Technical Connection Requirements and Compliance Assessment in Hybrid Power Systems

Dipl.-Ing. Theofilos Xanthos M.Sc.
Grid Integration of Generating Plants
FGH GmbH
Mannheim, Germany
Theofilos.Xanthos@fgh-ma.de

Dipl.-Wirt.-Ing. Frederik Kalverkamp
Grid Integration of Generating Plants
FGH GmbH
Mannheim, Germany
Frederik.Kalverkamp@fgh-ma.de

Dipl.-Wirt.-Ing. Christian Scheefer
Power Generating Plants
FGH Zertifizierungsgesellschaft mbH
Aachen, Germany
Christian.Scheefer@fgh-zertifizierung.de

Dipl.-Phys. Bernhard Schowe-von der Brelie
Executive Manager
FGH GmbH
Mannheim, Germany
Bernhard.Schowe@fgh-ma.de

***Abstract*— The increase of distributed generation in the energy mix of modern energy systems as well as the rapid progress in the technical characteristics and functionalities of most generating units and their components call for a standardized approach regarding the technical requirements for their design and installation. Both on utility level as well as unionwide within Europe, there is a lot of ongoing research in order to establish and further pursue the maturity of texts (grid codes) defining the characteristics of newly connected generation, storage and loads, in order to ensure a secure and economical operation of the grid, as well as of processes to ensure compliant planning and operation of those facilities. This paper presents the latest developments on the European level regarding the topics of grid code requirements and compliance assessment for hybrid interconnected systems and tries to present similarities for non-interconnected systems.**

Keywords: grid codes; compliance assessment; storage systems

I. Introduction

Hybrid power systems are defined as electrical power systems containing conventional and renewable energy systems (RES), storage units and consumer loads. Within such systems, it is crucial that newly installed generation and storage systems equally contribute in maintaining system stability and operational limits. The harmonization of such rules is within the scope of the latest framework developments on the European level, with the target to provide a unified legal and market basis for all participants as well as to promote system security and RES integration. This paper presents the current trends in the field of European level requirements for newly installed generation and storage units in the interconnected power systems, gives a brief overview of the existing framework on the topic of compliance assessment and indicates simple analogies that can be drawn for non-interconnected systems.

II. Technical Requirements on Power Generation

A. European status quo

The electrical requirements for newly installed generator units is a heated topic on European level. Following the introduction of the 2016/631 Commission Regulation *establishing a network code on requirements for grid connection of generators*, (RFG) [1], the implementation on the national level started in many Member States in April 2019. Within this Regulation, a wide range of electrical characteristics related to the behavior of power-generating modules (PGMs) during synchronization with the electrical network, normal operation and fault condition are covered. The RFG Regulation is relevant for PGMs operating within the European interconnected synchronous areas in the transmission or the distribution grid, does however not cover non-interconnected systems and storage systems apart from pump-storage PGMs. The electrical energy storage units (EES) were partially taken along in subsequent European Standards, namely CENELEC EN 50549-1/-2 regarding *requirements for generating plants to be connected in parallel with distribution networks* [2], [3] and are separately handled in III.

The core concept of the RFG Regulation is the categorization of PGMs in four “Type” groups according to a maximum capacity threshold and the nominal voltage of the connection point, with a different complexity of technical requirements being relevant for each Type. The capacity thresholds are defined on a TSO level, must however not exceed the limits defined in Table 1. Type A PGMs have a maximum capacity between 0,8 kW and the limit value of Type B. With regard to voltage, Type A, B and C PGMs are connected below 110 kV while Type D PGMs have a connection point at 110 kV or above.

TABLE I. LIMITS FOR THRESHOLDS FOR TYPE B, C AND D PGMS [1]

Synchronous area	Maximum capacity threshold limits		
	Type B	*Type C*	*Type D*
Continental Europe	1 MW	50 MW	75 MW
Great Britain	1 MW	50 MW	75 MW
Nordic	1,5 MW	10 MW	30 MW
Ireland and Northern Ireland	0,1 MW	5 MW	10 MW
Baltic	0,5 MW	10 MW	15 MW

The electrical requirements handled within [1] mainly refer to the following functional groups:

- Frequency stability
- Voltage stability
- Robustness - Fault-ride-through (FRT) capability
- System restoration
- System management

It is within the scope of this paper to provide further insight on those functional groups and present more detailed information about the related ancillary services.

