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Specifications for the Operational Performance of Power Generating Facilities VJV2013

Contents

1 Introduction

This document contains the Specifications for the Operational Performance of Power Generating Facilities (hereinafter referred to as “Specifications”) required by Fingrid Oyj (hereinafter referred to as “Fingrid”), by virtue of the system responsibility imposed on Fingrid, of Power Generating Facilities connected to the Finnish Power System. In addition to these Specifications, Power Generating Facilities shall fulfil Fingrid’s General Connection Terms (YLE) valid at the time of connection and the data exchange principles specified in the main grid contract.

The Specifications are based on the Nordic Grid Code. With respect to the power quality, the design of the Power Generating Facility shall take into account the factors affecting the power quality described in the report “Power quality in Fingrid’s 110 kV grid”. The report is available on Fingrid’s website.

The purpose of the Specifications for the Operational Performance of Power Generating Facilities is to ensure that:

- the Power Generating Facility withstands the voltage and frequency fluctuations occurring in the Power System,
- the Power Generating Facility supports the operation of the Power System during disturbance situations, and works reliably during and after such situations,
- while synchronised to the Power System, the Power Generating Facility does not cause any inconvenience to the other installations connected to the Power System, and
- the Relevant Network Operator and Fingrid obtains the data on the Power Generating Facility, necessary in the planning of the Power System and its operation and in the maintaining of system security.

The requirements set out in chapters 3–10 concern both Synchronous Power Generating Modules and Wind Power Park Modules. The requirements set out in chapters 11–15 only concern those power generating facilities that have Synchronous Generators Connected directly to the grid. The requirements set out in chapters 16–20 only concern such Wind Power Park Modules where the electric power generated by the generators is supplied into the Power System partly or completely through a power converter. This document does not present specifications for the operational performance of other types of Power Generating Facilities. If other types of Power Generating Facilities are to be connected to the Power System, Fingrid will determine their requirements separately.

2 Terms and definitions

Active Power: Real component of the Apparent power; unit MW.

Apparent Power: Product of voltage and current at fundamental frequency; unit MVA.

Automatic Voltage Regulator (AVR): An Automatic Voltage Regulator controls either the Terminal Voltage of Generator or the voltage of the VJV Reference Point.

Black Start Capability: The ability of a Power Generating Facility to start electricity generation by means of its own power source, without any external power supply from the electricity network.

Branch Connection: A line or substation connected to a transmission line either directly or by means of a switching device.

Compliance Testing: Compliance Testing related to the Specifications for the Operational Performance of Power Generating Facilities.

Connection Agreement: An agreement between the Power Generating Facility Owner and the Relevant Network Operator, specifying the terms and conditions for connecting the Power Generating Facility to Relevant Network Operator's network.

Connection Point: Ownership limit as specified in the Connection Agreement.

Control Mode: Various modes of control of a Power Generating Facility, such as constant Active Power control, Frequency Control, constant Reactive Power control, or constant voltage control.

Droop: Relative change of Active Power generated by a Power Generating Facility in relation to the frequency change.

Frequency Control: A Power Generating Facility controls its Active Power generation in relation to the frequency of the Power System defined by a specified Droop. In this way, the Power Generating Facility supports the maintenance of frequency stability in the Power System.

House Load: Apparent Power consumed by the house load equipment of a Power Generating Facility. House load equipment covers those Power Generating Facility equipment and machines that are needed at the Power Generating Facility to generate electricity or heat and electricity, to maintain the capability for generation, and to eliminate or reduce the adverse environmental impacts of the facility.

Minimum Output (P_{min}): The Minimum Output of a Power Generating Facility is the smallest possible Active Power production level of the Power Generating Facility measured at the VJV Reference Point, at which power the Power Generating Facility can operate continuously without a time limit.

Mode: See Control Mode.

Normal Operating Voltage: The voltage at the VJV Reference Point as specified by the Relevant Network Operator (voltage corresponding to 100% value). Expressed as a per unit value, the Normal Operating Voltage is 1.0 p.u.

