Australian Wind Energy Forecasting System (AWEFS) and Australian Solar Energy Forecasting System (ASEFS)

September 2022

An overview of ASEFS and AWEFS design and usage for forecasting available capacity for semi-scheduled generators in the NEM.

Important notice

Purpose

AEMO has prepared this document to provide information about the Australian Wind Energy Forecasting System (AWEFS) and Australian Solar Energy Forecasting System (ASEFS), as at the date of publication.

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Version control

Version	Release date	Changes
1	~~D/M/YYYY~~May 2016	Previous version.
2	19/~~0~~9/2022	Included the Australian Solar Energy Forecasting System (ASEFS) and updated sections to be inclusive of wind and solar where appropriate. Removed references to MTPASA Updated the document to reflect the National Electricity Amendment (Integrating Energy Storage Systems into the NEM) Rule 2021. Updated template

AEMO acknowledges the Traditional Owners of country throughout Australia and recognises their continuing connection to land, waters and culture. We pay respect to Elders past and present.

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Glossary

In this document, a word or phrase in *this style* has the same meaning as given to that term in the National Electricity Rules.

In this document, capitalised words or phrases or acronyms have the meaning set out opposite those words, phrases, or acronyms in the table below.

Unless the context otherwise requires, this document will be interpreted in accordance with Schedule 2 of the *National Electricity Law*.

Term	Meaning
5MPD	5-minute Pre-dispatch
AWEFS	Australian Wind Energy Forecasting System
ASEFS	Australian Solar Energy Forecasting System
ECM	Energy conversion model
EMMS	Electricity Market Management Systems
EMS	Energy Management System
ESOO	Electricity Statement of Opportunities
FCST	Short for 'forecast' - AEMO's EMS calculated dispatch UIGF
MW	Megawatts
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
POE	Probability of Exceedance
SCADA	Supervisory Control and Data Acquisition
SDC	Semi-dispatch Cap
ST PASA	Short term Projected Assessment of System Adequacy
TNSP	Transmission Network Service Provider
UIGF	Unconstrained Intermittent Generation Forecast

1 Introduction

The purpose of this document is to provide a ~~high-level~~high-level overview of the Australian Wind Energy Forecasting System (AWEFS) and Australian Solar Energy Forecasting System (ASEFS) design, detailing the inputs, outputs and their usage. The document also provides information about the linkage between ~~wind~~ generator Supervisory Control and Data Acquisition (SCADA), Australian Wind Energy Forecasting System (AWEFS), Australian Solar Energy Forecasting System (ASEFS) and NEM Dispatch Engine (NEMDE), and how NEMDE generates dispatch instructions (dispatch level and semi-dispatch cap) for semi-scheduled generators using AWEFS and ASEFS forecasts.

The intended audience for this document is anyone interested in gaining an understanding of ~~the Australian Wind Energy Forecasting System (~~AWEFS~~)~~ or ~~the Australian Solar Energy Forecasting System (~~ASEFS~~)~~.

2 Overview

Under National Electricity Rules (NER) Clause 3.7B, AEMO is required to prepare forecasts of the available capacity of semi-scheduled generating unit~~or~~s, in order to schedule sufficient generation in the Dispatch process. AEMO is also required to prepare Unconstrained Intermittent Generation Forecasts (UIGF)[1] to be used in Projected Assessment of System Adequacy (PASA) processes (NER Rule Clause 3.7.1 (c) (2)) for reserve assessment purposes. In order to meet these requirements, the Australian Wind Energy Forecasting System (AWEFS) and Australian Solar Energy Forecasting System (ASEFS) produces wind or solar generation forecasts for all semi-scheduled wind and solar generating units~~ors~~ in the NEM. AWEFS also produces wind generation forecasts for~~and~~ significant non-scheduled wind generating units~~ors~~ in the NEM.

[1] Unconstrained Intermittent Generation Forecasts (UIGF) is the forecast generation output of individual semi-scheduled generating units (wind/solar farms) ~~wind generators~~ without considering network limitations modelled in AEMO constraints, economical decisions or the dispatch optimisation process.

3 Types of forecasts

AWEFS and ASEFS generate~~s~~ forecasts for the Dispatch, 5MPD, Pre-Dispatch, and Short term PASA ~~and Medium Term PASA~~ processes. The horizon (period up to which forecasts are generated), frequency (how often forecasts are generated) and resolution (period for which the forecast applies) of the forecasts for each process are provided in Table 1~~Table 1~~.

Table 1 Forecast horizons, frequency of updates and resolution

	Horizon	Frequency of updates	Resolution
Dispatch	5 min	5 min	5 min
5MPD	2 hours	5 min	5 min
Pre-dispatch	Up to 40 hours	30 min	30 min
Short term PASA	8 days	30 min	30 min
~~**Medium term *PASA***~~	~~2 years~~	~~Daily~~	~~Daily~~

4 Inputs

There are two sets of inputs that are used for generating forecasts in AWEFS and ASEFS.

1. A set of static data related to the technical specifications of the wind/solar generator (from the Energy Conversion Model[2]), in order to develop the forecasting models for different types of wind/solar generators.
2. A set of dynamic data, consisting of real-time measurements (through SCADA) and numerical weather predictions, are used in the forecasting models to generate the forecasts for the different timeframes.

4.1 Static data – Energy ~~c~~Conversion ~~m~~Model

New ~~wind~~ semi-scheduled generators connecting to the NEM, and some intermittent non-scheduled generators (where network conditions require it)~~, *connecting* to the *NEM*~~, are required to submit an Energy ~~c~~Conversion ~~m~~Model (ECM) consisting of the wind/solar generator details~~, historical meteorological measurements as well as~~and attributes of the individual clusters. Due to the different locational parameters and wind turbine / solar farm technologies associated with different wind/solar generators, it is necessary to develop forecasting models specific to each ~~wind g~~generator. The static data ~~and historical measurements~~ provided as part of the ~~*Energy conversion model*~~ECM assists in choosing and developing the forecasting models for each wind/solar generator. ~~The spreadsheet *Energy conversion model* Guidelines can be found at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Solar-and-wind-energy-forecasting.The *Energy conversion model* template and some of the key static data items contained in it are provided in Appendix A – *Energy conversion model* template and some key static data items.~~

4.2 Dynamic data

The dynamic data that are used in generating the forecasts vary based on the processes (or timeframes). The inputs for each process are listed below.

4.2.1 Dispatch and 5-~~-~~minute pre-dispatch (5MPD)

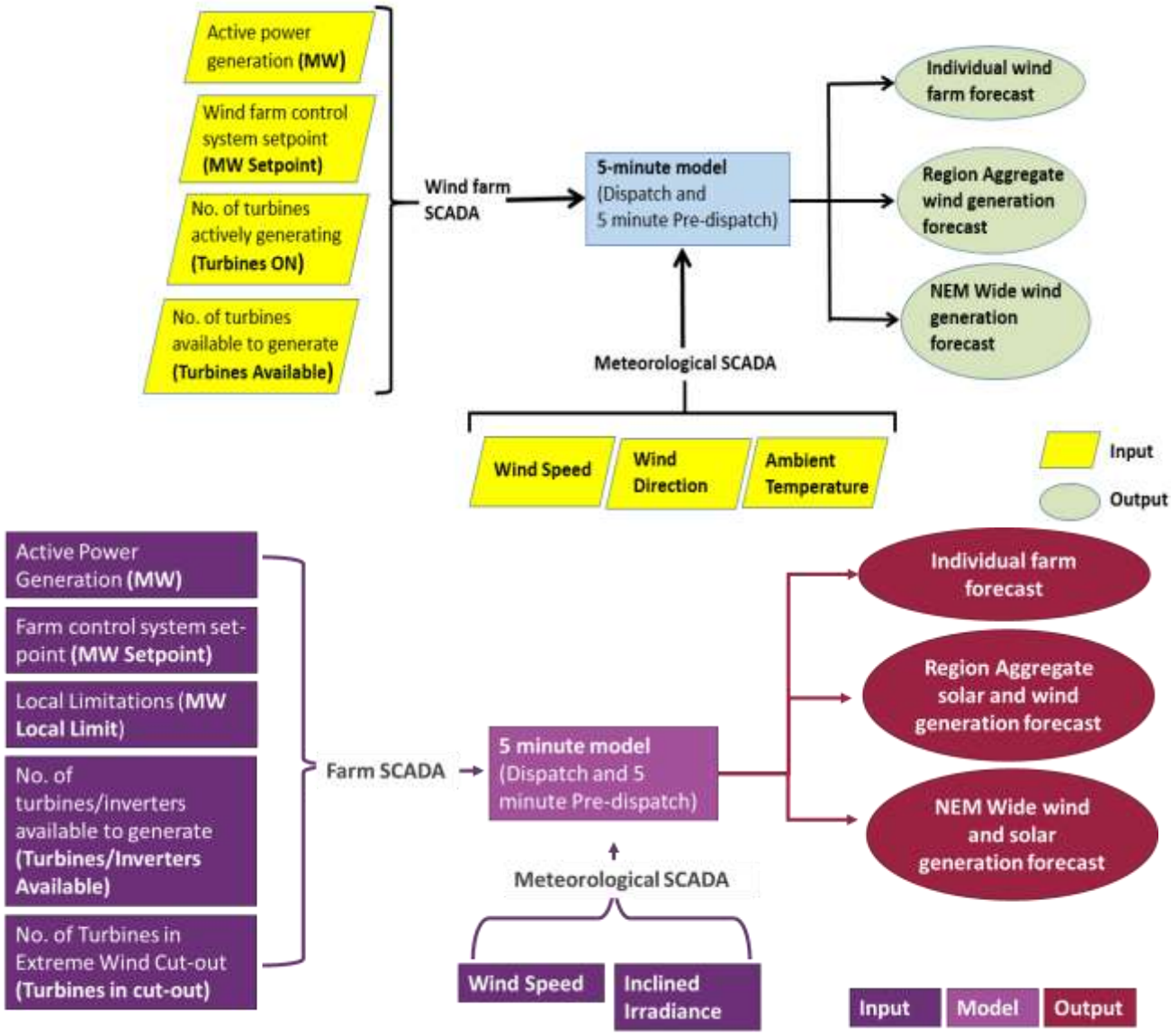
The forecasts in the Dispatch and 5-~~-~~minute Pre-dispatch processes (5MPD) depend on real-time measurements (SCADA[3]). Figure 1 below summarises the various SCADA inputs that are needed to generate the forecasts in the Dispatch and ~~5- minute Pre-dispatch~~ 5MPD processes ~~(5MPD).~~

