UL Solutions Grid Code Compliance

Streamline grid code compliance activities through a single provider that supports more than 60 standards around the world.

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Introduction

Renewable power production continues to expand and evolve as the world moves toward decentralized renewable energy production powered by distributed energy resources (DER). In 2023, the world added nearly 50% more renewable energy capacity than in 2022, and significant growth is expected to continue over the next five years.[1] Manufacturers find markets eager for these products and systems, and policies continue to not only support but also drive much of this transition. However, compliance with grid codes must be demonstrated before any of these products can be put into use.

Although grid codes may vary by region, these codes are designed to help ensure safety and establish a standardized framework for all connects to the grid.

With these codes in place, a transmission system operator (TSO) can fairly assess all products and systems before allowing a connection to the grid. Similarly, at the distribution level, grid codes often include rules from the distribution system operator (DSO).

Why grid codes exist

Power discontinuity can occur for several reasons. Aside from equipment failures, two main factors affect the power system:

- Weather events
- Grid instability

As the number of decentralized power-generating units and systems increases, the number of factors in the grid to stabilize or destabilize the voltage and frequency increases, as well. Each of these must follow specific rules to reduce power discontinuity events and obtain a safe and stable operation and power supply worldwide. In other words, although renewable energy is fundamental as the world transitions away from fossil-based energy sources, the introduction of non-programmable and intermittent energy resources such as renewables increases grid instability.

Grid codes help bring stability to the energy transition while also presenting a new challenge for manufacturers.

Grid codes apply in many countries around the world. The ultimate goals of safety and reliability exist in all regions, but codes vary from one region to the next. This guide will explore Europe and North America in greater detail.

The global grid code landscape

UL Solutions provides comprehensive services to support compliance with grid code standards worldwide.

Grid codes in Europe

Europe began working on grid code harmonization in Entso-E after the blackout events in Italy in 2003 and regional islanding (Netherlands 2006). The result of these efforts was the NetCode “Requirements for Generators (EU) 2016/631” (RfG) published by the ENTSO-E. This code defines the general requirements for power generating units, systems and their components that connect to the European transmission grid.

Today, two European standards serve as a technical reference for the definition of nationalrequirements where the RfG European Network Code requirements allow flexible implementation.

- **EN 50549-1** provides technical requirements for the connection of generating plants, which can be operated in parallel with a public low voltage (Un ≤ 1 kV) distribution network.
- **EN 50549-2** provides technical requirements for the connection of generating plants, which can be operated in parallel with a public medium voltage (1 kV < Un ≤ 36 kV) distribution network.

The requirements in both focus on:

- Power vs. frequency
- Active power control
- Reactive power capabilities
- Reactive power response
- Voltage and frequency protection
- Rate of Change of Frequency (RoCoF)
- Fault ride through (FRT)

Many countries have also established local grid codes, and many have been recently updated. In countries without a specific local regulation from the national authorities, the European Standards can be applicable.

Spain

Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters...)
NTS	Grid code requirements for main land	From low to high voltage	≥800W	Units	Photovoltaic, wind, synchronous generator, storage converter
NTS SENP	Grid code requirements for islands	From low to high voltage	≥100W		
PO.9	Grid code requirements	110kV	No power limits	Systems	Photovoltaic, wind and hybrid power plants

Protection type	Protection name	Default settings	Protection scheme logics
Voltage	UV, OV	85%-110% Un, 1.5-1s	NA
Frequency	UF, OF	47.49 - 51.51 Hz, 0.2-0.2s	
Power	See requirements 5.7 and 5.8		
HVRT/LVRT	See chapter 5.11.		

Metering and control	Requirements
Measurement accuracy and scheme	Voltage accuracy = ±0.5% of Un | Current accuracy = ±0.5% of In | ±10mHz
Frequency regulation	Yes, see chapter 5.1-5.3
Voltage regulation	See chapter 5.11
Islanding	NA
Power quality	EN standards
Plant controler	PPC shall be certified
Interoperability	NA
Others	Damping oscillation and PO 9.

Certification Process	Requirements	
Simulation/model validation	Yes according chapter 6	
Testing	Samples	1
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Test plan • Testing • Model validation • PGU certification • Complementary simulation PGS • PGS certification
Certification	Documentation required	Datasheet for Unit and full description for PGS
	Upload to local database	NA
	Update if engineering changes/validity time	yes/NA
Inspection	NA	

These data reflect the 2024 version of this standard. For more updated versions, contact us or refer to the standard document.

Spain

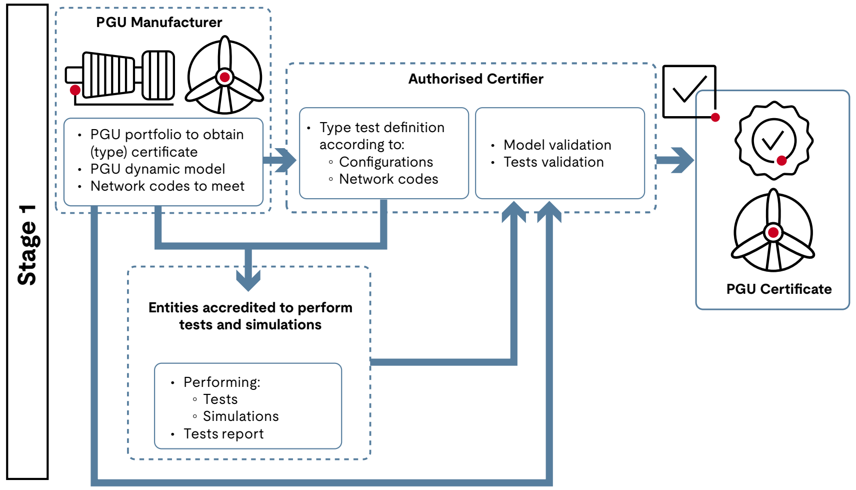

Figure 1. Scheme for obtaining the PGU certificate.

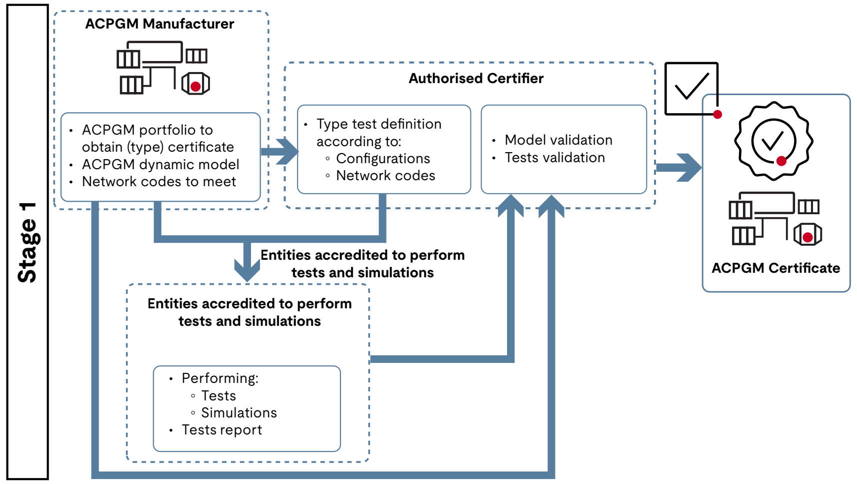

Figure 2. Scheme for obtaining the ACPGM certificate.