Numerical: Data is indicated digitally as numbers in a computer-readable and modifiable format; for example a measurement time series in Compliance Testing.

Overexcitation Limiter: A limiter of AVR, intended to prevent the overexcitation of the generator and generator transformer by limiting the excitation current.

Power Class 1: The Rated Capacity of a Power Class 1 Power Generating Facility is at least 0.5 MW but less than 10 MW.

Power Class 2: The Rated Capacity of a Power Class 2 Power Generating Facility is at least 10 MW but less than 25 MW.

Power Class 3: The Rated Capacity of a Power Class 3 Power Generating Facility is at least 25 MW but less than 100 MW.

Power Class 4: The Rated Capacity of a Power Class 4 Power Generating Facility is at least 100 MW. Moreover, Power Class 4 covers those Power Generating Facilities with a Maximum Capacity of at least 10 MW which are connected in Lapland to the network located beyond the Isoniemi and Kokkosniva feeder bays of the Valajaskoski and Pirttikoski 220 kV substations.

Power Generating Facility: A unit built for power generation, capable of supplying electric power to the VJV Reference Point. A Power Generating Facility is built around one or more Turbine Generators and includes, depending on the form of power generation, the equipment and systems required for the production of energy, the Power Generating Facility level control and automation system, the internal electricity network of the Power Generating Facility, the generator, step-up and house load transformers, and other auxiliary equipment of the Power Generating Facility.

Power Park Module: A Power Generating Facility where the electric power generated by the Power Generating Facility is supplied into the Power System partly or completely through a power converter.

Power Generating Facility Owner: A party whose Power Generating Facility is connected to the Power System.

Production Power: Active Power production generated by a Power Generating Facility at a specific time.

PSS: Power system stabiliser. An additional function of an AVR, aiming to improve the damping of low-frequency power oscillations with regard to local facility-level oscillation and inter-area oscillation of the Power System.

p.u.: per unit value. A variable is compared to a predetermined base value.

Rated Capacity (P_{max}): The Rated Capacity of a Power Generating Facility is the highest Active Power production level of the Power Generating Facility measured at the VJV

Reference Point, at which power the Power Generating Facility can operate continuously without a time limit.

Reactive Power: Imaginary component of the Apparent Power; unit Mvar.

Reactive Power Capacity: The highest measured Reactive Power (measured at the synchronous generator terminals or at the VJV Reference Point of a Wind Power Park Module), which the Power Generating Facility can continuously generate or consume without a time limit. The Reactive Power Capacity depends on the Active Power generation level.

Reserve Gas Turbine: A Power Generating Facility which is only used during disturbances in the Power System and for restoring the Power System to the normal state after disturbances as well as for the management of power balance in the Power System in situations where all commercially available resources have been used.

Reserve Power Generating Facility: A Power Generating Facility which is designed to operate only during exceptional or disturbance situations of the Power System or in island operation. Reserve Power Generating Facilities shall fulfil the Specifications if they are synchronised occasionally to the Power System, for example during test operation.

Slope: The relative change of Reactive Power generated by a Power Generating Facility in relation to the voltage change.

Specifications: Specifications for the Operational Performance of Power Generating Facilities VJV2013.

Step-up Transformer: A transformer between the busbar and Connection Point of a Wind Power Park Module, through which transformer the power generated by the Wind Power Park Module is supplied into the Power System.

Synchronous Power Generating Module: A Power Generating Facility with one or more synchronous generators and where the synchronous generators operate at the synchronous speed of the Power System when the generators are connected to the Power System.

Terminal Voltage: The Terminal Voltage is the voltage of the generator busbar.

Terminal Voltage of Generator: See Terminal Voltage.

Turbine Generator: A combination of turbine and generator that converts the kinetic energy of the medium flowing through the turbine into electrical energy.

Underexcitation Limiter (UEL): A limiter of AVR in a synchronous generator, intended to maintain a sufficient generator excitation current so that synchronous operation is maintained.