[2] The *Energy Conversion Model* Guidelines spreadsheet can be found at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Solar-and-wind-energy-forecasting

[3] A guide to SCADA data requirements for AWEFS and ASEFS can be found at: https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/dispatch/policy_and_process/guide-to-data-requirements-for-awefs-and-asefs.pdf

~~Figure 1~~ Inputs and outputs for dispatch, 5MPD processes

~~Figure 2~~Figure 1



~~The Australian Wind Energy Forecasting System (~~AWEFS~~)~~ and ~~the Australian Solar Energy Forecasting System (~~ASEFS~~)~~ compute a~~n~~ ~~Unconstrained Intermittent Generation Forecast (~~UIGF~~)~~ for the dispatch timeframe (5 minutes ahead) ~~up~~to ST-PASA timeframe ~~to MT-PASA (~~27 days ~~years~~ ahead). These are forecasts of the available capacity of generation ~~assuming no network constraints apply~~ without considering network limitations modelled in AEMO constraints, economical decisions or the dispatch optimisation process. The process used for the 5-minute dispatch timeframe is described in detail below.

For non-scheduled ~~wind~~ farms, the AWEFS/ASEFS forecast is not used in the dispatch process – ~~–~~instead a persistence level is assumed.

For semi-scheduled wind and solar farms in the dispatch timeframe, AWEFS and ASEFS compute the 5-minute dispatch UIGF as follows:

1. A 1-minute average of SCADA data (live feed from wind/solar farm) is captured each minute. This SCADA includes MW generation, wind speed / global inclined irradiance, turbines / inverters available,

and control system set point, local limit and other signals as specified in the Energy Conversion ModelECM.

2. AWEFS/ASEFS determines if the wind/solar farm's output is constrained. It is assumed to be constrained if the current dispatch interval is a semi-dispatch interval (i.e. the wind/solar farm is capped by NEMDE), or if the MW generation is close to the SCADA cControl sSystem sSet pPoint (within 5% of the generating unit's nameplate rating).
3. AWEFS/ASEFS will input the current MW generation into the UIGF calculation if the farm's output is not constrained. If the output is constrained as determined in step 2, AWEFS/ASEFS will input into the UIGF calculation a potential power based on the SCADA wWind sSpeed / Inclined iIrradiance and SCADA tTurbines / iInverters available, using a dynamically tuned power curve[4]. The higher of the current MW generation and the calculated potential power is used.
4. Steps 1-3 occur every minute. At 3 minutes into the current dispatch interval AWEFS/ASEFS calculates a forward forecast for the end of the next dispatch interval (7 minutes hence), based on filtering of the previous hour of 1-minute samples, heavily weighted to the lastrecent 1-minute averages.

A final step is to mix in a small proportion of the current pre-dispatch wind/solar forecast, which is in part based on numerical weather prediction models.

5. The UIGF is then capped by the SCADA Local Limit signal, representing local MW limitations on the plant (e.g. transformer outages, limitations due to reactive plant outages, network outages not reflected in AEMO constraints, derating effects). The UIGF is also capped by the optional Turbines Extreme Wind Cut-out signal, where the cap is at (turbine rated capacity * (SCADA Turbines Available – SCADA Turbines Extreme Wind Cut-out)).

Details of all the required SCADA can be found in the energy conversion modelECM guidelines[5]. spreadsheet *Energy conversion model* Guidelines at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Solar-and-wind-energy-forecasting.

During normal operation or periods when a wind generator is not *constrained off*, the UIGF forecasts are based on the active power generation (MW) SCADA from the wind generator, which is more reliable than a weather model-based forecast. That is, a wind generator's forecast for the next five minutes will be close to the wind generator's actual output in the previous five minutes. However at times when a wind generator is *constrained off*, the UIGF forecasts produced by the AWEFS system is based only on the wind speed, number of turbines available to generate and MW Setpoint SCADA.

The MW Setpoint is used by AWEFS to determine if the wind generator is constrained off (refer to Appendix C – but is not used to limit the Dispatch or 5 minute Pre-dispatch forecasts.

Appendix B – SCADA input used in Dispatch, 5MPD processes provides a description of each SCADA input used in the Dispatch and 5MPD processes.

The Turbines/Inverters UnaAvailable and Upper MW Limit information entered via AEMO's EMMS Participant WebMarkets Portal do not apply to the Dispatch and 5-minute Pre-dispatch timeframes. Local limitations on the plant are managed in the Dispatch and 5-minute Pre-dispatch timeframes using the SCADA Local Limit signal and the SCADA Turbines/Inverters Available signal.; to manage local limits in the Dispatch and 5 minute Pre-dispatch timeframes refer to the *Guide to Intermittent Generation* document on the *AEMO* website.

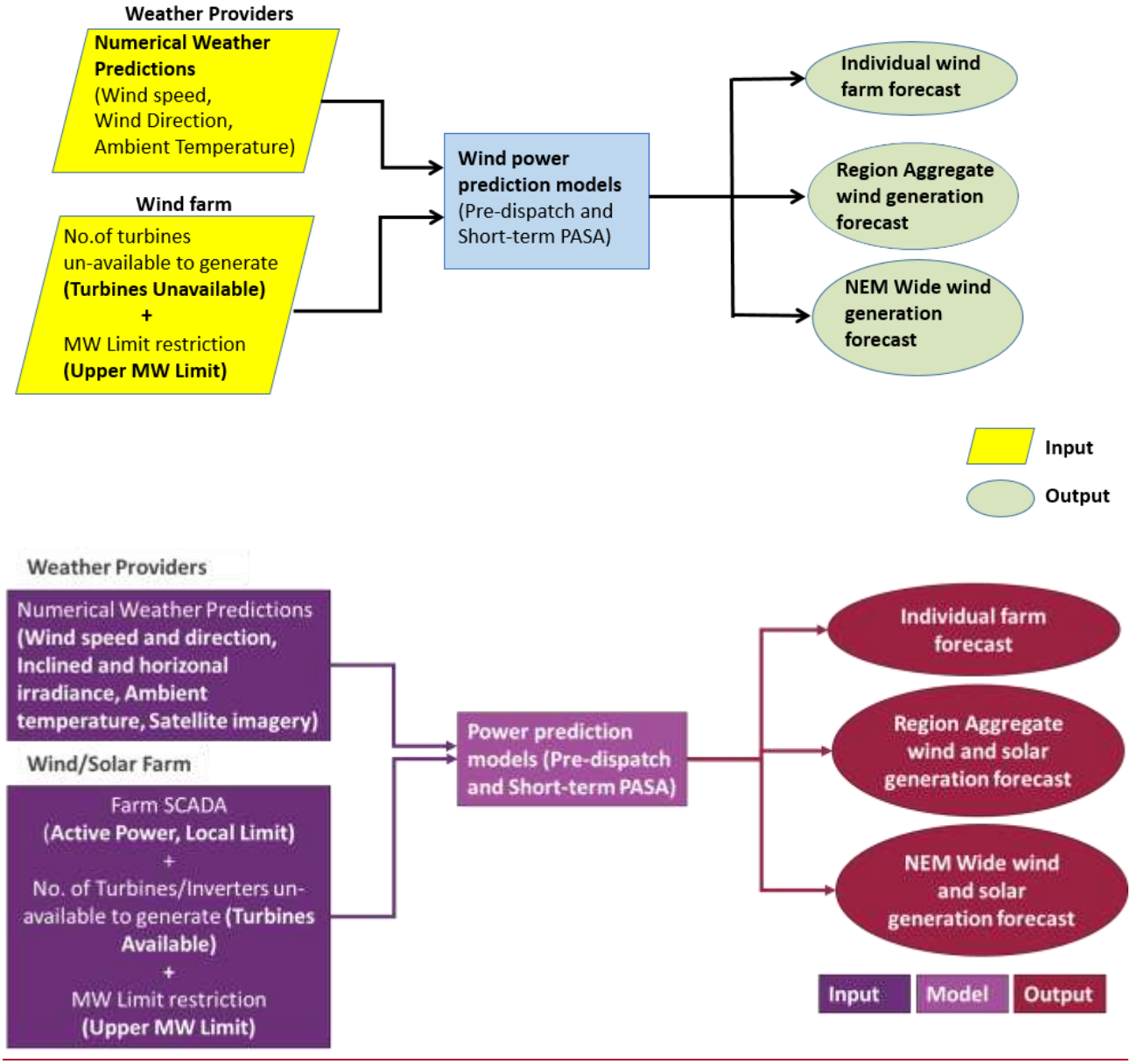
[4] Once sufficient unconstrained site-SCADA data is attained, wind farm power curve are updated on a daily basis and solar farm power curves are updated once every three months.

