# SCHEDULING ERROR REPORT

## AWEFS AND ASEFS UNCONSTRAINED INTERMITTENT GENERATION FORECAST (UIGF) SCHEDULING ERRORS – 2012 TO 2016

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**UPDATED:** DECEMBER 2016

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

# IMPORTANT NOTICE

## Purpose

This report has been updated from the version published on 29 February 2016 using information available as at 29 November 2016, unless otherwise specified.

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# 1. SUMMARY

AEMO has determined that the following scheduling errors have occurred because the Australian Wind Energy Forecasting System (AWEFS) and Australian Solar Energy Forecasting System (ASEFS) produced incorrect unconstrained intermittent generation forecasts (UIGFs) in some circumstances. The UIGF is the available capacity of each semi-scheduled generating unit.

- Scheduling Error 1: During consecutive semi-dispatch intervals, in some circumstances, the UIGFs produced by AWEFS or ASEFS were incorrect, being less than a wind or solar farm's generation capability based on prevailing wind or solar irradiance conditions. For such periods, the UIGFs used in the National Electricity Market Dispatch Engine (NEMDE) caused the Dispatch levels to oscillate and, in some cases, erode to zero.

  This scheduling error began at Dispatch Interval (DI) ending 0215 hrs on 14 March 2012[1] and was resolved by DI ending 1800 hrs on 07 April 2016. All semi-scheduled wind farms and two solar farms, Broken Hill and Nyngan, in the National Electricity Market (NEM) were affected by this scheduling error.

- Scheduling Error 2: When the UIGF produced by AWEFS or ASEFS for wind farms or solar farms exceeded their maximum capacity, the UIGF values were rejected by the UIGF validation logic within the central dispatch system. The wind farm's or solar farm's InitialMW was applied instead. When this occurred for semi–dispatch intervals, the Dispatch levels for the relevant wind farm or solar farm were less than its generation capability (after consideration of network constraints and other limitations) at the time.

  This scheduling error began at DI ending 0445 hrs on 30 June 2012 and was resolved by DI ending 1120 hrs on 24 March 2016. Oaklands Hill, Hallett Hill, Boco Rock and North Brown Hill Wind Farms, and Broken Hill Solar Farm were affected by this scheduling error.

In each case, the Dispatch levels for the affected wind farm or solar farm would have been higher with the correct UIGFs.

Under clause 3.16.2(a) of the National Electricity Rules (NER), Market Participants affected by a scheduling error may apply to a dispute resolution panel established under clause 8.2.6A for a determination of compensation.

# 2. THIS REPORT

AEMO has prepared this report to declare a National Electricity Market (NEM) scheduling error[2].

AEMO published an earlier version of this scheduling error report on 29 February 2016. At the time of publication of that report, the scheduling errors listed in Section 1 were unresolved. The scheduling errors have since been resolved and the report has now been updated to incorporate the market impact due to all scheduling error affected intervals, until the resolution date and time (listed in Section 1).

AGL and Infigen Energy approached AEMO about the oscillation of Dispatch levels at Oaklands Hill, Macarthur and Lake Bonney wind farms. The information provided by these participants was considered in assessing the impact of the scheduling errors. The impact assessment is largely based on analysing data from AWEFS, AEMO's Energy Management System (EMS) and Electricity Market Management System (EMMS).

All references to time in this report are to Australian Eastern Standard Time.

[1] For details relating to why 14 March 2012 was determined to be the first day of error, please refer to Section 5.
[2] For AEMO's obligations, see clause 3.8.24(a)(2) of the NER.

# 3. BACKGROUND

Clause 3.7B(a) of the NER requires AEMO to prepare and make available at all times a UIGF of each semi-scheduled generating unit's available capacity. When preparing a UIGF, AEMO must take into account the real-time information provided by the semi-scheduled generating units in accordance with their energy conversion model and the assumption that no network constraints affect their generation.

The UIGFs are then applied in the central dispatch process as an upper limit on each unit's Dispatch level (calculated by NEMDE), as required by clause 3.8.1 (b)(2)(ii) of the NER. For a semi–dispatch interval, the relevant generating unit must cap its output at, or below, this NEMDE-calculated Dispatch level by the end of the relevant dispatch interval (DI) if its semi–dispatch flag is also set for that DI. Otherwise the generating unit is free to operate at any level.

## 3.1 Cause of Scheduling Error 1: Incorrect Identification of semi–dispatch intervals in AWEFS and ASEFS

In the 5-minute dispatch time frame the UIGF is, absent of any constraint, based on the real-time active power Supervisory Control and Data Acquisition (SCADA) output from the wind farm or solar farm. This is because an active power-based forecast is more reliable than a wind speed-based forecast (for wind farms) or irradiance-based forecast (for solar farms). That is, the generation forecast for the next five minutes will be close to the actual generation output during the previous five minutes.

However, if a network constraint or local limitation reduces wind farm or solar farm output, a wind speed-based forecast (from AWEFS) or solar irradiance-based forecast (from ASEFS) is used instead. The wind speed-based forecast produced by AWEFS uses real time wind speed, turbines available to generate and wind turbine power curves[3] as inputs to determine UIGF. The irradiance-based forecast produced by ASEFS uses real time solar irradiance, inverters available and inverter power curves[4] as inputs to determine UIGF. The power curves in AWEFS and ASEFS are tuned on a daily basis to correlate actual electrical output of a wind farm or solar farm to observed windspeed (for AWEFS) or irradiance (for ASEFS).

During semi-dispatch intervals (periods when a wind farm or solar farm's Dispatch level is limited to, or below its UIGF due to a binding constraint equation[5] in NEMDE), the UIGF produced by AWEFS or ASEFS should be a wind speed-based forecast (for wind farms) or irradiance-based forecast (for solar farms)[6].

AWEFS and ASEFS perform three validation checks (section 3.1.1) prior to every DI to determine if a wind farm or solar farm's output is limited due to a network constraint or a local limitation.

The incorrect identification of semi-dispatch intervals as non semi-dispatch intervals in AWEFS or ASEFS occurs when any of the three validation checks fail. As a result, for some semi-dispatch intervals, the UIGF produced by AWEFS or ASEFS is an active power output–based forecast rather than the correct wind speed-based or irradiance-based forecast.

[3] The power curve of a wind turbine is a graph that correlates the electrical power output from the wind turbine to varying wind speeds.
[4] The power curve of a solar inverter is a graph that correlates the electrical power output from the PV array through the inverter to varying solar irradiance.
[5] A constraint equation is binding when it is actively influencing central dispatch outcomes.
[6] If the actual output from the wind farm or solar farm exceeds the wind speed–based or irradiance–based forecast, UIGF is produced based on the actual output.

### 3.1.1 UIGF and Validation checks in AWEFS

The UIGFs are produced by AWEFS or ASEFS. For each DI, all inputs required by AWEFS or ASEFS to produce a UIGF are captured approximately two minutes prior to the end of the previous DI.

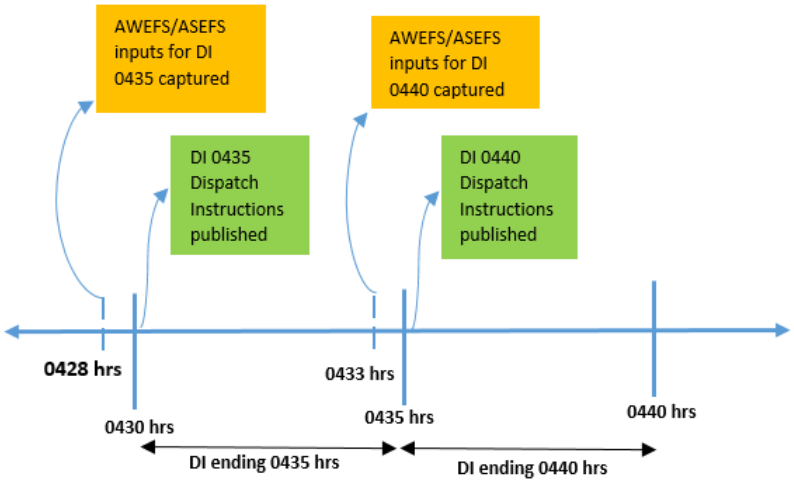


**Figure 1 AWEFS and ASEFS inputs capture timelines**

To determine if a network constraint or a local limitation is reducing the wind farm or solar farm output, AWEFS and ASEFS use the real-time control system set-point[7] SCADA output.

For each DI, when a wind farm or solar farm is not limited (by a network constraint or a local limitation reducing the wind farm or solar farm output), its control system setpoint SCADA indicates a value at or above its registered capacity[8]. During DIs when a wind farm or solar farm output is limited by a network constraint or local limitation, the control system setpoint generally drops below its registered capacity to a set point that reflects the intended MW level limit of the wind farm or solar farm's control system for the end of the DI.

AWEFS and ASEFS perform the following three validation checks prior to every dispatch interval to determine if a wind farm or solar farm's output is being limited below its wind speed-based or irradiance-based forecast (potential power):

I. *Is the wind farm (or solar farm) control system setpoint < the Registered Capacity of the wind farm (or solar farm)*?