VJV Reference Point: A point in the Power System defined according to the Specification by the Relevant Network Operator, at which point the Specifications shall be fulfilled.

Wind Power Park Module: A Power Generating Facility with one or more Wind Turbine Generators.

Wind Turbine Generator: A Power Generating Facility which converts the kinetic energy of wind into electrical energy.

YLE: Fingrid Oyj's General Connection Terms.

3 Scope

These Specifications shall apply to those Power Generating Facilities connected or to be connected to the Finnish Power System where the Rated Capacity of the Power Generating Facility is at least 0.5 MW. The Specifications differ on the basis of the form of power generation, Rated Capacity of the Power Generating Facility, and its geographical location.

The Specifications are applied to new Power Generating Facilities to be connected to the Power System, but they shall apply to existing Power Generating Facilities when their technical characteristics are changed. The change shall be agreed with Fingrid in accordance with section 5.2.

It is the responsibility of the Power Generating Facility Owner to fulfil and maintain the Specifications that were in force when the Connection Agreement for the Power Generating Facility was concluded. The Specifications shall be fulfilled at the VJV Reference Point or at a point defined by a specific requirement.

The Specifications do not apply to Reserve Power Generating Facilities unless they are synchronised to the Power System. Reserve Power Generating Facilities shall fulfil the Specifications if they are synchronised occasionally to the Power System, for example during test operation.

The Specifications are bound to specific power classes on the basis of the Rated Capacity. The power classes applied in this document are presented in Table 3.1.

Table 3.1. Power classes of Power Generating Facilities on the basis of Rated Capacity and geographical location.

Power class	Rated Capacity P_{max} of Power Generating Facility
Power Class 1	The Rated Capacity of the Power Generating Facility is at least 0.5 MW but less than 10 MW. ($0.5\ MW \leq P_{max} < 10\ MW$)
Power Class 2	The Rated Capacity of the Power Generating Facility is at least 10 MW but less than 25 MW. ($10\ MW \leq P_{max} < 25\ MW$)
Power Class 3	The Rated Capacity of the Power Generating Facility is at least 25 MW but less than 100 MW. ($25\ MW \leq P_{max} < 100\ MW$)
Power Class 4	1) The Rated Capacity of the Power Generating Facility is at least 100 MW ($P_{max} \geq 100\ MW$), or 2) The Rated Capacity of the Power Generating Facility is at least 10 MW and the Power Generating Facility is connected in Lapland to the network located beyond the Isoniemi and Kokkosniva feeder bays of the Valajaskoski and Pirttikoski 220 kV substations.

4 Specific study requirements

The Power Generating Facility Owner shall request from Fingrid the assessment of a need for a specific study during the preliminary planning stage of the Power Generating Facility if the Power Generating Facility is of Power Class 2, 3 or 4. Fingrid assesses the need for a specific study with regard to at least the following issues: subsynchronous interaction, geomagnetically induced currents, and low short circuit ratio.

If the technical execution of a Power Generating Facility connection requires specific studies, the Power Generating Facility Owner shall conduct the studies in co-operation with Fingrid and the Relevant Network Operator no later than in the planning stage of the Power Generating Facility grid connection. The Power Generating Facility Owner is responsible for executing and co-ordinating the specific studies.

If the specific studies indicate that the connection of the Power Generating Facility requires specific measures in order to ensure technical feasibility of the Power Generating Facility, the measures are treated as equivalent to the Specifications, and the Power Generating Facility Owner is responsible for their execution.

5 Compliance monitoring process of the Specifications, continuous monitoring, and related responsibilities

This chapter defines the compliance monitoring process of the Specifications for all Synchronous Power Generating Modules and Wind Power Park Modules as well as continuous monitoring of whether the Power Generating Facility meets the requirements that were in force at the time when the Connection Agreement was concluded. Moreover, this chapter defines the responsibilities, obligations and rights of the Power Generating Facility Owner, Relevant Network Operator and Fingrid during the compliance monitoring process and continuous monitoring. The details of the responsibilities, obligations and rights for specific requirements are recorded in chapters 6–20 of this document.

