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Topic 1 – Inverter Design - Development of capabilities, services, design methodologies and standards for Inverter-Based Resources (IBRs)

2024/25 1a) Grid Forming Standard Development

Commonwealth Scientific and Industrial Research Organisation

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1. Introduction

The CSIRO is working in partnership with the Global Power System Transformation Consortium (G-PST) and the Australian Energy Market Operator (AEMO) on a comprehensive “Research Roadmap” that identifies and explores 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 from G-PST.

The Stage 4 Topic 1a Grid Forming Standard Development is a new project that was initiated this year. The objective of this project is to complement the technical research that is being undertaken in this field by 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. The intention is to provide leadership and coordination on the joint standards development effort with the major players in this space. This includes, but is not limited to the IEC, IEEE, GPST Pillar 4, GPST Secretariate, 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.

Stage 3 Topic 1 Final Report of the Australian Research Planning for Global Power System Transformation (Stage 3) project Australia is in a rapid transition towards an inverter-dominated structure as the majority of synchronous generators are displaced by inverter-based resources (IBRs) over the next two decades. Renewable energy plants, such as wind and solar farms, are typically located in regions where wind and solar resources are abundant, yet usually distant to synchronous generators (SGs) and loads. These resources, interfaced by power electronic inverters, may face stability challenges in weak areas of the grid. To address this, grid-forming inverters are deployed in these regions to enhance the stability of the local network. As a consequence, the transmission of generated power from these remote energy plants to centralised urban areas necessitates the use of various network topologies, including radial and meshed configurations in transmission networks.

Currently a great deal of research and development is being undertaken in multiple areas internationally to both properly understand the technical issues that are being faced to ensure stable and proper operation of such systems and with a view to development of a consistent international standard that can be developed to define the requirements of such Grid Forming Inverters. ENTSOE (European Network of Transmission System Operators); UNIFI Consortium (a consortium co-let by the National Renewable Energy Laboratory, the University of Texas-Austin and EPRI); NERC (North American Electric Reliability Council), for instance are all undertaking research activity to try to facilitate the development of specifications addressing grid forming functionality.

Within the IEC a number of committees are actively involved including IEC TC8 “ System aspects of electrical energy supply” and its subcommittees, in particular IEC SC8A “Grid Integration of Renewable Energy Generation”, IEC TC 82 “Solar photovoltaic energy systems”, IEC TC88 “Wind energy generation systems” and IEC TC 120 “Electrical Energy Storage (EES) systems”. A range of documents have been produced dealing with aspects of operation of inverter based resources.

Within the IEEE, IEEE 2800-2022 IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems has been published.

This part of the project is to drive the coordination and development of a dual logo IEC/IEEE standard (or series of standards) over a period of time defining the requirements of a Grid Forming Converter. The intention is to draw on the resources of the various organisations referred to above to develop a road map to progress to an international standard. This will provide a solid foundation for the adoption of an appropriate Australian Standard which is consistent with international practice.

The project is structured to provide leadership and coordination in the development of Dual Logo Standards with the IEC and IEEE defining the requirements and capabilities of GFM Technology.

Very high shares of Inverter Based Resources (IBRs) without grid-forming technology pose critical threats to power system reliability. This is evident in the form of grid and IBR 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

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 with the AEMO Voluntary Specification for Grid-forming Inverters May 2023) 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 G-PST. 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.

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 on "Technical Requirements for 200 kW to 5 MW connections", Sep 2024 it states in the section on System Strength, that n future, a portion of DER connections are likely to include GFM capabilities. In the short term this is most likely to be 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."

The Grid Forming Technology Implementation Council (GFMIC) is taking a global approach to development and dissemination of grid forming requirements. Institutional standards drafted by industry through IEEE and IEC are trusted sources of equipment and system design and industry practice. IEEE generally covers 60Hz systems (mostly North American focus) and IEC covers 50Hz systems (rest of the world).

For the first time, the GPST Pillar 4 covering standardization and technology adoption and the GFMIC are leading an effort to develop a joint standard across IEEE and IEC, based on a recently developed IBR standard specifying minimum capabilities in IEEE. The GFMIC will then develop recommended grid forming requirements that will be added to this joint standard. This joint standard may then be referenced globally to develop minimum capability requirements in grid codes and interconnection requirements worldwide. The GFMIC has developed a plan to disseminate the GFM standard recommendations that it develops through a comprehensive global standardization campaign, implemented country-by-country. This is a first-of-a-kind effort that will accelerate the adoption and deployment of grid forming technology at speed and scale around the world.