II. *Is the wind farm (or solar farm) control system setpoint < Active power + 5% of Registered capacity*? [9]

III. *Is the wind farm (or solar farm) control system setpoint < Potential power*[10]?

If all three validation checks pass, AWEFS or ASEFS produces a wind speed-based or irradiance-based UIGF. If any of these checks fail, AWEFS or ASEFS reverts to producing a UIGF based on the active power SCADA output.

[7] MW Setpoint applied in the wind farm or solar farm's control system to limit (down regulate) its output to at or below the level required by AEMO or the Network Service Provider.
[8] Same as nameplate rating of the wind farm or solar farm.
[9] Prior to 07 April 2014, this validation check was applied in AWEFS as: Is Wind farm control system setpoint < Active power + 15% of Registered capacity?
[10] The wind speed-based forecast (for wind farms) or irradiance-based forecast (for solar farms) of generation output.

## 3.2 Cause of Scheduling Error 2: Rejection of UIGF exceeding maximum capacity in Dispatch

At registration, all Generators are required to provide AEMO with the nameplate rating (also referred to as registered capacity) and maximum capacity[11] of their generating units. Generally, the nameplate rating of a generating unit is less than or equal to its maximum capacity. Some semi-scheduled generating units, however, are registered with a nameplate rating exceeding the maximum capacity.

For all semi-scheduled generating units, AWEFS or ASEFS is designed to produce a UIGF up to their nameplate rating. For Oaklands Hill, Hallett Hill, Boco Rock and North Brown Hill Wind Farms, and Broken Hill Solar Farm), under high wind speed or irradiance conditions, the UIGF exceeded the maximum capacity of these units, but remained below the nameplate rating.

The validation logic (section 3.2.1) within the central dispatch system rejected these UIGF values since they exceeded the relevant generating unit's maximum capacity, and the unit's InitialMW was applied instead.

For some semi–dispatch intervals when UIGF exceeded the maximum capacity of a wind farm or solar farm, the InitialMW value applied instead of the UIGF in NEMDE reflected a value lesser than the wind farm or solar farm's available capacity, thus limiting the dispatch level below the wind farm or solar farm's generation capability.

### 3.2.1 Validation logic in Central Dispatch

For all scheduled and semi-scheduled generating units, the central dispatch system performs a comprehensive validation of all bids submitted in the energy and Frequency Control Ancillary Services (FCAS) markets[12]. This includes a validation check to ensure the available capacity of a generating unit does not exceed its maximum capacity (specified at the time of registration). The validation check is as follows:

i. *Is Maximum Availability <= Maximum Capacity*?

For semi-scheduled generating units, the maximum availability is the same as the UIGF produced by AWEFS or ASEFS. If the UIGF produced by AWEFS or ASEFS exceeds the maximum capacity, the UIGF is ignored and the generating unit's InitialMW is substituted in NEMDE as its available capacity.

# 4. EVENT DETAILS

## 4.1 Scheduling Error 1: Incorrect Identification of semi–dispatch intervals in AWEFS and ASEFS

AGL and Infigen Energy approached AEMO in relation to oscillations they had seen in the Dispatch levels at Oaklands Hill, Macarthur and Lake Bonney wind farms. During consecutive semi–dispatch intervals, the Dispatch levels for these wind farms oscillated between high and low values. A plot of the Dispatch level oscillation for Oaklands Hill on 27 January 2015 is provided in Appendix A.

Following investigations in November 2015, AEMO determined that these high–to–low value oscillations were a consequence of the oscillations in the UIGF produced by AWEFS. On further assessment, these

[11] The maximum amount of electricity capable of being produced by a generating unit as measured at its terminals.
[12] List of all validation checks are available at: http://aemo.com.au/-/media/Files/PDF/Participant-Input-Interface-EnergyMNSPFCAS-Bid-File-Submission.ashx

oscillations were also observed for the UIGF produced by ASEFS. During some consecutive semi–dispatch interval periods, AWEFS or ASEFS incorrectly identified:

- Every second semi-dispatch interval to be a non semi-dispatch interval, and thus produced a low UIGF based on actual power output rather than a wind speed-based or irradiance-based forecast.
- Consecutive semi-dispatch intervals to be non semi–dispatch intervals, when wind farms consistently generated below their control system setpoint. In some cases, this resulted in the Dispatch levels for wind farms reducing to zero.

The validation checks in AWEFS or ASEFS were the main cause of the incorrect identification of semi-dispatch intervals as non semi–dispatch intervals. For each semi-dispatch interval, the second validation check expects the active power output from the wind farm or solar farm to exceed the wind farm or solar farm's control system setpoint, or, if below the setpoint, within a margin equal to 5% of its registered capacity. That is, AWEFS or ASEFS expects the wind farm or solar farm to have responded to its dispatch instructions[13] by the time the inputs to determine the UIGF for the next semi-dispatch interval are captured. If the active power output did not exceed the control system setpoint or, if the active power output was below the setpoint, but not within the 5% of registered capacity margin, AWEFS or ASEFS incorrectly assumed the wind farm or solar farm was unable to follow its setpoint due to a reduction in wind speed or irradiance. The next DI was then treated as a non semi-dispatch interval and the UIGF was based on the wind farm or solar farm's active power output rather than a wind speed-based or irradiance-based forecast.

Wind farms or solar farms impacted by this scheduling error consistently failed the second validation check. See Appendix B for an example of how the 5% of registered capacity margin in the second validation check results in incorrect identification of semi-dispatch intervals.

There were also intervals when AWEFS or ASEFS failed to detect a semi-dispatch interval when the second validation check passed, but the first or third validation checks failed.

Under clause 3.8.24 (a)(2) of the NER, a scheduling error occurs when AEMO determines it has failed to follow the central dispatch process set out in clause 3.8.

AEMO has determined it failed to follow the central dispatch process in that UIGFs used in Dispatch for some semi-dispatch intervals did not reflect available capacity based on prevailing wind or irradiance conditions. The scheduling error mainly occurred during every second DI in consecutive semi–dispatch intervals, where the wind farm or solar farm's Dispatch level was capped by its UIGF, which was less than its available capacity.

## 4.2 Scheduling Error 2: Rejection of UIGF exceeding maximum capacity in Dispatch

Oaklands Hill, Hallett Hill, Boco Rock and North Brown Hill Wind Farms, and Broken Hill Solar Farm are currently registered with a nameplate rating exceeding each farm's maximum capacity.

**Table 1 Semi-scheduled generators with nameplate rating exceeding maximum capacity**

| Semi-scheduled generator | Nameplate rating | Maximum capacity |
|---|---|---|
| Oaklands Hill | 67.2 MW | 63 MW |
| Hallett Hill | 71.4 MW | 71 MW |

[13] For semi-scheduled generating units, the dispatch instructions include their Dispatch levels and a semi–dispatch flag to indicate whether the DI is a semi–dispatch interval.

| Semi-scheduled generator | Nameplate rating | Maximum capacity |
|---|---|---|
| Boco Rock | 113.18 MW | 113 MW |
| Broken Hill | 53.6 MW | 53 MW |
| North Brown Hill | 132.3 MW | 132 MW |

The maximum capacity for Oaklands Hill is less than its nameplate rating due to a limitation imposed contractually by the local Distribution Network Service Provider, which requires the output from the wind farm to be limited below its nameplate rating. For the remaining generators in Table 1, due to rounding limitations in AEMO registration systems, the maximum capacity was recorded as a whole number, thus being lesser than the nameplate rating.

During high wind speed or irradiance conditions, these generators are capable of generating up to their nameplate rating, but must limit their output to the maximum capacity.

AWEFS or ASEFS is designed to produce a UIGF up to the nameplate rating of these generators. However, the validation logic (section 3.2.1) within the central dispatch system rejected these UIGF values exceeding the wind farm or solar farm's maximum capacity. For such DIs, central dispatch replaced the UIGF with their InitialMW which, in some cases, was less than the AWEFS or ASEFS-produced UIGF.

See Appendix C for an example of Oaklands Hill's Dispatch levels being limited due to the central dispatch system's rejection of UIGFs that exceed maximum capacity.

AEMO has determined that it has failed to follow the central dispatch process in that the UIGFs used in Dispatch for Oaklands Hill, Hallett Hill, Bock Rock and North Brown Hill Wind Farms, and Broken Hill Solar Farm, under high wind speed or irradiance conditions, did not reflect their available capacities. Specifically, the scheduling error occurs for semi-dispatch intervals when AWEFS or ASEFS produced UIGFs exceeding the maximum capacity of these generators, but their Dispatch levels in NEMDE were limited to their InitialMW.

# 5. MARKET IMPACT

In June 2012, AEMO had declared a scheduling error[14] relating to the UIGF calculation in AWEFS which resulted from the lack of availability of the wind farm control system setpoint SCADA from wind farms. This lack of availability meant AWEFS could not detect semi-dispatch intervals and a UIGF could not be correctly calculated. AEMO then consulted on an amendment to the Energy Conversion Model Guidelines[15] to make provision of the control system setpoint SCADA a mandatory requirement. Subsequent to that, all wind farms provided AEMO with their control system setpoint SCADA. While this improved the detection of semi-dispatch intervals in AWEFS, it did not fully resolve the issue.

