, participants can request the AEMO Control Room to apply a quick constraint to the actual MW availability level if ECM SCADA signals fail to reflect the farm's true availability and if the energy bid is unable to be updated.

It is important to understand that the availability information entered in the Production Markets Portal or API has an impact on the generating unit's Pre-Dispatch and PASA forecasts[13]. If the submitted availability information does not reflect the actual plant availability, the accuracy of the Pre-Dispatch, PDPASA and STPASA forecast will be impacted. This has potential to impact the pre-dispatch price schedule and the reserve assessment process, and participants can be deemed non-compliant with NER 3.7B(b). Thus, it is in participants' best interests to ensure compliance with the above activities.

Semi-scheduled generating units (and non-scheduled intermittent generating units with semi-scheduled obligations) must submit plant availability as per Clause 3.7B(b) in the NER. The plant availability is an input to the forecasting model when preparing the UIGF in the pre-dispatch and PASA timeframes and is required under NER clause 3.7B(c)(2).

2.3 Forecasting model development and implementation

A forecasting model must be developed to produce a UIGF in all timeframes. AEMO requires sufficient operational data to initiate the model development process, so the forecast model cannot be developed until the farm is operational. In addition, developing the forecasting model relies on accurate, good quality inputs which reflect the conditions at the generator (including the SCADA signals and availability information described in this document).

In the interim (early stages of commissioning), AEMO will be collecting and analysing this data to ensure it is suitable for model development. AEMO will inform participants of any issues with respect to operational SCADA or availability data.

Until the forecasting model is implemented, the generator's dispatch UIGF will be produced using a simple start-up dispatch forecast model, named the 'FCST' analog. This analog utilises the following real-time SCADA data in conjunction with a power conversion curve:

- Wind farms:
  - Local Limit.
  - Farm-Wide Turbines Available.

[13] Intermittent Generation Availability information entered in the Pre-Production Markets Portal is not reflected in the Pre-Production pre-dispatch and PASA forecasts. Instead, the availability information entered in the Production Markets Portal is used in the creation of the Pre-Production pre-dispatch and PASA forecasts, for the convenience of participants.

  - Farm-Wide Wind Speed.
  - Wind Turbine Power Conversion curve (provided in the ECM).
- Solar farms:
  - Local Limit.
  - All Cluster-Level Inverters Available.
  - Cluster 1 Inclined Irradiance.
  - Participant-provided Solar Power Conversion Curve or default solar power conversion curve (developed by AEMO using the farm's solar ECM).

If any of the above SCADA signals are bad quality, the FCST value will be rejected, which will result in the generator's dispatch UIGF equalling the generator's initial output ('persistence dispatch forecast'). In addition, if any of the above SCADA signals are not configured correctly, producing stuck values, or don't reflect actual farm availability, the FCST value will be impacted, causing impacts to dispatch forecast accuracy. If this occurs, the AEMO Control Room has the ability to disable the FCST analog, which will result in the generator receiving a persistence dispatch forecast. This increases the risk of the dispatch UIGF, and dispatch targets, eroding to 0 MW when consecutive semi-dispatch cap periods apply. This is due to semi-scheduled generators' obligation for output to not exceed the semi-dispatch cap. Thus, it is in the generator's interest to have all ECM SCADA signals working as expected to ensure the FCST analog is functioning correctly, and the forecasting model is implemented as early as possible.

The requirements to develop and implement the forecasting model are:

- Operational data
  - Sufficient accumulation of operational data via SCADA signals (at least 2 days).
  - Generator is online and currently generating.
- Critical ECM SCADA signals
  - Configured and scaled correctly, working as expected, and are deemed 'good' quality.
  - Representative of conditions at the generator site.
  - Refer to Appendix A for further information regarding this requirement.
- Availability information
  - 'Upper MW Limit' and 'Elements Available' information is updated in the Production Markets Portal to reflect actual farm availability as indicated in their SCADA Local Limit and Turbines/Inverters Available signals.

AEMO has a monthly forecasting model rollout schedule. If the requirements above are achieved by the monthly cut-off date (first or second Monday of the month), the farm will be included in the monthly batch and will have their forecast model implemented within approximately 2-3 weeks of the cut-off date.