5.1 Responsibilities, obligations and rights during the compliance monitoring process and continuous monitoring

5.1.1 Responsibilities, obligations and rights of the Power Generating Facility Owner and the Relevant Network Operator

The Power Generating Facility Owner is responsible for the compliance monitoring process and fulfilment of the Specifications as well as for the associated costs. It is the responsibility of the Power Generating Facility Owner to fulfil and maintain the specifications that were in force when the Connection Agreement for the Power Generating Facility was concluded.

The Relevant Network Operator shall determine the VJV Reference Point of the Power Generating Facility project in accordance with the Specifications.

The Relevant Network Operator has a right specify additional requirements if they are needed because of an electricity network located close to the Power Generating Facility. Potential conflicts between the Specifications and the additional requirements specified by the Relevant Network Operator shall be resolved between Fingrid and the Relevant Network Operator.

The Relevant Network Operator shall verify the data supplied by the Power Generating Facility Owner. The Relevant Network Operator shall supervise the compliance monitoring process of the Specifications during the Power Generating Facility project, and take care of the data exchange required by the process with the Power Generating Facility Owner and Fingrid.

The Power Generating Facility Owner shall maintain the operation of the Power Generating Facility in accordance with the Specifications also after the accepted execution of the compliance monitoring process of the Specifications. If the Power Generating Facility Owner discovers that the operation of the Power Generating Facility is in conflict with the Specifications, the Power Generating Facility Owner shall inform the Relevant Network Operator and Fingrid of this without delay, and take the necessary measures to eliminate the conflict.

The Relevant Network Operator shall inform the Power Generating Facility Owner and Fingrid without delay if the Relevant Network Operator discovers at any stage of the Power Generating Facility project or during the normal operation of the Power Generating Facility that the Power Generating Facility deviates from the Specifications.

5.1.2 Fingrid's responsibilities, obligations and rights

The responsibilities, obligations and rights of the Relevant Network Operator apply to Fingrid when the Power Generating Facility is connected to Fingrid's grid.

If Fingrid receives information or discovers that the Power Generating Facility deviates from the Specifications at any stage of the Power Generating Facility project or during the normal operation of the Power Generating Facility, Fingrid may require additional clarifications and measures to correct the deviation. If the shortcomings in the operation of the Power Generating Facility related to the Specifications influence the operation of the Power System, Fingrid, as the transmission system operator, has the right to restrict the operation of the Power Generating Facility and to impose conditions related to the operation of the Power Generating Facility. Fingrid has the right to keep the restrictions imposed in force until the shortcomings detected in the operation of the Power Generating Facility have been corrected and the capability of the Power Generating Facility to fulfil the Specifications has been verified.

Fingrid's representative has the right to participate in the Compliance Testing when the Power Generating Facility is connected to the electricity network of a third party.

5.2 Amendment of Power Generating Facility technical characteristics

If changes are made to a Power Generating Facility which is in operation or to the equipment or systems influencing its technical characteristics, the Power Generating Facility Owner shall, before making the changes, inform the Relevant Network Operator and Fingrid of the changes and of their impact on the capability of the Power Generating Facility to fulfil the Specifications.

It is Fingrid's responsibility to evaluate and set new requirements to the equipment or systems being changed, in accordance with the Specifications for the Operational Performance of Power Generating Facilities valid at the time of the change.

The measures related to the fulfilment of the Specifications shall be successfully performed within 12 months from the date on which the executing of changes to the existing equipment started. If the change project requires a longer execution period, Fingrid can extend the execution period at the Power Generating Facility Owner's justified request.