B. Electrical requirements overview

The RFG Regulation [1] is based on a structure which builds up the electrical requirements for four different PGM Types on top of each other, from Type A to Type D. The requirements are separated between general requirements, requirements for synchronous PGMs and non-synchronous (inverter based) PGMs. The RFG Regulation allows most of the specific values for the different services to be defined on the TSO or system operator level and focuses on the functionalities' description and the definition of permitted ranges.

In addition to the requirements of the RFG Regulation, the European Standards EN 50549-1/-2 [2], [3] serve as universal technical references giving detailed description of the various functional groups defined within the RFG Regulation, even setting new technical requirements not previously defined within [1]. As [2], [3] represent the state of the art on the European level, some of their additions will be highlighted within this passage, although these are not automatically obligatory until the national implementation of the standards by the Member States occurs and are merely related to PGM Types A and B.

Frequency stability:

All PGMs must be able to operate, either permanently or for a specified period of time within specific frequency ranges. An example of those ranges as defined for the Continental Europe synchronous area is given in Table 2. Apart from that, all PGMs have to withstand specific rates of change of frequency up to a specific value, as well as be able to operate in an automated linear decrease of their active power output, in case of an overfrequency above a specific threshold. The last function is called "limited frequency sensitive mode – overfrequency" (LFSM-O) and must be activatable within a maximum of 2 seconds. Further characteristics for exact response of this function are given in [2],[3].

TABLE II. MINIMUM TIME PERIODS FOR WHICH A PGM HAS TO STAY CONNECTED WITH THE NETWORK IN RELATION TO DIFFERENT OPERATING FREQUENCIES FOR THE CONTINENTAL EUROPE SYNCHRONOUS AREA [1]

Synchronous area	*Frequency range*	*Time period for operation*
Continental Europe	47,5 Hz-48,5 Hz	To be specified by each TSO, but not less than 30 minutes
	48,5 Hz-49,0 Hz	To be specified by each TSO, but not less than the period for 47,5 Hz-48,5Hz
	49,0 Hz-51,0 Hz	Unlimited
	51,0 Hz-51,5 Hz	30 Minutes

For PGMs of Type C and D, a similar concept is applicable at underfrequencies under a specific threshold, with the active power output linearly increasing as a function of the falling frequency, keeping however into consideration the availability of primary energy resources, restrictions on maximum power capability at low frequencies and restrictions related to the stable operation of the PGM (limited frequency sensitive mode – underfrequency "LFSM-U"). [2] and [3] however, suggest (but not mandate) the expansion of the LFSM-U requirement for the Type A and B PGMs. Automated frequency responses have generally a priority in regard to other active power control signals.

Furthermore, an activatable frequency sensitivity mode (FSM) is envisaged for Type C and Type D PGMs, where the active power output is a direct function of the frequency deviation from the nominal value, with the regulation however occurring within the whole frequency operation range. The characteristics of the FSM may be variable and remotely set through the TSO.

Voltage stability:

Within [1], the thematic of the contribution to the steady state voltage stability of the network starts from the Type B generators. For this generator group, the requirements (if any) on the capability to provide reactive power are to be defined by the relevant system operator. For Type C and D generators, stricter requirements are set, as the system operator is called to define a so-called U-Q/P_{max} profile, setting the requirement for the reactive power injection and consumption capability of the PGM as a function of the maximal active power for the different operational voltage values at the connection point (CP). Using this concept, the network operator can diversify its requirement in relation with the CP voltage, and has the possibility to limit its requirement of reactive power injection at high voltages and reactive power consumption at low voltages, thus promoting an efficient system operation and generating facility design.

The requirement for the reactive power capability is set for the operation point of maximum capacity P_{max}, must however always be met when the PGM is operating with an active power output below that point. The requirement of the network operator may be not identical for synchronous and non-synchronous PGMs and must lie within specific "envelope" graphs defined in the Regulation. [1]. Such an envelope graph, giving the minimum and maximum possible requirement boundaries for non-synchronous PGMs is shown in Fig. 1.