AEMO will review and re-tune the forecasting models of all new wind and solar farms after a period of operation has passed and a sufficient number of model input unconstrained data samples have been accumulated. This review and re-tuning could take place any time from a few weeks to a few months after registration, depending on the quality of input data, the range of input conditions observed, and how often output was constrained.

It is critical ECM SCADA signals continue to work and reflect actual generation available capacity and site conditions to ensure accurate dispatch forecasts and targets are produced. In addition, the intermittent generation availability in the Markets Portal must also be updated in the Markets Portal or via API to reflect the farm-wide and element availability which will ensure accurate pre-dispatch, PDPASA and STPASA forecasts are produced.

2.4 Monitoring and updating information during operation

This section expands on Section 2.2.1 and provides specific examples during generator commissioning, hold point testing and normal operating conditions where participants are required to actively manage forecast conditions of their plant in both the dispatch, pre-dispatch and PASA horizons. These requirements are mandatory and are monitored by the Australian Energy Regulator (AER) to ensure compliance[14].

2.4.1 High wind and high temperature de-rating or cut-out

Extreme wind conditions can severely impact the output of a wind generator; however, due to the nature of the average wind speed forecasts with large temporal resolutions in AWEFS, high wind de-rating is generally not anticipated in the UIGF in pre-dispatch or PASA. This can cause risk of over-forecasting the available wind resource at times where extreme weather may be impacting numerous aspects of the NEM. Previous events of high wind cut-out that were not forecast have resulted in deviations from forecast reserves in pre-dispatch in the order of 800 MW four hours ahead and 600 MW half-an-hour ahead in South Australia.

Extreme temperature conditions can severely impact the output of both solar and wind generators. Wind generators are typically more impacted by extreme temperature conditions which are not considered when calculating the UIGF by AWEFS in pre-dispatch or PASA. This can cause risk of over-forecasting the available wind resource at times where extreme weather is very likely to be impacting numerous aspects of the NEM. Previous events of high temperature cut-out on wind farms that were not forecast have resulted in deviations from forecast reserves in pre-dispatch in the order of 450 MW in Victoria[15].

AEMO published investigations into forecasting of temperatures above cut-out thresholds in its *Temperature Forecast Analysis for Summer 2019-20* paper[16]. The analysis found that from the three days ahead time horizon, temperature forecasts in regional Victoria for 20 December 2019 provided sufficient signal that temperature de-rating was likely to occur, such that participants could estimate reductions in availability and submit to AEMO via the Markets Portal.

Participants are required to follow the below requirements in the dispatch, pre-dispatch and PASA timeframes for high wind and high temperature de-rating/cut-out:

- Dispatch timeframe:
  - High wind de-rating/cut-out: Updating the SCADA Local Limit and Number of Turbines in Extreme cut-out signals (if available) to reflect the reduced active power export limit.
  - High temperature de-rating/cut-out: Updating the SCADA Local Limit or Turbines/Inverters Available signals to reflect the reduced active power export limit.
- Pre-dispatch and PD/STPASA timeframe:
  - In accordance with Clause 3.7B(b) of the NER, non-scheduled generating units with semi-scheduled obligations and all semi-scheduled participants are required to update and reflect anticipated plant availability to ensure accuracy of Pre-Dispatch and PASA is maintained. Participants are encouraged to monitor local site conditions, obtain site-based temperature and wind speed forecasts and monitor Bureau of Meteorology (BoM) severe weather warnings in order to provide their best estimate of the Upper MW Limit via the Markets Portal. Estimates should be updated as the uncertainty of an event reduces at shorter time horizons.

[14] Changes in forecast or operating conditions may trigger compliance and notification requirements under several NER provisions, including, but not limited to, clauses 3.7B (availability information for UIGF purposes), 3.8.22A (dispatch offers not to be false or misleading), 4.9.8 (compliance with dispatch instructions) and clause 4.15 (non-compliance with GPS).

[15] For further information on the high temperature de-rating from 31 January 2020, see Section 5.1 of AEMO, Reliability and Emergency Reserve Trader (RERT) Quarterly Report Q1 2020, at https://aemo.com.au/-/media/files/electricity/nem/emergency_management/rert/2020/rert-quarterly-report-q1-2020.pdf.