AEMO has estimated the assessment period and market impact for the two scheduling errors detailed in Sections 4.1 and 4.2.

The assessment period for both scheduling errors were determined as follows:

- For wind farms that received compensation as a result of the 2012 Scheduling error, the assessment period covers all affected semi–dispatch intervals following the last date for which compensation was paid until the date and time of resolution (refer Section 1).
- For the wind farms and solar farms that did not claim compensation following the 2012 Scheduling error, the assessment period covers all affected semi-dispatch intervals from the date when each wind farm or solar farm was functional in AWEFS or ASEFS until the date and time of resolution (refer Section 1). Note, during early stages of commissioning of a wind farm or solar farm, the forecasting modules are not functional until sufficient active power generation (MW) and wind speed (or irradiance) data has been accumulated for the wind farm (or solar farm)[16].

Appendix D lists the assessment start dates for all affected wind farms and solar farms. The earliest date when at least one wind farm or solar farm was impacted by either scheduling error was 14 March 2012. The market impact assessment covers all affected semi-dispatch intervals between DI ending 0215 hrs on 14 March 2012 and DI ending 1800 hrs on 07 April 2016 (referred to as ‘assessment period’).

## 5.1 Scheduling Error 1: Incorrect Identification of semi–dispatch intervals in AWEFS and ASEFS

To assess the market impact of the scheduling error, AEMO first identified the affected semi–dispatch intervals during the assessment period.

Appendix E details the assumptions and methodology used by AEMO to:

- Identify the affected semi-dispatch intervals due to Scheduling Error 1.
- Calculate the What-If UIGF that should have applied for these semi-dispatch intervals.

Based on AEMO’s analysis, there were 44,888 affected semi-dispatch intervals due to Scheduling Error 1 during the assessment period.

[14] The report for the 2012 UIGF scheduling error is available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/-/media/17A44958F3654502B1FB220651BB89F9.ashx

[15] The issues paper, final determination and report relating to the 2013 amendment to the energy conversion model guidelines are available at: http://www.aemo.com.au/Stakeholder-Consultation/Consultations/Amendment-to-the-Energy-Conversion-Model-Guidelines

[16] Refer Appendix C.3 in the AWEFS process description available at: http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/2016/Australian-Wind-Energy-Forecasting-System-AWEFS.ashx

## 5.2 Scheduling Error 2: Rejection of UIGFs exceeding maximum capacity in Dispatch

Appendix F details the assumptions and methodology used by AEMO to:

- Identify the affected semi-dispatch intervals due to Scheduling Error 2.
- Calculate the What-If UIGF applicable to these semi-dispatch intervals.

There were 1,556 affected semi-dispatch intervals due to Scheduling Error 2 during the assessment period. A total of 714 affected semi-dispatch intervals due to Scheduling Error 2 also overlapped with Scheduling Error 1.

## 5.3 Market impact due to Scheduling Errors 1 and 2

Following discussions with some affected Market Participants, AEMO was made aware of the potential for lost energy (MWh) not just in the affected DIs, but also in the subsequent DIs. To allow for compensation for lost energy in the subsequent DIs, AEMO also estimated lost MWh for one subsequent DI immediately following each affected DI.

There were 45,730 DIs affected by Scheduling Errors 1 or 2. With one subsequent DI for each affected DI, the total number of affected and subsequent DIs increased to 65,423 DIs.

AEMO conducted a simulated rerun of the NEMDE Dispatch files for the affected and subsequent intervals for Scheduling Errors 1 or 2 by replacing the original UIGF with the correct UIGF. The assumptions and methodology involved in the simulated rerun and calculation of constrained-off MWh are detailed in Appendix G.

Based on the simulated rerun, total generation from semi-scheduled wind farms and solar farms was 86,492 MWh lower (constrained-off) due to Scheduling Errors 1 and 2.

The number of affected and subsequent DIs, and MWh constrained-off during the assessment period for all semi-scheduled wind farms and solar farms impacted are noted in Table 2 (in descending order of MWh constrained-off). Appendix H provides the MWh constrained-off for all scheduled generators that were impacted by these scheduling errors.

**Table 2 No. of DIs affected and MWh constrained-off for affected semi-scheduled wind and solar farms**

| Wind Farm or Solar Farm | No.of DIs Affected | No.of DIs Affected+Subsequent | MWh constrained-off[17] |
|---|---|---|---|
| Oaklands Hill | 11,303 | 18,838 | 30,196 |
| Macarthur | 5,230 | 8,963 | 21,929 |
| Lake Bonney 2 | 15,786 | 25,498 | 11,018 |
| Mt Mercer | 4,808 | 6,926 | 7,732 |
| Lake Bonney 3 | 12,846 | 21,816 | 2,735 |
| Bald Hills | 2,096 | 3,869 | 2,504 |
| Musselroe | 2,147 | 3,199 | 2,467 |
| North Brown Hill | 546 | 1,002 | 1,958 |

[17] The MWh constrained off reported in Table 2 were rounded to the nearest whole number.

| Wind Farm or Solar Farm | No.of DIs Affected | No.of DIs Affected+Subsequent | MWh constrained-off[17] |
|---|---|---|---|
| Bluff | 572 | 1,066 | 1,123 |
| Hallett 1 | 462 | 800 | 873 |
| Clements Gap | 1,632 | 2,315 | 824 |
| Hallett Hill | 592 | 934 | 705 |
| Snowtown | 608 | 1,060 | 518 |
| Snowtown North | 194 | 345 | 354 |
| Broken Hill | 534 | 725 | 328 |
| Boco Rock | 106 | 134 | 309 |
| Snowtown South | 380 | 650 | 284 |
| Waterloo | 472 | 856 | 261 |
| Gunning | 350 | 601 | 188 |
| Woodlawn | 65 | 116 | 99 |
| Gullen Range | 19 | 36 | 68 |
| Taralga | 17 | 32 | 15 |
| Nyngan | 5 | 9 | 2 |

# 6. RESOLUTION

## 6.1 Scheduling Error 1: Incorrect Identification of semi–dispatch intervals in AWEFS and ASEFS

On 3 February 2016, AEMO implemented the following change as a short-term solution to mitigate the oscillation of Dispatch levels:

1. The 5% of registered capacity margin in the second validation check (detailed in section 3.1.1) was adjusted for each wind farm or solar farm based on analysis of historical data. The margin was adjusted to identify semi–dispatch intervals more accurately.

On 7 April 2016, AEMO implemented the following as a permanent solution to the oscillation of Dispatch levels:

1. Dispatch instructions from NEMDE are issued to wind farms via the AEMO market systems[18] or SCADA. Prior to resolution, AWEFS (or ASEFS) design required the dispatch instructions to be received by the wind farms or solar farms and communicated back to AWEFS (or ASEFS) via the control system SCADA setpoint. The permanent solution involved establishing a link between AEMO's market systems and AWEFS (and ASEFS) whereby the semi-dispatch flag (within the dispatch instruction) for each wind farm or solar farm is provided as an input to AWEFS (or ASEFS). This ensures all semi-dispatch intervals are correctly identified in AWEFS (or ASEFS) and reduces dependence on SCADA inputs from the wind farms or solar farms for identifying semi-dispatch intervals.
2. Amended the AWEFS and ASEFS constrained-off detection logic whereby a semi-scheduled wind farm or solar farm is deemed to be constrained-off if:
    a. *Semi–dispatch flag = 1 ('On') in the current or previous DI (new test), ELSE*
    b. *All validation checks detailed in section 3.1.1 are TRUE (existing test)*

## 6.2 Scheduling Error 2: Rejection of UIGFs exceeding maximum capacity in Dispatch

On 24 March 2016, AEMO implemented an interim solution to prevent NEMDE rejecting a valid AWEFS or ASEFS UIGF (less than its registered capacity) but greater than the wind farm's maximum capacity. This involved amending the UIGF validation logic detailed in Section 3.2.1 to detect this condition and cap the UIGF at its maximum capacity before input to NEMDE, as follows:

1. *Is AWEFS UIGF <= Maximum Capacity*?

    If TRUE, Maximum Availability = AWEFS UIGF.

    If FALSE,

        *Is AWEFS UIGF <= nameplate rating + 1 MW?*

            If TRUE, Maximum Availability = Maximum Capacity

            If FALSE, Maximum Availability = InitialMW.

[18] Generally as NEM Reports files for Participants to collect via File Transfer Protocol (FTP) or via AEMO EMMS web portal.

The interim solution has resolved this scheduling error.

AEMO will implement a permanent solution to this along with the AWEFS and ASEFS updates following the current consultation on the Energy Conversion Model (ECM) Guidelines. The consultation is due to complete in December 2016 and implementation of system changes will commence after this. The permanent solution involves AWEFS and ASEFS capping the UIGF for all semi-scheduled generation to its maximum capacity.