[5] Energy conversion model Guidelines available at : http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Solar-and-wind-energy-forecasting.

4.2.2 Pre-dispatch and Short term PASA

Figure 2~~Figure 2~~~~Figure 2: Inputs and Outputs for *Pre-dispatch* and *Short term PASA* forecasts~~~~Inputs and Outputs for *Pre-dispatch* and *Short term PASA* forecasts~~ below summarise the inputs required to generate the Pre-dispatch and Short term PASA forecasts.

~~Figure 3~~Figure 2 Inputs and outputs for Pre-dispatch and Short term PASA forecasts



The forecasts in the Pre-dispatch and Short term PASA timeframes are dependent on:

- Numerical Weather Predictions: AEMO has contracted with ~~two~~ several commercial weather forecast providers, to provide weather predictions that are used to generate the Pre-dispatch and ST PASA wind generation forecasts. The weather prediction that has the most impact on these forecasts is Wind speed/Global Inclined Irradiance.
  - No. of turbines/inverters ~~unaa~~Available to generate (Turbines ~~Una~~Available/Inverters Available~~)/inverters unavailable (Inverters Unavailable)~~: All wind and solar generators are required to

provide information regarding the number of turbines/inverters ~~unaA~~available for generation in each cluster. ~~This includes T~~turbines/inverters are considered unavailable to operate when they are (but not limited to):

- ~~that are under maintenance/repair and turbines that are being manufactured/installed.~~ Not yet built.
- Still being commissioned and not released for operation.
- Out of service due to a forced or planned outage. For example, maintenance or distribution network outage not reflected in AEMO constraints.
- Unable to generate due to unavailable connection network.

This information is used by AWEFS/ASEFS to determine the generation capability of the ~~wind~~ generator. The information is entered by wind/solar generator operators via AEMO's EMMS ~~Participant Web~~Markets Portal[6]. ~~Refer to the Guide to Intermittent Generation[7] document on the AEMO website.~~

- MW Limit restriction (Upper MW Limit): All wind/solar generators (including non-scheduled intermittent generators with an ECM) are also required to provide information regarding generation (MW) restrictions affecting the wind/solar generator. ~~These restrictions could be imposed on the wind generator by AEMO or the relevant NSP due to network limitations.~~ The restrictions could ~~also~~ be limitations within the ~~wind~~ generator itself, which may prevent the ~~wind~~ generator from generating above a certain limit. Non-scheduled generators may request AEMO to enter limitations on their behalf due to ~~from AEMO and/or the~~ TNSP outages. This information is used by AWEFS/ASEFS to determine the generation capability of the wind/solar generator. ~~The information is entered by wind/solar generator operators via AEMO's EMMS Participant Web Portal. Refer to the *Guide to Intermittent Generation* document on the *AEMO* website.~~
- The Turbines/Inverters ~~Una~~Available and Upper MW Limit entered via AEMO's EMMS ~~Participant Web~~Markets Portal do not apply to the Dispatch and 5-minute Pre-dispatch timeframes~~; to manage local limits in the Dispatch and 5-minute Pre-dispatch timeframes refer to the Guide to Intermittent Generation document on the AEMO website~~.

[6] Refer to the Guide to Intermittent Generation document on the AEMO website, available at https://aemo.com.au/-/media/files/market-it-systems/guide-to-intermittent-generation.pdf.

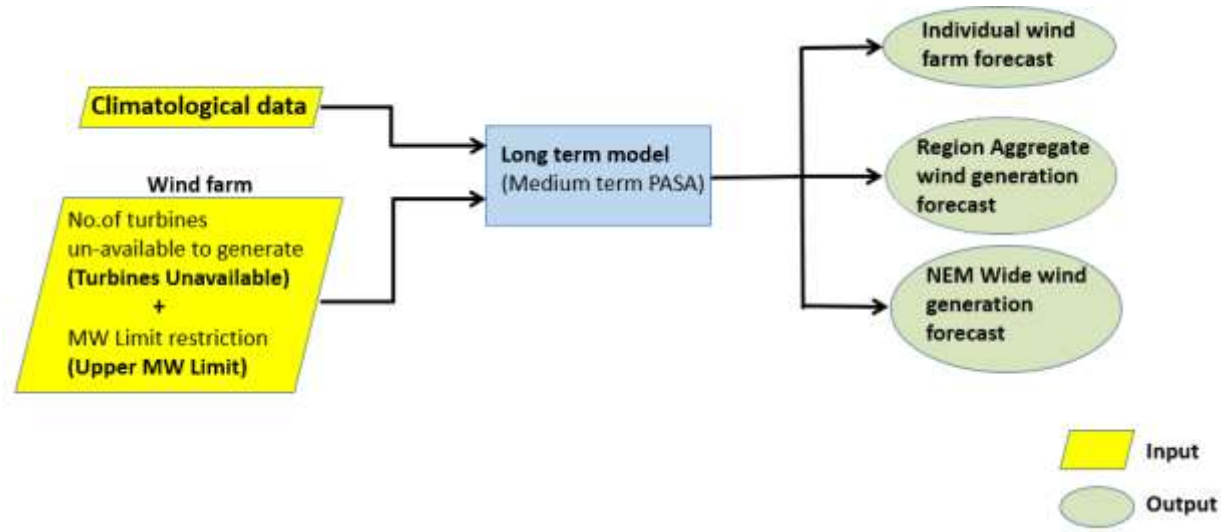
~~[7] Guide to Intermittent Generation available at https://aemo.com.au/-/media/files/market-it-systems/guide-to-intermittent-generation.pdf.~~

4.2.3 **Medium Term** *PASA*

Figure 3Figure 3: Inputs and Outputs for Medium-term PASA forecasts below summarise the inputs required to generate the Medium term f

5 orecasts.

~~Figure 4 Inputs and Outputs outputs for Medium-term *PASA* forecasts~~



~~The forecasts in the medium term timeframe are dependent on the following inputs.~~

~~Climatological data: Medium term forecasts are based on long term weather behaviour, at the wind/solar generator site or region. Medium term forecasts are not dependent on real-time measurements or numerical weather predictions since their accuracy is very limited for timeframes exceeding 10 days.~~

~~No.of turbines/inverters unavailable to generate (Turbines/Inverters Unavailable): Same as *Pre-dispatch* and *Short term PASAPre-dispatch* and *Short term PASA*~~

~~MW Limit restriction (Upper MW Limit): Same as *Pre-dispatch* and *Short term PASAPre-dispatch* and *Short term PASA*.~~

~~6~~5 Outputs

~~6.1~~5.1 Types of forecasts generated

The AWEFS/ASEFS system generates four different types of UIGF forecasts:

- Individual wind/solar generator forecasts: It generates wind/solar generation forecasts for all semi-scheduled and non-scheduled wind/solar generators individually (of registered capacity greater than or equal to 30 MW).
- NEM Wide forecast: It generates ~~a~~separate NEM Wide wind and ~~a~~ NEM Wide solar generation forecast comprising of generation due to semi-scheduled and non-scheduled wind or solar generators across the NEM.
- Region forecasts: It generates forecasts on a regional basis for New South Wales (NSW), Queensland (QLD), Victoria (VIC), South Australia (SA) and Tasmania (TAS), separately for wind and solar. Similar to the NEM Wide wind/solar generation forecasts, the regional forecasts include semi-scheduled and non-scheduled wind or solar generation within each region.

- Uncertainty forecasts: In Pre-dispatch, and Short term PASA ~~and Medium Term *PASA*~~ timeframes, AWEFS/ASEFS generates 10% Probability of Exceedance (POE) and 90% POE forecasts for the three types of forecasts listed above.

~~7~~6 Usage

This section details how UIGF forecasts are used in the different processes.

~~7.1~~6.1 Semi-scheduled wind and solar generation forecasts

- In Dispatch, 5MPD and Pre-dispatch processes, the UIGF forecasts for individual semi-scheduled wind/solar generators are used as available capacity. Available capacity refers to the generation capability of a ~~wind~~ generator that is available for Dispatch (without consideration of network limitations modelled in AEMO constraints, price bids etc.). For conventional generators, the available capacity for each unit is submitted by the ~~generators~~participant through their bid MaxAvail. However, for semi-scheduled and non-scheduled wind generators the available capacity is the same as their UIGF forecasts produced by AWEFS/ASEFS. ~~A bid of maximum availability~~The MaxAvail bid submitted by a semi-scheduled generator is ~~over-ridden~~not used in currently ignored when producing ~~by~~ the UIGF from AWEFS/ASEFS.
- In the Short term PASA process~~and Medium-term *PASA* processes~~, the UIGF forecasts for individual semi-scheduled wind and solar generators are used as PASA Availability. Similar to available capacity in the Dispatch, 5MPD and Pre-dispatch processes, PASA Availability in the Short term PASA ~~and Medium-term *PASA*~~ timeframe~~s~~ indicate the generation capability of the wind or solar generator without consideration of network limitations modelled in AEMO constraints, price bids etc.

