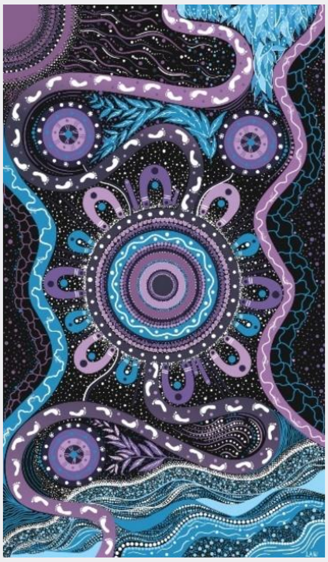
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

# East Country Oscillation Incident in SWIS on 23 August 2024

January 2026

An incident report for the Wholesale Electricity Market under section 3.8 of the Electricity System and Market Rules.



**We acknowledge the Traditional Custodians of the land, seas and waters across Australia. We honour the wisdom of Aboriginal and Torres Strait Islander Elders past and present and embrace future generations.**

**We acknowledge that, wherever we work, we do so on Aboriginal and Torres Strait Islander lands. We pay respect to the world's oldest continuing culture and First Nations peoples' deep and continuing connection to Country; and hope that our work can benefit both people and Country.**

'Journey of unity: AEMO's Reconciliation Path' by Lani Balzan

AEMO Group is proud to have launched its first Reconciliation Action Plan in May 2024. 'Journey of unity: AEMO's Reconciliation Path' was created by Wiradjuri artist Lani Balzan to visually narrate our ongoing journey towards reconciliation - a collaborative endeavour that honours First Nations cultures, fosters mutual understanding, and paves the way for a brighter, more inclusive future.

# Important notice

## Purpose

Under clause 3.8.1(a) of the Electricity System and Market Rules (ESM Rules), AEMO must investigate any incidents, including incidents in the operation of equipment comprising the SWIS, that endanger Power System Security or Power System Reliability to a significant extent. AEMO has prepared this report in accordance with clause 3.8.3 of the ESM Rules which details findings from the event investigation conducted by AEMO with regards to the East Country Oscillation Incident in SWIS on 23 August 2024.

## Disclaimer

To inform its review and the findings expressed in this report, AEMO has been provided with data by participants as to the status or response of some facilities before, during and after the incident, and has also collated information from its own observations, records and systems[1]. AEMO has made reasonable efforts to ensure the quality of the information in this report but cannot guarantee its accuracy or completeness. Any views expressed in this report are those of AEMO unless otherwise stated and may be based on information given to AEMO by other persons. Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this report:

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## Copyright



### Version control

| Version | Release date | Changes |
| --- | --- | --- |
| 1.0 | 07/01/2026 | First Release |

[1] Involved participants, including WP, Merredin Solar Farm, Collgar Wind Farm and Cunderdin Solar Farm, are gratefully acknowledged for their support in providing essential background information.

# Contents

# Tables



# Figures

# 1 Interpretation

## 1.1 Definitions

1.1.1. Terms defined in the ESM Rules have the same meaning in this report unless the context requires otherwise

## 1.2 Abbreviations

1.1.2. The following abbreviations apply in this report unless the context requires otherwise.

| Abbreviation | Term |
|---|---|
| **CGW** | Collgar Wind Farm / INVESTEC_COLLGAR_WF1 |
| **CSF** | Cunderdin Solar Farm / SBSOLAR1_CUNDERDIN_PV1 |
| **EC** | East Country |
| **EGF** | Eastern Goldfields |
| **EMT** | Electro-Magnetic Transient |
| **HTSD** | High-resolution time synchronised data |
| **HTSDR** | HTSD recorder |
| **IBR** | Inverter-based resource |
| **MRS** | Merredin Solar Farm / MERSOLAR_PV1 |
| **MRT** | Merredin Terminal |
| **PMU** | Phasor measurement unit |
| **PoC** | Point of connection |
| **RMS** | Root-mean-square |
| **SCR** | Short circuit ratio |
| **SSF** | Semi-Scheduled Facility |
| **SSO** | Sub-synchronous oscillation |
| **WAMS** | Wide area monitoring system |
| **WP** | Western Power |

