WHITE PAPER

Energising Ireland: A Guide to Grid Code Compliance for Renewables

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1. Introduction

In electrical power systems, codes are defined as a comprehensive set of technical regulations governing the planning, operation and management of the networks and can be categorised into three distinct types:

- ***Network codes:*** *developed and enforced at the regional or continental level*
- ***Grid codes:*** *specific to a particular electrical grid, typically at the national level for high-voltage networks operated by transmission system operators*
- ***Distribution codes:*** *govern the operation of low-voltage and medium-voltage electricity distribution networks*

These codes serve as a foundational framework for electricity generation, transmission, and distribution systems, outlining the requirements that must be met to ensure the safe, reliable, and efficient functioning of the grid. They encompass a wide range of specifications, connection and operational procedures, and compliance mechanisms, all aimed at facilitating the integration of diverse energy sources and technologies while maintaining network reliability and security.

Compliance with the codes is essential because it ensures the secure and reliable operation of the electrical grid, minimising the risk of disruptions, blackouts, and other adverse events. It involves meeting and maintaining the prescribed standards as stipulated in the codes. By enforcing compliance, network operators and regulatory authorities can safeguard the stability of the power system, enable efficient electricity transmission and distribution, and promote the integration of renewable energy sources and advanced technologies.

As countries strive for cleaner and more sustainable energy systems with ambitious net-zero goals, the role of wind farms, solar PV installations, and battery energy storage connections is pivotal. Consequently, integrating an ever-increasing number of such units into electrical networks is a reality. These units, characterised by their connection to the grid—either non-synchronously or through power electronics—fall under the categorisation of Power Park Modules (PPMs) in ENTSO-E's Network Code [1].

Given that grid codes primarily serve the transmission level and impose the most stringent requirements, compliance with grid codes are of utmost importance for fostering an electrical grid infrastructure that is resilient, flexible, and sustainable, capable of meeting evolving energy demands while upholding the highest standards of safety and reliability.

Therefore, in this document, the focus will be on delving into the Grid Code compliance procedure, specifically tailored to address Power Park Module (PPM) connections within the Irish transmission network under the purview of EirGrid.

2. The Electricity Landscape in Ireland

Before exploring the technical requirements in detail, it's beneficial to provide a concise overview of the electricity landscape in Ireland, often referred to as the Emerald Isle.

Notably, Ireland is an EU (European Union) member. However, post-Brexit, Northern Ireland, located within the UK, is no longer a member of the EU.

EirGrid is a state-owned company that functions as the licensed Electricity Transmission System Operator (TSO) for Ireland. Furthermore, SONI (System Operator for Northern Ireland) serves as the TSO for Northern Ireland and has been an integral part of the EirGrid Group since 2009.

ESB Networks (Electricity Supply Board) is a semi-state company holding the license for the Distribution System Operator (DSO) in Ireland. Meanwhile, NIE Networks (Northern Ireland Electricity) serves as the DSO for Northern Ireland and has been part of the ESB Group since 2010. Figure 1 visually represents the system operators and their respective service areas.