# APPENDIX A. SCHEDULING ERROR 1 EXAMPLE

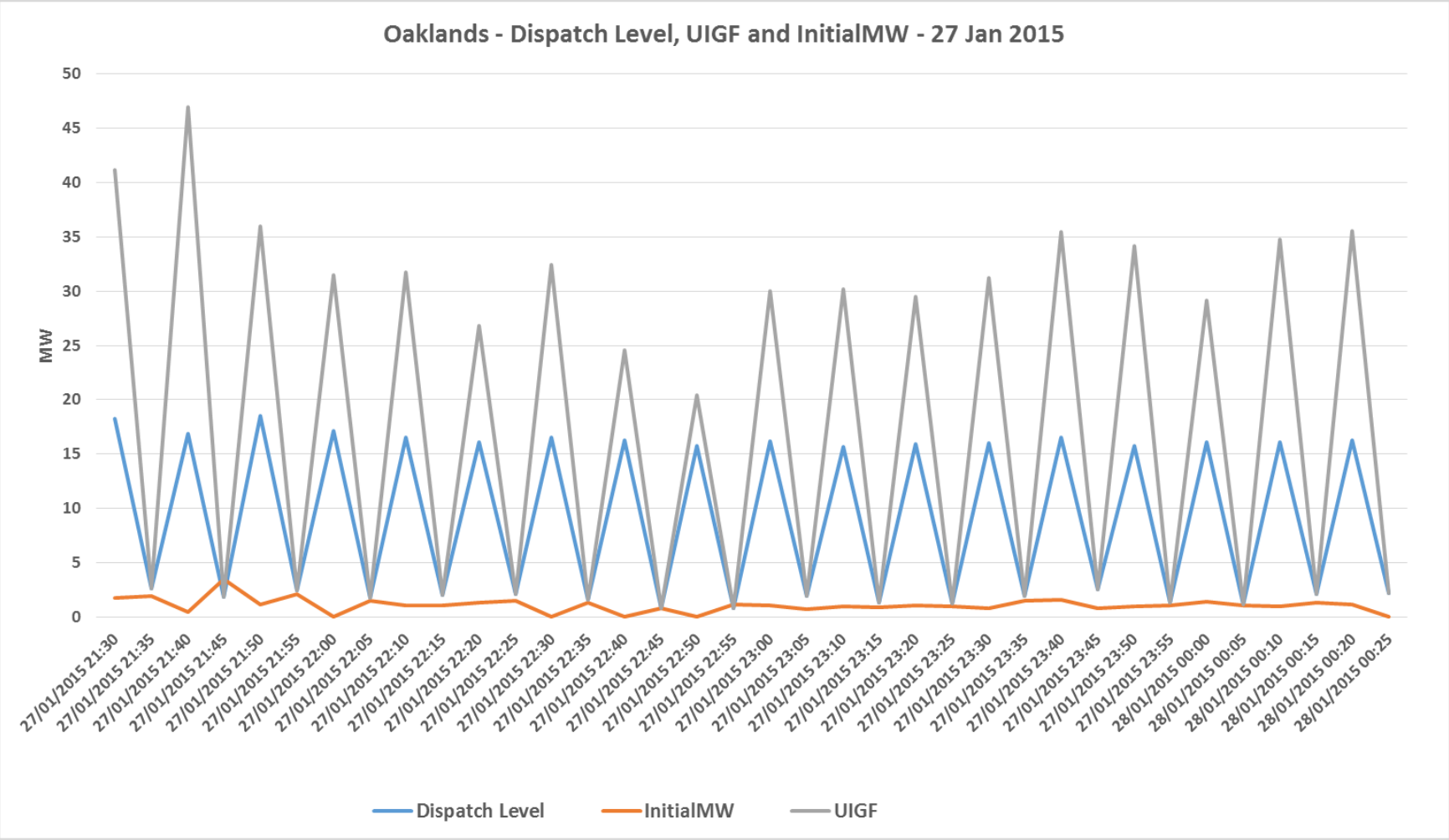


**Figure 2 Oscillations of Dispatch levels for Oaklands - 27 January 2015**

# APPENDIX B. SCHEDULING ERROR 1 – INCORRECT IDENTIFICATION OF SEMI–DISPATCH INTERVALS IN AWEFS

In this example, consecutive semi–dispatch intervals for Macarthur wind farm between DIs ending 0540 hrs and 0600 hrs on 03 July 2014 are analysed. 138 turbines (out of a total of 140 turbines) were available during this period. There was steady wind speed ranging between 11.5-11.6m/s during the half-hour. Note, in the graph below, the wind farm control system setpoint, UIGF and Dispatch level overlay each other.

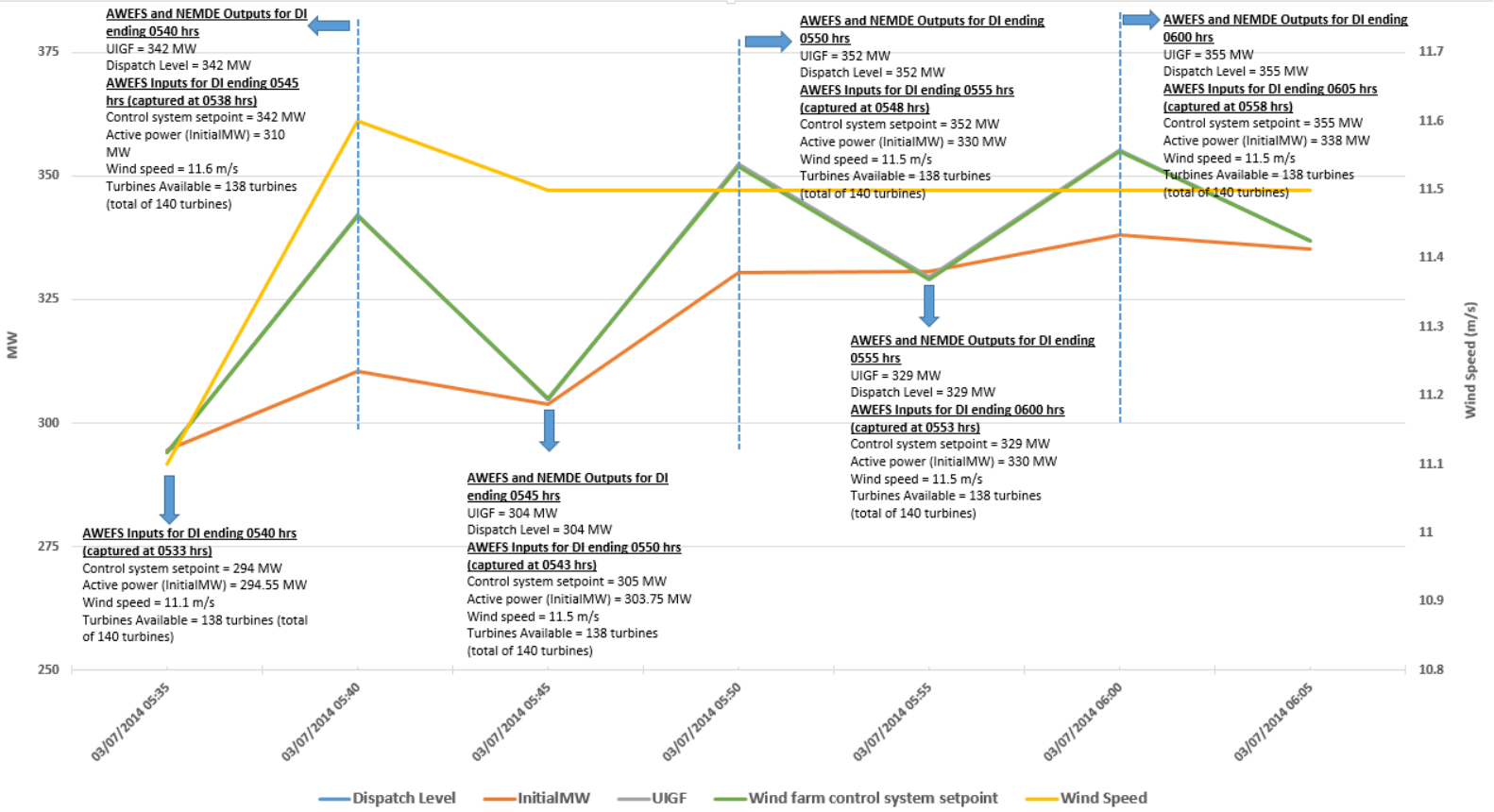


**Figure 3 Incorrect Identification of semi–dispatch intervals in AWEFS**

For each semi–dispatch interval, the following are shown in the graph:

- Inputs captured by AWEFS three minutes into each semi-dispatch interval to determine UIGF for the next semi–dispatch interval
- UIGF produced by AWEFS for each semi-dispatch interval
- Dispatch levels from NEMDE

DI ending 0540 hrs:

AWEFS inputs for DI ending 0540 hrs (captured at 0533 hrs) indicated a wind farm control system setpoint of 294 MW. The validation checks detailed in Section 3.1.1 were applied as follows:

- Is wind farm control system setpoint (294 MW) < registered capacity (420 MW)? – TRUE
- Is wind farm control system setpoint (294 MW) < active power (294) + 5% of registered capacity (21 MW)? – TRUE
- Is wind farm control system setpoint (294 MW) < potential power (342 MW) – TRUE

Since all three validation checks were TRUE, this interval was correctly determined by AWEFS to be a semi–dispatch interval. A wind speed–based UIGF of 342 MW (based on 11.1m/s wind speed and 138 turbines available) was used in NEMDE as the maximum availability for Macarthur wind farm.