# 2 Overview

## 2.1 Incident

This report relates to a sub-synchronous oscillation (SSO) incident in the South West Interconnected System (SWIS) that occurred at 1113 hrs on Friday, 23 August 2024, in the East Country (EC) / Eastern Goldfields (EGF) areas (referred to as the Primary Incident[2]), where an undamped oscillatory behaviour (without any fault in the system) was identified by a protection relay at Merredin Terminal (MRT) resulting in a disconnection of the 220-kV MRT-CGT line, which left the EGF area with no power. This has been identified as one of the first observable sub-synchronous oscillatory events in the SWIS resulting in unplanned outages.

Facility names in this report relate to registered Facilities as indicated in the following Table 1.

**Table 1 Facility names**

| Report name | Participant Code | Facility Code | Facility Class | System size (MW) |
|---|---|---|---|---|
| **MRS** | SUNAUST22 | MERSOLAR_PV1 | SSF | 100 |
| **CGW** | COLLGAR | INVESTEC_COLLGAR_WF1 | SSF | 218.5 |
| **CSF** | SBSOLAR1 | SBSOLAR1_CUNDERDIN_PV1 | SSF | 100.0 |

## 2.2 Observations

On 21 August 2024 at 0840 hrs, one of the two reactive plants at MRT tripped. These reactive plants are critical for maintaining voltage stability at MRT. On 23 August 2024 at 1113 hrs, the protection relay at MRT operated and disconnected the MRT-CGT X1 line due to an undamped and growing sub-synchronous voltage oscillation, resulting in a supply loss in the EGF region.

Further damped oscillations were observed between the reactive plant trip (21 August 2024 at 0840 hrs) and the Primary Incident (23 August 2024 at 1113 hrs). During these events, MRS, CGW and CSF were operational and in service. No suspected issue was observed regarding Market dispatches for Energy and Frequency Co-optimised Essential System Service. During the Primary Incident, the SWIS frequency remained within the Normal Operating Frequency Band[3], however, an 8-9 Hz SSO with an increasing magnitude with a peak-to-peak root-mean-square (RMS) up to approximately 6% was observed in voltage profiles in the EC area over the course of approximately one minute[4] - refer to section 4 for more details. It is worth noting that the Network Operator's high-resolution time synchronised data recorders (HTSDRs) were not triggered for the majority of these oscillations.

The re-energisation was challenging for the Network Operator, Western Power (WP), due to over-voltage issues in the area. Eventually, EGF was successfully re-energised after 4 hours and 37 minutes, by decoupling the 220 kV and 132 kV lines at MRT and constraining the Semi-Scheduled Facilities (SSFs) to zero (0) MW.

[2] There had been other oscillatory events between 21 to 23 August 2024 that were damped and did not lead to a trip, known as Damped Oscillatory Incidents.

[3] Defined in Appendix 13 of the ESM Rules.

[4] The sub-synchronous oscillation was apparent in voltage, active and reactive power profiles, measured at MRS and CGW PoC.

During the oscillatory events, CSF was online and undergoing hot commissioning, operating at less than 1 MW / MVAR of both active and reactive power output. Given the uncertainty regarding the influence of CSF on the observed oscillations, WP isolated the 220 kV and 132 kV feeders at MRT, as a precautionary measure to remain in effect until suitable mitigation strategies are established, and the potential risk is known and managed.

At 1204 hrs on 23 August 2024, AEMO issued Market Advisory 210909 referred to in Table 2, to advise Market Participants of the event and the subsequent constraint actions it had taken to manage power system security.

Table 2 Market Advisory 210909 Details

| Market Advisory Number | Date and Time Issued | Details |
|---|---|---|
| **210909** | 12:04 on 23 August 2024 | Due to a Forced Western Power Network outage on the MRT-CGTX1, CGT-YLNX1 and YLN-WKTX1. The Eastern Goldfields area is currently disconnected from the SWIS and de-energised. INVESTEC_COLLGAR_WF1 have been constrained to 0MW.Constraint set – Island (EGF) has been invoked. |

## 2.3 Summary of findings, recommendations and actions

Table 3 provides a consolidated summary of AEMO's findings, recommendations, and associated actions. It is important to highlight that several of these recommendations take a broader view, extending beyond the immediate context of the Primary Incident. This wider lens reflects systemic challenges within the power system and underscores the need to expand on these recommendations. Doing so is essential not only for addressing current gaps but also for reinforcing the resilience and long-term reliability and security of the power system in the face of future events.