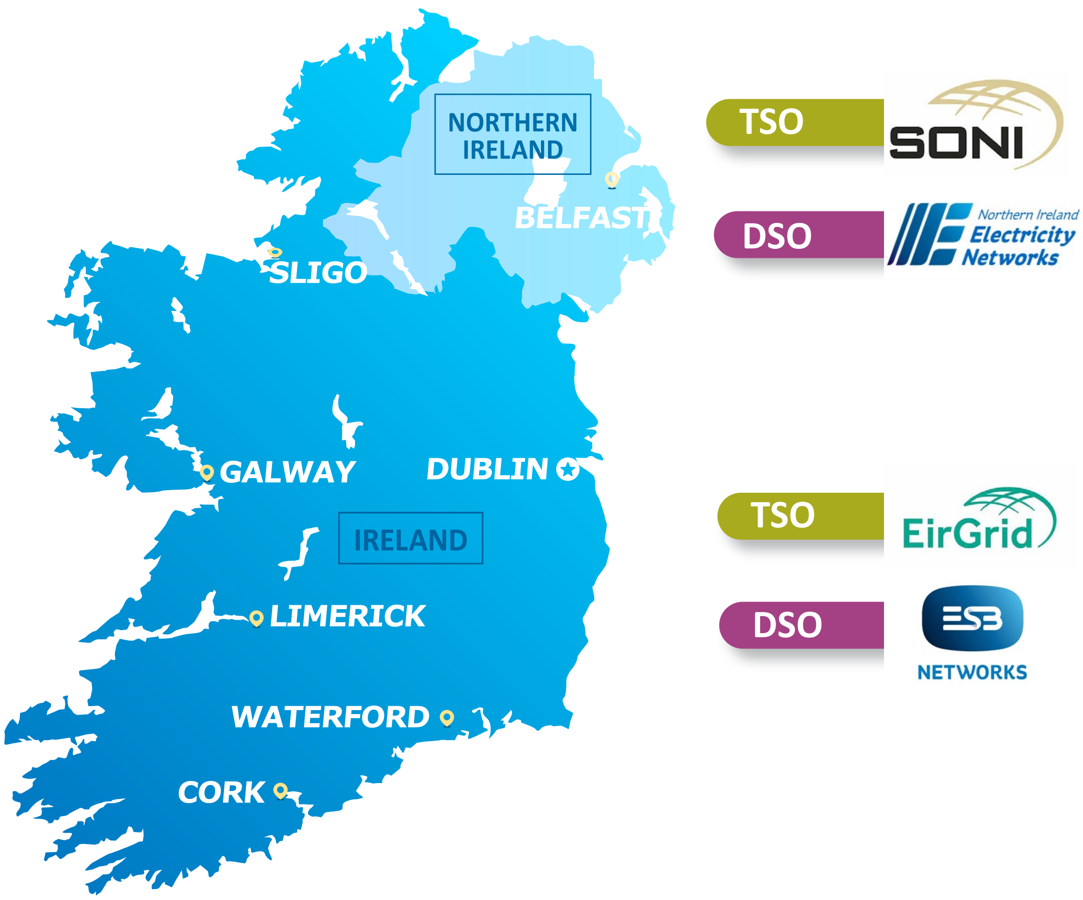

Figure 1
Electricity System Operators in Ireland

Table 1 provides details on the current generation levels and 2030 targets for each type of energy source in Ireland. Given the focus of this document on the Grid Code Compliance Process at EirGrid, only generation capacities for Ireland are presented. Therefore, data for Northern Ireland is not included. These targets are defined to achieve the Res-E (Renewable energy share in electricity) goal of attaining 80% from renewables by 2030. Additionally, the targets aim to accomplish a 75% reduction in greenhouse gas emissions from the electricity sector by 2030, compared to 2018 levels.

The present generation capacities are extracted from the 'System and Renewable Data Summary Report' on the EirGrid website [2], indicating capacity levels in September/October 2023.

The 2030 targets are derived from the report published by EirGrid following the consultation works of the Shaping Our Electricity Future Roadmap project [3]. These activities included workshops, meetings, road shows, webinars, surveys, and engagements with both industrial and public stakeholders.

Source Type	Current Capacities		2030 targets	
	MW	%	MW	%
Onshore Wind	4,713.1	37.7%	9,000	26.5%
Offshore Wind	0	0%	7,000 (incl. 2000 MW assigned to hydrogen production)	20.6%
Solar PV	436.2	3.5%	8,000 (incl. micro-generation)	23.5%
Battery Energy Storage	548.9	4.4%	3,225	9.5%
Hydro Generation & Pumped Hydro Energy Storage	526.8	4.2%	830	2.4%
Non-RES (Gas, Distillate Oil, Bio, CHP, Waste and others)	6,272.6	50.2%	5,950	17.5%
TOTAL	**12,497.6**	**100%**	**34,005**	**100%**

Table 1
*Present capacities & 2030 targets in Ireland**

* These figures are only for the EirGrid service area, which is Ireland. Data from Northern Ireland is not included.