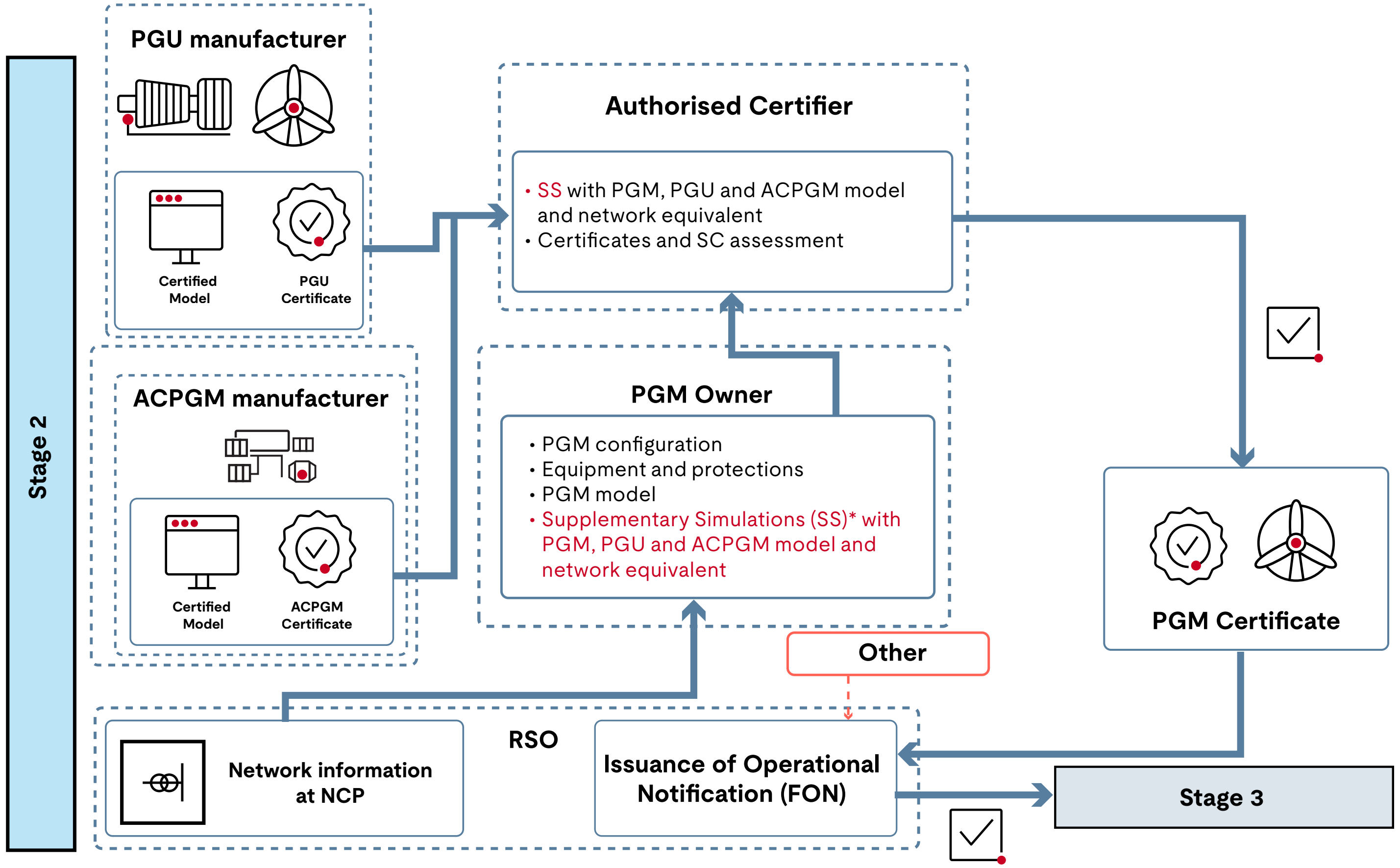

Figure 3. Scheme for obtaining the final PGM certificate from equipment certificates.

These examples are elaborated based on the mentioned Country standards. For the details, contact us or refer to the standard document.

Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters...)
UNE217001	Safety requirements for grid converters	From low to high voltage	No power limits	Units	Photovoltaic, wind, synchronous generator, storage converter
UNE217002	Safety requirements for self-consumption systems	From low to high voltage	No power limits	Systems	Photovoltaic, wind and hybrid power plants

Protection type	Protection name	Default settings	Protection scheme logics
Voltage	UV, OV	85%-110% UN, 115% Un, 1.5, 1s, 0.2s	NA
Frequency	UF, OF	48-50.5Hz, >3s-<0.5s	
Power9	NA	NA	
HVRT/LVRT	NA	NA	

Metering and control	Requirements
Measurement accuracy and scheme	Voltage accuracy = ±0.5% of Un | Current accuracy = ±0.5% of In ±10mHz
Frequency regulation	NA
Voltage regulation	NA
Islanding	Double anti-islanding
Power quality	Yes, according EN standards.

Certification Process	Requirements	
Testing	Samples	1
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Testing • Certification
Certification	Documentation required	Drawings and datasheet
	Upload to local database	NA
	Update if engineering changes/validity time	Yes/5 years
Inspection	NA	

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Spain

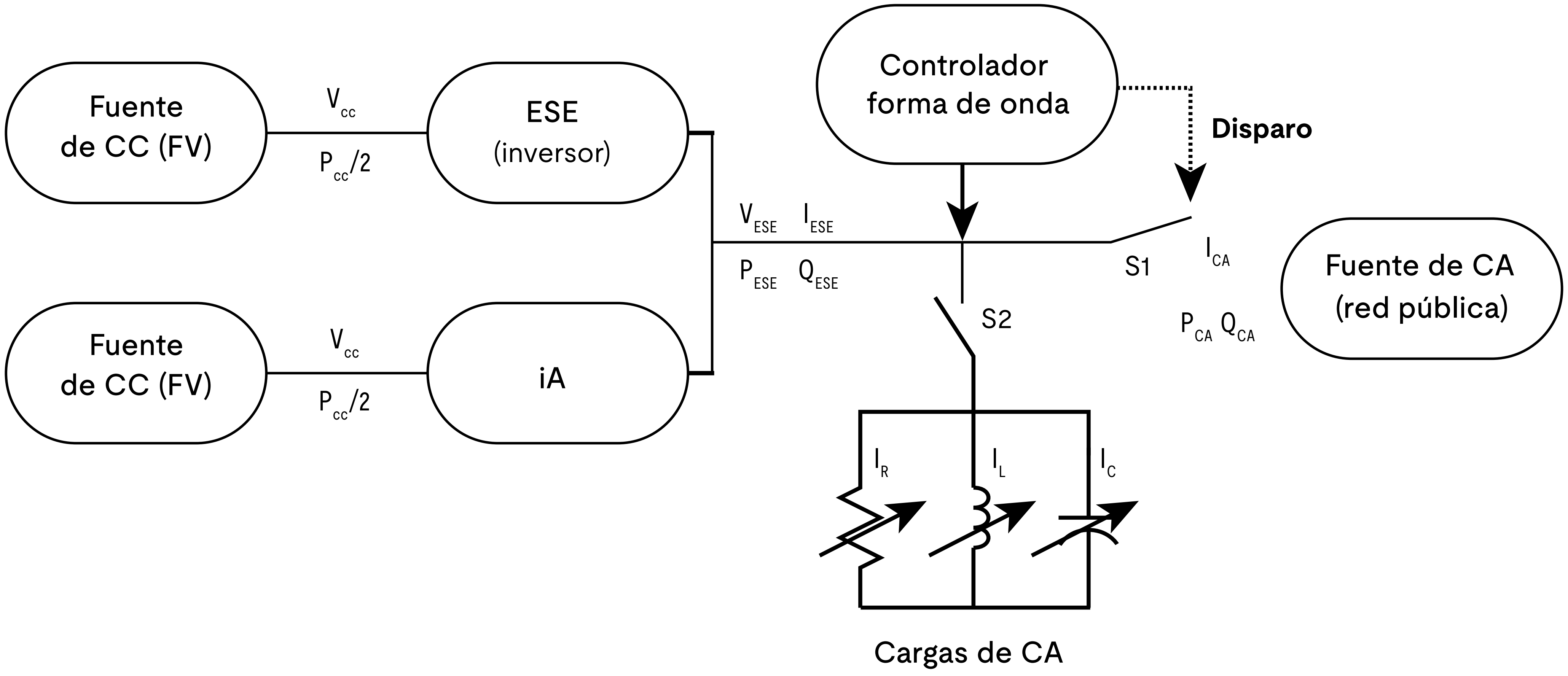

Figure 4. Anti islanding test included into UNE217002

These examples are elaborated based on the mentioned Country standards. For the details, contact us or refer to the standard document.

Germany

Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters...)
VDE-AR-N 4100 and VDE-AR-N 4105	Grid code requirements	Low voltage	< 130 kW	Components and units	Photovoltaic, wind, synchronous generator, storage converter
VDE-AR-N 0124-100	Testing guideline	Low voltage	< 130 kW		

Protection type	Protection name	Default settings	Protection scheme logics
Voltage	UV 1, UV 2, OV 1, OV 2	115-125% Un - 0.1s, 110% Un - 0.1s, 80% Un - 0.1-3.0s, 45% Un - 0.3s	NA
Frequency	UF, OF	47.5 Hz – 1s, 51.5 Hz – 0.1s	
Power	See requirements 5.7 and 5.8		
HVRT/LVRT	See chapter 5.7 of VDE-AR-N 4105 (not required depending on the power level)		

Metering and control	Requirements
Measurement accuracy and scheme	Acc. to IECEE CTL-OD 5010 Frequency accuracy = ±10mHz
Frequency regulation	Yes, see 5.7.4.3 of VDE-AR-N 4105
Voltage regulation	Yes, see 5.7.2 of VDE-AR-N 4105
Islanding	Protection against islanding required
Power quality	IEC 61000 standards depending on the current output, see 5.4
Plant controler	Needed for some units
Interoperability	NA

Certification Process	Requirements	
Simulation/model validation	Yes, model must be validated according to FGW TG4	
Testing	Samples	1 per certification family
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Test plan • Testing • PGU certification
Certification	Documentation required	Datasheet of the unit, test report, manufacturer declaration
	Upload to local database	ZEREZ (database from FGW)
	Update if engineering changes/validity time	Yes/ 5 years
Inspection	NA	

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Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters…)
VDE-AR-N 4110	Grid code requirements	Medium voltage	From 130 kW to 36 MW	Units	Photovoltaic, wind, synchronous generator, storage converter
FGW TG3, TG4 and TG8	Testing (TG3), model validation (TG4) and certification guidelines (TG8)	From medium to extra-high voltage	From 130 kW to 36 MW	Systems	Photovoltaic, wind and hybrid power plants

Protection type	Protection name	Default settings	Protection scheme logics
Voltage	UV 1, UV 2, OV	125% Un - 0.1s, 80% Un - 1.5-2.4s, 30% Un - 0.8s	NA
Frequency	UF 1, UF 2, OF	47.5 Hz – 0.1s, 51.5 Hz – 5s, 52.5 Hz – 0.1	
Power	See chapter 10 of VDE-AR-N 4110		
HVRT/LVRT	See chapter 10.2.3 of VDE-AR-N 4110		

Metering and control	Requirements
Measurement accuracy and scheme	Frequency accuracy = ±10mHz | Voltage ≤ 0.5% Un | Current ≤ 0.5% In
Frequency regulation	Yes, see chapter 10.2.4.3 of VDE-AR-N 4110
Voltage regulation	Yes, see 10.2.2 of VDE-AR-N 4110
Islanding	Protection against islanding might be required
Power quality	IEC 61000 standards depending on the current output, see 5.4
Plant controler	Needed for some units
Interoperability	NA

Certification Process	Requirements	
Simulation/model validation	Yes, model must be validated according to FGW TG4	
Testing	Samples	1 per certification family
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Test plan • Testing • PGU certification
Certification	Documentation required	Datasheet of the unit, test report, manufacturer declaration
	Upload to local database	ZEREZ (database from FGW)
	Update if engineering changes/validity time	Yes/ 5 years
Inspection	For PGU not needed unless the manufacturer does not have a ISO 9001 certificate. For PGS required after the Plant Certification.	