Table 3 Summary of AEMO's findings, recommendations and actions

| Findings | Recommendations / Actions |
|---|---|
| **Scope: Event 23 August 2024** | |
| • **A close correlation between active power step changes of an inverter-based resource (IBR) and the start and/or amplification of oscillations observed in the EC area on 22 and 23 August 2024, while one of the reactive plants at MRT was out-of-service.** | **Recommendation(s):** Relevant Market Participant to investigate the root cause of the active power step change and to work towards full resolution.<br><br>**Taken Action(s):**<br>• AEMO is investigating potential undesired behaviour regarding active power ramping at other Facilities in this region. |
| • **Undesired reactive power regulation and damping performance of some IBRs during Primary Incident.** | **Recommendation(s):** WP should undertake a targeted review of the control and tuning parameters at IBRs in EC, with the objective of identifying and, where necessary, implementing de-tuning measures to mitigate latency and oscillatory behaviour. This process should ensure a positive damping response across the identified oscillation mode(s). Engagement with relevant stakeholders is recommended to facilitate this assessment, with AEMO available to provide technical support and coordination if required.<br><br>**Taken Action(s):** WP is conducting an Electro-Magnetic Transient (EMT) study of the SWIS aiming to de-tune the IBR facilities in EC and to prevent excitation in the MRT area. AEMO to provide support where necessary. |
| • **Primary Incident occurred while both MRS and CGW were close to their maximum active power output.**<br>• **Oscillations sustained longer, up to 3 minutes, when MRS was generating above 65 MW.**<br>• **CGW was generating close to 200 MW during oscillations sustained between 1-3 minutes.** | **Recommendation(s):** WP to conduct studies to identify secure network and dispatch conditions and provide AEMO with a Limit Advice if required. The scope could be extended to include both SSO and System Strength since the existing low short circuit ratio (SCR) level in EC can exacerbate SSO in the area.<br><br>**Taken Action(s):**<br>• Constraints implemented by AEMO as advised by the WP under a Limit Advice, ensuring CGW and MRS are respectively constrained to below 130 MW and 60 MW when one of the reactive plants at MRT is out of service<br>• Further collaboration with WP is required to assess the network conditions—such as dispatch patterns and system configuration—that increase EC's susceptibility to SSO, and to determine whether additional operational constraints and/or the implementation of remedial action schemes are warranted |
| **Scope: General** | |
| **Visibility Gaps in Oscillation Detection and Event Awareness** | **Recommendation(s):** It is recommended that WP, having already initiated a wide area monitoring system (WAMS) investment, establish a comprehensive real-time monitoring framework to facilitate the detection and characterisation of power system events, with data sharing provisions to the AEMO. Central to this framework is the timely installation of phasor measurement units (PMUs) at strategically selected locations across the network. This capability is considered critical in the context of increasing connections of IBRs. The deployment of PMUs will enable:<br>• Improved real-time situational awareness and operational decision-making<br>• Post-event analysis using high-resolution measurement data, particularly where oscillatory behaviour cannot be reliably detected by existing HTSDRs deployed by WP<br><br>This recommendation is aligned with AEMO's Engineering Roadmap and supports the broader implementation of a WAMS within the SWIS, with a focus on areas exhibiting known performance concerns, including EC. |