The current capacities and 2030 targets are also illustrated in Figure 2 and Figure 3. The ambitious goals, such as almost doubling onshore wind capacity from 4,713.1 MW to 9,000 MW, establishing offshore wind capacity from zero to 7,000 MW, and expanding solar PV from 436.2 MW to 8,000 MW, are noteworthy. Figure 2 offers further insight by visually portraying targets that aim for a more balanced distribution in the installed capacity levels of resources, considering the existing shares.

As it can also be seen in Figure 3, in 2030, the goal is to establish wind as the most significant energy source, comprising 26.5% onshore and 20.6% offshore, amounting to a total share of 47.1%. Solar PV is targeted to contribute 23.5% to the overall installed capacity. To improve flexibility in the network, the target for battery energy storage capacity is nearly six times higher, increasing from 548.9 MW to 3,225 MW, capturing a 9.5% share in the 2030 capacities.

For Hydro Generation and Pumped Hydro Energy Storage plants, the aim is to increase the current capacity slightly beyond half of the current capacity, rising from 526.8 MW to 830 MW. However, due to the overall increase in total capacity, its share appears to decrease from 4.2% to 2.4% in 2030.

Finally, in the rightmost bar of Figure 3, the intended result of all the efforts becomes apparent. The primary objective is to reduce the share of the installed capacity of Non-RES (Non-renewable energy sources) from 50.2% to just 17.5% of the total connected capacity.

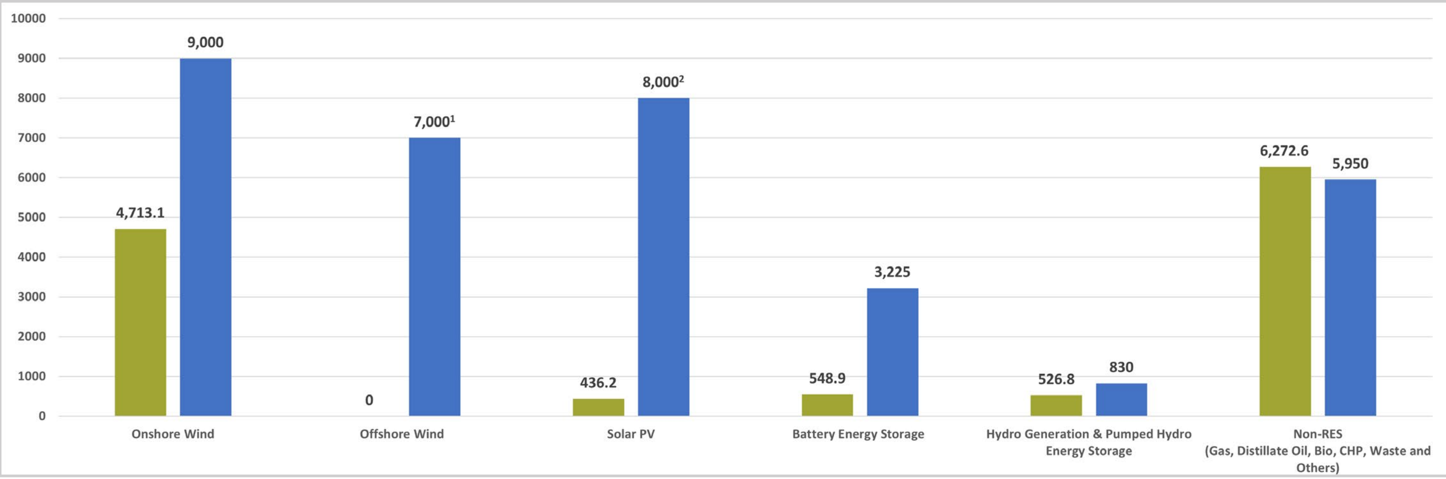

Figure 2
Current generation capacities & 2030 targets in Ireland

* These figures are only for the EirGrid service area, which is Ireland. Data from Northern Ireland is not included.