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Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters...)
VDE-AR-N 4120	Grid code requirements	High voltage	No power limits, range defined by PCC	Units	Photovoltaic, wind, synchronous generator, storage converter
FGW TG3, TG4 and TG8	Testing (TG3), model validation (TG4) and certification guidelines (TG8)	From medium to extra-high voltage	No power limit, range defined by PCC	Systems	Photovoltaic, wind and hybrid power plants

Protection type	Protection name	Default settings	Protection scheme logics
Voltage	UV 1, UV 2, OV 1, OV 2	125% Un - 0.1s, 110% Un - 0.18s, 80% Un- 1.5-2.4s, 30% Un - 0.8s	NA
Frequency	UF, OF	47.5 Hz — 0.1s, 51.5 Hz — 5s	
Power	See chapter 10 of VDE-AR-N 4110		
HVRT/LVRT	See chapter 10.2.3 of VDE-AR-N 4110		

Metering and control	Requirements
Measurement accuracy and scheme	Frequency accuracy = ±10mHz | Voltage ≤ 0.5% Un | Current ≤ 0.5% In
Frequency regulation	Yes, see chapter 10.2.4.3 of VDE-AR-N 4120
Voltage regulation	Yes, see 10.2.2 of VDE-AR-N 4120
Islanding	Protection against islanding might be required
Power quality	IEC 61000 standards depending on the current output, see 5.4
Plant controler	Needed for some units
Interoperability	NA

Certification Process	Requirements	
Simulation/model validation	Yes, model must be validated according to FGW TG4	
Testing	Samples	1 per certification family
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Test plan • Testing • PGU certification
Certification	Documentation required	Datasheet of the unit, test report, manufacturer declaration
	Upload to local database	ZEREZ (database from FGW)
	Update if engineering changes/validity time	Yes/ 5 years
Inspection	For PGU not needed unless the manufacturer does not have a ISO 9001 certificate. For PGS required after the Plant Certification.	

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Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters...)
VDE-AR-N 4130	Grid code requirements	Extra high voltage	No power limit, range defined by PCC	Units	Photovoltaic, wind, synchronous generator, storage converter
FGW TG3, TG4 and TG8	Testing (TG3), model validation (TG4) and certification guidelines (TG8)	From medium to extra-high voltage	No power limits, range defined by PCC	Systems	Photovoltaic, wind and hybrid power plants

Protection type	Protection name	Default settings	Protection scheme logics
Voltage	UV 1, UV 2, OV	125% Un - 0.1s, 80% Un - 3s, 30% Un - 1.5s	NA
Frequency	UF 1, UF 2, OF	47.5 Hz – 0.1s, 52.5 Hz – 0.1s	
Power	See chapter 10 of VDE-AR-N 4130		
HVRT/LVRT	See chapter 10.2.3 of VDE-AR-N 4130		

Metering and control	Requirements
Measurement accuracy and scheme	Frequency accuracy = ±10mHz | Voltage ≤ 0.5% Un Current ≤ 0.5% In
Frequency regulation	Yes, see chapter 10.2.4.3 of VDE-AR-N 4130
Voltage regulation	Yes, see 10.2.2 of VDE-AR-N 4130
Islanding	Protection against islanding might be required
Power quality	IEC 61000 standards depending on the current output, see 5.4
Plant controler	Needed for some units
Interoperability	NA

Certification Process	Requirements	
Simulation/model validation	Yes, model must be validated according to FGW TG4	
Testing	Samples	1 per certification family
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Test plan • Testing • PGU certification • PGS Certification • PGS Conformity declaration
Certification	Documentation required	Datasheet of the unit, test report, manufacturer declaration
	Upload to local database	ZEREZ (database from FGW)
	Update if engineering changes/validity time	Yes/ 5 years
Inspection	For PGU not needed unless the manufacturer does not have a ISO 9001 certificate. For PGS required after the Plant Certification.	

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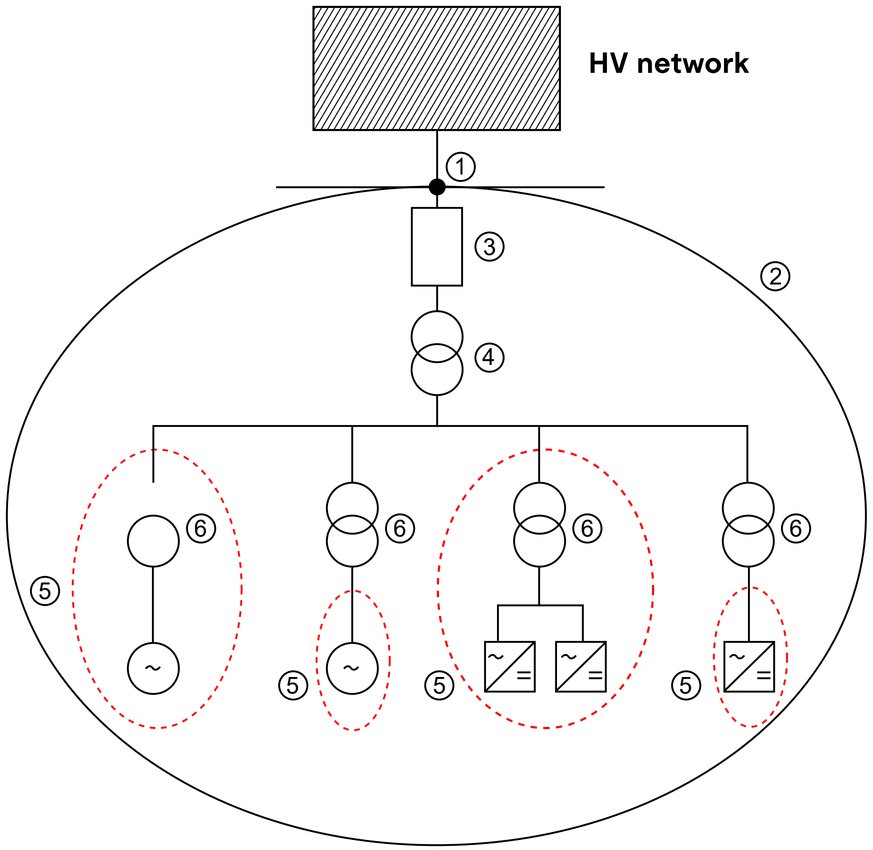
Germany



Key

1 Network connection point
2 Power generating plant
3 Transfer station
4 Mains transformer
5 Power generating unit
6 Generator transformer (possibly not a part of the power generating unit; to be shown in the unit certificate)