NEMDE produced a Dispatch level of 342 MW (same as UIGF) for DI ending 0540 hrs.

DI ending 0545 hrs:

AWEFS inputs for DI ending 0545 hrs (captured at 0538 hrs) indicated a wind farm control system setpoint of 342 MW. The validation checks were applied as follows:

- Is wind farm control system setpoint (342 MW) < registered capacity (420 MW)? – TRUE
- Is wind farm control system setpoint (342 MW) < active power (310 MW) + 5% of registered capacity (21 MW)? – FALSE
- Is wind farm control system setpoint (342 MW) < potential power (360 MW) – TRUE

Since one validation check is FALSE, this interval is incorrectly determined by AWEFS to be a non semi–dispatch interval. An active power output based UIGF of 304 MW was used in NEMDE as the maximum availability for Macarthur wind farm.

DI ending 0550 hrs:

AWEFS inputs for DI ending 0550 hrs (captured at 0543 hrs) indicated a wind farm control system setpoint of 305 MW. The validation checks were applied as follows:

- Is wind farm control system setpoint (305 MW) < registered capacity (420 MW)? – TRUE
- Is wind farm control system setpoint (305 MW) < active power (303.75) + 5% of registered capacity (21 MW)? – TRUE
- Is wind farm control system setpoint (305 MW) < potential power (352 MW) – TRUE

Since all three validation checks were TRUE, this interval was correctly determined by AWEFS to be a semi–dispatch interval. A wind speed–based UIGF of 352 MW (based on 11.5m/s wind speed and 138 turbines available) was used in NEMDE as the maximum availability for Macarthur wind farm.

NEMDE produced a Dispatch level of 352 MW (same as UIGF) for DI ending 0550 hrs.

DI ending 0555 hrs:

AWEFS inputs for DI ending 0555 hrs (captured at 0548 hrs) indicated a wind farm control system setpoint of 352 MW. The validation checks were applied as follows:

- Is wind farm control system setpoint (352 MW) < registered capacity (420 MW)? – TRUE
- Is wind farm control system setpoint (352 MW) < active power (330 MW) + 5% of registered capacity (21 MW)? – FALSE
- Is wind farm control system setpoint (342 MW) < potential power (360 MW) – TRUE

Since one validation check is FALSE, this interval is incorrectly determined by AWEFS to be a non semi–dispatch interval. An active power output based UIGF of 329 MW was used in NEMDE as the maximum availability for Macarthur wind farm.

DI ending 0600 hrs:

AWEFS inputs for DI ending 0600 hrs (captured at 0553 hrs) indicated a wind farm control system setpoint of 329 MW. The validation checks were applied as follows:

- Is wind farm control system setpoint (329 MW) < registered capacity (420 MW)? – TRUE
- Is wind farm control system setpoint (329 MW) < active power (330) + 5% of registered capacity (21 MW)? – TRUE
- Is wind farm control system setpoint (305 MW) < potential power (352 MW) – TRUE

Since all three validation checks were TRUE, this interval was correctly determined by AWEFS to be a semi–dispatch interval. A wind speed–based UIGF of 355 MW (based on 11.5m/s wind speed and 138 turbines available) was used in NEMDE as the maximum availability for Macarthur wind farm.

NEMDE produced a Dispatch level of 355 MW (same as UIGF) for DI ending 0600 hrs.

Based on the above analysis, it is noted that the UIGFs for Macarthur oscillated between high values and low values for the consecutive semi–dispatch interval periods. The UIGF oscillated from a high value of 342 MW (for DI ending 0540 hrs) to a low value of 304 MW (for DI ending 0545

hrs), then increased to 352 MW (for DI ending 0550 hrs) followed by a reduction to 329 MW (for DI ending 0555 hrs). Consequently, the Dispatch levels oscillated as well.

In this example, between DIs ending 0540 hrs and 0600 hrs, Macarthur was incorrectly dispatched for DIs ending 0545 hrs and 0555 hrs. This was because AWEFS incorrectly identified those DIs as non semi–dispatch intervals and produced UIGFs based on Macarthur's actual generation output rather than prevailing wind conditions.

# APPENDIX C. SCHEDULING ERROR 2 – ANALYSIS OF REJECTION OF UIGF > 63 MW AT OAKLANDS HILL

In this example, consecutive semi–dispatch intervals for Oaklands Hill wind farm between DIs ending 2225 hrs and 2235 hrs on 31 July 2015 are analysed. All 32 turbines were available to generate during this period. Wind speed ranged between 15.7–16.3 m/s during the period.

Table 3 lists the AWEFS produced UIGF, all inputs that were used to determine the UIGF, InitialMW, Maximum Availability and Dispatch level for each semi–dispatch interval during this period.

**Table 3 No. of DIs affected and MWh constrained-off for Oaklands Hill**

| Semi–dispatch interval | Wind speed (m/s) | Number of Turbines Available to generate | Wind farm control system setpoint | Wind farm active power SCADA (used in AWEFS) | AWEFS produced UIGF (MW) | InitialMW (used in NEMDE) | Maximum Availability used in NEMDE (MW) | Dispatch level (MW) |
|---|---|---|---|---|---|---|---|---|
| 31/07/2015 22:25:00 | 15.9 | 32 | 43 | 41.2 | 60.921 | 39.4 | 60.921 | 54.4 |
| 31/07/2015 22:30:00 | 15.7 | 32 | 54 | 40 | 40.241 | 42.5 | 40.241 | 40.241 |
| 31/07/2015 22:35:00 | 16.3 | 32 | 40 | 37.3 | **66.005** | 36.5 | **36.5** | 36.5 |

DI ending 2225 hrs:

Based on a wind speed of 15.9 m/s and 32 turbines available to generate, AWEFS produced a UIGF of 60.92 MW. This UIGF was applied as the maximum availability for the wind farm in NEMDE. Due to a binding network constraint equation, NEMDE limited the Dispatch level of the wind farm to 54.4 MW and a semi–dispatch flag = 1 was issued as part of the dispatch instruction.

DI ending 2230 hrs:

At 2223 hrs (when AWEFS captured its inputs for DI ending 2230 hrs), the wind farm's control system setpoint SCADA indicated 54 MW. To determine whether the DI was a semi–dispatch interval, AWEFS performed the validation checks detailed in Section 3.2.1. The second validation check failed, whereby the active power output was not within a 5% margin of the control system setpoint. AWEFS produced an active power output based forecast of 40.24 MW. It should be noted that the UIGF thus produced was incorrect, and is part of scheduling error 1 covered in section 4.1.

The UIGF of 40.24 MW was applied as the maximum availability for the wind farm in NEMDE. Due to a binding network constraint equation, NEMDE limited the Dispatch level of the wind farm to 40.24 MW and a semi–dispatch flag = 1 was issued as part of the dispatch instruction.

DI ending 2235 hrs:

At 2228 hrs (when AWEFS captured its inputs for DI ending 2235 hrs), the wind farm's control system setpoint SCADA indicated 40 MW. To determine whether the DI was a semi-dispatch interval, AWEFS performed the validation checks detailed in Section 3.1.1. The active power output was within a 5% of registered capacity margin of its control system setpoint and hence, AWEFS produced a wind speed-based UIGF of 66 MW.

However, the bid validation logic in central dispatch rejected this UIGF value since it exceeded Oakland Hill's maximum capacity of 63 MW. Instead, the wind farm's InitialMW of 36.5 MW was used in NEMDE as its maximum availability.

As a result, Oakland Hill's Dispatch level for DI ending 2235 hrs was limited to 36.5 MW, 26.5 MW less than its available capacity of 63 MW.

# APPENDIX D. MARKET IMPACT ASSESSMENT START DATES FOR EACH WIND FARM AND SOLAR FARM

The start dates of the assessment period for all affected wind farms and solar farms were determined based on criteria listed in Section 5.