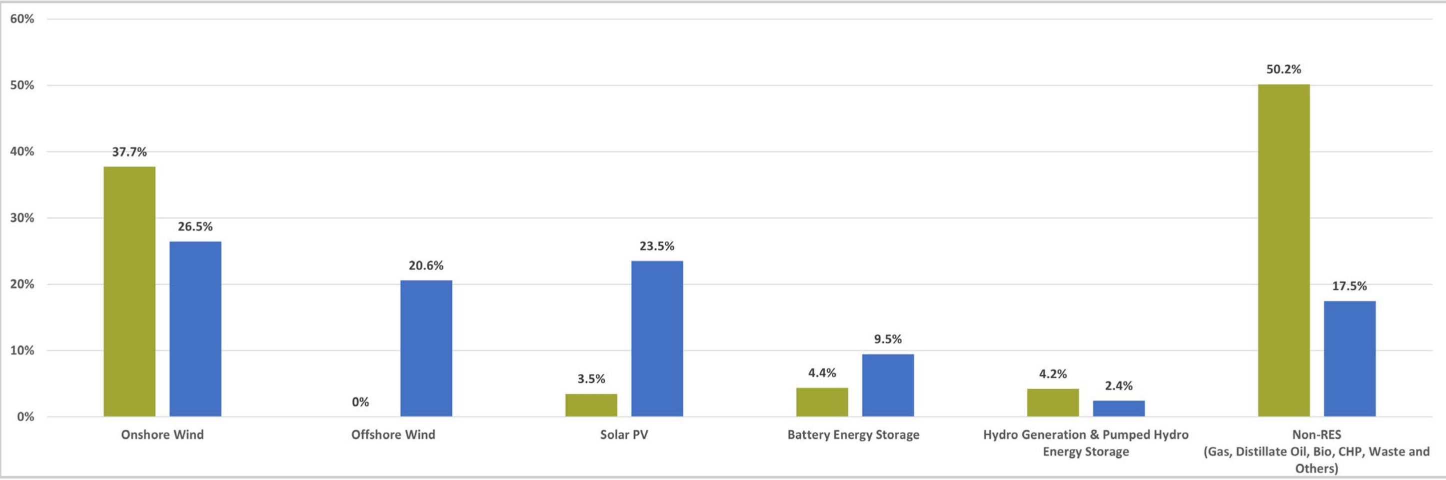

Figure 3
% Distribution in current generation capacities & 2030 targets in Ireland

* These figures are only for the EirGrid service area, which is Ireland. Data from Northern Ireland is not included.

3. Grid Code Compliance

To establish a connection to the network and achieve operational status, it's essential to satisfy Grid Code requirements. Compliance testing is the process to demonstrate that the new facility follows the requirements laid out in the grid code as closely as possible. These requirements come in different forms:

- Documentation submission
- Declarations of fitness for equipment
- Technical studies and simulations
- Physical tests

In accordance with current EirGrid Grid Code, the grid code compliance process includes an operational notification procedure that progresses through sequential steps, as depicted in Figure 4, and the successful completion of each step holds specific significance such as:

- Energisation Operational Notification (EON): Generators are ready to be energised
- Interim Operational Notification (ION): Generators can temporarily operate using the grid connection
- Final Operational Notification (FON): Generators can now become fully operational
- System Services: Optional, test data will be gathered from FON checklist

Notably, the issuance of the Final Operational Certificate upon successful completion of FON by EirGrid marks a crucial milestone for the connection, signifying the successful fulfilment of Grid Code requirements.

The operational notification procedures from the ENTSO-E Network Code 2016/631 [1], which include EON, ION, and FON, were integrated into EirGrid's Grid Code during its update from version 8 to version 9 in 2020.

Consequently, operational notification naming conventions have been employed in place of the previous Phase A, B, C, and D conventions. Both terminologies have been shown in Figure 4 to provide historical context.