| | |
|---|---|
| **Gaps in EMT Assessment of SSOs** | **Recommendation(s):** As part of the connection process, AEMO recommends WP undertake complementary EMT assessments to evaluate the sub-synchronous damping capability of IBRs. This evaluation should encompass a range of small-signal testing methodologies across both time and frequency domains to determine the suitability of the IBRs within the network. Appropriate tools for frequency-domain analysis, such as impedance scanning, is regarded as a promising approach for identifying oscillatory modes and characterising device and control interactions; however, its efficacy is highly dependent on detailed power systems computer aided design (Power systems computer aided design (PSCAD)/EMT modelling and accurate frequency-dependent representation of converter dynamics. |
| **Regulatory Limitations in EMT Modelling of Legacy Generators** | **Recommendation(s):** The development and implementation of validated EMT models are essential for accurate system representation and analysis. High-fidelity EMT models serve multiple critical functions, including replication of power system events for root cause analysis and identifying key contributing factors, as well as supporting robust and reliable connection studies.<br><br>While EMT modelling from original equipment manufacturers is typically mandated for new generator connections, significant challenges persist in relation to legacy generator facilities. These challenges primarily concern model validation and ensuring accurate alignment between modelled behaviour and real-world performance—posing risks to the appropriateness and reliability of existing models.<br><br>To address these issues, a supportive regulatory framework should be established, coupled with targeted investment in modelling infrastructure and processes. It is recommended that the relevant WEM Procedure under clause 3A.4.2 of ESM Rules be reviewed by WP to determine whether there is scope to include additional requirement for the provision of reliable EMT models for legacy generators. AEMO acknowledges that provision of EMT models may not be simple for some existing generator and therefore necessitates active collaboration with key industry stakeholders to ensure the continued integrity of power system planning and operation. |

# 3 Pre-event conditions

## 3.1 Weather condition

The weather[5] in Kalgoorlie and Merredin was mild on Friday morning, 23 August 2024, and the sky condition was respectively mostly clear and partly cloudy for these locations. Further information is available in Table 4. It is worth noting that the weather conditions were not found to be a contributing factor to the observed oscillations.

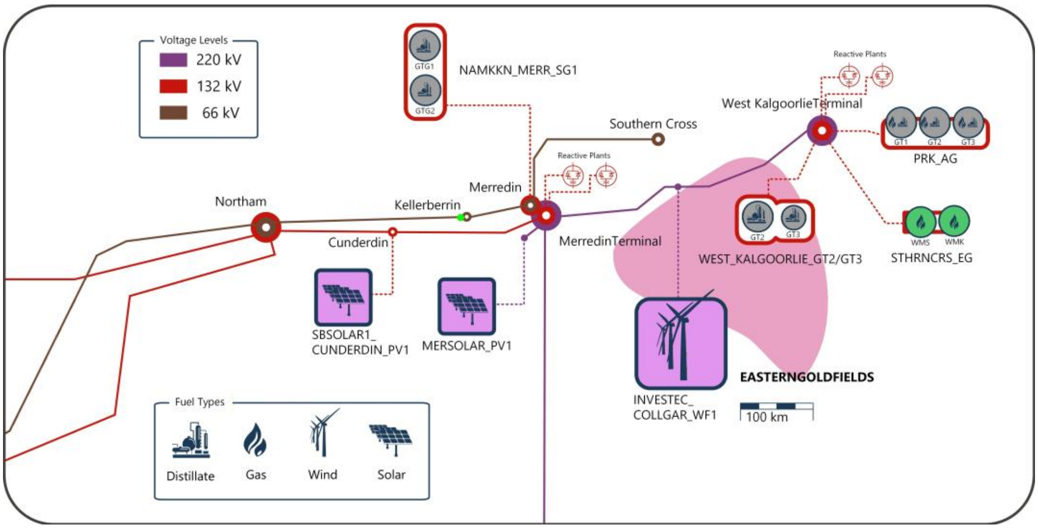
**Table 4 Weather conditions in EC at 9 am Friday, 23 August 2024**

| Report name | Kalgoorlie, WA | Merredin, WA |
|---|---|---|
| Minimum temperature (°C) | 14.7 | 13.0 |
| Maximum temperature (°C) | 24.1 | 21.5 |
| Rainfall (mm) | 0.4 | 2.4 |
| Humidity (%) | 82 | 94 |
| Wind condition | Up to 52 km/h from the northwest | Light north-westerly breezes at 6 km/h |

## 3.2 System condition

Prior to the Primary Incident, the SWIS was in a Satisfactory, Secure and Reliable Operating State. Figure 1 shows the local network topology, including generation Facilities in EC and the two reactive plants in MRT (one of which was out-of-service). At the beginning of the Trading Interval leading to the Primary Incident, the output of MRS, CGW and CSF were, respectively, 90.4 MW, 112.4 MW, and 0.2 MW, with CSF undergoing hot commissioning.