[16] At https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/load-forecasting/temperature-forecast-analysis-for-summer-2019-20.pdf.

Intermittent generators may want to consider whether to engage a third-party forecast vendor that can commission local, site-based forecasts and provide situational awareness and risk management tools to ensure safe, efficient operations during extreme weather.

2.4.2 Module stow for solar farms

Solar farms that stow their modules at a fixed position, due to high winds on-site, vegetation management, or faulty tracking system, must ensure their SCADA Inclined Irradiance signal reflects the stow module orientation/inclination. In addition, the intermittent generation availability should be updated in the Markets Portal or via API to reflect the reduced plant availability. This will ensure ASEFS captures the stow position of the modules and reflect this in the dispatch, Pre-dispatch and PASA UIGF.

If modules are stowed in different positions across the farm, an average inclination of the stow position should be communicated to AEMO. For example, if the solar farm has been set up as one cluster in ASEFS, AEMO would be receiving only one SCADA Inclined Irradiance signal which should be communicated to AEMO as an average of all pyranometer inclined irradiance measurements on site. If half the modules were facing 15 degrees west and the other half facing 15 degrees east, the SCADA Inclined Irradiance signal should show 0 degrees.

2.4.3 Network outages and generator runbacks

Network outages and generator runback events that are not managed by AEMO through the central dispatch process (for example, via constraints) need to be communicated to AEMO as a technical limitation to export energy.

Transmission outages are normally submitted to the Network Outage Scheduler (NOS) by the transmission network service provider (TNSP), and are consequently managed by AEMO through the central dispatch process. To ensure a generator remains compliant with transmission network outage limits and minimises risks to power system security, the generator is advised to limit their active power controller to no higher than the outage level for the outage period. Generators cannot rely on a semi-dispatch cap to set during this period as a dispatch UIGF lower than the network outage constraint limit results in no semi-dispatch cap being set.

Distribution outages are typically not managed by AEMO's dispatch process, so participants need to liaise and confirm with the distribution network service provider (DNSP) whether the outage or generator runback has been communicated to AEMO and thus, managed in central dispatch.

If not, participants should use the following methods to communicate these events to AEMO in the dispatch, pre-dispatch and PASA timeframes:

- Dispatch timeframe – updating the SCADA Local Limit signal to reflect the reduced export limit:
  - As a backup or if SCADA Local Limit isn't configured, the energy offer can be updated by shifting capacity to higher priced bands – note, there is a risk the farm could be dispatched if the market price reaches the band price. In addition, the 'Max Avail' feature is ignored for semi-scheduled generators and replaced with the dispatch UIGF calculated by AWEFS/ASEFS.
  - As a last resort, participants can also request the AEMO Control Room to apply a quick constraint to the outage or runback level if SCADA Local Limit and energy bid are unable to be updated.
  - Generators participating in self-forecasting must incorporate the reduced export limit (due to outages or runbacks) in their self-forecasts.
- Pre-dispatch and PD/STPASA timeframe:
  - Updating the intermittent generation availability (Upper MW Limit, Elements Available) in the Markets Portal or via API.

2.4.4 Responding to price (active bidding)

Generators who wish to change their availability for commercial reasons, including in response to low or negative spot prices or exposure to high FCAS prices, must do so by actively updating their energy dispatch offers to ensure they receive an appropriate dispatch target prior to changing their energy output. Offers must not be misleading (NER clause 3.8.22A) and rebids must be consistent with the requirements in clause 3.8.22.

2.4.5 System strength constraints

A generator may have to reduce its output due to system strength requirements. There are currently two types of system strength constraints in NEMDE:

- Limitations in MW output (MW constraint).
- Limitations in the number of turbines/inverters available (element constraint).

Binding of the MW constraint will require the generator to reduce its output to the constraint MW level. Furthermore, if a generator exceeds the number of turbines/inverters available stated in the element constraint, the generator will receive a 0 MW semi-dispatch cap and require reducing its output to 0 MW. A 0 MW semi-dispatch cap will continue to apply until the number of inverters/turbines available reduces to at or below the number stated in the element constraint.