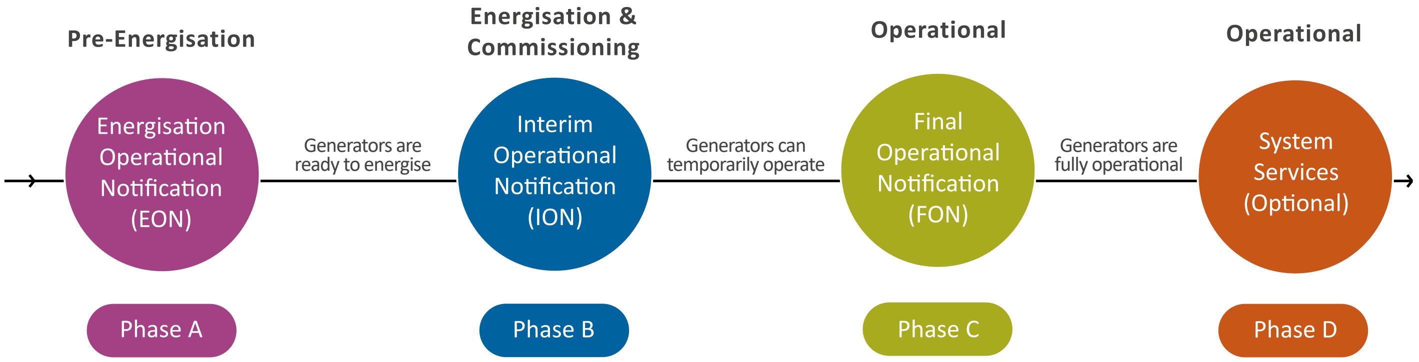

Figure 4
Grid Code Compliance Testing Processes

EON checklist represents the pre-energisation stage, involving various critical tasks that must be completed before the new connection's initial energisation. These tasks include conducting technical studies based on data provided by EirGrid, preparing signal lists, configuring protection settings, compiling data sheets, and submitting the type test reports for the necessary equipment.

ION checklist, the Energisation & Commissioning stage, involves the first power export from the new connection. During this process, EirGrid verifies signals and controls, conducts a plant survey, and performs active and reactive power dispatch testing.

FON checklist, the Operational stage, is the last process to obtain the Final Operational Certificate. It involves on-site Grid Code compliance testing and harmonics assessment conducted by EirGrid.

System Services is an optional stage covering testing for various System Services that EirGrid compensates at regulated rates for eligible connection technologies on a contractual basis. These services include Synchronous Inertial Response (SIR), Steady State Reactive Power (SSRP), and various types of Reserve and Ramping services.

4. Schedule of Tests

At the time of writing, a spreadsheet named the 'Schedule of Tests', accessible on the EirGrid website [4], presents a comprehensive list of all the tests the new connection must successfully complete to obtain an Operational Certificate FON. Note that these tests are called EON, ION and FON checklists as per Grid Code. It also includes submission timelines corresponding to each of these test requirements.

This section explores the prominent requirements for each operational notification procedure along with the submission timeline.

4.1 EON: Pre-Energisation

This process begins 18 months before the first energisation of the facility, during which EirGrid provides the new facility with the following data to be considered at the connection point:

- Minimum system strength data
- Transmission system impedance loci
- Power quality limits such as harmonics, rapid voltage changes, and flicker

Using the data provided by the system operator, the customer is required to conduct and submit the following technical studies within a six-month timeframe, subject to review and acceptance by EirGrid:

- Power quality report covering voltage harmonics and voltage fluctuations including rapid voltage changes and flicker [5]
- Fault ride-through (FRT) report [6]
- Dynamic simulation model of the facility

Details regarding simulation studies can be accessed on the EirGrid website [7]. Additionally, the customer needs to provide the following information regarding the new facility:

- Reactive power capability data with model reference (i.e., simulation report) if the data is based on modelled results
- Tap changer settings
- ROCOF capability
- Signal list
- Western Electricity Coordinating Council (WECC) model parameters
- Datasheets and type test reports of required equipment

Following these submissions, EirGrid carries out the following actions:

- Verifies and confirms the signals, controller, and protection settings
- Issues Operation and Energisation Instruction Documents

After successfully completing all submissions, EirGrid issues the Energisation Operational Notification (EON) to the new facility, authorising it to proceed with energisation.

Figure 5 illustrates the key test requirements and associated timeframes during EON.