**Figure 1 Local network topology in EC**




[5] https://www.bom.gov.au/wa/?ref=hdr

# 4 The Incident

## 4.1 Primary Incident– 1113 hrs on 23 August 2024

On the 23 August 2024, multiple SSOs were observed in EC between 1023 hrs and 1113 hrs, leading to the Primary Incident picked up by the protection system. As shown in Figure 2 oscillations appeared and disappeared multiple times, each lasting between approximately 1 to 3 minutes.

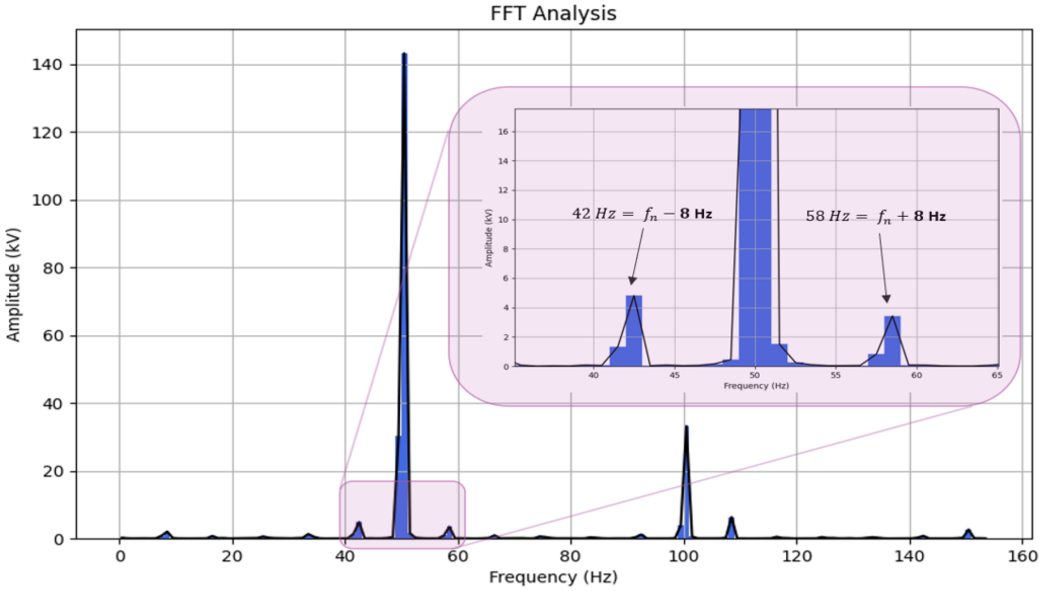
Figure 2 Multiple voltage oscillations in EC on 23 August 2024 prior to Primary Incident


Undamped growing voltage oscillations can be observed, starting at 1112.55 hrs. At 1113.48 hrs, the protection system tripped the 220 kV line, MRT-CGT X1.

Analysis of instantaneous voltage traces at the point of connection (PoC) of nearby Facilities during the Primary Incident, along with the application of Fast Fourier Transform (FFT) to the waveforms, reveals the presence of sideband components at 42 Hz and 58 Hz around the fundamental frequency (50 Hz). These are characteristic of frequency modulated oscillations, with a modulation frequency of 8-9 Hz (shown in the Figure 3).