~~7.2~~6.2 Non-scheduled wind / solar generation forecasts

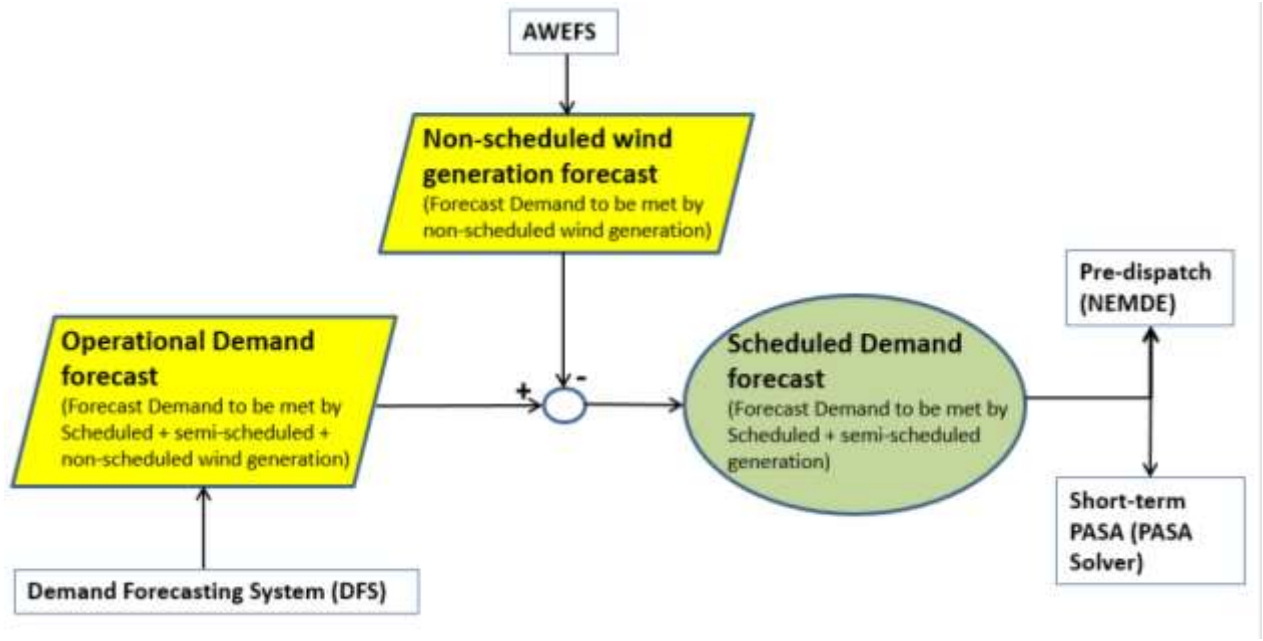
- In Pre-dispatch and Short term PASA processes, non-scheduled wind / solar generation forecasts are used in deriving the Scheduled Demand[8] used for reserve assessment. The individual non-scheduled wind and solar generation forecasts in each region are deducted from the Operational Demand[9] forecast generated by AEMO's Demand Forecasting System for the respective regions. The Scheduled Demand value thus produced is used in assessing generation and reserve availability in Pre-dispatch and Short term PASA processes. The Scheduled Demand value is also published to the market.

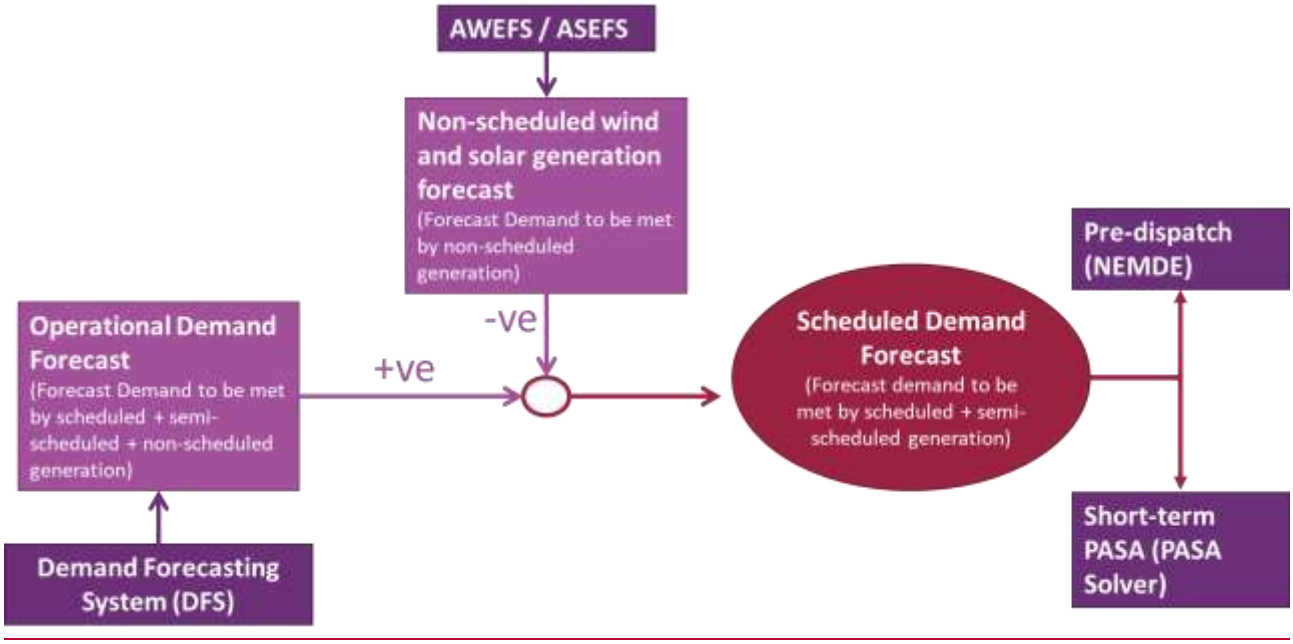
~~Figure 3Figure 3Figure 3Figure 4: Usage of non-scheduled wind/solar generation forecast in determining Scheduled Demand *for* Pre-dispatch and STPASAUsage of non-scheduled wind generation forecast in determining Scheduled Demand for *Pre-dispatch* and STPASA~~ below provides a summary of the above process.

[8] **Scheduled Demand** in a region is demand that is met by local scheduled and semi-scheduled generation and by generation imports to the region. **Scheduled Demand** differs from the other key demands in that it excludes the demand met by all non-scheduled (wind and non-wind) generation and exempt generation, and includes the demand of local scheduled loads.

[9] **Operational Demand** in a region is demand that is met by local scheduled generation, semi-scheduled generation and non-scheduled wind generation of aggregate capacity ≥ 30 MW (with some exceptions). This also includes generation imports to the region but excludes the demand of local scheduled loads. Further information can be found at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/Demand-terms-in-EMMS-Data-Model.pdf

~~Figure 5~~Figure 3 Usage of non-scheduled wind/solar generation forecast in determining scheduled demand for Pre-dispatch and ST PASA



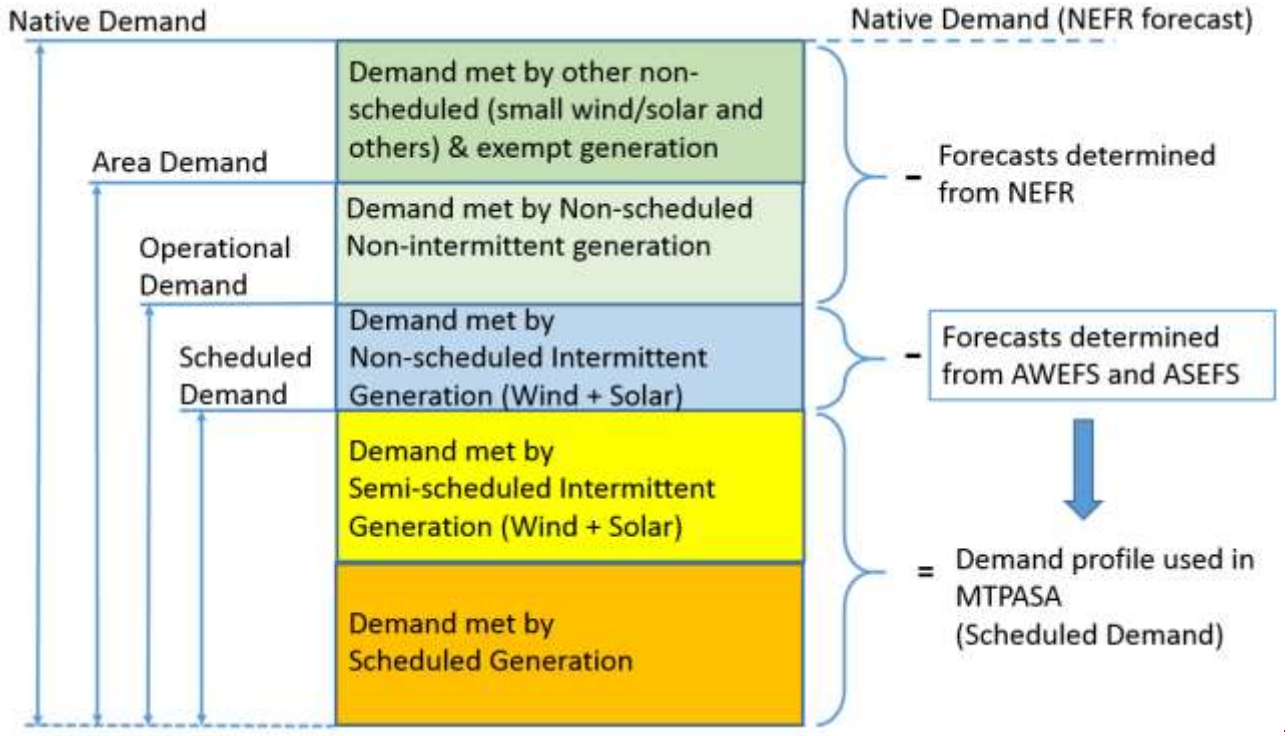


In the Medium-term *PASA* process, non-scheduled wind generation forecasts are deducted from the ESOO Native Demand[10] to determine the Scheduled Demand used for *reserve* assessment.