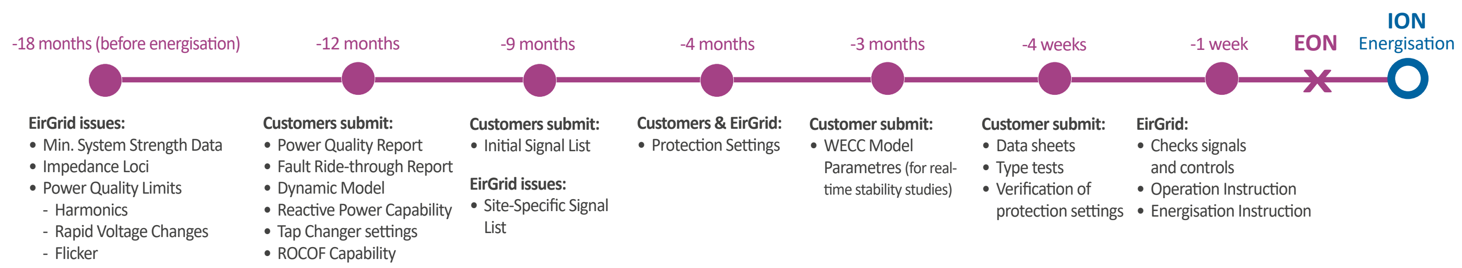

Figure 5
Test Schedule of EON

4.2 ION: Energisation & Commissioning

After successfully completing EON checklist, the new facility can proceed with energisation. With the issuance of the Interim Operational Notification (ION) by EirGrid, the facility can temporarily operate using the grid connection. During this limited period, dispatch tests are conducted to verify compliance with the system operator's controllability requirements.

After the first export using the grid connection and within six weeks after installing the last module in the facility, EirGrid conducts a plant survey and carries out active and reactive power dispatch testing. These tests serve the purpose of issuing an Operational Readiness Confirmation (ORC).

Achieving ORC indicates that the facility complies with the controllability requirements and is promoted from Category 3 (Commissioning Units) to Category 2 (Controllable Units). Conversely, failing to obtain ORC status or meet the controllability requirements results in a downgrade from Category 3 to Category 1 (Uncontrollable Status).

Figure 6 depicts the testing procedures conducted during ION.

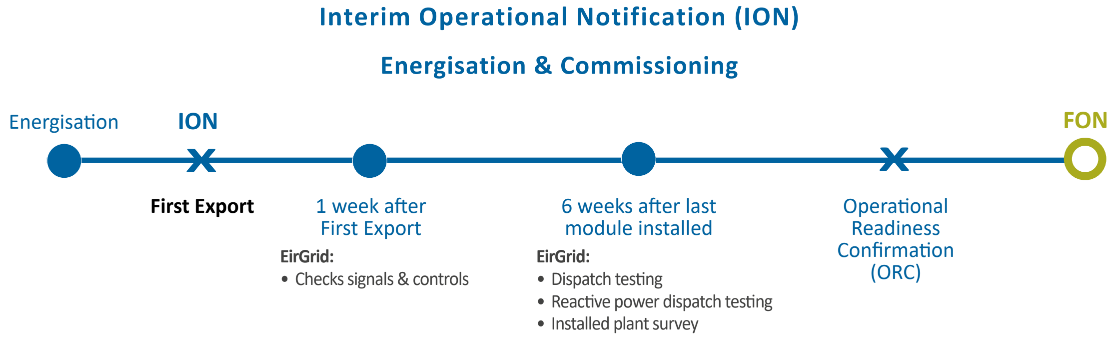

Figure 6
Test Schedule of ION

4.3 FON: Operational

After the completion of ION, the EirGrid National Control Centre coordinates on-site testing with the new facility, to be conducted within 12 months of the facility's energisation, with additional time allowed for sites > 50 MW. These tests assess the facility's ability to respond to changes in setpoints and conditions at the connection point. This evaluation encompasses active power, reactive power, voltage, frequency, and power factor. These tests include:

- Active power control
- Frequency response
- Reactive power control
- Reactive power capability
- Black start shutdown

After the on-site tests are completed, customers need to submit the corresponding test reports for review and acceptance by EirGrid. Following this, customers must provide a validation report, incorporating simulation studies that compare the WECC model parameters submitted during EON with the actual results obtained from the chosen on-site tests. This validation report must be submitted within six weeks of concluding the on-site tests, including the acceptance of the test reports by EirGrid. Further information regarding the submission of the WECC model parameters can be found in [8].