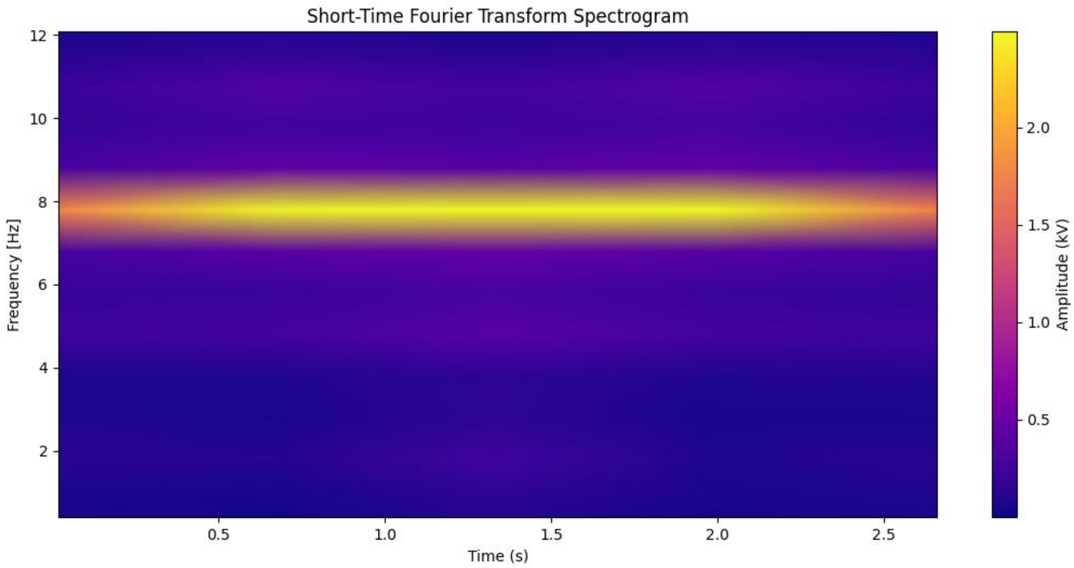
The FFT results illustrate an SSO in the 8-9 Hz frequency range, with a total amplitude of 6.1 kV (sum of 4.8 kV and 1.3 kV for this frequency range). Moreover, voltage harmonics are apparent from the FFT analysis, resulting in a broader distribution of amplitude across frequencies above the fundamental frequency.

**Figure 3 FFT analysis of instantaneous phase voltage waveform at 1113 hrs on 23 August 2024**




Furthermore, Short-Term Fourier Transform (STFT) analysis of several seconds of RMS voltage data suggests a dominant SSO at 8 Hz, as illustrated in Figure 4.

**Figure 4 STFT spectrogram of oscillations from RMS voltage at 1113 hrs on 23 August 2024**




## 4.2 Merredin Solar Farm behaviour

HTSD data provided by MRS at the 220-kV side indicates that there is a correlation between active power step changes at MRS and the start and/or amplification of oscillations observed in the EC area on 22 and 23 August 2024, while one of the reactive plants at MRT was out of service.

## 4.3 IBRs contribution to the oscillation

Investigating the three-phase RMS voltage versus total reactive power, as well as conducting phasor analysis at the frequency of oscillation, provide insights into the contributions of the three IBRs during oscillatory events.

### 4.3.1 Voltage and reactive power relationship

Since there is a strong interdependency between the reactive power and voltage response in the IBR control system, exploring the in-phase and/or out-of-phase relationships between the two can provide insights into how an IBR may have contributed to the oscillation by adjusting its reactive power output. Prior to the Primary Incident, the relationship was in-phase for some IBRs; however, voltage and reactive power at one of the IBR's PoC was partially out-of-phase (though not completely anti-phase). It is worth noting that this IBR was operating on voltage control mode, which means that it is responsible for regulating its terminal voltage by dynamically adjusting its reactive power output. Under such a circumstance, not displaying an in-phase relationship between voltage and reactive power may indicate a delay or oscillatory behaviour in the IBR's control loop, leading to a concern around maintaining voltage stability.

