European Network of
Transmission System Operators
for Electricity

entsoe

Instrumentation, simulation models and protection

ENTSO-E guidance document for national implementation for network codes on grid connection

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DESCRIPTION

Code(s) & Article(s)	Network Codes (NCs) Requirements for Generators (RfG), Demand Connection Code (DCC) and High Voltage Direct Current (HVDC). All articles with non exhaustive requirements for which a national choice is requested for instrumentation, simulation models and protection (see tables per code below)
Introduction	For each NC, provide the precise list of the non-exhaustive instrumentation, simulation models and protection parameters which will need a national choice. When possible, the most challenging existing value of the parameter, as a general guidance has been provided. These parameters will provide a reference to what has been shown to be achievable so that system operators can contextualise their proposals i.e. are their functional requirements asking ofr something new from the industry. Instrumentation, simulation models and protection parameters collectively provide a framework that ensures that a number of other requirements will function correctly. However the instrumentation, simulation models and protection parameters will be different for different types of grid users (generators, DR) and the network (HVDC converters). Instrumentation parameters are required in the context of the Connection Network Codes to ensure the capability to provide the necessary signals back to the systems operators, notably the control room. These are required to be able to evaluate the performance of the user's plant and equipment to meet other requirements in the codes. Protection scheme parameters are required in the context of the Connection Network Codes to ensure that user's protection does not detrimentally interact with other requirements in the code and with the system operators own protection schemes. Simulation model parameters are required to ensure adequate modelling by the system operator (and as applicable users) to ensure that the requirements are met where they cannot be physically tested through compliance testing and/or in order that the system operator can model the users influence on the system. The modelling of users influence on the system will be used in both operation and planning of the network. This will allow both functional capability parameters to be set at the time of connection, and in an operational timeframe to define the settings that should be applied.
NC frame	These non-exhaustive topics are those for which the European level Connection Network Codes do not contain all the information or

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	parameters necessary to apply the requirements immediately. These requirements are typically described in the Connection Network Codes as "TSO / relevant system operator shall define" or "defined by / determined by / in coordination with the TSO / relevant TSO". For instrumentation, simulation models and protection parameters the need to co-ordinate parameters vary on the impact of the parameter. Ideally parameters do not vary from country to country, and in some cases must not vary. For instrumentation and protection however most of these parameters will be specific to national operational practices and are highly likely to be site specific. Simulation models parameters are likely to be national, but given the need to model adjacent networks for many types of planning and operational analysis these should be cognizant of the needs of other system operators. Therefore although a model maybe site specific the basic performance characteristics (i.e. the mechanical and electrical systems, exciters, control actions, valves, limiters) that the model will represent, and the format the model should be provide in (i.e. software language, block diagram, International Electro-technical Committee (IEC) standard models, or datasheets) should be specified with the wider use of the simulation model in mind. See tables below.
Further info	IGD Real Time Monitoring Redundancy

INTERDEPENDENCIES

Between the CNCs	As instrumentation, simulation models and protection are forms of support requirements to ensure that other requirements are met; there is a shared need across the connection codes. The main source of interaction is in ensuring that these parameters do not inadvertently impact on the ability of other users requirements to meet their intended purpose. For example Rate Of Change Of Frequency (ROCOF) protection specified at the TSO/DSO interface could unnecessarily disconnect generators embedded in the Distribution System Operator (DSO) network from the transmission network for lower ROCOF than the generator has been designed to be able to withstand. Similarly simulation models need to be specified such that they not only allow their requirements to be modelled for compliancy purposes, but also are adequate to model their influence on the network as part of providing parameters to other types of users' connections. As each type of user, generator, demand and HVDC circuits have many similar requirements all the codes have some instrumentation, simulation models and protection response requirements.

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In other NCs	There are many links nationally to the implementation of the codes applying the connection capabilities in both system and market operation (System Operation Committee and Market Committee topics). In some cases these topics will be at a national level and contained in combined documents (e.g. broader content Grid Codes). Furthermore consistency needs to be maintained in these cases, i.e. it needs to be ensured that national connection code instrumentation, simulation models and protection capabilities are actually defined before the settings need to be applied. Notable the guideline on system operation in Article 24 'Availability of TSO's means, tools and facilities' sets out the requirements which will need to be made available for system operation and which will inform many of the capabilities required for users plant and equipment in the connection codes. These cover control, monitoring and communication requirements and these are elaborated in: ➢ Chapter 3 : Data exchange between TSOs and DSOs within the TSO's control area ➢ Chapter 4 : Data exchange between TSOs, owners of interconnectors or other lines and power generating modules connected to the transmission system ➢ Chapter 5 : Data exchange between TSOs, DSOs and distribution connected power generating modules ➢ Chapter 6 : Data exchange between TSOs and demand facilities
System characteristics	The suitability of the types of instrumentation, modelling and protection schemes are highly dependent on the operational approach and issues arising from the design and function of the network. Simple load flow models are frequently required across Europe, but more detailed models for example Electro-Magnetic Transient modelling are much more infrequently required. The need for these will be dependent very much on local conditions and therefore the requirement placed on users to provide these models will vary. The need for complex studies is often driven by the susceptibility of the network to resonance. Therefore smaller weaker networks or areas of networks are more likely to require detailed models. The less damped the network and hence prone to oscillate, the higher the detail of model that can reasonably be expected. Frequency scans of the network and calculated dampening coefficients can be a simple and quick way of screening the needs for more detailed models. Instrumentation is in general closely aligned to system operation. System operation in turn can be linked to many requirements, but are mainly defined by: • the necessary information to operate the market (e.g. directional

