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Australian Research in Power System Transformation

Topic 1 – Converter Design

2025/26 Topic 1-2 - Grid Forming Converter Standard Development

Commonwealth Scientific and Industrial Research Organisation

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Contents

1. Introduction

The Commonwealth Scientific and Industrial Research Organisation (CSIRO)is working with the Australian Energy Market Operator (AEMO) on a comprehensive research program referred to as the Australian Research in Power Systems Transformation (AR-PST) and related research on the electricity system transformation. It is based on the existing research plan submitted to CSIRO in 2021 (**Australia's Research Roadmap for Power System Transformation - CSIRO**). It seeks to identify and explore the research required to continue Australia's transition to a more secure, affordable, and decarbonized electricity system. The Research Roadmap is a collaborative effort and based on input from leading Australian and international system operators, as well as research agencies.

In Stage 5, the objective of this part of the research plan (Topic 1-2 Grid Forming Converter Standard Development) is to continue the work initiated in the **Stage 4 phase as Topic 1a Standards Development** and foreshadowed for future stages to complement the technical research that is being undertaken in this field. This involves leading and coordinating at an international level to assist in creating a path to the development of consistent international standards associated with Grid Forming Converters. Processes have now been put in place to provide leadership and coordination on the joint standards development effort with the major players in this space. Various initiatives are under way in this field including, but not limited to the IEC, IEEE, **G-PST Pillar 4**, ISON, UNIFI, CENELEC and AEMO. Other organisations that are actively involved in seeking to define requirements with respect to Grid Forming capability include: NGESO, ERCOT, Fingrid, Amprion, ENTSO-E and NERC. This activity is part of a multi-year project to lead the development of a joint dual logo standard(s) between the IEC and the IEEE related to grid forming converters (GFM).

The ultimate objective is to develop a Standard that can be adopted as an Australian Standard. That would occur after the dual logo Standard is developed and outside the scope of the Stage 5 deliverable.

Renewable energy plants, such as wind and solar farms whose output is from power electronic converters, are typically located in regions where wind and solar resources are abundant, yet usually distant to synchronous generators (SGs) and loads. More significantly the closure of coal fired power stations has resulted in a significant reduction of synchronous generation on the overall system. To address this, grid forming converters are deployed in particular to enhance the stability of the l networks.

Note: For the purpose of this report, the IEC term "Converter" is the preferred term except where the term "inverter" is a title or being referenced. Common industry usage (particularly in the USA) is the term used is inverter. However, inverters are a subset of the broader category of converters and only applies to DC to AC conversion.

2. Research completed

Task	Completed Activity	Key Items
1	Worked with leaders of the IEC TC 8 (System aspects of electrical energy supply) and SC 8A (Grid Integration of Renewable Energy Generation), IEEE 2800-2022 (Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems) and G-PST Pillars 1, 2, and 4, to implement the process and schedule for standards development within IEEE and IEC regarding development of a joint, dual logo GFM standard. Liaison Category C established between IEC SC 8A and IEEE P2800 (Standard for Interconnection and Interoperability of Inverter/Converter-Based Resources (IBRs/CBRs) Interconnecting with Transmission Electric Power Systems) development team	Participated in fortnightly joint IEC/IEEE coordination meetings

2	Arranged for the guide on "Development of an IEC/IEEE Dual Logo Standards on GFM Converters" to be updated. Continued to use this as a guide, to ensure that processes that are put in place avoid the pitfalls that could affect successful efforts for joint dual logo standards.	Guide updated by original author.
3	Development of the draft joint IEC/IEEE GFM Converter Standard has now progressed from the initial outline to an initial draft of the initial parts of the document. This has included uploading an initial draft based on consideration of a range of inputs including the UNIFI version 2 document, AEMO documents (AEMO Voluntary Specification for Grid forming Inverters, May 2023)) and VDE documents (VDE FNN Technical requirements for grid-forming capabilities including provision of inertia Requirements and verifications for grid-forming units Version 2.0) In addition to regular virtual meetings, face-to-face meetings of SC 8A Working Group held in Kassel Germany 4-6 March 2025, Rome Italy 10-12 June 2025 and attended virtually at the IEC Plenary Meeting in Delhi India, September 2025.	Ongoing activity
4	Continue to serve as a liaison among IEC, IEEE and AEMO. Coordinate exchange of information from IEC and IEEE to AEMO through presentation of IEC GFM standard development projects and activities at AEMO and related conferences and meetings.	Ongoing activity

3. Outstanding activities

As this is a multi-year project, the development of the standard evolves over time with input from the contributors to a working draft. The **IEC Online Standard Development** tool is being used and arrangements being made to enable the work to progress as a dual logo document with input from IEC and IEEE contributions.