In FON, EirGrid also conducts an on-site harmonics analysis by taking measurements at the connection point to verify that harmonic emissions are within the specified limits.

Upon the successful completion of all the tests, EirGrid issues the Operational Certificate to the customer, confirming that the new facility has demonstrated compliance with all Grid Code requirements.

Figure 7 outlines the schedule for FON.

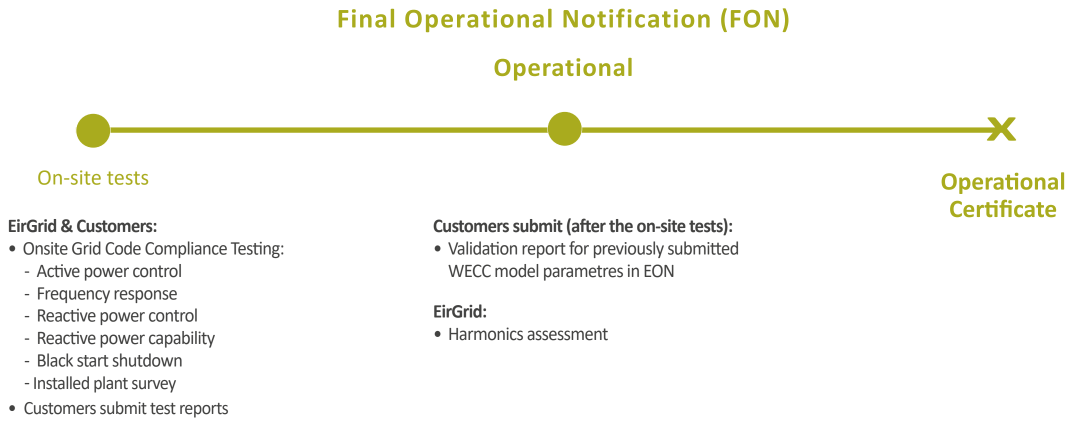

Figure 7
Test Schedule of FON

4.4 System Services

This process is optional for facilities that wish to participate in System Services. Much of the data needed would be gathered through the standard Grid Code compliance tests. To secure a contract for providing System Services, connecting units must demonstrate their capabilities through compliance and testing processes before contracting.

EirGrid provides compensation to eligible connection technologies through regulated rate contractual agreements. There are a number of services available for different connection technologies such as Synchronous Inertial Response (SIR), Steady State Reactive Power (SSRP), Reserve and Ramping Services.

Wind and solar PV connections have access to Reserve and SSRP services, while battery energy storage facilities also have access to Ramping services in addition to Reserve and SSRP.

SSRP is the dispatchable reactive power range that can be provided across the full range of the facility's active power output.

Reserve and Ramping services involve either providing extra active power output or reducing demand when the frequency breaches a specified level. Ramping services are based on dispatch instruction. The key distinction lies in the speed of response and the duration for which these services must remain fully available and sustainable, ranging from ten (10) seconds to eight (8) hours following an event.

Reserve services:

- Fast Frequency Response (FFR)
- Primary Operating Reserve (POR)
- Secondary Operating Reserve (SOR)
- Tertiary Operating Reserve Band 1 (TOR 1)
- Tertiary Operating Reserve Band 2 (TOR 2)

Ramping services:

- Tertiary Operating Reserve Band 2 (TOR 2)
- Replacement Reserve Desynchronised/Replacement Reserve Synchronise (RRD/RRS)
- Ramping Margin 1 (RM1)
- Ramping Margin 3 (RM3)
- Ramping Margin 8 (RM8)

Detailed information about System Services can be found on EirGrid website [9].