Figure 5. Power Generating System with connection to the High-Voltage grid

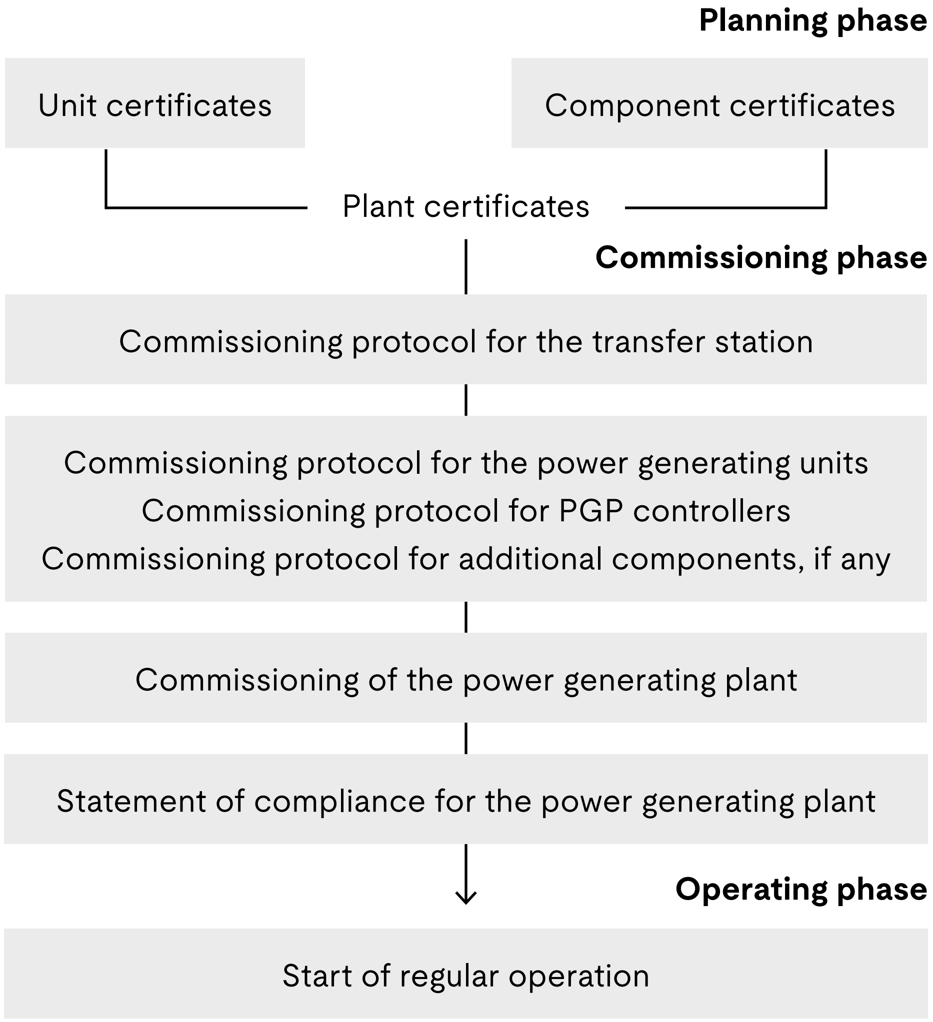


Figure 6. Process for power generating systems

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Italy

Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters...)
CEI 0-21	Grid code requirements	Low voltage	< 100kW	Components and units	Photovoltaic solar, wind, synchronous generator, energy storage converter, grid feeding protection
CEI 0-16	Grid code requirements	Medium voltage	> 100kW, < 6MW		

Protection type	Protection name (ANSI code)	Default settings	Protection scheme logics
Voltage	UV (27), OV (59), 59V0, 59Vi, 27Vd	See fig. 7	“Sblocco Voltmetrico” See fig. 7
Frequency	UF (81<S1/2), OF (81>S1/2)	See fig. 7	
Power	None		
HVRT/LVRT	See picture		

Metering and control	Requirements
Measurement accuracy and scheme	Frequency accuracy=±10mHz | Class TA ≤ 0.5 | Class TV ≤ 0.5
Frequency regulation	Working area: 85%Vn ≤ V ≤ 110%Vn, Active Power regulation
Voltage regulation	Working area: 47,5 Hz ≤ f ≤ 51,5 Hz, Reactive Power regulation
Islanding	Anti-islanding
Power quality	Harmonics, flicker, voltage ripple
Plant controler	«Controllore Centrale di Impianto»
Interoperability	IEC 61850 in Italy certified by UCA (Level A)
Others	Synchronization and load shedding («interrompibilità»)

Certification Process	Requirements	
Simulation/model validation	No model validation	
Testing	Samples	1
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Test plan • Type Testing • In-field testing
Certification	Documentation required	Datasheet for Unit and full description for PGU
	Upload to local database	ANIE
	Update if engineering changes/validity time	Yes, especially about fw version
Inspection	Every 5 years in the field	

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Italy

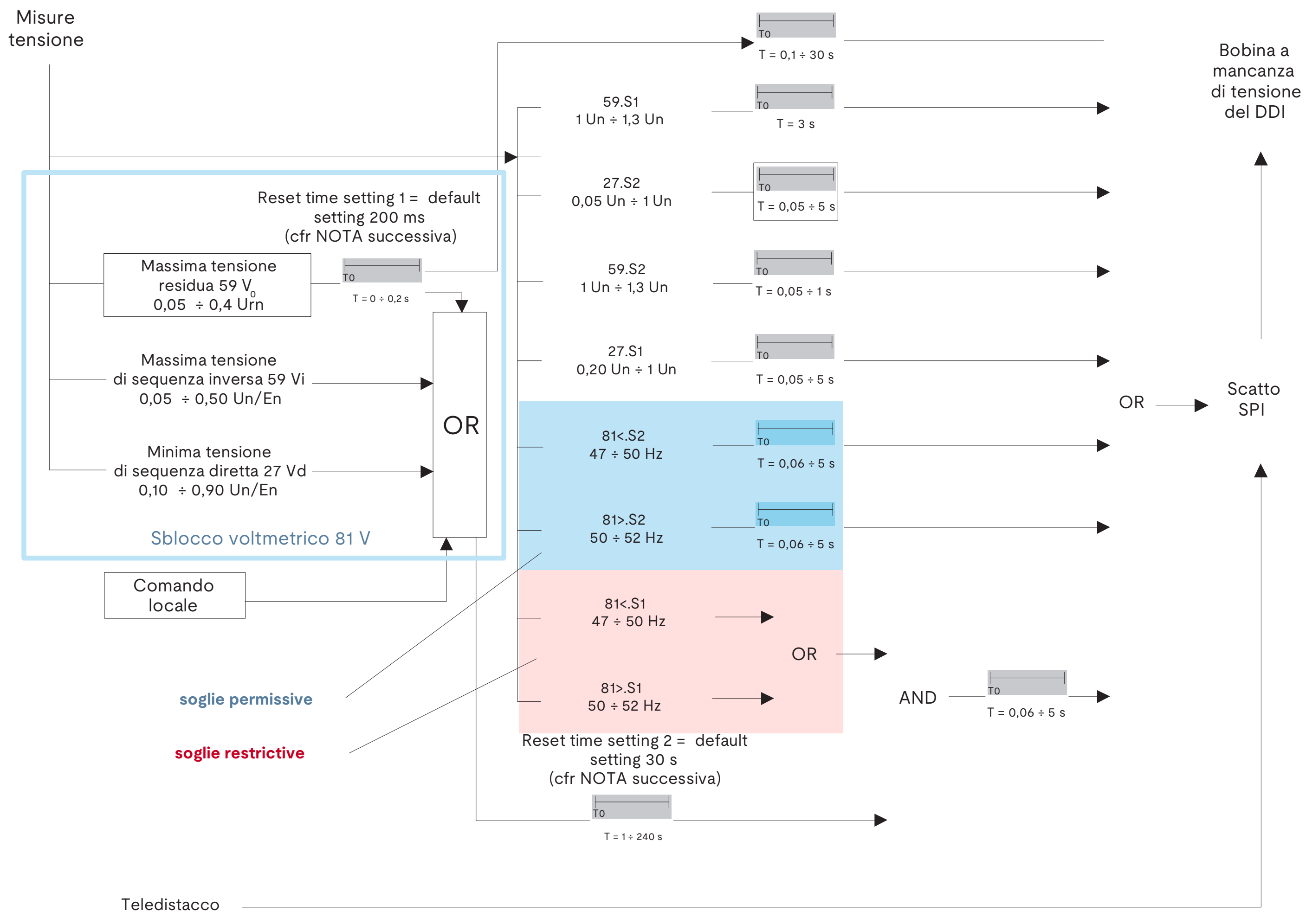

Figure 7. Protection settings (including “Sblocco voltmetrico”)

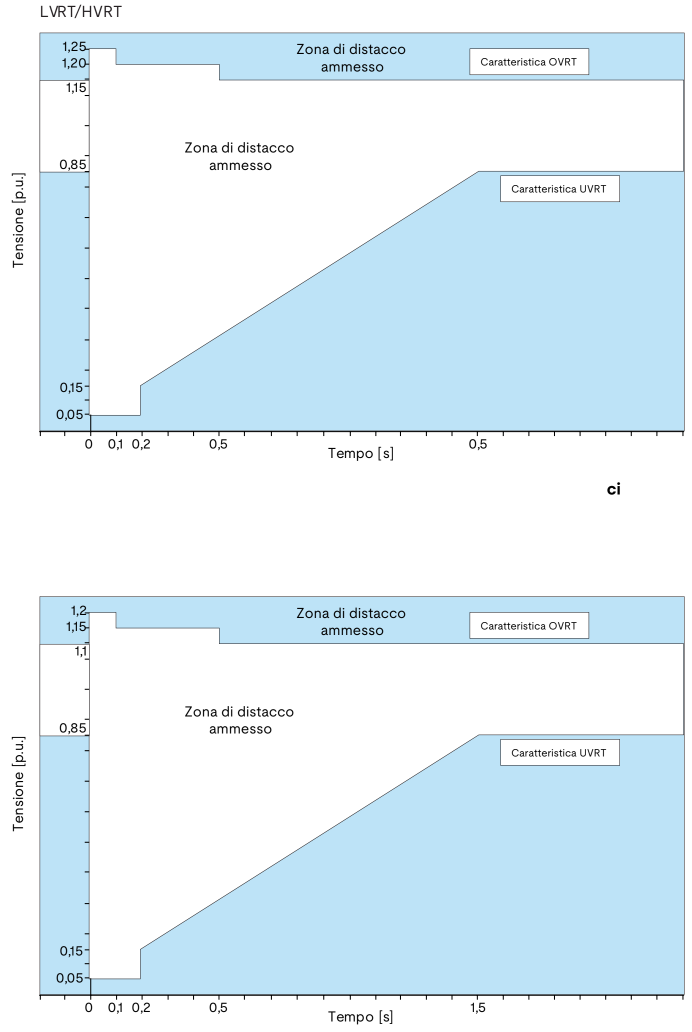

Figure 8. UVRT and OVRT curves for static generators

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PPC - Power Plant Controller