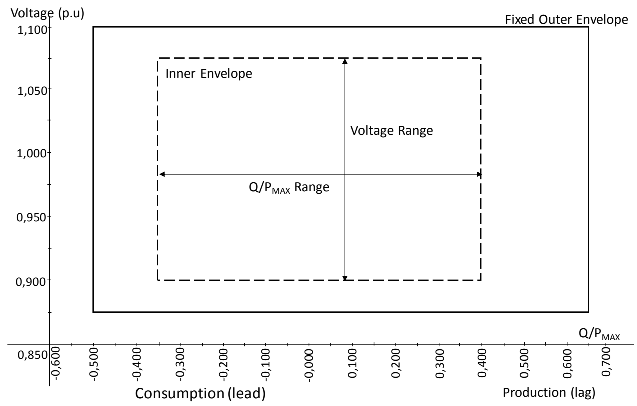

Figure 1. U-Q/P_{max} envelope graph regarding reactive power capability requirement boundaries [1]

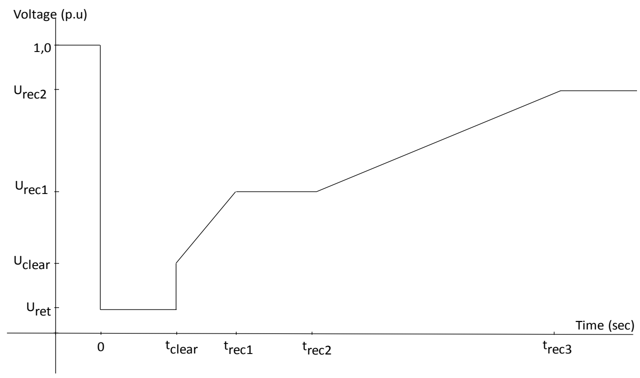

Figure 2. Example fault ride through profile of a PGM [1]

The voltage control scheme for Type C and D PGMs may take the form of voltage control mode, reactive power control mode or power factor control mode. Various further specifications are defined in [1] for those modes e.g. minimum step sizes for remotely defined values, tolerances and time windows for the reactive power control loop etc.

Regarding the definition of the operational voltage range for the different generator Types, those are not strictly defined in the Regulation for Types A to C, with only some limit values being given for the envelop graph of Fig.1.

For Type D PGMs, [1] clearly defines the required voltage ranges for permanent and limited-time operation separately for the 110 kV-300 kV and the above 300 kV voltage levels.

Robustness - FRT capability:

Starting with Type B PGMs, the RFG Regulation [1] calls the TSOs to define a voltage-against-time profile for fault conditions, which indicates within which ranges must the PGMs stay connected to the network during a fault but also continue to operate stably after fault clearance. The RFG Regulation loosely defines the form of such a diagram separately for synchronous and non-synchronous PGMs, allowing the TSOs to choose the fault clearing times and certain limits of voltage recovery after fault clearance within a specific range.

Such an example profile including a marking of the relevant adjustable voltage and time values defined in the RFG Regulation is depicted at Fig. 2. The voltage values are phase-to-phase voltages at the CP. Apart from synchronous and non-synchronous PGMs, the voltage-against-time profiles are also separately defined for the Types B and C and the Type D PGMs.

During the faults, the non-synchronous PGMs have to inject a fast fault current with specific characteristics set by the relevant TSO, with the aim of assisting fault identification through protection measures as well as supporting voltage retention during the fault and voltage restoration after fault clearance.

The requirements for the voltage-against-time profile and the provision of fast fault current apply to three-phase faults, but can be expanded to the cases of two-phase and one-phase faults through the relevant TSO. It is often highlighted through the RFG Regulation, that internal protection functions may not jeopardize the FRT capability of a PGM. After the fault, the PGMs are required to participate in an active power recovery mode.

The European Standards [2] and [3] introduce an additional FRT mode related to voltage swells, namely OVRT mode (as compared to the LVRT mode defined within [1]), which is considered mandatory for all generating units. The praxis indicates that OVRT constitutes state of the art and was already incorporated as a technical requirement on national documentation not necessarily related to Type A and B PGMs (e.g. VDE-AR-N 4120 [4]).