2. Research completed

This activity is a multi-year project to develop a joint dual logo standard between the IEC and the IEEE. This is a process which has taken as long as 6-10 years in the past under a business as-usual scenario. Because of the urgency of the need to rapidly deploy massive amounts of renewable energy globally to achieve carbon neutrality globally by 2050, the time to achieve this must be cut in half. The tasks undertaken to date and to be undertaken in the future as referenced in Section 3 below assume a schedule of three years in an optimistic scenario, but could be as much as five years in a less optimistic scenario.

Task	Activity	Progress
1	Work with leaders of the IEC TC 8 and SC 8A, IEEE 2800-2022 and GPST Pillars 1, 2, and 4, to identify the process and schedule for standards development within IEEE and IEC regarding development of a joint, dual logo GFM standard.	Organisational structure options have been examined and agreed in principle. IEC awaiting formal process from IEEE.

2	Examine previous successful efforts for joint dual logo standards and identify lessons learned which are applicable to the current situation with a GFM standard.	Report prepared "Development of an IEC / IEEE Dual Logo Standards on GFM Converters". Initial phase completed. Implementation phase yet to commence.
3	Work with leaders of the IEC TC 8 and SC 8A, IEEE 2800-2022 and GPST 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 harmonize the two different approaches and develop a harmonized schedule. This task will be undertaken by way of appropriate engagement with relevant personnel, direct attendance at relevant scheduled conferences and meetings, and through remote participation where travel is not possible.	Process initiated and under way. Attended ,meetings of IEC TC8, SC Plenaries in Paris, September 2024.
4	Serve as a liaison among GPST, 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. Given the leading role that Australia is playing in addressing issues related to stable operation of high penetration renewable energy ensure that AEMO's contribution setting out their requirements are considered in the process of international standards development. Identify mechanisms to deploy recommendations from a joint dual branded GFM standard into Australian technical regulatory codes and standards.	Process underway. Attended All Energy Australia Conference and Exhibition in Melbourne.. Presentations made to CSIRO research team, GPST Webinar AEMO documents reviewed

3. Outstanding activities

Task	Anticipated Activity	Key Items
1	Continue to work with leaders of the IEC TC 8 and SC 8A, IEEE 2800-2022 and GPST 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	Using the detail provided in the report by "Development of an IEC / IEEE Dual Logo Standards on GFM Converters".as a guide, ensure that processes that are put in place avoid the pitfalls that could affect successful efforts for joint dual logo standards.	No specific action but matters in the report need to be taken into account in addressing Tasks 1, 3 and 4

3	Work with leaders of the IEC TC 8 and SC 8A, IEEE 2800-2022 and GPST 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 harmonize the two different approaches and develop a harmonized schedule. This task will be undertaken by way of appropriate engagement with relevant personnel, direct attendance at relevant scheduled conferences 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.	Attend IEC AhG3 and JWG5 meeting being held in Kassel Germany 4-6 March 2025 to coordinate and formulate anticipated structure and start development of technical content of GFM Converter standards. Formulate and then participate in technical expert meeting jointly between IEC and IEEE Q2 2025.
4	Continue to serve as a liaison among GPST, 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 development of standards related to GFM converters is a practical outcome that can evolve from all of the research effort that is being undertaken

Topic 1a is a new addition to the Roadmap for Stage 4 and is thus at the start of the anticipated development, optimistically over the next 3 years.

5. Research relevance to Australia

As set out in AEMO's "Voluntary Specification for Grid-forming Inverters" May 2023, with increasing penetration of inverter-based resources (IBR) and retirement of synchronous generators (SG) 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) inverters have the potential capability to address some of the operational challenges associated with high levels of IBR 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 with the AEMO Voluntary Specification for Grid-forming Inverters May 2023) 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 G-PST. 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 Inverter Based Resources (IBRs) without grid-forming technology pose critical threats to power system reliability. This is evident in the form of grid and IBR 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 on “Technical Requirements for 200 kW to 5 MW connections”, Sep 2024 it states in the section on System Strength, that n future, a portion of DER connections are likely to include GFM capabilities. In the short term this is most likely to be 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 products and facilitate interoperability of multiple converters supplied by various OEMs.

6. Recommendation research priorities

Given the long term nature of the development of Dual Logo GFM Converter standards, it is anticipated that the level of activity and need for direct involvement to facilitate the necessary development in a coordinated way will increase.

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