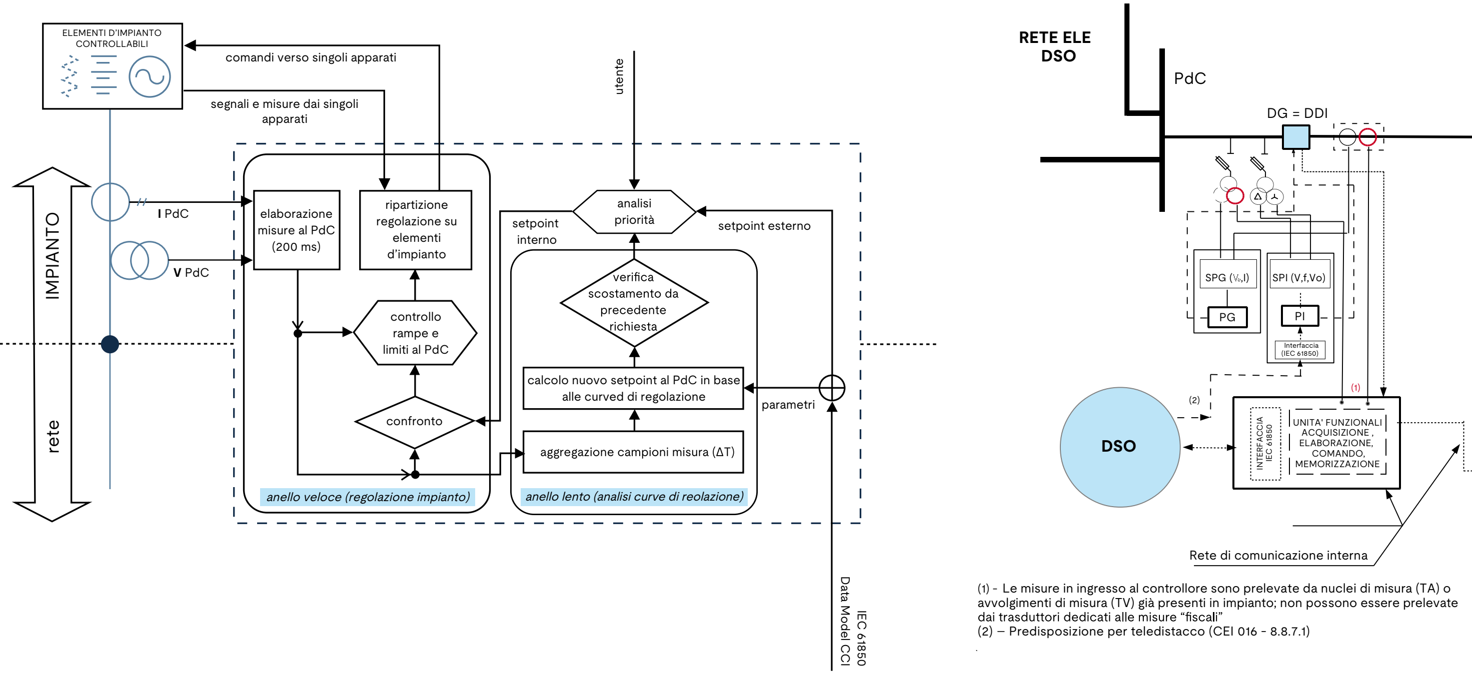

Figure 9. PPC - Power Plant Controller

Reactive /Active power regulation

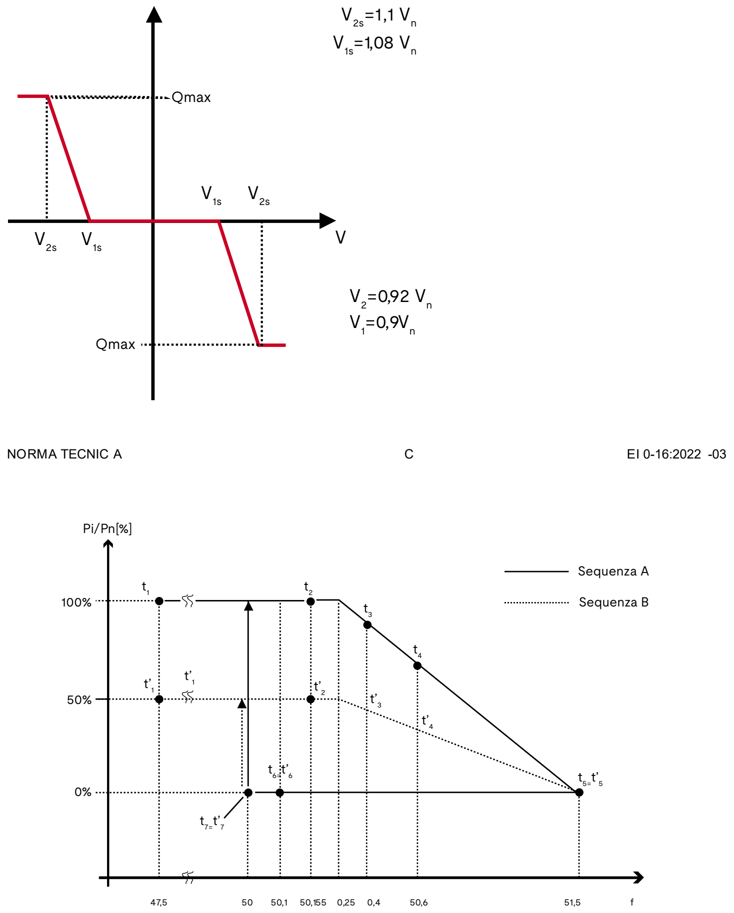

Figure 10. Reactive / Active power regulation

These data reflect the 2024 version of this standard. For more updated versions, contact us or refer to the standard document.

		Inverter PV	Eolici FC P≤100 kW (+ ORC, IDRO, ...)	Eolici FC P>100 kW (+ ORC, IDRO, ...)	Eolici DFIG
N.3	**Misure per la qualità della tensione**	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove in campo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove in campo (simul. rete, gr. elettrogeno, rete pubblica)
N.4	**Campo di funzionamento in tensione e frequenza**	(potenza piena o ridotta) - prove su banco di prova	(potenza piena o ridotta) - prove su banco di prova	(potenza piena o ridotta) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno)	(potenza piena o ridotta) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno)(154)
N.5	**Condizioni di sincronizzazione e presa di carico**	(potenza piena o ridotta) - prove su banco di prova - prove sul controllo e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche) - prove in impianto su rete pubblica con simulazione delle misure di tensione e frequenza o modifica dei parametri di controllo	(potenza piena o ridotta) - prove su banco di prova - prove sul controllo e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche) - prove in impianto su rete pubblica con simulazione delle misure di tensione e frequenza o modifica dei parametri di controllo	(potenza piena o ridotta) - prove su banco di prova - prove sul controllo e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche) - prove in impianto su rete pubblica con simulazione delle misure di tensione e frequenza o modifica dei parametri di controllo	(potenza piena o ridotta) - prove su banco di prova - prove sul controllo e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche) - prove in impianto su rete pubblica con simulazione delle misure di tensione e frequenza o modifica dei parametri di controllo
N.6	**Requisiti costruttivi circa lo scambio di potenza reattiva**	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica) - prove sul controllo, limitatamente a N.6.3 e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche)	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica) - prove sul controllo, limitatamente a N.6.3, e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche)	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica) - prove sul controllo, limitatamente a N.6.3, e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche)

Table 1. List of test required for the different units

These examples are elaborated based on the mentioned Country standards in Italian. For the details, contact us or refer to the standard document.