System restoration:

Automated reconnection of Type A PGMs after disconnection due to fault conditions is allowed within specified frequency ranges, while a specific gradient for the active power ramp has to be withheld. For Type B PGMs, reconnection after fault may be subject to additional conditions specified by the relevant TSO while automated reconnection shall be additionally subject to authorization by the relevant system operator. Type C and D PGMs may additionally need to fulfill black start capability, being able to support voltage, frequency and the connection of loads in a grid area, without an external supply source. Upon request, Type C and D PGMs must be able to support islanding operation, within the same voltage and frequency limits of as in normal grid operation, while also being able to fulfill its frequency control functionalities.

System management:

Type A PGMs are solely equipped with an emergency disconnection input port. For Type B PGMs, an input port to allow a reduction of the active power output as well as other control schemes in strict coordination with the TSO and the system operator are required. Regarding information exchange in relation to system management, real time or time stamped periodical exchange must take place, with the exact specifications being in the jurisdiction of the system operator.

For the more complex PGM Types, the required functionalities of the system management equipment is significantly higher, with explicit requirements being defined for the recording of network parameters, quality of supply information, status of protection equipment etc. For Type D PGMs, the synchronization procedure requires an authorization from the system operator and is subject to specific allowed ranges, thus requiring the installation of appropriate synchronization equipment.

Finally, two important aspects related to system management are the specification, design and installation of the various protection schemes and settings from Type B PGMs and onward as well as the provision of PGM simulation models. Regarding simulation models, at the request of the relevant system operator or the relevant TSO, the power-generating facility owner (PGFO) shall provide simulation models which allow the accurate simulation of the steady state, dynamic and electromagnetic transient behavior of the PGM. The format of the models, the relevant documentation and other data relevant to the simulations are to be exchanged between the relevant TSO and the PGFO.

III. STATUS QUO REGARDING STORAGE SYSTEMS

In the last decade, significant breakthroughs have been achieved in regard to the development and maturity of storage systems of various capacity sizes and connection voltage ranges, either synchronous or non-synchronous (inverter-based). These developments call for a standardized approach on the topic of technical requirements and although storage systems are not addressed within [1], the latest developments on European level have begun to address the issue. With respect to the increasing importance of storage systems the Grid Connection European Stakeholder Committee (GC ESC) has triggered a corresponding expert group for the "identification of storage requirements" (EG Storage) in summer 2018 to fill this regulatory gap in order to deduce electrical requirements for a future revision of [1].

Furthermore, the EN 50549-1/-2 European Standards [2], [3] address the EES topic, for the Type A and B PGMs, this is however considered sufficient for the scope of this paper. Within these documents, the EES are differentiated in charging and discharging mode, for which different requirements may apply. Following to the presentation structure of II, the following technical requirements on storage systems are defined:

Frequency stability:

The role of EES in frequency stability is crucial according to [2] and [3] and as such, it is obligatory for these to participate in the LFSM-O and LFSM-U functions in both operational modes. More specifically, in case of an overfrequency above a specific threshold, storage units in discharging mode must behave equally to a PGM. Storage units in charging mode shall not decrease and should (if possible) increase charging power according to the required droop curve until frequency returns below a specific threshold. If maximum charging capacity is reached or to prevent risk of injury or equipment damage, a reduction of charging power is permitted. A charging mode change is not discussed for LFSM-O.

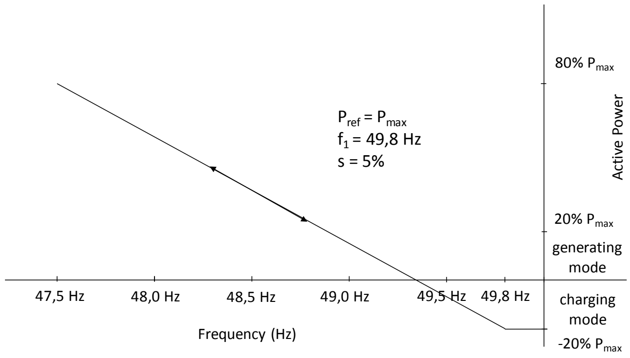

Figure 3. Example of active power frequency response to underfrequency in case of a storage device with 20% power charging at the point of activation [3]

In case of an underfrequency under a specific threshold, EES units must participate in LFSM-U for both charging modes according to the required droop. A change from charging to discharging mode is allowed. The minimum state of charge of the ESS unit is one of the conditions for the provision of the service in this case. This response is visualized within Fig. 3. Inverter based storage systems may be able to follow an active power gradient equal to 100% P_{nom} within an 1 sec range.