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	MWs); • the parameters that are vital to safely and securely operate the network (e.g. Amps, vars, phasor measurement and switched in/out), and; • the information to accurately assess the performance of the network to improve operation and practice (e.g. system recorders). As each system operator may influence the operation of another within a synchronous area there must be appropriate collaboration within a synchronous area.
Technology characteristics	Instrumentation, simulation models and protection response capabilities, and withstand capabilities requirements will vary between technologies. Instrumentation, modelling and protection are all likely to have common basic functional requirements. This is commonly achieved in modern equipment through standardized component protection, instrumentation devices and model blocks. These are then bespoke in their combination and settings to match the needs of the users' site and installed technology.
COLLABORATION	
TSO – TSO	Instrumentation, simulation models and protection non-exhaustive requirements will require limited co-ordination between TSOs to ensure their adequacy, protection co-ordination and modelling capability is insured, typically at the synchronous system level.
TSO – DSO	Instrumentation, simulation models and protection non-exhaustive requirements will require co-ordination between the TSO and DSO to ensure their function, protection co-ordination and modelling capability is insured to meet the functional requirements in the Connection Network Codes. These will be identifed in the associated tables.
Regional System Operator (RSO) – Grid User	Instrumentation, simulation models and protection non-exhaustive requirements will require co-ordination between the RSO and end user to ensure their function protection co-ordination and modelling capability is insured to meet the functional requirements in the Connection Network Codes. These will be identifed in the associated tables. The RSO should be aware of users' desire to avoid embedded plant having to interface with more than one network operator system. Users prefer single connection covering all network operator needs with the DSO passing on signals to the TSO and hence taking care of equipment compatibility, grouping and configuration.

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Table 1 – RfG Non-Exhaustive Requirements

Non-Exhaustive Requirement	Non-Mandatory Requirement	Article	Applicability	Parameters to be defined	Definition
CONTROL SCHEME AND SETTINGS		14.5.a	B, C, D	control schemes and settings of the control devices	agreement and coordination between the TSO, the RSO (TSO and DSO) and the Power Generating Facility Owner (PGFO)
ELECTRICAL PROTECTION SCHEMES AND SETTINGS		14.5.b	B, C, D	protection schemes and settings	agreement and coordination between the RSO and the PGFO
INFORMATION EXCHANGES		14.5.d	B, C, D	content of information exchanges and precise list and time of data to be facilitated.	RSO (DSO or TSO) or TSO
MANUAL, LOCAL MEASURES WHERE THE AUTOMATIC REMOTE DEVICES ARE OUT OF SERVICE		15.2.b	C, D	Time period and tolerance requested to reach the set point in cases where the automatic remote control devices are out of service	RSO (DSO or TSO) or TSO
LOSS OF ANGULAR STABILITY OR LOSS OF CONTROL		15.6.a	C, D	criteria to detect loss of angular stability or loss of control	agreement between the PGFO and the RSO (DSO or TSO), in coordination with the TSO.
INSTRUMENTATION	**X**	15.6.b.(i)	C, D	Definition of the quality of supply parameters	RSO
		15.6.b.(ii)	C, D	Settings of the fault recording equipment, including triggering criteria and the sampling rates	agreement between the PGFO and the RSO (DSO or TSO), in coordination with the TSO.
		15.6.b.(iii)	C, D	Specifications of the oscillation trigger detecting poorly damped power oscillations	RSO in coordination with the TSO
		15.6.b.(iv)	C, D	Protocols for recorded data.	agreement between the PGFO, the RSO and the relevant TSO
SIMULATION MODELS	**X**	15.6.c.(iii)		Specifications of the simulation models	RSO in coordination with the TSO