Figure 5Usage of non-scheduled wind generation forecast in determining Scheduled Demand for MTPASA below shows the different components of the NEFR Native Demand and how scheduled demand used in the Medium-term *PASA* process is derived by deducting the non-scheduled components.

[10] **Native Demand** in a region is demand that is met by local scheduled, semi-scheduled, non-scheduled and exempt generation and by generation imports to the region, excluding the demand of local scheduled loads.

~~*Figure 6 Usage of non-scheduled wind generation forecast in determining scheduled demand for MTPASA*~~



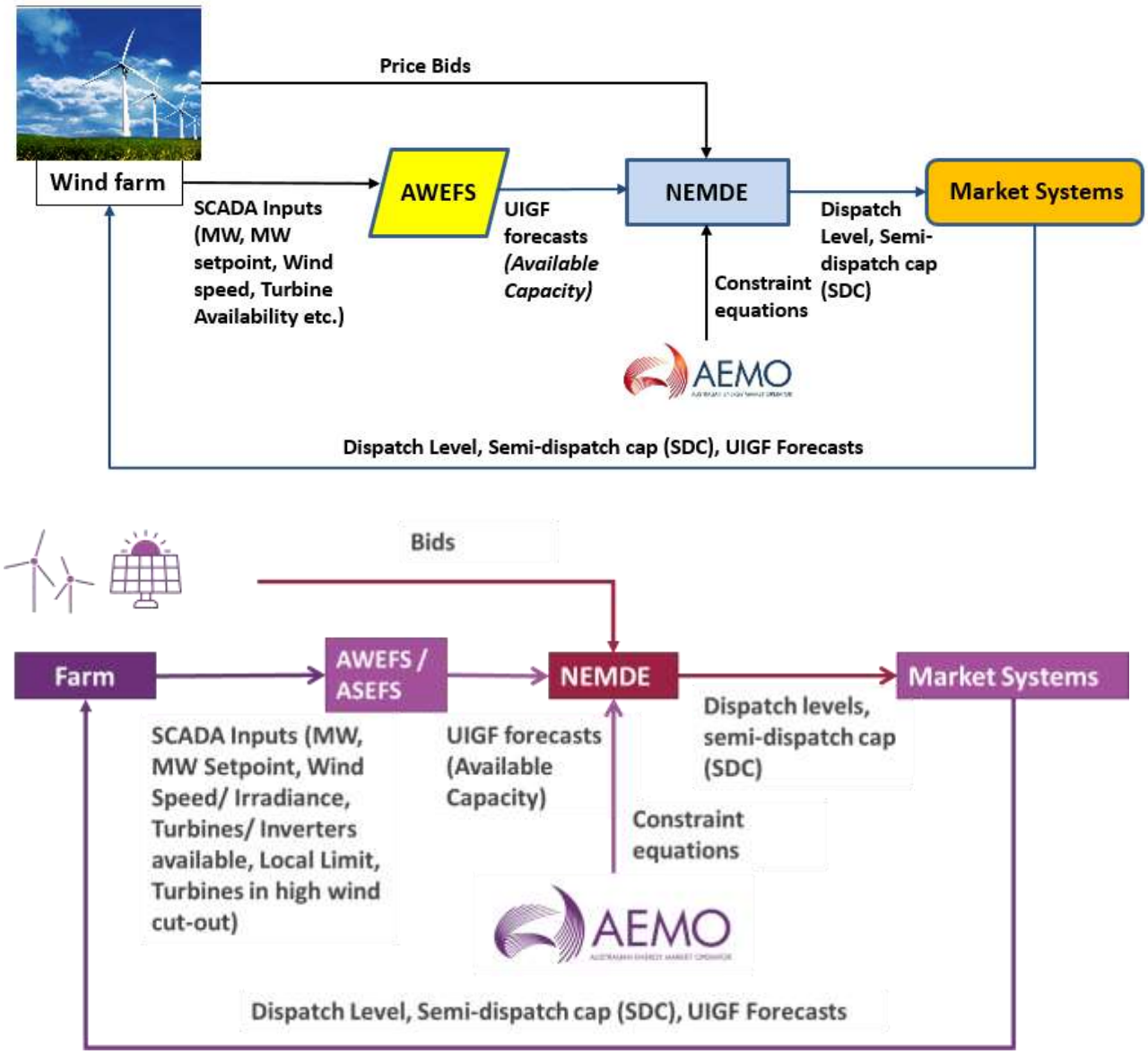
~~8~~7 Linkage between wind/solar generator SCADA, AWEFS/ASEFS and NEMDE

~~8.1~~7.1 Dispatch and 5-minute Pre-dispatch (5MPD)

The linkage between wind/solar generator SCADA, AWEFS/ASEFS and NEMDE in dispatch and 5MPD is summarised in Figure 4~~Figure 4Figure 6Linkage between Wind generator SCADA, AWEFS/ASEFS and NEMDE in Dispatch and 5MPDLinkage between Wind generator SCADA, AWEFS/ASEFS and NEMDE in Dispatch and 5MPD~~ below.

Figure 4 Linkage between wind/solar generator SCADA, AWEFS/ASEFS and NEMDE in Dispatch and 5MPD

~~Linkage between wind/solar **generator SCADA, AWEFS/ASEFS and NEMDE in Dispatch and** 5MPD~~



The SCADA inputs from each wind and solar generator feed into the AWEFS/ASEFS system, to generate ~~*Unconstrained Intermittent Generation Forecasts (*~~UIGF~~)~~ for the Dispatch or 5MPD~~-~~. UIGF represents the available capacity of the wind generator during the 5-minute d~~D~~ispatch interval. The forecasts are then used in NEMDE, where network constraints and price bids submitted by each ~~wind~~ generator are taken into consideration, for determining dispatch levels and semi-dispatch cap (SDC) for the d~~D~~ispatch ~~i~~interval. ~~Wind g~~Generators receive the dispatch instruction (comprising the dispatch level (in MW) and semi-dispatch cap (0/1)) and UIGF forecasts via AEMO's Market Systems Interface. ~~and~~ Generators respond to the dispatch

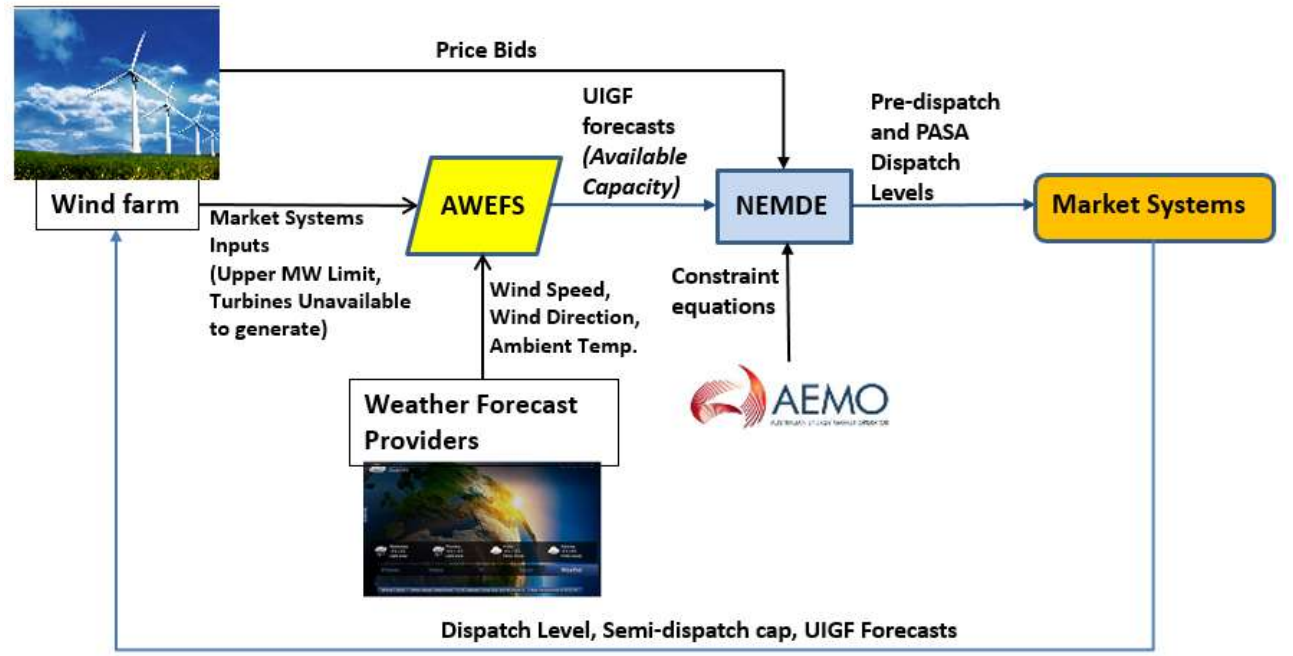
instruction by linearly capping their output[11] at the dispatch level when the semi-dispatch cap (= 1) is applied. When the semi-dispatch cap is not applied (= 0), semi-scheduled generators are permitted to generate at their available resource.