Voltage stability:

Regarding the provision of reactive power in steady state, [2] and [3] state no additional requirements on the ESS units. It is assumed that, within the discharging mode, the same requirements apply as for PGMs. The charging mode is not separately defined, ensuring a uniform approach, although it could be considered a load-like operation.

Robustness – FRT capability:

Being considered for the first time within [2] and [3], ESS units must fulfill the newly introduced OVRT capability. Apart from that, [2] and [3] suggest the fulfillment of the LVRT requirements also from Type A PGMs. After the clarification of the legal question on the validity of such a requirement LVRT capability may be uniformly required for Type A PGMs and ESS units. The FRT requirement does not differentiate between charging and discharging mode.

Regarding the topics of *system management* and *system restoration*, no additional requirements specific for ESS systems are defined within [2] and [3].

IV. COMPLIANCE ASSESSMENT SCHEMES

The evolution of the energy systems in the last decades from a centralized structure involving only a few players to a free market involving a high number of manufacturers, project planners, PGFOs, and unbundled network operators created a need for verification schemes for the commissioning and normal operation phase of newly installed capacity. Already before the enactment of [1], compliance schemes were active on national level. The RFG regulation unifies the compliance assessment procedure incorporating it to a process connected to the process of the so-called operational notification procedure, potentially involving independent certifying bodies.

More specifically, [1] foresees operation notification procedures of different complexity for the various PGM Types. For Type A PGMs, the PGFO or it's representative must submit an installation document to the system operator, containing factual and personal information about the PGM but may also refer to an equipment certificate about the specific PGM. Equipment certificates are defined as documents issued by authorized certifiers assessing the capability of a PGM to comply to a specific range of requirements and may contain data or simulation models verified against actual test results.

For PGMs of Type B, C and D, [1] introduces the term of a project-specific "power-generating module document" (PGMD), a document issued by the PGFO including a statement of compliance, detailed technical documentation of the PGM as well as compliance test reports and results of simulation studies assessing steady state and dynamic performance. For Type C and D PGMs, the simulation models discussed in II are part of the PGMD. Further Articles within [1] indicate which scope shall the compliance tests and simulation have for the specific PGM Types and technologies (synchronous, non-synchronous, offshore).

For example, for a Type C non-synchronous PGM, compliance tests must be performed for the following functions:

- LFSM-O response
- LFSM-U response
- FSM response
- Active power controllability and control range
- Frequency restoration control
- Reactive power capability
- Voltage control mode
- Reactive power control mode
- Power factor control mode

More in-depth verification of the PGM's compliance to specific technical requirements, which would not be possible or would require unproportional effort and costs to be tested are covered through the compliance simulations. Apart from that, simulation results are cross-verified with compliance tests results as an additional validation. For example, compliance simulations for a Type C non-synchronous PGM shall cover:

- LFSM-O response
- LFSM-U response
- FSM response
- Island operation
- FRT capability
- Post fault active power recovery
- Reactive power capability

In general, although the use of equipment certificates and the issuing of the PGMD by an authorized certifier are not explicitly required, the procedure and content of the simulation tests and simulations is aligned with the utilization of equipment certificates. Within the context of [1], the equipment certificate can contain all or a part of the compliance tests and simulations in a form of type testing and may be provided from the PGFO to the system operator, instead of being performed every time on project level, thus accelerating the commissioning processes, in particular for non-custom, mass produced PGMs. However, the system operator is nevertheless entitled to require additional or alternative tests complementary to the compliance tests, which are covered through the equipment certificate or the standardized compliance tests on project level. The definition of the exact extent, content, workflow and timeline for the compliance process lies in the responsibility of the relevant system operator. In this context the following clarifications can help.