As the reduced MW availability has been captured in AEMO's central dispatch process, the participant is not required to update its intermittent generation availability in the Markets Portal or API.

2.4.6 Dispatch and linear ramping

When a semi-dispatch cap is set for a dispatch interval, the generator's active power output must not consistently exceed the dispatch level, otherwise AEMO will declare the farm as non-conforming as per NER 3.8.23(b). Furthermore, the generator is expected to ramp linearly from its initial active power output to its semi-dispatch cap applying at the end of the 5-minute dispatch interval, subject to energy availability. This requirement applies to semi-scheduled generating units that have an active power control system capable of linear ramping as agreed in the relevant GPS. When a semi-dispatch cap is not set, the generator is free to generate at the available resource although, larger deviations from the generators dispatch level can contribute to increased Causer Pays factors. Refer to Dispatch - SO_OP_3705[17] for further information on dispatch requirements.

2.4.7 Wind farm curtailment

- Wind sector management:
  - Wind farms with turbines placed in close proximity can experience wake effects which may require certain turbines to shut down for certain wind conditions. The shut-down of these turbines reduces the overall MW capacity to export power, so it must be reflected in the SCADA Local Limit signal if not already reflected in SCADA Turbines Available signal. The intermittent generation availability in the Markets Portal must also be updated to reflect the reduced MW capacity/turbine availability if the reduction is 6 MW or greater.
- Other scenarios:
  - Some or all wind turbines within a wind farm may need to reduce output or stop operating due to environmental conditions, or to ensure compliance with semi-dispatch instructions. To achieve this, wind farms may enable feathering of the blades or place turbine(s) in pause mode. Feathering of the turbine blades reduces the MW capacity of that turbine and should be reflected in the SCADA Local Limit signal to ensure AWEFS captures the MW capacity reduction. Turbines placed in pause mode to comply with a semi-dispatch cap should be counted as available in the SCADA Turbines Available signals. When no semi-dispatch cap applies following the capped period, the turbine may still be in

[17] At https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/procedures/so_op_3705-dispatch.pdf.

pause mode. In this case, the SCADA Local Limit should reflect the reduced MW capacity of that turbine(s) to ensure AWEFS does not over-forecast availability as the SCADA Turbines Available signal includes the turbines in pause mode.

3. Participant self-forecasting

In early 2018, AEMO and the Australian Renewable Energy Agency (ARENA) began undertaking a Market Participant 5-minute self-forecasting program to demonstrate the potential benefits of wind and solar generator self-forecasting to the operation of the power system.

To date, participant self-forecasting has delivered system-wide benefits by providing greater autonomy to existing semi-scheduled generating units and reducing generation dispatch forecast error compared with AWEFS/ASEFS dispatch forecasts. This has led to reductions to generators' Causer Pays factors, in turn reducing participants' regulation FCAS charges. Participants currently using self-forecasting have expressed positive feedback on the program.

AEMO recommends all intermittent generators consider their self-forecasting capability and if appropriate apply for participant self-forecasting for their generating unit(s).

Participant self-forecasting allows a generator to provide dispatch self-forecasts of the UIGF from their semi-scheduled generating units for use in dispatch. Semi-scheduled generating units must register with AEMO to submit dispatch self-forecasts, and can do so from the generator registration effective date. Following this, AEMO will then work with the generator (or their delegated third-party forecast provider) to establish secure access to the self-forecasting Application Programming Interface (API), where they will be able to submit dispatch self-forecasts.

AEMO will conduct weekly assessments of the dispatch self-forecast according to the assessment procedure outlined on AEMO's website, for a minimum period of eight weeks. Once the dispatch self-forecast meets the minimum performance criteria, the participant's dispatch self-forecast will be accredited and used in dispatch unless it falls below the minimum performance criteria or AEMO determines it is impacting system security.

More information on participant self-forecasting and how to register can be found on AEMO's website[18].

Participants must meet both reliability and performance requirements for the self-forecast to be used in dispatch. If self-forecasts are causing large dispatch errors (that is, significantly affecting dispatch outcomes or threatening system security), AEMO will suppress the self-forecast for up to one week.

[18] At https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Solar-and-wind-energy-forecasting/Participant-forecasting.