5.3 Power Generating Facility projects progressing in stages

The Power Generating Facility Owner shall take into account the trend in the generation capacity of the Power Generating Facility during the various stages of the project, and the final Rated Capacity of the Power Generating Facility. With Power Generating Facility projects progressing in stages, the Specifications are determined on the basis of the final Rated Capacity of the Power Generating Facility.

It is the Power Generating Facility Owner's responsibility to verify that the Power Generating Facility fulfils the Specifications when one or both of the following conditions are met:

1) the Rated Capacity of the Power Generating Facility exceeds the power limit related to the Specifications, shown in table 3.1,

2) the structure or functionalities of the Power Generating Facility change in a way which affects the technical characteristics and functionalities of the Power Generating Facility.

5.4 Stages and schedule of the compliance monitoring process of Specifications

5.4.1 Compliance monitoring process of Specifications for Power Generating Facilities of Power Class 1

The Power Generating Facility Owner shall perform Compliance Testing to verify that the Power Generating Facility operates in accordance with the Specifications, and provide the Relevant Network Operator with data conforming to the Specifications after the Compliance Testing.

Once the Power Generating Facility Owner has carried out the measures required by the compliance monitoring of the Specifications, the Relevant Network Operator shall review the data delivered by the Power Generating Facility Owner and give a statement of the compliance monitoring of the Specifications. After the giving of a supporting statement, the Relevant Network Operator shall deliver the data conforming to the Specifications to Fingrid. If the Relevant Network Operator gives a declining statement, the statement with grounds shall be presented to the Power Generating Facility Owner.

The documentation and delivery of Power Generating Facility data is specified in chapter 6. The compliance monitoring of the Specifications by means of Compliance Testing is specified in chapters 14 and 19. The measurements and data exchange are specified in chapter 8.

The measures related to the compliance monitoring of the Specifications shall be successfully completed no later than 12 months from the date on which the Power Generating Facility supplied Active Power to the Power System for the first time.

5.4.2 Compliance monitoring process of Specifications for Power Generating Facilities of Power Classes 2, 3 and 4

The compliance monitoring process of the Specifications for Power Generating Facilities of Power Classes 2, 3 and 4 is carried out in stages. The compliance monitoring process has four stages in accordance with Table 5.1.

Table 5.1. Compliance monitoring process and schedule requirements of the Specifications for Power Classes 2, 3 and 4.

Process stage	Schedule requirement
Stage 1: Delivery of general Power Generating Facility data, determination of VJV Reference Point, and handling of potential derogations	As soon as possible but no later than after the selection of the supplier of the main components of the Power Generating Facility.
Stage 2: Delivery of project-specific Power Generating Facility data and Compliance Testing Planning	No later than 3 months prior to the start of the Compliance Testing related to the Specifications.
Stage 3: Accepted execution of Compliance Testing, and documentation of Compliance Testing	The Compliance Testing shall be performed in an accepted manner within 9 months from the date on which the Power Generating Facility supplied Active Power to the Power System for the first time.
Stage 4: Acceptance of the compliance monitoring process of the Specifications	The data required by the acceptance of the compliance monitoring process shall be submitted within 3 months after the Compliance Testing related to the Specifications.
	The measures related to the compliance monitoring of the Specifications shall be completed successfully no later than 12 months from the date on which the Power Generating Facility supplied Active Power to the Power System for the first time.

The Power Generating Facility Owner shall carry out the measures conforming to the Specifications in stages in accordance with the compliance monitoring process. Once the Power Generating Facility Owner has carried out the measures conforming to the Specifications in each stage in the required scope, the Relevant Network Operator shall verify the data supplied and confirm the execution of the required measures in each stage. The Relevant Network Operator shall supervise the compliance monitoring process of the Specifications, including the Compliance Testing, during the Power Generating Facility project, and take care of the data exchange required by the process with the Power Generating Facility Owner and Fingrid. The Relevant Network Operator shall deliver the data conforming to the Specifications to Fingrid after the confirmation of each stage of the process.