Compliance Testing:

With respect to compliance testing, it is reasonable to distinguish between type testing and commissioning tests. Type testing (e.g. with an accreditation to IEC 17025 [6]) is intended to serve as a reference measurement for all pieces of the same type. That means, a PGM with the specification A, only has to be tested once with respect to e.g. frequency behavior if the corresponding manufacturer is equipped with a quality management system as ISO 9001. In consequence, it can be expected, that if the test has been successfull, every PGM of the same specification will have the same general frequency behavior as the tested one, what can be verified with an equipment certificate (e.g. with an accreditation to IEC 17065 [5]).

Commissioning tests are intended to check a functionality in a project related realization, e.g. the correct installation of the system operator's remote control, taking into account different interfaces of devices and communication infrastructure. For the system operator it is important, that he can send or receive signals from the individual PGM. These kinds of tests cannot be conducted in a laboratory. On the contrary, it has to be noticed that some parts of compliance testing are not applicable during an on-site commissioning test due to economical limitations or even technical on-site restrictions, e.g. FRT tests at every individual PGM in electricity networks with a low short-circuit power. It is obvious that tests on each single project levels are macro-economically more cost-intensive than type tests being performed only once. In general, commissioning tests may be supported by underlying type testing and/or type certificates in order to avoid detailed assessments.

Compliance Simulation:

An equipment certificate will always restrict the proof of compliance on electrical characteristics with respect to the PGM's terminal. It may also be applied sufficiently if the electrical infrastructure (cabling transformer, etc.) is negligible. The latter can be assumed for small PGMs, that's why an equipment certificate for PGMs of type A sounds reasonable.

In large-scale PGMs with large electric distances and further influencing components the proved behavior of the PGM during type testing and within the equipment certificate will change significantly from the PGM's terminal towards the connection point of the system operator due to system interactions. Furthermore, the impact on the distribution or transmission system grows with the increasing size of a PGM. For this purpose, the implementation of compliance simulations is useful. When it comes to compliance simulations, it is important to distinguish between simulations in order to prove grid code compliance on the one hand and simulations to be performed as system and stability analyses of electricity networks by the relevant system operator on the other. While simulations for grid code compliance are conducted using simulation models with a generally very high level of detail, system and stability analyses of electricity networks need rather aggregated and simplified simulation models due to performance requirements of network simulation software. It is quite comprehensible, that not every single PGM above an installed active power of e.g. 1 MW (PGM of type B and higher) can be respected in detail when the system operator is executing e.g. its load flow optimization. Therefore, even the requirements concerning simulation models have to be distinguished.

With focus on grid code compliance for PGMs including storage systems, compliance simulations for type B, C and D are a useful approach to reduce efforts of compliance testing (commissioning tests), e.g. concerning reactive power capability. The equipment certificate serves to use reliable input data while performing the simulations (grid code compliance), the most crucial aspect for simulations in general. In addition, the simulation models which are used for the verification of grid code compliance, can represent the basis for an aggregated simulation model which has to be delivered to the system operator in order to perform system stability analysis.

Therefore, it is highly recommended by the authors to differentiate between standardised (certification) and individual (compliance testing and simulation) compliance schemes. In general, especially for mass-products, certification should be applied in a multiple step of: type testing, equipment certificate of the PGU (including a validated simulation model), PGMD and commissioning testing. Alternatively, for non-mass PGMs, procedures for compliance testing and simulations as described in [1] shall be used.

Compliance Monitoring:

Finally, a topic addressed within [1] is compliance monitoring, a procedure not related to the commissioning phase, but to the full operational lifetime of the PGM. Even after the commissioning a process to ensure compliance of the facility to the requirements formulated within [1] lies within the responsibility of the PGFO. The PGFO must report any modifications or incidents at the PGM level that may affect compliance with the discussed requirements and may perform relevant verification tests. The system operator has the right to request compliance tests and simulations according to a repeat plan or after a specific incident.