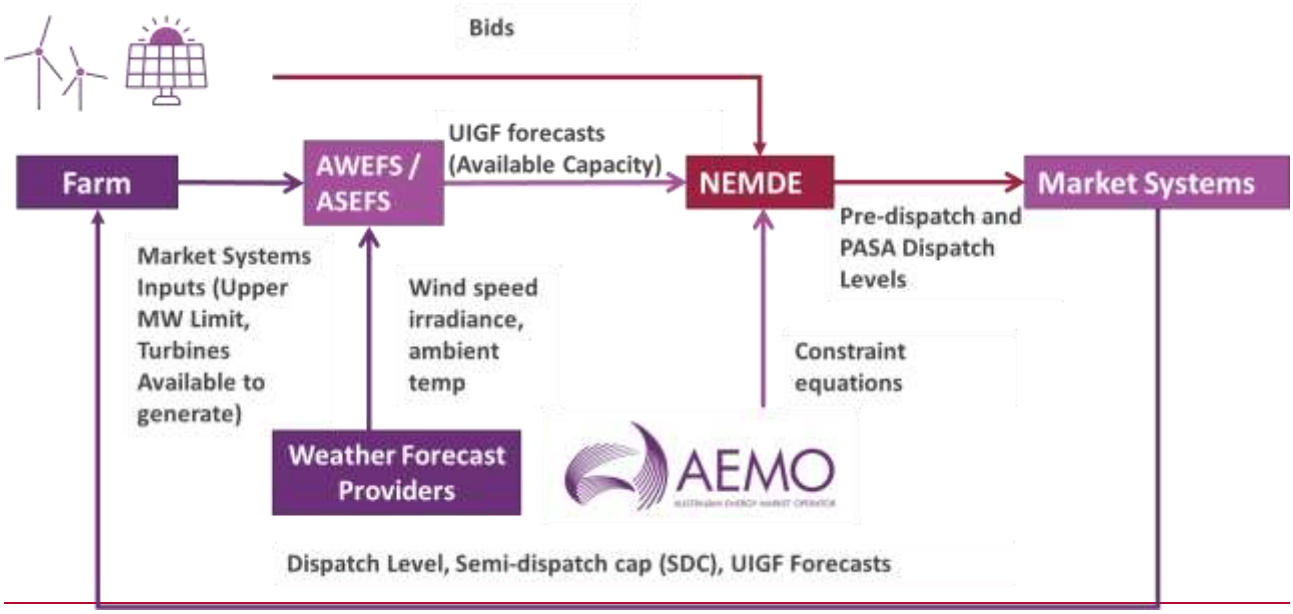
[11] Ramping requirements can be found at: https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/procedures/so_op_3705-dispatch.pdf.

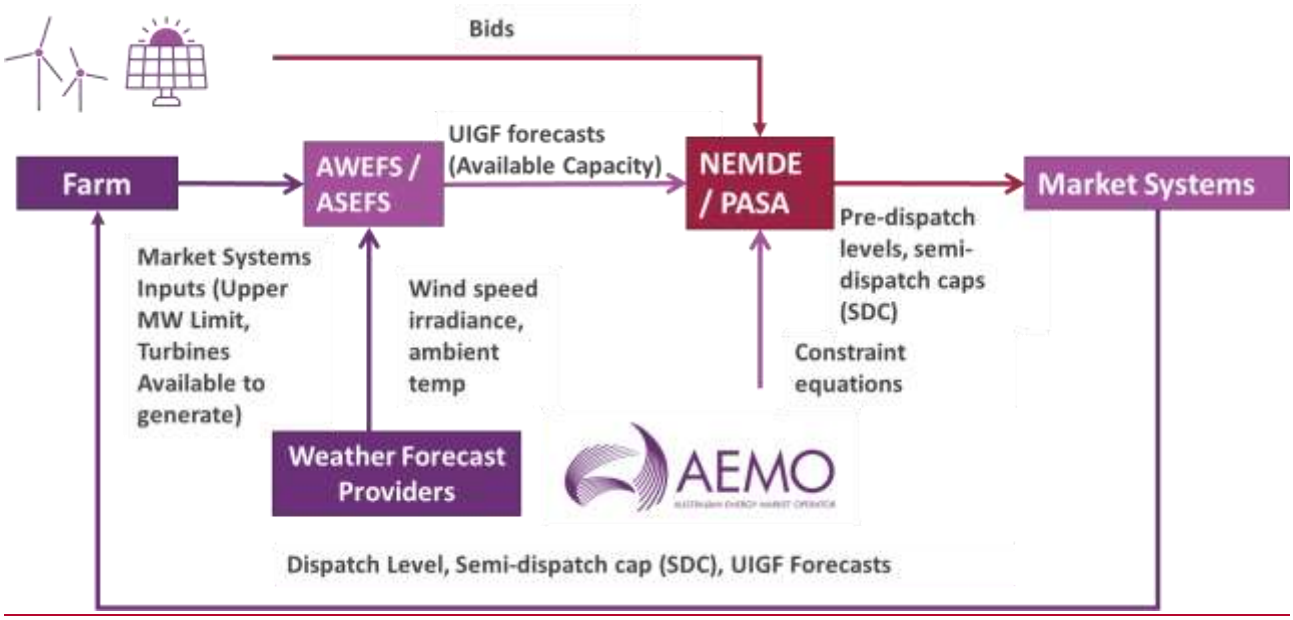
~~8.~~27.2 Pre-dispatch and PASA processes

The linkage between ~~wind~~ generator market systems inputs, weather predictions from weather forecast providers, AWEFS, ASEFS and NEMDE in Pre-dispatch and PASA is shown in Figure 5~~Figure 5Figure 5Figure 7Linkage between Wind generator market systems inputs, Weather forecasts, AWEFS and NEMDE in *Pre-dispatch* and PASA processesLinkage between Wind generator market systems inputs, Weather forecasts, AWEFS and NEMDE in *Pre-dispatch* and PASA processes~~ below.

~~Figure 7~~Figure 5 Linkage between wind generator market systems inputs, weather forecasts, AWEFS/ASEFS and NEMDE in Pre-dispatch and PASA processes







The market systems inputs (Upper MW Limit, Turbines/Inverters ~~una~~Available to generate) submitted by each wind/solar generator via the EMMS ~~Participant Web~~Markets Portal feed into the AWEFS/ASEFS system, to generate ~~Unconstrained Intermittent Generation Forecasts (~~UIGF~~)~~ for the Pre-dispatch, and Short term PASA ~~and Medium term PASA~~ processes. The UIGF forecasts are then used in NEMDE, where network constraints and price bids submitted by each wind/solar generator are taken into consideration, for determining the dispatch levels for the Pre-dispatch, and Short term PASA ~~and Medium term PASA~~ processes.

~~9~~8 Dispatch level and Semi-dispatch cap

This section provides an overview of how NEMDE determines dispatch levels for semi-scheduled wind and solar generators in the Dispatch, 5MPD and Pre-dispatch processes, based on the ~~*Unconstrained Intermittent Generation Forecasts* (~~UIGF~~)~~ produced by AWEFS and ASEFS.

~~9.1~~8.1 NEMDE and ~~wind~~ generator dispatch levels

NEMDE uses price bids, available capacity information and constraint equations (which represent limitations on the network) to determine dispatch levels for generators. ~~Conventional~~ Scheduled generators submit both price bids and available capacity information to NEMDE. However, ~~wind~~ semi-scheduled generators only submit price bid information since available capacity is determined by AWEFS and ASEFS. The price bids (submitted by the ~~wind~~ generator), available capacity (determined by AWEFS and ASEFS) and constraint equations (formulated by AEMO) feed into NEMDE, where ~~wind~~ intermittent generators are treated similar to conventional generators. Based on the inputs, NEMDE generates dispatch levels for semi-scheduled ~~wind~~ generators in Dispatch, 5MPD and Pre-dispatch processes. Semi-scheduled ~~wind~~ generators are only required to follow the dispatch levels when the semi-dispatch cap (SDC) is applied (on) otherwise they are permitted to generate at their available energy resource.

Similarly, in the Short term ~~and Medium-term~~ PASA process~~es~~, the PASA availability for semi-scheduled ~~wind~~ generators is determined by AWEFS and ASEFS and is equivalent to the ~~*Unconstrained Intermittent Generation Forecasts* (~~UIGF~~)~~. PASA solver determines targets (after consideration of network limitations) for semi-scheduled ~~wind~~ generators based on the PASA availability information (determined by AWEFS and ASEFS).