Task	Anticipated Activity	Key Items
1	Continue to work with leaders of the IEC TC 8 and SC 8A, IEEE 2800-2022 and G-PST Pillars 1, 2, and 4, to implement the process and schedule for standards development within IEEE and IEC regarding development of a joint, dual logo GFM standard. Identify in detail the individual processes and commonalities between them.	Participate in joint IEC/IEEE Coordination meetings
2	Continue to work with leaders of the IEC TC 8 and SC 8A, IEEE 2800-2022 and AR-PST Pillars 1, 2, and 4, to coordinate the standards development processes of IEC and IEEE, and develop a jointly coordinated process for the joint dual logo GFM standard. Identify discrepancies between the two processes and potential issues that will need to be resolved to harmonise the two different approaches and develop a harmonised schedule. This task will be undertaken by way of appropriate engagement with relevant personnel, direct attendance at relevant scheduled conferences	Participate in remote virtual meetings and face-to-face meetings for the development of technical content of GFM Converter standards.

	and meetings, and through remote participation where travel is not possible. In this phase more detailed examination is to be undertaken of the technical aspects that characterise the performance of GFM Converters as against Grid Following Inverters. This will include an examination of how these aspects are defined by the various organisations and researchers in the field, what overlaps, gaps and inconsistencies may exist whether any alignment is evolving. The key objective is to achieve alignment for each of the particular features that are required. In particular, with the publication of UNIFI Specifications for Grid-forming Inverter-based Resources Version 3, effort will be made to get alignment with that document.	Formulate and then participate in technical expert meeting jointly between IEC and IEEE Q2 20256
3	Continue to serve as a liaison among G-PST, IEC, IEEE and AEMO. Coordinate exchange of information from IEC and IEEE to AEMO through presentation of IEC GFM standard development projects and activities at AEMO and related conferences and meetings.	Ongoing activity.

4. Progress against the Roadmap

The actual and anticipated progress against the Roadmap is shown in the following table.

Activity	Year 1 2024-25	Year 2 2025-26	Year 3 2026-27	Year 4 2027-28
Development of Strategy for Joint Project IEC IEEE	80%	20%		
Conversion of Proposed Work Item to a New Work Item Proposal IEC	10%	90%		
Define cooperation arrangement IEC/IEEE	30%	70%		

Activity	Year 1 2024-25	Year 2 2025-26	Year 3 2026-27	Year 4 2027-28
Development of Working Draft for IEC and IEEE	20%	50%	30%	
Process Committee Draft through approval stages within IEC		10%	60%	30%
Review and process with IEC and IEEE through Committee draft stages		10%	60%	30%

5. Research relevance to Australia

As set out **in** AEMO's "Voluntary Specification for Grid-forming Inverters" May 2023, with increasing penetration of converter-based resources (CBR) and retirement of synchronous generators in power grids worldwide, new operational challenges with respect to system strength, voltage and frequency control, synchronous inertia, power system protection, and other phenomena will need to be considered by power system operators. Grid-forming (GFM) connverters have the potential capability to address some of the operational challenges associated with high levels of CBR penetration.

Internationally, there is a critical gap in grid forming standards, codes and requirements that address the complex grid and equipment stability problems. Only one or two advanced system operators (one of which is AEMO) have taken measures to define grid forming requirements today with a couple more in the process of developing them. These early efforts of development and replication from one country to another have been supported by the learnings shared between system operators in ISON. There is an urgent need to more universally define a baseline of grid forming requirements that may be used in all systems around the world when they are needed.