### 4.3.2 Phasor analysis at oscillation frequency

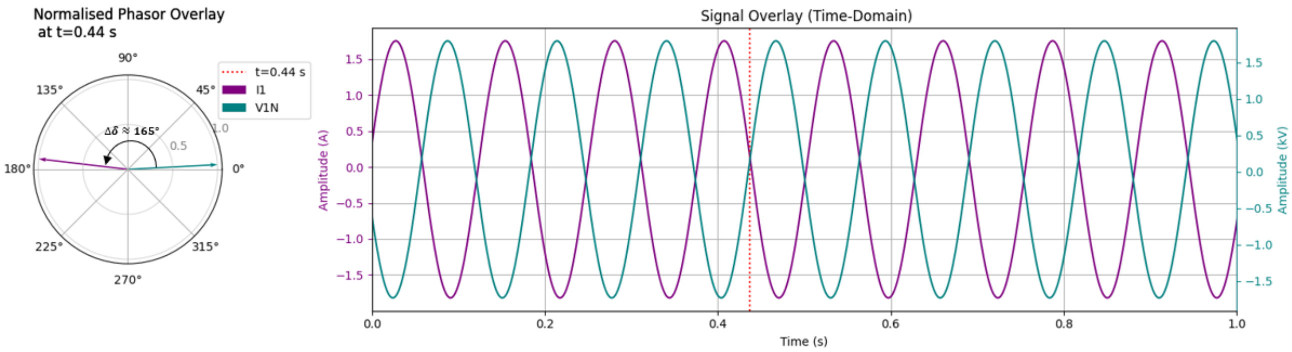
Phasor analysis of voltage and current at the oscillation frequency provides valuable insight into the dynamic behaviour of the IBR, revealing whether its control system contributed positively to damping (associated with positive resistance) or negatively amplified the oscillation (associated with negative resistance).

Figure 5 illustrates the phase volage and current waveforms at the oscillation frequency during the Primary Incident for two of IBRs, respectively[6]. The phasor plots at a given time show the phase angle difference between voltage and current components. As shown, the phase difference for IBR1 is approximately 165°, corresponding to a negative resistance characteristic and indicative of negative damping. Similarly, the phase angle difference related to IBR2 is 120°, also suggesting a negative damping response, though less pronounced than that of IBR1[7]. Additionally, similar phasor analysis conducted for Damped Oscillatory Incidents occurred between 1040 hrs – 1045 hrs on 21 August 2024 revealed a comparable damping performance to that of the Primary Incident.

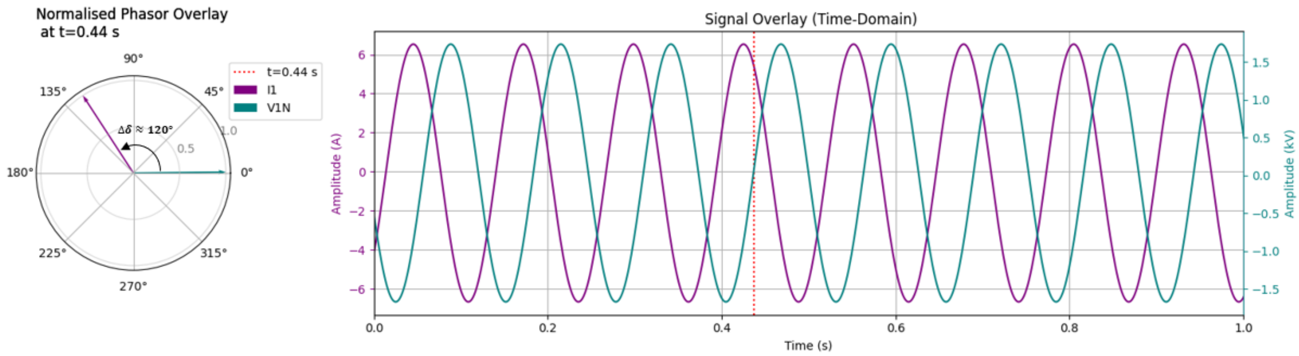
[6]The analysis is conducted under the assumption that the HTSD (Elspec) provided by the Market Participants is synchronised.

[7] Zero phase angle difference between voltage and current waveform at the frequency of oscillation is ideal to exhibit a positive resistance behaviour or positive damping.

**Figure 5 Phase voltage / current waveforms / phasors at the oscillation frequency at 1113 hrs on 23 August 2024.**




(a) IBR1




(b) IBR2

## 4.4 System Strength

System strength is an umbrella term for a range of power system phenomena and issues that are loosely related to network fault levels (also called short circuit levels), including fault current contribution for the correct operation of protection systems, voltage sensitivity and the propensity for voltage oscillations, and voltage waveform stability for grid-following IBR to remain synchronised after disturbances.