~~9.2~~8.2 Semi-dispatch cap (SDC) and conditions for trigger

In the Dispatch process, semi-scheduled ~~wind~~ generators are required to follow the dispatch levels generated by NEMDE only when the semi-dispatch cap (SDC) is applied (on). When the semi-dispatch cap applies for a particular DI, ~~wind~~ semi-scheduled generators are required to generate at or below the dispatch level generated for that DI, ensuring to linearly ramp towards their dispatch level, subject to energy resource availability. At times when the semi-dispatch cap is not applied, ~~wind~~ semi-scheduled generators are free to generate ~~to any level~~at their available energy resource.

The conditions that trigger NEMDE to apply a semi-dispatch cap are listed below:

1. If the dispatch level determined by NEMDE is less~~er~~ than the available capacity (determined by AWEFS and ASEFS), then semi-dispatch cap is set to 1 (normally 0). This could occur when there are:
   - network limitations that require the ~~wind~~ generator to generate less~~er~~ than its capability
   - inter-regional limitations
   - Price bid or market-related limitations including ramp rate, fixed loading level, non-dispatch of uneconomic price bands or marginal dispatch of economic price bands.

OR

2. If the dispatch level determined by NEMDE ~~-~~is equal to the available ~~capacity (~~capacity (determined by AWEFS and ASEFS), but a generic constraint would be violated if the ~~wind~~ generator's generation were to exceed the dispatch level for that DI, then semi-dispatch cap is set to 1.

A1~~A10Appendix A – Appendix C – AWEFS forecasts during abnormal conditions~~ details how AWEFS and ASEFS generates forecasts during abnormal conditions such as periods when:

- Bad/failed quality SCADA is input from the ~~wind~~ semi-scheduled generator.
- High wind speed conditions exceed the cut-out speed of wind turbines.
- AWEFS/ASEFS UIGF forecasts are suppressed and;
- ~~Wind g~~Semi-scheduled ~~G~~generators are constrained off~~; and~~
  - ~~Overrides are applied by AEMO.~~

In addition, the NEM Operational Forecasting and Dispatch Handbook for wind and solar generators document[12] provides further guidance of the key requirements of semi-scheduled generators and some non-scheduled intermittent generators for forecasting and dispatch in the NEM.

[12] Found at: https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/dispatch/policy_and_process/nem-operational-forecasting-and-dispatch-handbook-for-wind-and-solar-generators.pdf.

~~A2.~~A1. AWEFS/ASEFS forecasts during abnormal conditions

The purpose of this section is to provide an understanding on how AWEFS and ASEFS generates forecasts during certain abnormal conditions.

~~A2.1~~A1.1 Bad or failed quality SCADA

Bad or failed quality SCADA, which includes stuck 'good' quality data, has the potential to impact the accuracy of the dispatch UIGF which can lead to the semi-scheduled generator being over- or under-dispatched. 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[13].

During periods of bad or failed quality SCADA ~~a~~Active ~~p~~Power generation (MW) ~~SCADA~~ from ~~wind~~ semi-scheduled generators, the AWEFS and ASEFS systems will rely on information from numerical weather predictions (from weather forecast providers) and availability entered in the EMMS Markets Portal (i.e. Upper MW Limit, ~~n~~Number of turbines/inverters available to generate)~~,~~ to determine the dispatch UIGF forecast~~s~~.

However, the quality of the dispatch UIGF forecast~~s~~ will deteriorate over time, particularly after 1hr of bad MW SCADA, since there is no real-time information about the ~~wind~~ semi-scheduled generator's MW output.

If SCADA Control Set-Point is bad or failed quality, AWEFS/ASEFS is unable to determine if the semi-scheduled generator is self-constraining output due to a local limit thus, the dispatch UIGF is based on the generator's active power output which leads to under-forecasting output and hence, under-dispatching the generator.

If SCADA Local Limit is bad or failed quality, AWEFS/ASEFS will ignore this parameter which can lead to over-forecasting output and over-dispatching the semi-scheduled generator if local limitation(s) are actually applying during this period.

If SCADA Turbines/Inverters Available is bad or failed quality, AWEFS/ASEFS assumes all Turbines/Inverters in the cluster are available which can lead to over-forecasting output and thus, generator being over-dispatched if not all turbines/inverters are available. In addition, if SCADA Turbines in High-wind Cut-out (if available) is bad or failed quality, AWEFS will ignore this parameter which can lead to over-forecasting output if turbines at the wind farm are experiencing high-wind cut-out.

If SCADA farm-level Wind Speed/Cluster-level Inclined Irradiance is bad of failed quality and semi-dispatch cap is active (=1), AWEFS/ASEFS ignores these inputs and relies on the farm's active power output to produce the forecast which can lead to under-forecasting output and hence, under-dispatching the generator. However, for solar farms with more than one cluster, the bad/failed quality cluster SCADA Inclined Irradiance signal will be ignored and instead, ASEFS will rely on the remaining 'good' quality cluster-level SCADA Inclined Irradiance signals by taking an average of these readings to produce the dispatch UIGF during semi-dispatch or constrained off intervals.

[13] 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.

~~A2.2~~A1.2 ~~A2.~~ High wind speed cut-out

During periods when the wind speed increases above the cut-out speed[14] (as specified by the wind generator in the ~~Energy conversion model~~ECM), the forecasts generated by AWEFS are designed to reflect the reduced generation due to turbine cut-out (turbines that are automatically stopped or cut-out from generating), however the accuracy of the AWEFS forecasts may be reduced due to the difficulty in predicting high-wind-speed cut-out. ~~The forecasts generated under such conditions are primarily dependent on the wind speed and number of turbines available to generate.~~

The optional SCADA Turbines Extreme Wind Cut-out ~~SCADA~~ signal provides additional information to AWEFS that will improve the accuracy of dispatch forecasts where high-wind-speed cut-out is occurring.

[14] Minimum speed at which turbines are stopped to avoid damage to the rotor blades.

~~A2.3~~A1.3 ~~A3.~~ Periods when AWEFS/ASEFS UIGF forecasts are ~~turned off~~ suppressed

There are certain instances when AEMO ~~turns off~~suppresses the dispatch UIGF forecasts that are generated by AWEFS and ASEFS. These include:

- Early stages of commissioning for a new ~~wind~~ semi-scheduled generator: For newly commissioning ~~wind~~ semi-scheduled generators, the forecasting ~~modules~~ models in ~~the~~ AWEFS and ASEFS ~~system~~ require tuning and development, for which sufficient amount of active power generation (MW), turbine/inverter availability and wind speed/irradiance data needs to be accumulated. To allow sufficient time to build enough history, AEMO has the functionality to ~~turn off~~suppress the dispatch UIGF forecasts generated by ~~the~~ AWEFS and ASEFS ~~system~~ during this period. ~~Once~~ When the dispatch forecasts are ~~turned off~~suppressed, they are replaced with the FCST analog which is a start-up dispatch forecast model implemented in AEMO's EMS. The FCST uses real-time SCADA data inputs (Turbines/Inverters Available, Wind Speed/Inclined Irradiance, Local Limit) and static ECM information (Turbine/Inverter capacity, wind/solar power conversion curve) to create the dispatch UIGF. If any of the FCST inputs are bad quality, the dispatch UIGF is replaced with the SCADA ~~a~~Active ~~p~~Power generation (MW) ~~SCADA (initialMW)~~ from the ~~wind~~ semi-scheduled generator, in NEMDE, to generate the dispatch level for the next DI.
  - The Pre-dispatch/ST PASA forecasting models are typically developed prior to the semi-scheduled generator's registration effective date which results in Pre-dispatch/ST PASA UIGF forecasts from AWEFS and ASEFS being available from the registration effective date.
  - The dispatch/5MPD forecasting models are developed after the registration effective date, once sufficient operational data is available; SCADA data is 'good' quality, reliable and reflective of actual conditions; and the availability information in the EMMS Markets Portal is updated to reflect actual availability as shown via the equivalent SCADA signals.
  - AEMO will review and re-tune the AWEFS/ASEFS 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.
  - Further information on the AWEFS/ASEFS model development process can be found in the NEM Operational Forecasting and Dispatch Handbook for Wind and Solar generators document[15].

~~are _turned on, prior to the wind generator's date of completion for commissioning, and at a stage when AEMO has sufficient confidence in the quality of the forecasts that are generated by the AWEFS and ASEFSsystem.~~

- Periods when forecasts are seen to be ~~unreliable~~grossly inaccurate: If the forecasts generated by ~~the~~ AWEFS and ASEFS ~~system~~ is seen to be ~~unreliable or interfering with market outcomes~~inaccurate and a risk to system security, AEMO ~~wil~~may~~l~~ ~~turn off~~suppress the UIGF forecasts which will revert to active power (initialMW) for dispatch timeframe and Pre-dispatch timeframe (unless AEMO inputs a forecast

[15] Found at: https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/dispatch/policy_and_process/nem-operational-forecasting-and-dispatch-handbook-for-wind-and-solar-generators.pdf.

override), and 0MW for Short-term PASA timeframe (unless AEMO inputs a forecast override). ~~generated by AWEFS. Unreliable forecasts can be generated as a result of incorrect SCADA inputs from the wind generator or inaccurate weather forecasts.~~ AEMO will ~~turn on~~unsuppress the UIGF forecasts from AWEFS and ASEFS only at a stage when there is sufficient confidence in the quality of the forecasts.