As set out in Section 1, very high shares of CBRs without synchronous generation or grid-forming technology pose critical threats to power system reliability. This is evident in the form of grid and CBR equipment instabilities, unwanted grid oscillations, poor power quality and even local and region-wide blackouts. A deliberate framework of demonstrations, requirements and incentives to be deployed quickly is required so the energy transition can continue to accelerate and power system operators can manage to the increasingly aggressive global commitments required to address climate change.

Given the high percentage of renewable energy growth at the distribution level, it is projected that GFM converters will form an important function in the future grid. As set out in AEMO 's Public Consultation Report Technical Requirements for 200 kW to 5 MW DER connections September 2024,Section 2.3.4 System strength services states that *"in future, a portion of DER connections are likely to include GFM capabilities. In the short term this is*

most likely to be Battery Energy Storage Systems (BESS) in larger size projects. Some developers have expressed interest in GFM inverters in the sub-5 MW range of equipment. Some DNSPs are also exploring the possibilities for GFM technologies to support the local grid in abnormal power system conditions, including islanding of part of a distribution system."

Accordingly, the development of a dual logo IEC/IEEE GFM Converter standards will be invaluable for Australia and assist in ensuring international alignment of various OEM (Original Equipment Manufacturer) products and facilitate interoperability of multiple converters supplied by various OEMs.

6. Recommended research priorities

The whole area of GFM converters that may operate stably for connection to the power grid and that allow for interoperable operation of multiple vendors to the grid is still evolving at the research level.

Although there is general consensus on a definition of GFM, consensus has yet to be reached regarding how to qualify a newly connecting resource as GFM and how to test for GFM capability. GFM can be specified in a number of ways such as defining control topology, specifying quantitative response metrics, using frequency domain characterization, or using a set of test procedures. Research activity within Australia under the AR-PST program is expected to inform the development of the standard.

Although the ultimate objective is to qualify an overall plant for connection to the grid as a GFM converter, it is recognised that to define the performance of the plant it must first define the performance of individual units of plant, in order that on integration of all of the units, the overall performance of the plant can be achieved.

The functional performance verification tests determine whether an interconnecting plant can be classified as GFM. To date most of the performance requirements are being defined with respect to BESS. However, requirements also need to be developed for GFM solar and wind resources as those technologies evolve. These tests can be integrated as part of the interconnection study process to establish GFM requirements for newly interconnecting BESS.

As this whole area is evolving, criteria are being developed on the basis of not being overly prescriptive. They are intentionally being developed to be simple to implement and agnostic to GFM control topologies.

Glossary

Term	Definition
AEMO	Australian Energy Market Operator
Amprion	Transmission system operator active in Germany and Europe
AR-PST	Australian Research in Power Systems Transition
BESS	Battery Energy Storage System
CENELEC	European Committee for Electrotechnical Standardisation (*Comité Européen de Normalisation Électrotechnique)*
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DER	Distributed Energy Resources
DNSP	Distribution Network Service Provider
ENTSO-E	European Network of Transmission System Operators for Electricity
ERCOT	Electric Reliability Council of Texas
Fingrid	Finland's transmission system operator
GFM	Grid-forming
G-PST	Global Power System Transformation Consortium
IEC	International Electrotechnical Commission
IEC SC 8A	Grid Integration of Renewable Energy Generation. A subcommittee of the International Electrotechnical Commission.
IEC TC8	IEC Technical Committee 8 System aspects of electrical energy supply
IEEE	Institute of Electrical and Electronics Engineers
IEEE 2800	Standard for Interconnection and Interoperability of Inverter/Converter-Based Resources (IBRs/CBRs) Interconnecting with Transmission Electric Power Systems
IEEE 2800-2022	IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems
ISON	International System Operator Network
NERC	North American Electric Reliability Corporation
NGESO	National Grid Electricity System Operator (UK)
OEM	Original Equipment Manufacturer
SG	Synchronous generator
UNIFI	The UNIFI (Universal Interoperability for Grid-Forming Inverters) consortium is a U.S. Department of Energy Solar Energy Technologies Office funded effort to advance grid-forming inverter technology, led by the National Laboratory of the Rockies (NLR).
VDE	Association for Electrical, Electronic & Information Technologies