Once the Power Generating Facility Owner has carried out all the measures required by the compliance monitoring of the Specifications, the Relevant Network Operator shall review the data delivered by the Power Generating Facility Owner and give a statement of the compliance monitoring of the Specifications. After the giving of a supporting statement, the Relevant Network Operator shall deliver to Fingrid the data on stage 4 in accordance with the compliance monitoring process. If the Relevant Network Operator gives a declining statement, the statement with grounds shall be presented to the Power Generating Facility Owner.

The documentation and delivery of Power Generating Facility data is specified in chapter 6. The compliance monitoring of the Specifications by means of Compliance Testing is specified in chapters 14 and 19. The measurements and data exchange are specified in

chapter 8. The tables for the follow-up and documentation of the process stages are presented in Appendix A.

6 Documentation and delivery of Power Generating Facility data

6.1 Data on Power Generating Facilities of Power Class 1

The data specified in Table 6.1 shall be delivered on Power Generating Facilities of Power Class 1. The Power Generating Facility Owner shall submit this Power Generating Facility data to the Relevant Network Operator as electronic documents after the Compliance Testing. The data to be submitted shall be clear and unambiguous in terms of its layout and structure. The Relevant Network Operator shall deliver the data to Fingrid.

Table 6.1. Data to be delivered on Power Generating Facilities of Power Class 1.

1	Structure and location of Power Generating Facility
1.1	Single line diagram
1.2	Structure
	Type of Power Generating Facility (e.g. wind power, solar power, biomass, gasification)
	Basic data (e.g. on Wind Power Park Module: tower height, rotor diameter, converter operation etc.)
1.3	Location data (municipality, area, Connection Point, coordinates)
2	Technical details of Power Generating Facility transformer(s):
2.1	Number of transformers influencing the Reactive Power capacity of the Power Generating Facility
2.2	Design values of Power Generating Facility transformers
	Power [MVA]
	Current [A]
	Transformer ratio [primary/secondary]
	Control range and control step of off-load tap changer or on-load tap changer [%,%]
	Number of steps and selected step of off-load tap changer or on-load tap changer [quantity, status data]
3	Technical details of Power Generating Facility:
3.1	Number of generator units
3.2	Supplier(s) of generator units
3.3	Type(s) of generator units
3.4	Design values of generator units
	Power (apparent) [MVA]
	Rated Capacity [MW]
	Current [A]
	Voltage [V]
	Frequency [Hz]
	Electric parameters of Synchronous Power Generating Modules (resistances, reactances, etc.), see Table 6.5
3.5	Dependence of Production Power on the operating conditions (e.g. wind velocity, temperature)
3.6	Potentially used compensation devices and/or devices used for the correction of power factor
	Type(s)
	Number(s)
	Design values (power, current, voltage, frequency)
	If used for the filtering of harmonics, data on the structure and tuning frequency
4	Power Generating Facility operational characteristics:
	The following items may be replaced for example by the manufacturer's device documents, testing documentation or other testing documentation
4.1	Description of Reactive Power generation capacity, and PQ diagrams of generators
4.2	Description of the ability of the Power Generating Facility to operate at undervoltage and overvoltage
4.3	Description of the ability of the Power Generating Facility to operate at underfrequency and overfrequency
4.4	Description of the ability of the Power Generating Facility to operate during voltage disturbances
4.5	Description of the supply of fault current of the Power Generating Facility during voltage disturbance
4.6	Description of potential control features of the Power Generating Facility
4.7	Description of the impact of the Power Generating Facility on the power quality
5	Protection details of the Power Generating Facility:
5.1	Relay protection diagram of the Power Generating Facility
5.2	Final relay protection settings of the Power Generating Facility
5.3	Description of the operating principle of island protection
6	Commissioning documents:
6.1	Commissioning records
6.2	Final set values and Mode of Reactive Power control

6.2 Data on Power Generating Facilities of Power Classes 2, 3 and 4

6.2.1 Delivery and schedule of Power Generating Facility data

The Power Generating Facility Owner shall deliver Power Generating Facility data on Power Generating Facilities of Power Classes 2, 3 and 4 to the Relevant Network

Operator in accordance with the compliance monitoring process of the Specifications of the Power Generating Facility, specified in section 5.4.2:

1) The data specified in Table 6.2 shall be delivered in stage 1 of the compliance monitoring process. Moreover, the data specified in Table 6.5 shall be delivered on Synchronous Power Generating Modules.