4. Maintaining 24 hour generator control room contacts

At times, the AEMO Control Room may need to contact a generator to request information, issue a manual instruction or direction, or provide an update regarding SCADA, AWEFS/ASEFS forecasts, or participant self-forecasts. These calls may require urgent action to maintain or restore power system security and must be given priority. All generators need to ensure that operational personnel for each generating system can always be contacted by the AEMO Control Room. Those personnel must be capable of immediately implementing AEMO's instructions or responding to urgent requests.

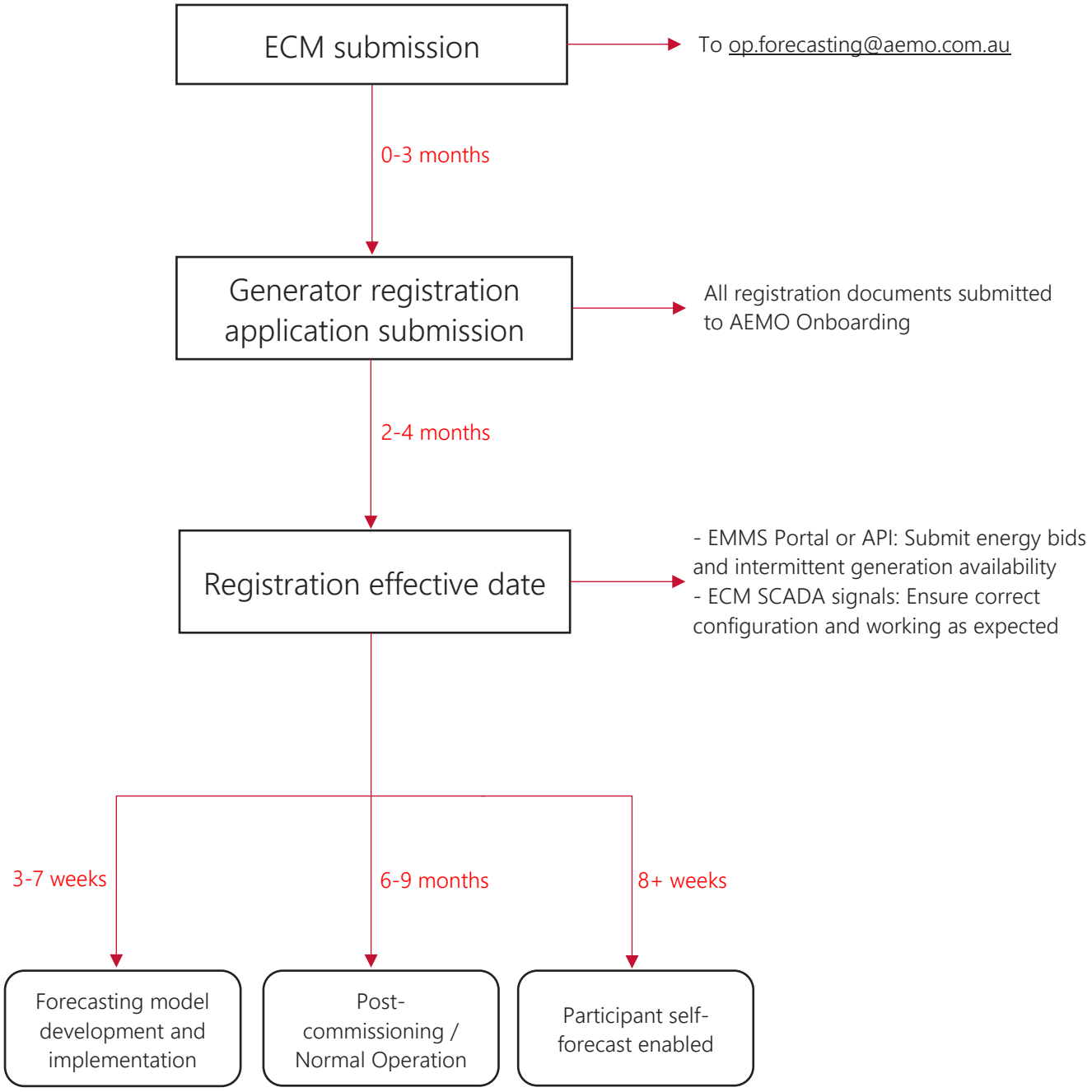
Participants need to ensure they maintain current contact details as required by NER clause 4.11.3 so the AEMO Control Room can contact the generator's operational personnel at all times. Participants can update a generator's contact details by submitting a query to AEMO's Support Hub[19]. Participants must ensure they include contact details for their trading team for bidding/dispatch purposes, as well as including contact details for voltage control and system security.