Regarding the issuing of equipment certificates, this is currently permitted to certification bodies complying to the ISO/IEC 17065 standard related to *Conformity assessment – Requirements for bodies certifying products and services* [5] while ISO/IEC 17025 [6] relates to the validation of the required type testing. The methodology for performing and validating such tests is considered quite mature, with the updated series of IEC 61400-21, -27 standards covering the fields of measurement and assessment of power quality characteristics and the validation of electrical simulation models for wind turbines, with technical specifications being transferable to other synchronous and non-synchronous technologies including ESS units [7], [8]. On the European standardization level, the CENELEC 50549-10 concerning *Tests demonstrating compliance of units* will be expectedly issued in 2019, addressing measurement procedures and type testing on the PGM level in accordance with [1].

V. RELEVANCE FOR NON-INTERCONNECTED SYSTEMS

As already stated within II, the RFG Regulation does not apply to non-interconnected systems, thus potentially creating a legality issue concerning the transferring of the analyzed frame directly to non-interconnected systems. However, this is not the case for the EN 50549-1/-2 Standards, which orient themselves on requirements related to distribution networks, also explicitly addressing and involving isolated systems. For example, it is stated within [3], that small isolated systems may need to consider broader frequency operational ranges for temporary operation or higher values for rate of change of frequency immunity. As a result, when these standards are transferred to national level, the RFG requirements and framework may also become binding for non-interconnected systems.

Apart from the legality issue, the system operators could profit from the utilization of the RFG framework regarding technical requirements and compliance assessment on the non-interconnected system level. Examining the Greek Network Code for non-interconnected islands [9], similarities can be drawn with [1] on the extent and scope of technical requirements for newly installed PGMs and ESS units while compliance assessment and monitoring tests partly similar to IV are required. The utilization of the RFG framework for the formulation and wording of those requirements could provide an advantage to system operators orienting from a unified and standardized approach. In addition, compatibility with a potential preexisting scheme of the mainland system regarding technical requirements and conformity assessment is addressed upfront, ensuring that in case of a future interconnection with the mainland system, those parts of the distribution grid will not be “black boxes” for the system operator, but the largest part of their required characteristics will be secured.

When it comes to equipment certificates and the involvement of accredited institutes in issuing of those documents, no barrier is identified in the transfer of this requirement at the non-interconnected system level. In fact, within [9], documents similar to equipment certificates from accredited institutes are already being required for wind and photovoltaic plants at the Greek non-interconnected system.

VI. SUMMARY

Within this paper, the latest developments regarding technical requirements on newly installed generation and storage capacity have been analyzed. The existing European documentation offers system operators a sufficient starting point to adapt their grid codes respectively. Sufficient insight regarding the establishment of an appropriate compliance assessment and monitoring scheme for the system operators was also given. Regarding transferring of the presented concepts to non-interconnected systems, similarities where drawn and possible advantages were identified.

REFERENCES

[1] European Commission in the Official Journal of the European Union, Commission Regulation (EU) 2016/631, Network Code on Requirements for Grid Connection of Generators, Brussels, April 2016."

[2] CENELEC, 50549-1 Requirements for generating plants to be connected in parallel with distribution networks – Part 1-1: Connection to a LV distribution network – Generating plants up to and including Type A, May 2018.

[3] CENELEC, 50549-2 Requirements for generating plants to be connected in parallel with distribution networks – Part 2: Connection to a MV distribution network, May 2018

[4] Verband der Elektrotechnik Elektronik Informationstechnik e.V., VDE-AR-N 4120, Technical requirements for the connection and operation of customer installations to the high voltage network, VDE VERLAG GMBH, Berlin, Mai 2018.

[5] International Organization for Standardization, ISO/IEC 17065: 2012 Conformity assessment -- Requirements for bodies certifying products, processes and services, last reviewed in 2018

[6] International Organization for Standardization, ISO/IEC 17025: 2017 General requirements for the competence of testing and calibration laboratories

[7] International Electrotechnical Commission, IEC 61400-21: 2008 Wind turbines - Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines; edition 2.0, 2008

[8] International Electrotechnical Commission, IEC 61400-27-1: 2015 Wind turbines - Part 27-1: Electrical simulation models - Wind turbines, edition 1.0, 2015

[9] Greek Regulatory Authority of Energy, Κώδικας Διαχείρισης Ηλεκτρικών Συστημάτων Μη Διασυνδεδεμένων Νησιών (in greek), 4th Edition, April 2018