2) The data specified in Table 6.3 shall be delivered in stage 2 of the compliance monitoring process.

3) The data specified in Table 6.4 shall be delivered in stage 4 of the compliance monitoring process.

The Power Generating Facility Owner shall submit this Power Generating Facility data to the Relevant Network Operator as electronic documents after the compliance monitoring process of the Power Generating Facility. The data to be submitted shall be clear and unambiguous in terms of its layout and structure. The Relevant Network Operator shall deliver the data to Fingrid.

6.2.2 Data to be provided

The data to be delivered on Power Generating Facilities of Power Classes 2, 3 and 4 is presented in Tables 6.2, 6.3 and 6.4. Table 6.5 specifies the additional data to be delivered on Synchronous Power Generating Modules. With some of the data to be delivered, the tables make reference to the chapters of this document where the topic and the data to be delivered have been elaborated.

Table 6.2. Data to be delivered on Power Generating Facilities of Power Classes 2, 3 and 4 as soon as possible but no later than after the selection of the supplier of the main components of the Power Generating Facility (Stage 1).

1	Data to be delivered in stage 1 of the compliance monitoring process of the Specifications	
1.1	Basic data, structure and location of Power Generating Facility	
1.1.1	Single line diagram	
		The main components of the Power Generating Facility and the electricity network that connects the components
		Electric parameters of the components and conductors presented in the single line diagram
1.1.2	Structure	
		Type of Power Generating Facility or Turbine Generators (e.g. wind power, hydropower, condensing power)
		Basic data (e.g. on Wind Power Park Module: tower height, rotor diameter, full-converter etc.)
1.1.3	Location data (municipality, area, Connection Point, coordinates)	
1.2	Reactive Power capacity of the Power Generating Facility	
1.2.1	Reactive Power capacity calculation (section **12.2.3** or **17.2.3**)	
1.2.2	PQ diagrams of generators	
		PQ diagrams of generators and data on their voltage-frequency dependence
1.2.3	Other components influencing Reactive Power (section **17.2.2**)	
		Components that generate (e.g. STATCOM) and consume Reactive Power, and their operation as a function of the variables (e.g. voltage, Active Power) influencing the components
1.3	Technical details to be delivered of the Power Generating Facility and generators	
	The data shall be delivered about the Power Generating Facility as a whole and separately about each individual generator	
1.3.1	General data	
		Number, supplier and type details of Turbine Generator units
1.3.2	Documentation and data sheets	
		Apparent power [MVA], Rated Capacity [MW], maximum output [MW], Minimum Output [MW], current [A], voltage [V], frequency [Hz]
		General description of the principles of Frequency Control and Active Power control; description of the implementation and functionalities of the control system, or alternatively a detailed description of the Power Generating Facility controllers (chapter **11** or **16**)
		General description of the principles of voltage control and Reactive Power control; description of the implementation and functionalities of the control system, or alternatively a detailed description of the Power Generating Facility controllers (chapter **13** or **18**)
		Start-up times of the Power Generating Facility to Minimum Output and Rated Capacity
1.3.3	Voltage and frequency operating ranges (section **10.2.1**)	
		Description of operation at undervoltage and overvoltage
		Description of operation at underfrequency and overfrequency
1.3.4	Data on the operation of the Power Generating Facility in momentary voltage disturbance (section **10.2, 10.3 or 10.4**)	
		Calculation of the operation of the Power Generating Facility during voltage disturbance, and potential reports of factory testing
		Description of the current injection of the Power Park Module during voltage disturbance
		Description of the power restoration of the Power Generating Facility after voltage disturbance
1.3.5	Description of the operation of the Power Generating Facility in house load operation (section **11.2.6**)	
		Magnitude of House Load of the Power Generating Facility, operating time in house load operation, potential delays in terms of transition to house load operation and synchronisation with the grid, and restrictions in terms of transition to house load operation
1.3.6	Changes in Generation Power	
		Changes in Generation Power in conjunction with frequency and voltage fluctuations
		Dependence of Output Power on the operating conditions (e.g. temperature, wind velocity)
		Operating conditions leading to the shutdown of Generation Power (e.g. limit value of maximum wind velocity)
		Rate of change of Active Power, functionality and constraints of limiters of rate of change
1.4	Data to be submitted on transformers and other Power Generating Facility components	
	The data shall be provided on each transformer influencing Reactive Power capacity and on every other Power Generating Facility component separately. The other components are devices which have an influence on the operation of the Power Generating Facility in terms of the Specifications (e.g. compensating devices, harmonic filters, reserve power feed units etc.).	
1.4.1	General data	
		Number, supplier and type details
1.4.2	Documentation and data sheets of transformers	
		Power [MVA], current [A], transformation ratio [primary, secondary], short-circuit impedance [%], short-circuit resistance [%], vector group and earthing details, control range and step of on- or off-load tap-changer [%, %], number of steps of on- or off-load tap-changer and selected step [quantity, step]
1.4.3	Documentation and data sheets of other components	
		As applicable, the same data as on generators (section 1.3) and transformers (section 1.4) as well as all data that is relevant in terms of the Specifications (e.g. structure, tuning frequency)
1.5	Modelling data	
	General data required for the modelling of the Power Generating Facility, or simulation models in accordance with the Specifications (section **15** or **20**)	
1.6	Specific studies	
	Required specific studies related to the Specifications (chapter **4**)	
1.7	Real-time measurement data	
	Description of the method in which the real-time measurement data is delivered to Fingrid (chapter **8**)	
1.8	Preliminary schedule of Power Generating Facility project	
	Preliminary schedule of the project and the planned timing of the Compliance Testing relating to the Specifications. Potential options for the expansion of the project and known future expansion plans shall also be reported.	