5. Conclusion

The Grid Code Compliance Testing procedures provide a systematic and structured framework for ensuring the reliable and secure integration of new connections into Ireland's grid. Each process, from the initial submissions in EON to the comprehensive on-site testing in FON, serves a crucial role in verifying the compliance of new facilities with grid code requirements. The diligent and coordinated efforts of both customers and system operator are instrumental in achieving successful compliance and obtaining the final Operational Certificate. These procedures not only safeguard the integrity of the power system but also foster a more stable and efficient grid, supporting the growth of renewable energy sources and ensuring the continued provision of high-quality electricity services.

As we move forward in an era of increasing renewable energy integration and a growing emphasis on grid resilience, the significance of Grid Code Compliance Testing procedures cannot be overstated. They are the linchpin for harmonious grid operations, facilitating diverse energy sources and technologies. With continuous advancements and adaptations in response to changing energy landscapes, these procedures will remain a cornerstone of grid management, guiding the path toward a sustainable and reliable energy future. In embracing these testing protocols and their underlying principles, we pave the way for a more robust, efficient, and environmentally friendly power grid that can meet the challenges and opportunities of tomorrow's energy landscape.

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7. Acknowledgements

The author would like to acknowledge the following colleagues for their invaluable feedback and diligent review, which enhanced the quality and clarity of this content.

- Zia Emin
- Kevin Smethurst
- Gayle Wooster

8. Disclaimer

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Kahraman is a Senior Power Systems Consultant with over 14 years of experience in the field of power networks. His expertise spans from power system modelling and analysis to the grid code compliance testing. He holds a Ph.D. in Electrical Engineering, and has work experience with system operator, inverter manufacturer and engineering consulting firms.

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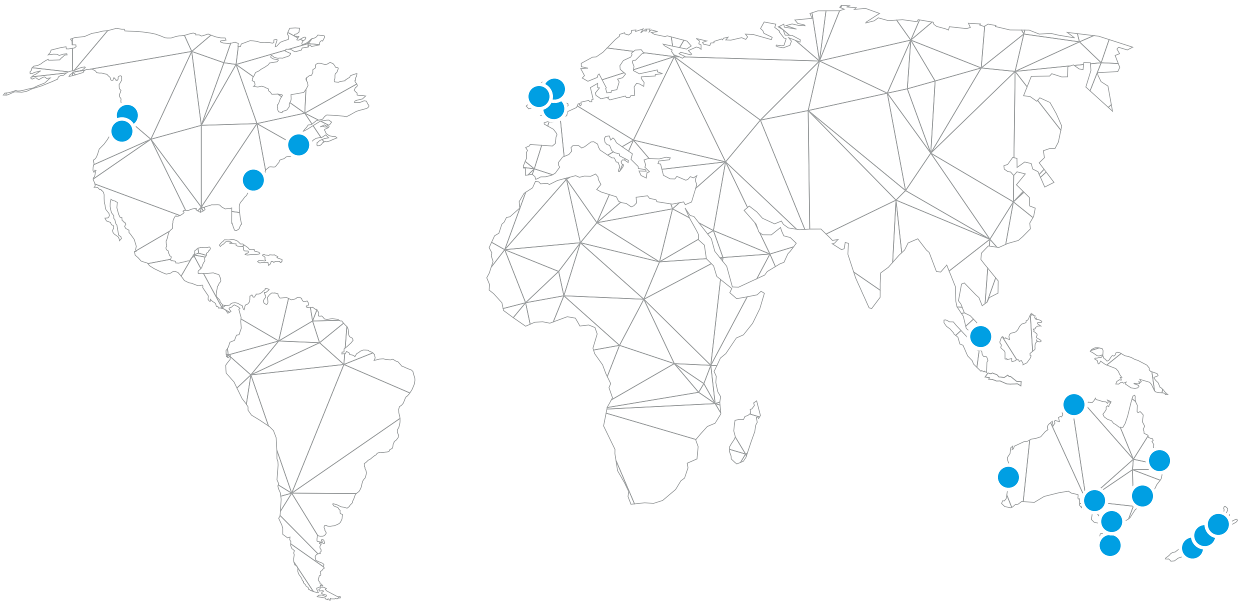

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