If a generator cannot be contacted by the AEMO Control Room, or if the request or instruction is not actioned by the generator, it will be considered non-compliant and the matter will be referred to the AER. If the operation or connection of a generating system is creating a security risk in real time and operational personnel cannot be contacted, the AEMO Control Room may need to instruct the NSP to take appropriate action, which can include disconnection.

[19] At https://aemo.com.au/en/contact-us

5. Timeline

Figure 1 Timeline



Appendix A – Configuration and checks for critical ECM SCADA signals

One of the pre-requisites for developing the AWEFS/ASEFS forecasting model is to ensure critical ECM SCADA signals are configured and scaled correctly, working as expected, are deemed 'good' quality, and are representative of site conditions. AEMO determines the generator's compliance with this requirement by assessing if the critical ECM SCADA signals are following the expected behaviour as outlined in Table 2.

Table 2 Expected behaviour of critical ECM SCADA signals

Technology type	Critical ECM signal	SCADA checks/Expected behaviour
Wind and Solar	Active Power (Wind: farm and cluster-level Solar: farm-level)	• Shows non-zero values during certain times, and appearing like live variable generation. No continuous constant value periods except if at zero, Maximum Capacity, available capacity or at a set point or local limit. • Does not exceed the SCADA Control Set-Point, SCADA Local Limit, and the Maximum Capacity. • Does not exceed 0 MW when SCADA Turbines/Inverters Available = 0, and SCADA Wind Speed is less than the cut-in wind speed, and Inclined Irradiance = 0. • Solar farms: Zero during night-time. On a clear sky day, typical rising morning ramp/ falling afternoon ramp shape – or below the typical shape on a more cloudy/overcast day. • Must not be quantised more than 0.1 MW. • Marked as 'good' quality or any of the 'replaced' quality flags.
	Control System Set-Point (farm-level)	• When the semi-dispatch flag is ON, this signal should be set to the semi-dispatch cap level to ensure the farm is compliant by reducing farm output to the semi-dispatch cap level. • When the semi-dispatch flag is OFF, this signal should be set to the maximum capacity. • If a local limitation is more restrictive than the above, this signal should be set to the limitation level. • Must show capping effect on active power (if active power reaches the limit). • Marked as 'good' quality.

Technology type	Critical ECM signal	SCADA checks/Expected behaviour
	Local Limit (farm-level)	• This signal must reflect all local limitations that would reduce the generator's ability to export Active Power. • Hybrid units sharing a local limitation need to apportion and reflect this in each generating unit's Local Limit signal whilst ensuring: – individual dispatch targets or the aggregate target at the point of dispatch are met and; – compliance with GPS limits at the POC. • Limits managed by AEMO's central dispatch process (eg. via constraints) must be excluded from Local Limit. • Examples of Active Power limitations are: – High wind speed cut-out for wind farms. – Temperature de-rating for turbines, modules and inverters. – Generator transformer outages – Reactive power provision – GPS requirements (for example, Hold Point limits, Maximum Capacity limits) – Distribution outages or operation of runback schemes not managed by AEMO's central dispatch process via constraints. – Wind sector management or if turbines are in 'pause' mode. • When the semi-dispatch flag is OFF, this signal should be less than or equal the SCADA Control Set-Point. • When the semi-dispatch flag is ON, this signal should not equal the SCADA Control Set-Point. • Must show capping effect on active power (if active power reaches the local limit). • Marked as 'good' quality.
Solar only	Number of Inverters Available (cluster-level)	• Value is >= 0 and does not exceed the number of inverters in its cluster as per the approved ECM. • Value must be an integer. • Marked as 'good' quality.
	Global Inclined Irradiance (cluster-level)	• This signal must reflect the panel inclination. During the majority of the day, the global inclined irradiance should be greater than the global horizontal irradiance for farms with working tracking systems. • For solar farms with multiple pyranometers in each cluster, this signal should represent the average of all pyranometer readings in the cluster. It should filter any bad or stuck readings before averaging is calculated. • Must look like a live variable measurement. • Must be <5W/m2 overnight and >5W/m2 during daylight hours (except dawn/dusk). Must be below 1,650 W/m^2. • Must not be quantised more than 1 W/m^2. • Marked as 'good' quality.
Wind only	Number of Turbines Available (farm and cluster-level)	• Value does not exceed the number of turbines in its cluster. • Farm-level value does not exceed the total number of turbines at the farm. • Value must be greater than or equal to 0. • Value must be an integer. • Marked as 'good' quality.