		Inverter PV	Eolici FC P≤100 kW (+ ORC, IDRO, ...)	Eolici FC P>100 kW (+ ORC, IDRO, ...)	Eolici DFIG
.7.1	**Requisiti costruttivi circa la regolazione di potenza attiva: Verifica della limitazione della potenza attiva in logica locale, per tensioni prossime al 110%Vn**	(piena potenza o senza potenza) - prove su banco di prova - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica con simulazione della misura di tensione o modifica dei parametri di controllo) - prove sul controllo (senza potenza)	(piena potenza o senza potenza) - prove su banco di prova - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica con simulazione della misura di tensione o modifica dei parametri di controllo) - prove sul controllo (senza potenza)	(piena potenza o senza potenza) - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica con simulazione della misura di tensione o modifica dei parametri di controllo) - prove sul controllo (senza potenza) e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche, con potenza almeno pari al 50% di Pn)	(piena potenza o senza potenza) - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica con simulazione della misura di tensione o modifica dei parametri di controllo) - prove sul controllo (senza potenza) e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche, con potenza almeno pari al 50% di Pn)
N.7.2	**Requisiti costruttivi circa la regolazione di potenza attiva: Verifica della riduzione automatica della potenza attiva in presenza di transitori di sovrafrequenza sulla rete**	(piena potenza o senza potenza) - prove su banco di prova - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica con simulazione della misura di frequenza o modifica dei parametri di controllo) - prove sul controllo (senza potenza)	(piena potenza o senza potenza) - prove su banco di prova - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica con simulazione della misura di frequenza o modifica dei parametri di controllo) - prove sul controllo (senza potenza)	(piena potenza o senza potenza) - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica con simulazione della misura di frequenza o modifica dei parametri di controllo) - prove sul controllo (senza potenza) e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche, con potenza almeno pari al 50% di Pn)	(piena potenza o senza potenza) - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica con simulazione della misura di frequenza o modifica dei parametri di controllo) - prove sul controllo (senza potenza) e verifica della capacità del sistema di seguire il controllo (caratteristiche statiche e dinamiche, con potenza almeno pari al 50% di Pn)

		Inverter PV	Eolici FC P≤100 kW (+ ORC, IDRO, ...)	Eolici FC P>100 kW (+ ORC, IDRO, ...)	Eolici DFIG
N.7.4	**Requisiti costruttivi circa la regolazione di potenza attiva: Verifica della limitazione della potenza attiva su comando esterno proveniente dal e DSO**	(piena potenza) - prove su banco di prova - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove su banco di prova - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove in campo, agendo sul controllo (simul. rete, gr. elettrogeno, rete pubblica)
N.8	**Insensibilità agli abbassamenti di tensione (VFRT capability)**	(piena potenza) - prove su banco di prova - prove in campo, con rete di impedenze (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove su banco di prova - prove in campo, con rete di impedenze (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove su banco di prova - prove in campo, con rete di impedenze (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove su banco di prova - prove in campo, con rete di impedenze (simul. rete, gr. elettrogeno, rete pubblica)
N.9	**Insensibilità alle richiusure automatiche in discordanza di fase**	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica)	(piena potenza) - prove su banco di prova - prove in campo (simul. rete, gr. elettrogeno, rete pubblica)	

These examples are elaborated based on the mentioned Country standards in Italian. For the details, contact us or refer to the standard document.

Poland

Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters...)
PTPiREE – EqC V1.2	Certification guideline	From low to high voltage	> 800W	Components, units	Photovoltaic, wind, synchronous generator, storage converter
PSE – RoGA 2018-12	Grid code requirements	From low to high voltage	> 800W		

Protection type	Protection name	Default settings	Protection scheme logics
Voltage	Defined by grid operator	Defined by grid operator	NA
Frequency	ROCOF and Frequency ranges acc. EqC chapter 9	NA	NA
Power	See EqC chapter 6, 7 and 9	NA	NA
HVRT/LVRT	See EqC chapter 6 or 7	NA	NA

Metering and control	Requirements
Measurement accuracy and scheme	NA
Frequency regulation	ROCOF and Frequency ranges acc. to EqC chapter 9
Voltage regulation	See EqC chapter 6 or 7
Islanding	See EqC chapter 6 or 7
Power quality	Not required
Plant controler	See EqC chapter 6 or 7
Interoperability	NA

Certification Process	Requirements	
Simulation/model validation	Yes, model validation acc. to grid codes based on RfG 631/2016 e.g. FGW TG4 (Germany) is accepted	
Testing	Samples	1 per certification family
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Test plan • Testing • PGU certification
Certification	Documentation required	Datasheet of the unit, test report, manufacturer declaration
	Upload to local database	Yes, PGU certificates must be approved by PTPiREE
	Update if engineering changes/validity time	5 years
Inspection	Not needed	

These data reflect the 2024 version of this standard. For more updated versions, contact us or refer to the standard document.

Table 2 - Equipment certificates for power park modules (PPM)

PPM						
1	2	3	4	5	6	7
Requirement	Tests	Simulation	Type A	Type B	Type C	Type D
LFSM-O	B, C, D	B, C, D	Certificate hardware *	Certificate hardware	Certificate Component	Certificate Component
LFSM-U	C, D	C, D	-	-	Certificate Component	Certificate Component
FSM	C, D	C, D	-	-	Not applicable	Not applicable
Restoration regulation frequency	C, D	-	-	-	Not applicable	Not applicable
Adjustable active power	C, D	-	-	-	Not applicable	Not applicable
Regulation mode voltage	C, D	-	-	-	Not applicable	Not applicable
Power regulation mode passive	C, D	-	-	-	Not applicable	Not applicable
Regulation mode power factor	C, D	-	-	-	Not applicable	Not applicable
Introduction fast current short circuit	-	B, C, D	-	Certificate hardware	Certificate hardware	Certificate hardware
FRT	-	B, C, D	-	Certificate hardware	Certificate hardware	Certificate hardware
Post-fault restoration of power active	-	B, C, D	-	Certificate hardware	Certificate hardware	Certificate hardware
Island work	-	C, D	-	-	Not applicable	Not applicable
The ability to generate reactive power	C, D	C, D	-	-	Not applicable	Not applicable

Table 3 - Equipment certificates for synchronous power generating modules (SY PGM)

SY PGM						
1	2	3	4	5	6	7
Requirement	Tests compliance	Simulations compliance	Type A	Type B	Type C	Type D
LFSM-O	B, C, D	B, C, D	Certificate hardware *	Certificate hardware	Not applicable	Not applicable
LFSM-U	C, D	C, D	-	-	Not applicable	Not applicable
FSM	C, D	C, D	-	-	Not applicable	Not applicable
Control frequency reconstruction	C, D	-	-	-	Not applicable	Not applicable
Ability to boot autonomous	C, D	-	-	-	Not applicable	Not applicable
Ability to work for one's own needs	C, D	-	-	-	Not applicable	Not applicable
Ability to generation reactive power,	C, D	C, D	-	Certificate hardware *	Certificate hardware **	Certificate hardware **
FRT	-	B, C, D	-	Certificate hardware	Certificate hardware	Certificate hardware
Post-fault recovery active power	-	B, C, D	-	Not applicable	Not applicable	Not applicable
Capacity down work island	-	C, D	-	-	Not applicable	Not applicable
Damping power oscillations	-	D	-	-	-	Not applicable

1	2	3	4	5
Requirement	Type A	Type B	Type C	Type D
Required range frequency (Art. 1 lit. and)	Certificate Component	Certificate Component	Certificate Component	Certificate Component
The speed of change df / dt frequencies (Art.13 (1) (b)	Certificate Component	Certificate Component	Certificate Component	Certificate Component

These data reflect the 2024 version of this standard. For more updated versions, contact us or refer to the standard document.

France

The latest version of the standard was published in June 2020: “Arrêté du 9 juin 2020 relatif aux prescriptions techniques de conception et de fonctionnement pour le raccordement aux réseaux d’électricité. 4 août 2020.” This version adapts the requirements of version from April 23, 2008, (Arrêté du 23 avril 2008) with some of the following changes:

- LVRT – Voltage depth is higher and reactive current injection is required in the new standard.
- Operation field – Some parameters change from the previous version.
- Reconnection – Some parameters change from the previous version

Belgium

Belgium is a primary target in the global renewable market. The latest version of the standard was published in March 2021:
“Amendment C10/11 ed.2.2 of 15 March 2021: Technical prescription C10/11 of Synergrid, edition 2.2. Specific technical prescription regarding power generating plants operating in parallel to the distribution network.”
It adapts the requirements in version 2.1 from September 2019 to the 631 European requirements published in 2016:

- “COMMISSION REGULATION (EU) 2016/631 of 14 April 2016, establishing a network code on requirements for grid connection of generators.”

United Kingdom

The United Kingdom (U.K.) has been upgrading its grid code since the European regulation 2016/631 was published. Engineering Recommendation G99 Issue 1 – Amendment 8, 1st September 2021, “Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019,” published in September 2021, is the latest version, superseding Amendment 6, from March 2020, and Amendment 7, from August 2021. Updates include: Amendment 8 adapts the requirements to the publication from 2021 of Amendment 7 with some modifications over the previous amendment.

Also, the requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public Low Voltage Distribution Networks on or after April 27, 2019, were updated in September 2021 in G98 Issue 1 – Amendment 6.

Portugal

COMMISSION REGULATION (EU) 2016/631, Published April 14, 2016, was replaced with the latest version of the standard, published in March 2020: “Portaria nº73/2020 de 16 de marco. Requisitos nao exaustivos para ligacao dos módulos geradores a Rede Eletrica de Servico Publico (RESP).”

This new version adapts the specific requirements to the publication from 2016 of COMMISSION REGULATION (EU) 2016/631 of the “COMMISSION REGULATION (EU) 2016/631 of 14 April 2016, establishing a network code on requirements for grid connection of generators.”

Netherlands

Due to its proximity to the German Grid, manufacturers often question whether requirements for Netherlands are the same VDE requirements for Germany and the connection to its grid. Today, Netherlands is a common market for inverter manufacturers who test and certify their products with the other central Europe Country requirements.