**Table 4 Start Dates of assessment period for all affected wind and solar farms**

| Wind farm | Start Date |
|---|---|
| Bald Hills Wind Farm | 27 April 2015 |
| Bluff Wind Farm | 08 March 2012 |
| Boco Rock Wind Farm | 28 November 2014 |
| Broken Hill Solar Farm | 09 December 2015 |
| Clements Gap Wind Farm | 01 August 2012 |
| Gullen Range Wind Farm | 04 September 2014 |
| Gunning Wind Farm | 14 September 2012 |
| Hallett 1 Wind Farm | 20 March 2012 |
| Hallett 2 Wind Farm | 08 March 2012 |
| Lake Bonney 2 Wind Farm | 19 March 2012 |
| Lake Bonney 3 Wind Farm | 22 September 2012 |
| Macarthur Wind Farm | 01 November 2012 |
| Mt Mercer Wind Farm | 22 July 2014 |
| Musselroe Wind Farm | 17 July 2013 |
| North Brown Hill Wind Farm | 08 March 2012 |
| Nyngan Solar Farm | 06 July 2015 |
| Oakland Wind Farm | 14 April 2012 |
| Snowtown North Wind Farm | 30 June 2014 |
| Snowtown South Wind Farm | 30 June 2014 |
| Snowtown Wind Farm | 14 November 2012 |
| Taralga Wind Farm | 31 March 2015 |
| Waterloo Wind Farm | 20 March 2012 |

| Wind farm | Start Date |
|---|---|
| Woodlawn Wind Farm | 25 October 2012 |

# APPENDIX E. ASSUMPTIONS AND METHODOLOGY: SCHEDULING ERROR 1

## E.1 Assumptions – Incorrect Identification of semi-dispatch intervals in AWEFS and ASEFS

1. Only wind and solar farms are affected by Scheduling Error 1.
2. The period during which Scheduling Error 1 occurred is determined as follows:
   - For Semi-Scheduled Generators that were compensated following the 2012 Scheduling Error[19], the period following the last date for which compensation was paid, until 07 April 2016 1800 hrs (date and time of resolution of Scheduling Error 1).
   - For Semi-Scheduled Generators that did not claim compensation following the 2012 Scheduling Error, the period from the date when the Semi-Scheduled Generator was functional in AWEFS or ASEFS, until 07 April 2016 1800 hrs (date and time of resolution of Scheduling Error 1).
3. For non-semi-dispatch intervals, affected wind and solar farms are not required to comply with dispatch instructions and, hence, are unaffected by Scheduling Error 1. This is consistent with Appendix C2 of AEMO's Dispatch Procedure[20].
4. Scheduling Error 1 can no longer occur from the Resolution Date & Time[21].
5. Scheduling Error 1 cannot occur for the first DI in a series of consecutive semi-dispatch intervals in the Scheduling Error Period. A wind or solar farm's UIGF for the first DI is correctly based on its output at the beginning of the DI when the farm was unaffected by a network constraint.[22]
6. A semi-dispatch interval in the Scheduling Error Period is only affected by Scheduling Error 1 if the What-If UIGF exceeds both of the following:
   - Original UIGF produced by either AWEFS (wind farm) or ASEFS (solar farm).
   - Actual wind or solar farm output – This is based on the design of both AWEFS and ASEFS whereby a wind-speed (AWEFS) or irradiance (ASEFS) based forecast is only applied as a UIGF if it exceeds the actual wind or solar farm output.
7. A semi-dispatch interval in the Scheduling Error Period is only affected if there is good quality SCADA available for the following:
   - Wind speed (for wind farms) or irradiance (for solar farms).
   - Actual wind or solar farm output.

   This is based on the design of AWEFS and ASEFS whereby good quality SCADA is required for both items above for a good quality forecast to be produced.
8. Turbine/solar farm power curves for each affected wind or solar farm (provided at the time of registration) are tuned on a daily basis by both AWEFS and, as-needed, for ASEFS.

   The tuned power curves produced by AWEFS correlate turbine power to wind speed at increments of 0.5m/s. Linear interpolation is used to determine turbine power corresponding to the real-time measurement of wind speed.

[19] The report for the 2012 UIGF scheduling error is available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/-/media/17A44958F3654502B1FB220651BB89F9.ashx
[20] This procedure document is available on the AEMO website at: http://www.aemo.com.au/-/media/Files/PDF/SO_OP_3705--Dispatch-V81.ashx
[21] Unchallenged by the DRP in the 2012 Scheduling Error determination as to compensation.
[22] Unchallenged by the DRP in the 2012 Scheduling Error determination as to compensation.

The tuned power curves produced by ASEFS correlate solar farm power to global inclined irradiance at increments of 100W/m$^2$.

9. When good quality power curves are unavailable, the What-If UIGF for semi-dispatch intervals in the Scheduling Error Period is calculated using the last available good quality power curve, which is consistent with the design of AWEFS and ASEFS.
10. When good quality SCADA is unavailable for the count of turbines/inverters available, the What-If UIGF for the semi-dispatch intervals in the Scheduling Error Period is calculated assuming all turbines/inverters are available.
11. If the What-If UIGF exceeds the Maximum Capacity of an affected wind or solar farm, the What-If UIGF is capped to the Maximum Capacity.[23]
12. The following data sources are used in extracting historical data to identify affected intervals and calculate What-If UIGF for each affected wind or solar farm:
    - EMMS – Semi-dispatch intervals, Availability, Original UIGF, Maximum Capacity.
    - SCADA – Actual Wind Farm Output, Wind Speed, Turbines Available. Note, AWEFS primarily uses an average of the instantaneous values for these SCADA inputs between the second and third minute of the DI preceding the DI for which the What-If UIGF is calculated.
    - Time Series Data Repository (AWEFS database) – Potential Power Substituted Flag, SCADA quality flags for Actual Wind Farm Output, Wind Speed and Turbines Available.
    - Time Series Data Repository (ASEFS database) – Potential Power Substituted Flag, Actual Solar Farm Output, Global Inclined Irradiance, Power Available (calculated by ASEFS from Inverters Available SCADA), and associated SCADA quality flags. Note, ASEFS primarily uses an average of the instantaneous SCADA inputs between the second and third minute of the DI preceding the DI for which the What-If UIGF is calculated.
    - ECM – Turbine Capacity, Total No. of Turbines, Solar Farm Capacity.
    - AEMO archives – Daily power curves for AWEFS.
    - ASEFS vendor – solar power curves.

## E.2 Methodology – Incorrect Identification of semi-dispatch intervals in AWEFS and ASEFS

During semi-dispatch intervals, AWEFS applies a wind-speed based forecast as the UIGF, and ASEFS applies an irradiance-based forecast as the UIGF. For non-semi-dispatch intervals, an actual output-based forecast is applied as the UIGF.

For all Semi-Scheduled Generators, a Potential Power Substituted Flag is stored, which indicates whether a wind-speed- (or irradiance-) based forecast was applied as the UIGF for a DI. A Potential Power Substituted Flag=1 for a semi-dispatch interval indicates a wind-speed (or irradiance) based forecast was applied, i.e. AWEFS or ASEFS correctly identified the DI as a semi-dispatch interval. A Potential Power Substituted Flag=0 for a semi-dispatch interval indicates an actual output-based forecast was applied. An actual output-based forecast is applied as UIGF for a semi-dispatch interval when a wind or solar farm's actual output exceeds the UIGF produced by AWEFS (wind) or ASEFS (solar).

During the Scheduling Error Period, semi-dispatch intervals with a Potential Power Substituted Flag=0 also include DIs when AWEFS or ASEFS incorrectly identified a semi-dispatch interval to be a non-semi-dispatch interval. The Potential Power Substituted Flag information is used in addition to others to identify

[23] See paragraph 34 of the DRP's determination at: http://www.aer.gov.au/system/files/Dispute%20Resolution%20Panel%20-%20AGL%20Hydro%20%26%20Ors%20determination%20and%20reasons%20-%2027%20November%202012.pdf (citing paragraph 69(c) of the Joint Submission).

the affected DIs (i.e., when AWEFS or ASEFS incorrectly identified a semi-dispatch interval as a non-semi-dispatch interval).

The process followed in identifying affected DIs for each affected wind or solar farm is as follows:

1. Extract all semi-dispatch intervals (intervals where the semi-dispatch flag = 1)

For each semi-dispatch interval, the following checks are conducted:

2. Is the previous DI a semi-dispatch interval?

   If TRUE, Continue to 3. ELSE, Semi-dispatch interval is UNAFFECTED.

3. Is the wind speed or irradiance SCADA of good quality?

   If TRUE, Continue to 4. ELSE, Semi-dispatch interval is UNAFFECTED.

4. Is the Actual Wind or Solar Farm Output of good quality?

   If TRUE, Continue to 5. ELSE, Semi-dispatch interval is UNAFFECTED.

5. Is the What-If UIGF (calculated as per Appendix I) > Actual Wind Farm Output?

   If TRUE, Continue to 6. ELSE, Semi-dispatch interval is UNAFFECTED.

6. Is the What-If UIGF (calculated as per Appendix I) > Maximum Capacity?

   If TRUE, What-If UIGF = Maximum capacity AND Continue to 7.

   ELSE, Continue to 7.

7. Is the What-If UIGF > Original UIGF?

   If TRUE, Continue to 8. ELSE, Semi-dispatch interval is UNAFFECTED.

8. Is the Potential Power Substituted Flag=0?

   If TRUE, Semi-dispatch interval is AFFECTED.

   ELSE, Semi-dispatch interval is UNAFFECTED.