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Non-Exhaustive Requirement	Non-Mandatory Requirement	Article	Applicability	Parameters to be defined	Definition
INSTALLATION OF DEVICES FOR SYSTEM OPERATIONS AND SYSTEM SECURITY	**X**	15.6.d	C, D	Definition of the devices needed for system operation and system security	RSO or TSO and PGFO
NEUTRAL-POINT AT THE NETWORK SIDE OF STEP-UP TRANSFORMERS		15.6.f	C, D	Specifications of the earthing arrangement of the neutral-point at the network side of step-up transformers	RSO
AUTOMATIC DISCONNECTION	**X**	16.2.c	D	Definition of the threshold for automatic disconnection	RSO in coordination with the TSO
				Definition of the parameters	agreement between the RSO and the PGFO
SYNCHRONISATION		16.4	D	Settings of the synchronisation devices	agreement between the RSO and the PGFO
ANGULAR STABILITY UNDER FAULT CONDITIONS		19.3	Synchronous	Agreement for technical capabilities of the power generating module to aid angular stability.	agreement between the TSO and the PGFO
SYNTHETIC INERTIA CAPABILITY FOR POWER PARK MODEUL (PPM)	**X**	21.2	PPM: C, D	- Definition of the operating principle of control systems to provide synthetic inertia and the related performance parameters	TSO

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Table 2 – DCC Non-Exhaustive Requirements

Non-Exhaustive Requirement	Non-Mandatory Requirement	Article	Applicability	Parameters to be defined	Definition
ELECTRICAL PROTECTION SCHEMES AND SETTINGS		16.1	Transmission connected Demand Facility (DF) and Transmission connected DSO	protection schemes and settings	agreement between TSO and Transmission Connected (TC) DSO or TC DF
CONTROL REQUIREMENTS		17.1	Transmission connected DF and Transmission connected DSO	schemes and settings of the control devices	agreement between TSO and TC DSO or TC DF
INFORMATION EXCHANGES		18.1	Transmission connected DF and Transmission connected DSO	definition of the standards to exchange information and time stamping	TSO
		18.2	Transmission connected DF and Transmission connected DSO	definition of the standards to exchange information and time stamping	TSO
		18.3	Transmission connected DF and Transmission connected DSO	Make information exchange standards publically available	TSO
SIMULATION MODELS	**X**	21.3	Transmission connected DF, distribution systems and DF above 1000V providing Demand Response (DR)	Content and format of the simulation models or equivalent information	TSO
	X	21.5	Transmission connected DF, distribution systems and DF above 1000V providing DR	Definition of the requirements for the recordings to be compared with the response of the model.	RSO or TSO

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Table 3 – HVDC Non-Exhaustive Requirements

Non-Exhaustive Requirement	Non-Mandatory Requirement	Article	Applicability	Parameters to be defined	Definition
INTERACTION BETWEEN HVDC SYSTEMS AND OTHER PLANTS/EQUIPMENTS		29.2	HVDC Converter Station	Specify study required to examine interaction with adjacent equipment	TSO
		29.3	HVDC Converter Station	Specify all other relevant parties to the study	TSO
		29.4	TSO	Models/information for use in studies	Interacting 3rd Parties
		29.6	HVDC System	Specify transient levels of performance	TSO
NETWORK CHARACTERISTICS		32.1	HVDC System	Method and pre-fault and post fault conditions for minimum and maximum short circuit power	TSO
HVDC SYSTEM ROBUSTNESS		33.1	HVDC System	Specify changes in system conditions for HVDC system to remain stable	TSO
ELECTRICAL PROTECTION SCHEMES AND SETTINGS		34.1	HVDC System	Specify schemes and settings	TSO with RSO
		34.3	HVDC System	Acceptance of changes by owner to protection	TSO
		35.1	HVDC System	Control modes and parameters for a control scheme	Agreement with RSO, TSO and HVDC System Owner
	X	35.2	HVDC System	Change to priority order of protection and control	TSO
CHANGES TO PROTECTION AND CONTROL SCHEMES AND SETTINGS	**X**	36.1	HVDC System	Changes to control modes or protections settings	TSO
	X	36.2	HVDC System	Coordination of changes and agreement	Agreement with RSO, TSO and HVDC System Owner
CHANGES TO PROTECTION AND CONTROL SCHEMES AND SETTINGS	**X**	36.3	HVDC System	Equipment specification to enable remote control of control modes and setpoints	TSO
SYNCHRONIZATION		41.1	DC connected Power Park Modules	Provide limits (including transient max. magnitude, duration and measurement window) of any voltage change to a steady-state level (>5% pre-synchronisation voltage)	RSO in coordination with TSO
OUTPUT SIGNALS		41.2	DC connected Power Park Modules	Specify required output signals	RSO in coordination with TSO
METHOD OF PRE-FAULT AND POST-FAULT CONDITIONS		42.(a)	DC connected Power Park Modules	Method and pre-fault and post fault conditions for minimum and maximum short circuit power	RSO in coordination with TSO
EQUIVALENTS REPRESENTING THE COLLECTION GRID		42.(c)	DC connected Power Park Modules	Provide network equivalent for harmonic studies	RSO in coordination with TSO

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ELECTRICAL PROTECTION SCHEMES		43.1	DC connected Power Park Modules	Provide protection requirements	RSO in coordination with TSO
SCOPE		38	DC connected Power Park Modules	Non-exhaustive requirements of Articles 11 to 22 of the Network Code RfG will apply	-
SCOPE		46	Remote-end HVDC converter stations	Non-exhaustive requirements of Articles 11 to 39 will apply	-

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