Based on the European regulation “COMMISSION REGULATION (EU) 2016/631 of 14 April 2016,” and with many similarities with the “EN 50549-1 & -2; Requirements for generating plants to be connected in parallel with distribution networks,” Netbeheer Nederland published the update of “Power-Generating Modules compliance verification: Power-Generating Modules type B, C and D according to NC RfG and Netcode elektriciteit version: 1.2.1” in July 2020. This update defines the deviations and parametrization for the country and the connection to its grid, with references to the German testing protocol FGW TG3-2018 Rv. 25.

Romania

Although it is still a small market compared with other European Countries, Romania is on track to become a greener country in the next decade, exceeding the target of 30.7% for renewable energy by 2030. In recent years, the latest version of the standard was published in December 2018: “ORDIN 208: Technical norm on technical connection requirements for electrical networks of public interest for generating modules, central modules consisting of generators and plants consisting of offshore generating modules (located in the wider).” This replaced COMMISSION REGULATION (EU) 2016/631 from April 14, 2016. The current version adapts the specific requirements to the publication from 2016 of COMMISSION REGULATION (EU) 2016/631 of the “COMMISSION REGULATION (EU) 2016/631 of 14 April 2016, establishing a network code on requirements for grid connection of generators.”

Austria

The latest version of the standard was published in April 2022: “TOR Erzeuger: Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs A, B, C & D. Version 1.2” adapting the requirements to the publication also from 2019 of version V1.0.

Czech Republic

The latest version of the standard, replacing the Priloha-4-May 2016, was published in December 2020:

“Priloha-4-Dec 2020: rules for the parallel operation of production plants and storage facilities with the grid of the distribution system operator” adapts the requirements to the publication from 2016 of Priloha-4-May 2016 of the “rules for the parallel operation of resources with the distribution system operator’s network.”

Greece

Due to its geography, renewable energy has a primary role in Greece. The country has been a target for the global renewables market more than 10 years with a breach between wind and solar energy that has been reduced within the last five years, as both technologies have very similar installed power as of the end of 2021.

Adapting their regulation to the European, COMMISSION REGULATION (EU) 2016/631 of the “COMMISSION REGULATION (EU) 2016/631 of 14 April 2016, establishing a network code on requirements for grid connection of generators,” Greece updated its grid code as follows:

- Network Code “Requirements for Generators” (RfG); A Public Consultation Document for the integration of the Regulation (EU) 631/2016 in the Hellenic Grid Code; from INDEPENDENT POWER TRANSMISSION OPERATOR. July 2019
- ΕΦΗΜΕΡΙΔΑ ΤΗΣ ΚΥΒΕΡΝΗΣΕΩΣ; ΤΗΣ ΕΛΛΗΝΙΚΗΣ ΔΗΜΟΚΡΑΤΙΑΣ

ΑΠΟΦΑΣΕΙΣ Αριθμ. απόφ. 1165/2020 (Regulation number 1165/2020 from Sept. 7, 2020)

Bosnia

Bosnia and Herzegovina, in the middle of the Adriatic Countries, is a key country for interconnection in the area. The Law on Transmission of Electric Power, Regulator and System Operator in Bosnia and Herzegovina has been pushing to integrate renewable energies into the generation mix on the country, with the intention to increase the presence of solar (3% in 2021) and wind (7% in 2021), which are almost null together with the actual Hydro (90% in 2021).

In 2019, the country published a grid code, "Mrezni-Kodeks-2019," adapting the specific requirements to the publication from 2016 of COMMISSION REGULATION (EU) 2016/631 of the "COMMISSION REGULATION (EU) 2016/631 of 14 April 2016, establishing a network code on requirements for grid connection of generators."

Slovenia

Slovenia, connecting Austria and Italy with the Adriatic Countries, has been pushing to integrate renewable energies, particularly solar and wind. Both were almost null at the end of 2019 into the generation mix on the country, with the intention to achieve their 27% target by 2030.

The Country has two published documents, one for the transmission system ("ESLOVENIA_2011-01-1982; SYSTEM OPERATING INSTRUCTIONS For the electricity transmission system of the Republic of Slovenia") and the other for the Distribution system ("ESLOVENIA_2016-01-1194; SYSTEM OPERATING INSTRUCTIONS For the distribution network of electricity"). The documents adapt the specific requirements to the publication from 2016 of COMMISSION REGULATION (EU) 2016/631 of the "COMMISSION REGULATION (EU) 2016/631 of 14 April 2016, establishing a network code on requirements for grid connection of generators."

Finland

The European policy is helping the evolution of renewable energies in Finland, and the country is upgrading its grid code.

In February 2020, FINGRID published the "Grid Code Specifications for Grid Energy Storage Systems," which defines the particular deviations and parametrization for country and the connection to its grid. This works together with the "Power quality in Fingrid's 110 kV grid," which was published back in 2015 to control the grid quality of the new power plants.

The Grid Code Specifications for Grid Energy Storage Systems defines the specific regulation for power plants divided in four types as indicated in the (EU) 2016/631, depending on the power and voltage in the grid connection point.

Sweden

The European policy is helping the evolution of renewable energies in Sweden, as well. The document, "Energimarknadsinspektionens författningssamling," published in February 2018, defines the particular deviations and parametrization for this country and the connection to its grid, defining specific regulation for power plants divided in 4 types depending on the power and voltage in the grid connection point.

Ireland

EirGrid and ESB Networks are working on the generation of technical requirements in accordance with the articles 13-28 of the commission Regulation (EU) 2016/631, establishing a network code on requirements for grid connection of generators from Dec. 20, 2017. The latest version of the standard, "EirGrid Grid Code Version 10," was published in May 2021 and adapts the requirements to the publication from 2020 of version 9 with some of the following changes:

- Correction of RfG Derogation Process Form References
- Correction of Voltage Graphs110kV 220kV Systems Transmission
- Meteorological Signal Requirements
- Battery ESPS Grid Code Implementation Note; Version 3.0 – December 2021

Denmark

Denmark has been pushing to integrate renewable energies and storage into the generation mix since the update of the European regulation in 2016.

The country published the document, "TECHNICALREGULATION 3.3.1 FOR ELECTRICAL ENERGY STORAGE FACILITIES," effective from Dec. 18, 2019, adapting the specific requirements to the publication from 2016 of COMMISSION REGULATION (EU) 2016/631 of the "COMMISSION REGULATION (EU) 2016/631 of 14 April 2016, establishing a network code on requirements for grid connection of generators."

Northern Ireland

North Ireland, has a different grid code than the United Kingdom, has become a target country for the global renewable market and has also adapted their requirements to the European regulation 631.

The actual grid code is a deviation from the ENA-EREC G99 called:
Engineering Recommendation G99/NI: Issue 1 April 2019; Requirements for the connection of generation equipment in parallel with public distribution networks in Northern Ireland on or after April 27, 2019, with a revision scheduled on Q2-2024

The standard itself is a deviation of the G99 with a parametrization according to the requirements of the grid operator in North Ireland.

There is also a version for the G98 adapted to North Ireland:

Engineering Recommendation G98/NI Issue 1 April 2019 Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16A per phase) in parallel with public Low Voltage Distribution Networks in Northern Ireland on or after April 27, 2019, with a revision scheduled on Q2-2024.

Grid codes in North America

North America does not have a regulation similar to Europe. Rather, each country, state and province have a grid code developed with the local utility. However, most utilities recognize the unit certification accordingly to UL 1741SB, supplement B of the Standard for Inverters, Converters and Controllers for Use In Independent Power Systems, which is based on IEEE 1547 (2018) and IEEE 1547.1 (2020) technical reference and includes interoperability requirements from the unit to the utility (SunSpec Modbus, DNP 3, IEEE 2030.5).

The U.S. has about 3,300 electric utilities and many have different interconnection requirements.

Multiple U.S. utilities participate in the UL 1741 Standard development and most require UL 1741 certifications. In Ontario, Canada, utilities request CSA C22.3 No. 9, but UL 1741 is also accepted in Canada. Some jurisdictions prefer an alternative testing path from UL 1741SA + Source Requirement Documents (SRDs).

UL 1741 is the Standard for safety for inverters, converters, controllers and interconnection system equipment for use with distributed energy resources (DER). Supplement A and Supplement B include grid code performance and interoperability requirements.

United States

- UL 1741 is the UL horizontal gateway Standard for grid interconnection certifications.
- All UL Standards with generation functionality make use of UL 1741 for grid interconnection requirements.
- UL 1741 is recognized/required by most North American electric utilities as the certification standard for grid interactive inverters and generators.
- The U.S. has about 3,300 electric utilities and many have different interconnection requirements.
- Multiple U.S. utilities participate in the UL 1741 Standard development and most require UL 1741 certifications.