Technology type	Critical ECM signal	SCADA checks/Expected behaviour
	Number of Turbines in Extreme cut-out (farm and cluster-level)	• Value does not exceed the number of turbines in its cluster. • Farm-level value does not exceed the total number of turbines at the farm. • Value must be greater than or equal to 0. • At times when the farm level wind speed is between 5 and 15 m/s, the turbines in extreme wind cut-out value should typically be zero or very low. • Value must be an integer. • Marked as 'good' quality.
	Wind Speed (farm and cluster-level)	• For the farm-level wind speed signal, this must be calculated as an average of all turbine nacelle wind speeds. • For the cluster-level wind speed signal, this must be calculated as an average of turbine nacelle wind speeds within the cluster. • Must not be quantised more than 0.1 m/s. • Must look like a live variable measurement, typically ranging between 0 and 25 m/s, higher on stormy days (up to 35 m/s). • Marked as 'good' quality.

Appendix B – List of reference documents and AEMO contacts

Regulatory documents referenced in this handbook

Name	NER clause	Website link (landing page)
Energy Conversion Model Guidelines: AWEFS & AWEFS ECM templates and Guide to data requirements	2.1.3(b)(5)	https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/registration/register-as-a-generator-in-the-nem: Under heading "Wind and solar forecasting"
NEM Generator Registration Guide	2.1.3(a)	https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/registration/register-as-a-generator-in-the-nem
Power System Data Communication Standard	4.11.1(a)	https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections/transmission-and-distribution-in-the-nem/stage-3-application: Under heading "Related guides and policies"
Communication System Failure Guidelines		https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections/transmission-and-distribution-in-the-nem/stage-6-completion: Under heading "Related guides and policies"
Regulation FCAS Contribution Factors Procedure	3.15.6A(k)	https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services/ancillary-services-causer-pays-contribution-factors

List of AEMO contacts

Enquiry or submission type	Contact
ECM submissions and updates	op.forecasting@aemo.com.au
SCADA signals	gridmodellers@aemo.com.au
General registration enquiries	onboarding@aemo.com.au
Contact updates and other enquiries	support.hub@aemo.com.au or phone: 1300 236 600

Glossary

This document uses many terms that have meanings defined in the National Electricity Rules. The NER meanings are adopted unless otherwise specified. The main acronyms and abbreviations used in this document are listed below.

Term	Definition
API	Application programming interface
ASEFS	Australian Solar Energy Forecasting System
AWEFS	Australian Wind Energy Forecasting System
DNSP	Distribution Network Service Provider
ECM	Energy conversion model
EMMS	Electricity Market Management System
EMS	Energy Management System
FCAS	Frequency control ancillary services
FCST	Short for 'forecast' - AEMO's EMS calculated dispatch UIGF
FTP	File transfer protocol
GPS	Generator performance standard
IRP	Integrated Resource Provider
MMS	Market Management System
m/s	Metres per second
MW	Megawatt (one million watts (W))
NEM	National Electricity Market
NEMDE	NEM dispatch engine
NER	National Electricity Rules
NSP	Network Service Provider
PASA	Projected assessment of system adequacy
PD	Pre-dispatch
PDPASA	Pre-dispatch projected assessment of system adequacy
SCADA	Supervisory control and data acquisition
STPASA	Short term projected assessment of system adequacy
TNSP	Transmission Network Service Provider
UIGF	Unconstrained intermittent generation forecast