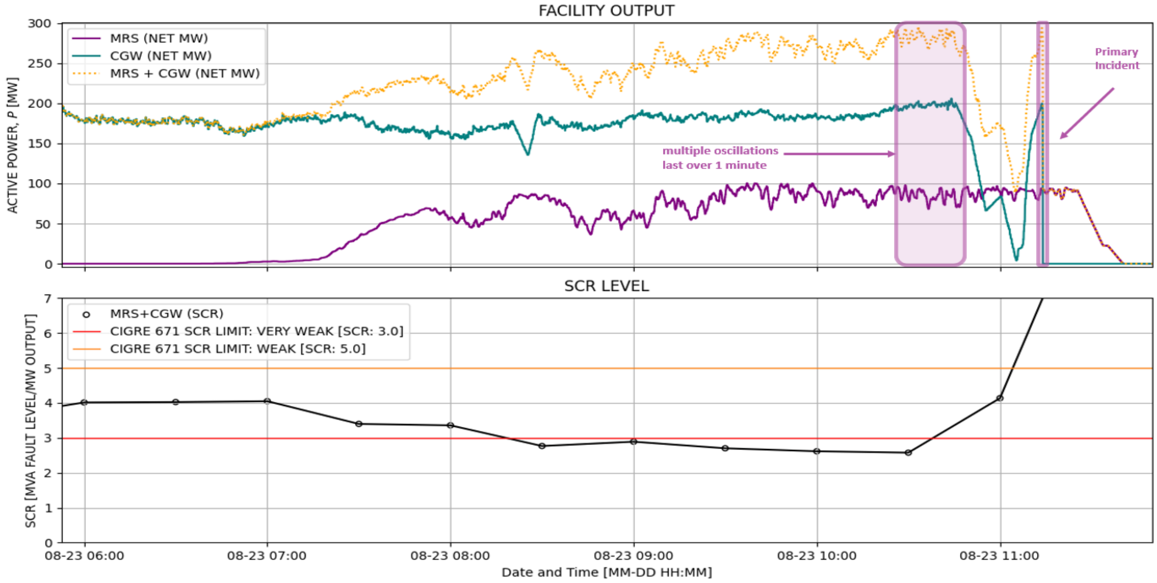
SCR is frequently used as an indicator of system strength at locations on the grid. In a three-phase electrical system like the SWIS, the three-phase fault level refers to the maximum amount of electrical current that flows through a power system when all three electrical phases (wires) are simultaneously short-circuited. Three-phase fault levels can also be used to calculate the SCR at specific network locations to understand the impact of IBR at the transmission connection point. The SCR represents the synchronous fault level (in MVA) divided by the rated output of an IBR generating system (in MW or MVA), measured at the IBR's connection point. As IBRs provide a different and significantly lower contribution towards fault level than synchronous generators, SCR calculations can provide insight into a power system's ability to operate stably at network locations with a large IBR presence.

For the purpose of the System Strength assessment, an SCR value below 5 indicates a weak network location with low level of System Strength, such that an SCR below 3 indicates a very weak network location with a very low level of System Strength[7].

[7] https://www.e-cigre.org/publications/detail/671-connection-of-wind-farms-to-weak-ac-networks.html

Figure 6 illustrates the IBRs output and SCR calculated for the combined facility (CGW and MRS)[8] based on 30 minutes intervals for a few hours leading to the Primary Incident. SCR was under 5 and had reached below 3 at some point. This is likely to have an impact on oscillations, however further studies are required to confirm upon replication of the incident in EMT model. It is worth noting that MRT is identified as a very weak location (SCR<3) in 2025 Wholesale Electricity Market Electricity Statement of Opportunities[9] in the region, and the fault level is expected to lower by 2028 with coal retirement. Without remediation, all IBR connection points within EC will continue to experience very low (and potentially declining) levels of System Strength and would benefit from an increase in fault level, particularly at MRT.

**Figure 6 MRS and CGW operational output along with SCR during 23 August 2024**




[8] MRS and CGW are considered as a single Facility for SCR calculation as they are reasonably close, both geographically and electrically.

[9] https://aemo.com.au/-/media/files/electricity/wem/planning_and_forecasting/esoo/2025/2025-wem-electricity-statement-of-opportunities.pdf?la=en