~~A2.4~~A1.4 Periods when a ~~wind~~ semi-scheduled generator is *constrained off* in Dispatch

During periods when a ~~wind~~ semi-scheduled generator output is restricted or constrained off due to network limitations or local ~~wind~~ generator restrictions, the forecasts generated by AWEFS and ASEFS do not reflect the ~~wind~~ semi-scheduled generator's active power (MW) output resulting from the limitations. The forecasts during such periods reflect the generation capability of the ~~wind~~ semi-scheduled generator in the absence of the external limitations. This is because NER Rule Clause 3.7B requires AEMO to prepare 'Unconstrained' forecasts at all times. The unconstrained forecasts, generated during periods when a ~~wind~~ semi-scheduled generator is constrained off, are dependent on the generator's SCADA wind speed/irradiance, SCADA number of turbines/inverters available to generate, ~~and~~ the ~~wind generator~~ SCADA control system setpoint (MW Setpoint) ~~SCADA inputs~~, the SCADA Local Limit, and the power conversion curve assigned to that semi-scheduled generator.

~~A2.4.1~~A1.4.1 ~~A4.1~~ Mode of operation for ~~wind~~ generator SCADA ~~c~~Control ~~s~~System ~~s~~Set-point (MW Setpoint) ~~SCADA~~ signal and SCADA Local Limit signal

The ~~wind~~ generator's SCADA control system setpoint (MW Setpoint) ~~SCADA~~ signal provides AWEFS and ASEFS with an indication on whether the generator's output is being limited, and does not reflect the unconstrained output possible given the wind/irradiance conditions. AWEFS and ASEFS uses this to determine how to calculate the dispatch UIGF and also to select which samples to use in tuning its forecasting models.

~~whether a reduced wind generator output is due to operator action resulting from external limitations or due to a reduction in wind speed.~~ As described in the ~~*Energy Conversion Model*~~ECM Guidelines, t~~T~~he MW Setpoint SCADA should operate as listed below:

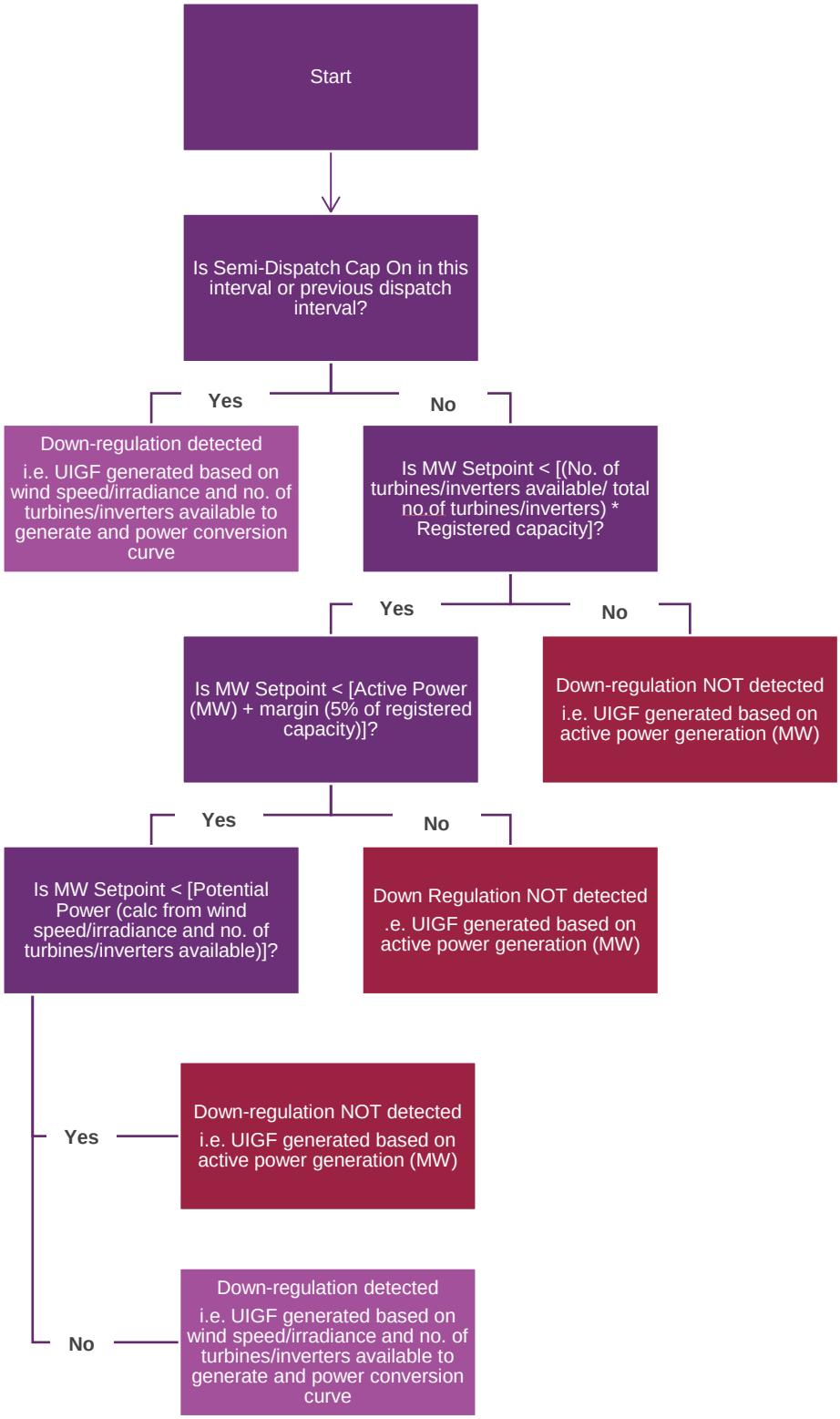
- During periods of normal operation (when ~~wind~~ generator output is not constrained off), the MW Setpoint should reflect a value above the ~~wind~~ generator's registered capacity (but below 250% of it).
- During periods when the ~~wind~~ generator is constrained off (eg. due to a semi-dispatch cap or local limit), the MW Setpoint should reflect the setpoint applied in the ~~wind~~ generator's control system to limit (down regulate) its output.
  - If the generator is constrained off due to a local limitation, the SCADA Local Limit should also reflect the MW set-point applied in the generator's control system (including other local limitations if applicable) to ensure the dispatch UIGF is limited to the MW set-point level, otherwise AWEFS/ASEFS could potentially over-forecast generator output.
  - If the generator is constrained off due to a semi-dispatch cap, only the MW set-point (not SCADA Local Limit) should reflect the semi-dispatch level issued by AEMO to ensure AEMO's compliance with NER3.7B in producing an 'unconstrained' forecast. In addition, this will also prevent the generator from being constrained off more than required. to at or below the level required by AEMO. During such periods, the MW set-point could be the same as the dispatch level generated by NEMDE (if the wind generator intends to generate at the level required by AEMO) or wind generator's own setpoint values (if the wind generator intends to generate at a level lesser than the level required by NEMDE).

~~A2.4.2~~A1.4.2 A4.2 How does AWEFS and ASEFS detect if a ~~wind~~ generator is constrained off?

AWEFS and ASEFS performs certain validation checks to determine if a ~~wind~~ generator is constrained off. ~~AWEFS checks if the Semi-Dispatch Cap is on for the current dispatch interval or the previous dispatch interval. If so, the "down-regulation detected" flag is set. If not, AWEFS checks if the wind generator's control system setpoint is below the nominal capacity of the wind generator (determined as No.of turbines Available/Total No.of Turbines * Registered Capacity). If yes, AWEFS checks further to see if the wind generator's active power generation (MW) + margin (5% of registered capacity) exceeds the MW Setpoint. If yes, AWEFS checks further to see if the wind generator's Potential Power (calculated from the wind speed and number of turbines Available) exceeds the MW Setpoint. If yes, AWEFS sets the wind generator output "down-regulation detected" flag. If the "down-regulation detected" flag is set, AWEFS uses the current wind speed from SCADA to calculate UIGF, provided it is of good quality. Otherwise, AWEFS will generate a forecast based on active power generation (MW).~~

These checks are summarised in ~~the~~ Figure 6 ~~flowchart~~ below.~~:~~

~~Figure 8~~Figure 6 AWEFS and ASEFS validation checks to determine if~~s~~ a generator is constrained off~~.~~


Start
Is Semi-Dispatch Cap On in this interval or previous dispatch interval?
Yes
No
Down-regulation detected
i.e. UIGF generated based on wind speed/irradiance and no. of turbines/inverters available to generate and power conversion curve
Is MW Setpoint < [(No. of turbines/inverters available/ total no.of turbines/inverters) * Registered capacity]?
Yes
No
Is MW Setpoint < [Active Power (MW) + margin (5% of registered capacity)]?
Down-regulation NOT detected
i.e. UIGF generated based on active power generation (MW)
Yes
No
Is MW Setpoint < [Potential Power (calc from wind speed/irradiance and no. of turbines/inverters available)]?
Down Regulation NOT detected
.e. UIGF generated based on active power generation (MW)
Yes
Down-regulation NOT detected
i.e. UIGF generated based on active power generation (MW)
No
Down-regulation detected
i.e. UIGF generated based on wind speed/irradiance and no. of turbines/inverters available to generate and power conversion curve