# APPENDIX F. ASSUMPTIONS AND METHODOLOGY: SCHEDULING ERROR 2

## F.1 Assumptions – Rejection of UIGF exceeding maximum capacity in Dispatch

1. The following Wind and Solar Farms were affected by Scheduling Error 2 because the available capacity (UIGF) for these generators exceeded their Maximum Capacity.
   - Oaklands Hill Wind Farm
   - Broken Hill Solar Farm
   - Hallett 2 Wind Farm
   - Boco Rock Wind Farm
   - North Brown Hill Wind Farm
2. Scheduling Error 2 can no longer occur from the Resolution Date & Time[24].
3. Only the semi-dispatch intervals in the scheduling error period are considered in identifying affected intervals. This is consistent with Appendix C2 of AEMO Dispatch procedure[25].
4. For the affected semi-dispatch intervals in the Scheduling Error Period, the What-If UIGF is equal to the wind or solar farm's Maximum Capacity. This is because a farm's UIGF should not have exceeded its Maximum Capacity.
5. The following data source was used to identify affected intervals:
   - EMMS – Semi-dispatch Intervals, Availability, Original UIGF, Maximum Capacity

## F.2 Methodology – Rejection of UIGF exceeding maximum capacity in Dispatch

The validation logic within NEMDE rejected the Original UIGF from AWEFS or ASEFS whenever it exceeded the wind or solar farm's Maximum Capacity, and instead substituted the farm's InitialMW before input to NEMDE.

The process followed in identifying affected DIs for Scheduling Error 2 is as follows:

1. Extract all semi-dispatch intervals (intervals with semi-dispatch flag = 1)

For each semi-dispatch interval, the following checks are conducted:

2. Is the Original UIGF > Maximum Capacity?

   If TRUE, Continue to 3. ELSE, Semi-dispatch interval is UNAFFECTED.

3. Is the InitialMW < Maximum Capacity?

   If TRUE, Semi-dispatch interval is AFFECTED.

   ELSE, Semi-dispatch interval is UNAFFECTED.

[24] Unchallenged by the DRP in the 2012 Scheduling Error determination as to compensation.
[25] This procedure document is available on the AEMO website at: http://www.aemo.com.au/-/media/Files/PDF/SO_OP_3705--Dispatch-V81.ashx

# APPENDIX G. ASSUMPTIONS AND METHODOLOGY: SIMULATED RERUN AND CONSTRAINED-OFF ENERGY

## G.1 Simulated Rerun

1. A list of all DIs that were rerun was developed as follows:
   I. Collated a single list of all affected DIs for Scheduling Errors 1 and 2 for all affected wind and solar farms.
   II. Removed duplicates from the list in I. The duplicate entries are due to multiple affected wind or solar farms being affected for the same DIs or overlaps between the affected DIs as a result of Scheduling Errors 1 and 2.
   III. Developed a list of DIs that are subsequent to each affected DI in the list from II.
   IV. Merged the subsequent DI list from III with the list from II.
   V. Removed duplicates from the merged list in IV. The duplicates are due to some affected DIs being subsequent DIs as well.
   VI. The final list from V. provides a list of all DIs (affected and subsequent) to be rerun.
2. For each affected DI, the Original UIGF for each affected wind or solar farm was substituted with the What-If UIGF determined as per Appendix I for Scheduling Error 1 and as per Step 4 in Appendix F.1 for Scheduling Error 2. This step resolves the scheduling errors due to incorrect UIGFs.
3. To allow compensation for the lost MWh in the subsequent DIs (see introduction to Section 5.3), the ramp rates for all semi-scheduled generators in the affected and subsequent DIs for all semi-scheduled generators was relaxed to 100 MW/min.
4. Except for the UIGF and ramp rate changes listed in Steps 2. and 3., all other inputs remained the same.
5. Each DI was rerun independently, and changes in dispatch outcomes resulting from one DI was not carried forward into subsequent DIs.

## G.2 Constrained-off Energy for semi-scheduled generating units

### Identifying "Affected", "Subsequent and Affected" and "Subsequent" intervals

For a semi-scheduled wind farm or solar farm directly affected by a scheduling error over a series of intervals, compensation is based on a comparison of the original dispatch against the "what-if no error" dispatch level determined from simulation reruns (referred to as "What-If Dispatch Level").

This comparison differs depending on whether it is the first DI of the error sequence, a subsequent DI of the error sequence, or the first DI after the error sequence:

I. **AFFECTED**: These are DIs when either Scheduling Error 1 or 2 resulted in an incorrect UIGF for the wind farm or solar farm. This is the first in a sequence of DIs where a scheduling error occurs.

II. **AFFECTED&SUBSEQUENT**: These are DIs when either Scheduling Error 1 or 2 resulted in an incorrect UIGF for the wind farm or solar farm **and** the DI is subsequent to the initial AFFECTED DI (identified as per Step I).

III. **SUBSEQUENT**: These are DIs when neither Scheduling Error 1 or 2 resulted in an incorrect UIGF for the wind farm or solar farm, but is subsequent to either an AFFECTED DI (as identified in Step I) or AFFECTED&SUBSEQUENT DI (as identified in Step II) for that farm. This is the DI immediately after a sequence of DIs where a scheduling error occurred for the farm.

IV. **NEITHER AFFECTED NOR SUBSEQUENT**: These are DIs when the dispatch of a semi-scheduled or a scheduled generating unit is only indirectly affected (constrained off) by the scheduling error of one or more other semi-scheduled generating units during the DI. This can occur for marginal units outside a binding constraint equation that involves a semi-scheduled generating unit constrained off by a scheduling error and another unit constrained on to meet the constraint equation. This cannot be a DI for a semi-scheduled generating unit that is directly **affected** by its scheduling error (an AFFECTED DI as identified in Step I, **or an** AFFECTED&SUBSEQUENT DI as identified in Step II).

### Compensation

Compensation is not payable to a semi-scheduled unit under the following conditions:

1. For an Affected DI:

- What-If Dispatch Level (from simulation rerun output) less than or equal to Original Dispatch Level

2. For an Affected and Subsequent DI:

- What-If Dispatch Level (from simulation rerun output) less than Original Dispatch Level in the previous DI
  **and**
- What-If Dispatch Level (from simulation rerun output) less than Original Dispatch Level in the current DI

3. For a Subsequent DI:

- What-If Dispatch Level (from simulation rerun output) less than or equal to Original Dispatch Level in the previous DI

4. For a Neither Affected nor Subsequent DI:

- What-If Dispatch Level (from simulation rerun output) less than or equal to Original Dispatch Level

Subject to the checks outlined in Steps 1-3, constrained-off energy (MWh) for Affected, Affected and Subsequent or Subsequent DIs will be determined as the difference between the What-If Dispatch Level (from simulation rerun output) and the InitialMW (actual output) times 1/12[26]. The InitialMW used to calculate constrained-off energy is based on the actual generation at the end of the DI[27].

This approach differs from that used in the 2012 UIGF Scheduling Error[28]. In particular, the approach used in 2012 took the difference between the What-If and Original Dispatch Level (rather than What-If Dispatch Level and InitialMW). Given the nature of the 2012-2016 scheduling error, using the previous approach could have underestimated the lost energy – particularly if there are technology issues that slow or delay ramp-up from low output states (i.e. turbine pausing, etc.).

Subject to the check outlined in Step 4, constrained-off energy (MWh) for Neither Affected nor Subsequent DIs will be determined as the difference between the What-If Dispatch Level (from simulation rerun output) and the larger of the Original Dispatch level and InitialMW[29] (actual wind farm output) times 1/12.

[26] The difference in MW is multiplied by 1/12 to convert to energy (MWh) during the DI.
[27] For example, the InitialMW at 10:00 hrs is recorded in the EMMS against the DI ended 10:05 solution
[28] See paragraph 34 of the DRP's determination at: : http://www.aer.gov.au/system/files/Dispute%20Resolution%20Panel%20-%20AGL%20Hydro%20%26%20Ors%20determination%20and%20reasons%20-%2027%20November%202012.pdf
[29] This logic avoids over-compensating units that are not complying with their original dispatch target

### Estimation of constrained-off energy

Affected DIs:

**IF** (What-If Dispatch Level $_{\textbf{Current DI}}$ <= Original Dispatch Level $_{\textbf{Current DI}}$)

**THEN** MWh Impact = 0,

**ELSE** MWh Impact

= MAX {0, (What-If Dispatch Level $_{\textbf{Current DI}}$ - InitialMW $_{\textbf{Current DI}}$) x 1/12}

Affected and Subsequent DIs:

**IF** (What-If Dispatch Level $_{\textbf{previous DI}}$ <= Original Dispatch Level $_{\textbf{previous DI}}$)

**AND IF** (What-If Dispatch Level $_{\textbf{Current DI}}$ <= Original Dispatch Level $_{\textbf{Current DI}}$)

**THEN** MWh Impact = 0,

**ELSE** MWh Impact

= MAX {0, (What-If Dispatch Level $_{\textbf{Current DI}}$ - InitialMW $_{\textbf{Current DI}}$) x 1/12}

Subsequent DIs:

**IF** (What-If Dispatch Level $_{\textbf{previous DI}}$ <= Original Dispatch Level $_{\textbf{previous DI}}$)

**THEN** MWh Impact = 0,

**ELSE** MWh Impact

= MAX {0, (What-If Dispatch Level $_{\textbf{Current DI}}$ - InitialMW $_{\textbf{Current DI}}$) x 1/12}

Neither Affected nor Subsequent DIs:

**IF** (What-If Dispatch Level $_{\textbf{Current DI}}$ <= Original Dispatch Level $_{\textbf{Current DI}}$)

**THEN** MWh Impact = 0,

**ELSE** MWh Impact =

MAX {0, (What-If Dispatch Level $_{\textbf{Current DI}}$

– MAX (Original Dispatch Level $_{\textbf{Current DI}}$, InitialMW $_{\textbf{Current DI}}$)) x 1/12}

## G.3 Constrained-off Energy for scheduled generators

The estimation of constrained-off energy for a scheduled generator that is indirectly affected by the Scheduling Error 1 or 2 of a semi-scheduled generating unit (ie a “Neither Affected nor Subsequent” interval) is exactly the same as for a semi-scheduled generating unit:

**IF** (What-If Dispatch Level Current DI <= Original Dispatch Level Current DI)

**THEN** MWh Impact = 0,

**ELSE** MWh Impact =

MAX {0, (What-If Dispatch Level $_{\textbf{Current DI}}$

– MAX (Original Dispatch Level $_{\textbf{Current DI}}$, InitialMW $_{\textbf{Current DI}}$)) x 1/12}

## G.4 Total constrained-off energy

For each scheduled and semi-scheduled generating unit:

The constrained-off energy for each TI in the Scheduling Error Period is determined as the sum of the constrained-off energy for all affected DIs within the TI.

The summation of the constrained-off MWh across all TIs is the total constrained-off energy.

# APPENDIX H. MWH CONSTRAINED-OFF FOR SCHEDULED GENERATORS

**Table 5 MWh constrained-off for Scheduled Generators**

| DUID | MWh constrained-off |
|---|---|
| UPPTUMUT | 112 |
| ER02 | 106 |
| ER04 | 106 |
| MURRAY | 98 |
| TUMUT3 | 84 |
| ER01 | 84 |
| TORRB4 | 83 |
| ER03 | 82 |
| TORRB1 | 81 |
| TORRB3 | 80 |
| TORRB2 | 73 |
| NPS1 | 71 |
| VP5 | 59 |
| NPS2 | 57 |
| PPCCGT | 56 |
| VP6 | 53 |
| MP1 | 53 |
| BW03 | 52 |
| GORDON | 45 |
| MP2 | 45 |
| POAT220 | 44 |
| BW02 | 39 |
| LYA3 | 35 |
| POAT110 | 30 |
| LOYYB2 | 30 |
| BW01 | 29 |
| BW04 | 27 |
| GSTONE3 | 26 |
| LYA1 | 25 |
| GSTONE5 | 24 |
| GSTONE4 | 24 |
| LD01 | 23 |
| REECE2 | 21 |
| CALL_B_2 | 19 |
| LD02 | 19 |
| TORRA3 | 19 |
| LYA2 | 19 |
| TARONG#4 | 18 |
| LOYYB1 | 18 |

| DUID | MWh constrained-off |
|---|---|
| STAN-2 | 18 |
| TORRA1 | 17 |
| LYA4 | 17 |
| LD04 | 17 |
| TORRA4 | 16 |
| STAN-3 | 15 |
| LD03 | 15 |
| JBUTTERS | 15 |
| TARONG#3 | 14 |
| TARONG#1 | 14 |
| GSTONE6 | 13 |
| TRIBUTE | 13 |
| STAN-4 | 13 |
| TORRA2 | 13 |
| STAN-1 | 11 |
| AGLHAL | 11 |
| GSTONE1 | 11 |
| MCKAY1 | 10 |
| GSTONE2 | 9 |
| QPS5 | 9 |
| WW8 | 8 |
| OSB-AG | 7 |
| W/HOE#2 | 6 |
| BRAEMAR5 | 6 |
| BRAEMAR2 | 6 |
| TVCC201 | 5 |
| CETHANA | 5 |
| BASTYAN | 5 |
| HWPS1 | 5 |
| TALWA1 | 5 |
| DARTM1 | 4 |
| CALL_B_1 | 4 |
| MINTARO | 4 |
| NPS | 4 |
| BRAEMAR7 | 4 |
| EILDON1 | 4 |
| OAKEY2 | 4 |
| BRAEMAR1 | 4 |
| OAKEY1 | 4 |
| BRAEMAR6 | 4 |
| LI_WY_CA | 4 |
| SWAN_E | 3 |
| BRAEMAR3 | 3 |
| DDPS1 | 3 |

| DUID | MWh constrained-off |
|---|---|
| YWPS2 | 3 |
| CPP_4 | 3 |
| WW7 | 3 |
| REECE1 | 3 |
| MORTLK12 | 3 |
| CPP_3 | 3 |
| MACKNTSH | 2 |
| DEVILS_G | 2 |
| HWPS5 | 2 |
| URANQ11 | 2 |
| URANQ14 | 2 |
| YWPS4 | 2 |
| TREVALLN | 2 |
| TUNGATIN | 2 |
| YWPS3 | 2 |
| WKIEWA2 | 2 |
| TARONG#2 | 2 |
| TNPS1 | 1 |
| LEM_WIL | 1 |
| HWPS8 | 1 |
| HWPS2 | 1 |
| HWPS6 | 1 |
| HWPS7 | 1 |
| YWPS1 | 1 |
| MORTLK11 | 1 |
| KPP_1 | 1 |
| BARRON-2 | 1 |
| BARRON-1 | 1 |
| URANQ12 | 1 |
| URANQ13 | 1 |

# APPENDIX I.SCHEDULING ERROR 1 – CALCULATING WHAT-IF UIGF

The Time Series Data Repository (AWEFS Database) does not store the wind-speed or irradiance based forecasts produced by AWEFS and ASEFS for each DI. To identify the affected DIs, the What-If UIGF has to be calculated.

## Wind Farms

What-If UIGF for a wind farm for each DI is calculated as follows:

**What-If UIGF = Turbine Power x Turbine Capacity x No. of Turbines Available**

Where:

- **Turbine Power** refers to the turbine power output (expressed as a % of turbine capacity) relative to the real-time wind speed measurement. Turbine power is determined based on linear interpolation between breakpoints of the daily tuned power curve that correlates turbine power to wind speed.
- **Turbine Capacity** refers to the capacity of individual turbines, as provided in each affected wind farm's ECM (provided to AEMO at registration).
- **No. of Turbines Available** refers to the total number of turbines available to generate for the DI. This information is provided via SCADA and historical values.

Note, for DIs when good quality SCADA is unavailable for No. of Turbines Available, What-If UIGF is calculated on the assumption that all turbines are available.

## Solar Farms

What-If UIGF for a solar farm for each DI is calculated as follows:

**What-If UIGF = Solar Power x Capacity Available**

Where:

- **Solar Power** refers to the solar farm power output (expressed as a % of solar farm capacity) relative to the real-time global inclined irradiance measurement. Solar power is determined based on linear interpolation between breakpoints of the tuned power curve that correlates solar farm power to global inclined irradiance.
- **Capacity Available** refers to the total inverter capacity available, which has been derived from inverter availability in ASEFS.

# GLOSSARY

| Term | Meaning |
|---|---|
| **AEMO** | Australian Energy Market Operator |
| **Available Capacity** | Total MW capacity available for dispatch by a semi–scheduled generating unit for each Dispatch Interval. |
| **AWEFS** | Australian Wind Energy Forecasting System |
| **ASEFS** | Australian Solar Energy Forecasting System |
| **DI** | Dispatch Interval |
| **Dispatch level** | The amount of electricity specified in a dispatch instruction as a semi–scheduled generating unit's maximum permissible active power at the end of the DI specified in the dispatch instruction. |
| **EMMS** | Electricity Market Management Systems |
| **EMS** | Energy Management System |
| **FCAS** | Frequency control ancillary services |
| **InitialMW** | The actual loading level of each generating unit, snapped at the start of each DI. |
| **Maximum Capacity** | The maximum amount of electricity capable of being produced by a generating unit as measured at its terminals. |
| **MW** | Megawatt |
| **MWh** | Megawatt Hour |
| **NEM** | National Electricity Market |
| **NER** | National Electricity Rules |
| **Registered Capacity** | Same as Nameplate Rating. It is the maximum continuous amount of electricity that can be produced by a generating unit as specified by the manufacturer, or as subsequently modified. |
| **Semi–dispatch Interval** | For a semi-scheduled generating unit, a dispatch interval for which either:<br>I. A network constraint would be violated if the semi–scheduled generating unit's generation were to exceed the Dispatch level specified in the related dispatch instruction at the end of the dispatch interval.<br>II. The Dispatch level specified in the dispatch instruction is less than the unconstrained intermittent generation forecast at the end of the dispatch interval |
| **UIGF** | Unconstrained Intermittent Generation Forecast. UIGF reflects a wind farm's available capacity in the National Electricity Market Dispatch Engine (NEMDE). |