Standard	Description	Voltage level	Power rating range	Objective (component, unit, system)	Type of generator (photovoltaic, wind, synchronous generator, storage converters…)
IEEE 1547-2018 (UL1741 SB)	Grid code requirements	Low voltage / Medium voltage	Different requirements for ranges < 500kVA, 500-1500kVA, > 1500kVA. No power limits.	Components, units	Photovoltaic solar, wind, synchronous generators, energy storage converter, grid feeding protection
IEEE 1547.1-2020 (UL 1741 SB)	Test requirements				

Protection type	Protection name	Default settings	Protection scheme logics
Voltage	UV 1, UV 2, OV 1, OV 2	120% Un – 0.16s, 110% Un – 13s, 88% Un – 21s, 50% Un – 2s	NA
Frequency	UF 1, UF 2, OF 1, OF 2	62Hz – 0.16s, 61.2Hz – 300s, 58.5Hz – 300s, 56.5Hz – 0.16s	NA
Power	NA	NA	NA
HVRT/LVRT	Yes	NA	NA

Metering and control	Requirements
Measurement accuracy and scheme	Voltage, RMS (± 1% Vnom) | Frequency (10 mHz)Active Power/ Reactive Power (± 5% Srated) | Time 1% of measured duration
Frequency regulation	See chapter 5.5 Test for response to frequency disturbances
Voltage regulation	See chapter 5.4 Test for response to voltage disturbances
Islanding	Protection against islanding required
Power quality	Harmonics, DC Injection, Synchronization, Interconnection integrity (EMI)
Plant controler	Optional
Interoperability	Yes. IEEE 2030.5, SunSpec Modbus, DNP3

Certification Process	Requirements	
Simulation/model validation	Not allowed	
Testing	Samples	1 per certification family
	Location (on site / lab)	UL Solutions or client facilities
	Power required	Some tests at full power
	Main phases	• Test plan • Testing • Certification
Certification	Documentation required	Datasheet of the unit, test report
	Upload to local database	ProductIQ (QIKH, QIKP, QIIP)
	Update if engineering changes/validity time	Yes. Pending review of changes
Inspection	Quaterly follow up inspection of the certified product at manufacturer location	

These data reflect the 2024 version of this standard. For more updated versions, contact us or refer to the standard document.

North America

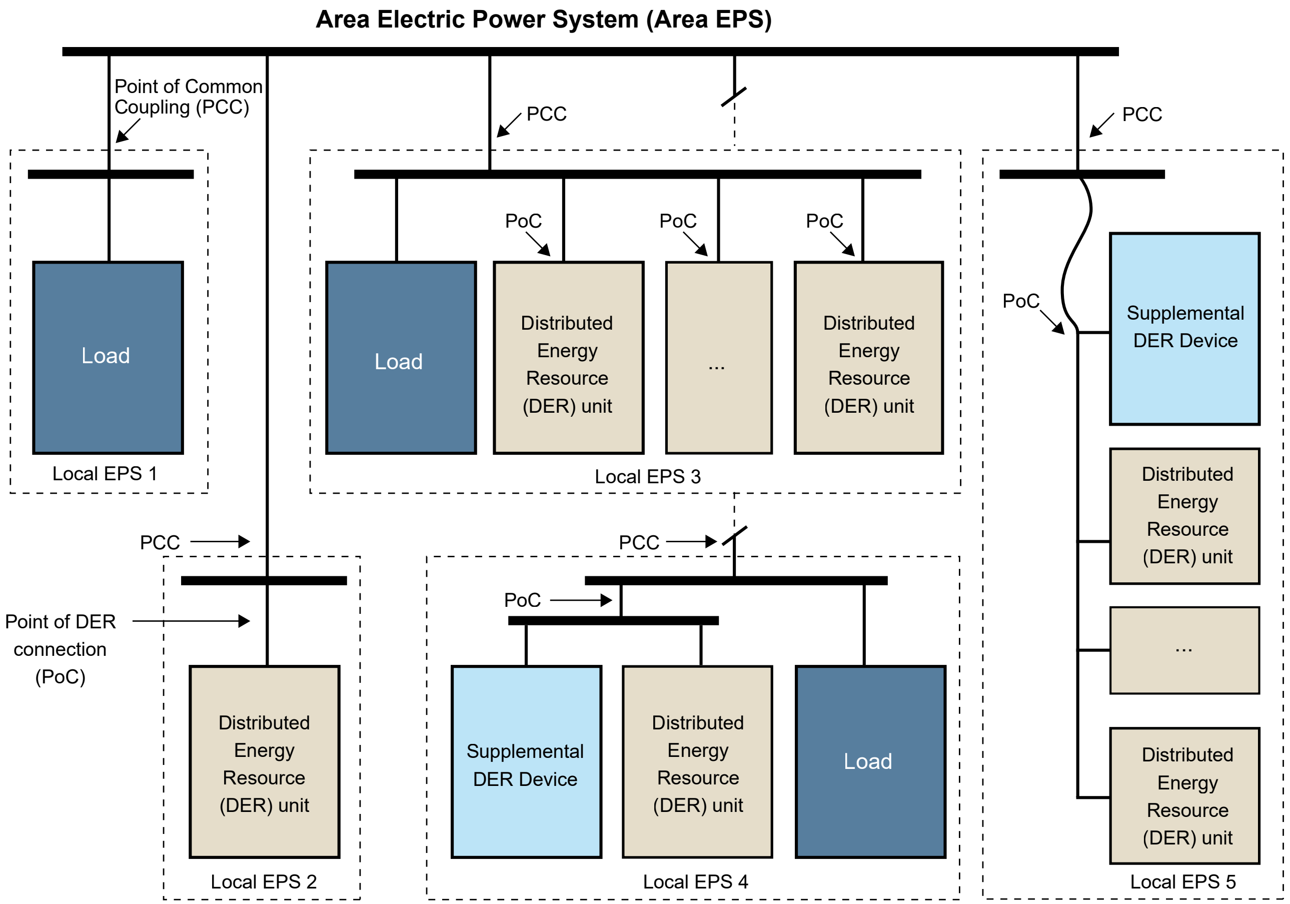

Figure 11. Definition of the area electric power system

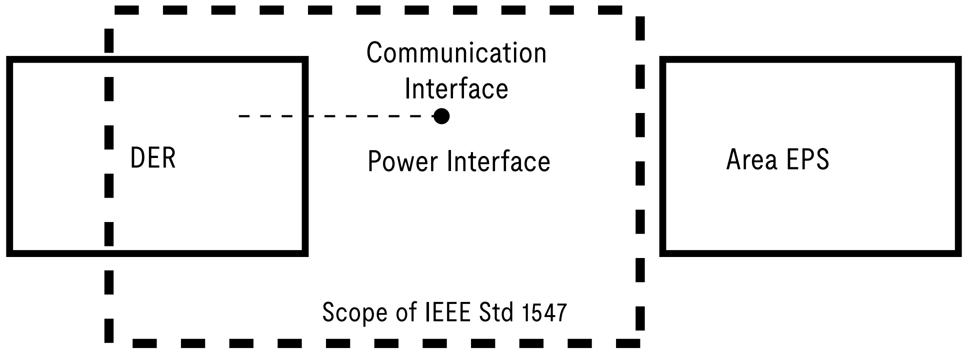

Figure 12. Scope of IEEE 1547

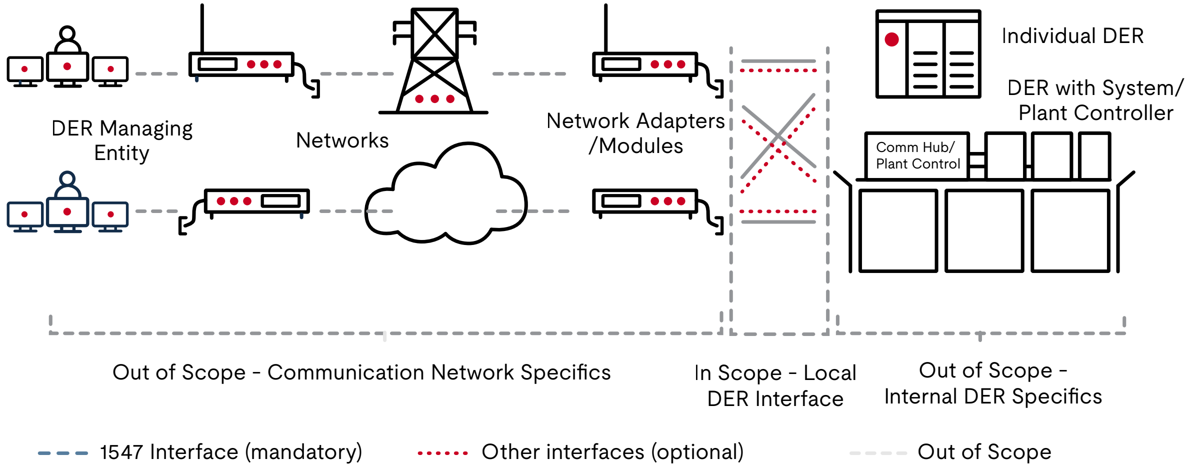

Figure 13. Interoperability requirements

These examples are elaborated based on the mentioned Country standards. For the details, contact us or refer to the standard document.

Working with UL Solutions for GCC

At UL Solutions, we connect manufacturers of energy equipment and developers of power plants with comprehensive grid code compliance services that address a wide range of standards, generating units and systems, including:

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- Bidirectional EV chargers
- CHP generators
- Mini-hydroelectric generators
- Synchronous generators
- Power plant controllers
- Solar power parks
- Wind installations
- Energy storage applications
- Microgrids
- Distributed energy resources (DER) systems

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