Table 6.3. Data to be delivered on Power Generating Facilities of Power Classes 2, 3 and 4 no later than 3 months prior to the launching of the Compliance Testing related to the Specifications (Stage 2).

2	Data to be delivered in stage 2 of the compliance monitoring process of the Specifications	
2.1	Changes and further specifications	
	Further specifications to the data required in stage 1 of the compliance monitoring process of the Specifications	
2.2	Protection settings of the Power Generating Facility and impact on the power quality	
2.2.1	Protection settings (section **9.1.2)**	
		Preliminary data on the relay protection diagram of the generators and on facility-level relay protection diagram as well as on the primary settings of the protection described. Related data shall be submitted on protection which leads to the disconnection of the generator/facility from the grid and on protection whose functioning leads to a restriction or automatic change of the Active Power, Reactive Power or voltage of the generator/facility.
2.2.2	Description of the impact of the Power Generating Facility/generator on the power quality (section **9.1.3**)	
		Description of the change in the power quality caused by the connection of the Power Generating Facility to the grid, and potential reports of factory testing
2.2.3	Description of the operating principle of potential island protection	
		Operating principles and restrictions when shifting to island operation and when re-synchronising after island operation
2.3	Frequency Control and Active Power control of Power Generating Facility	
2.3.1	Documentation and description (chapter **11** or **16**)	
		Specified documentation, at the transfer function level as applicable (functional, not detailed), concerning the implementation and operating principles of Frequency Control and Active Power control of the Power Generating Facility/generator.
2.3.2	Settings of controllers	
		Preliminary parameters and operating delays set in controllers
2.4	Voltage control and Reactive Power control of Power Generating Facility	
2.4.1	Documentation and description (chapter **13** or **18**)	
		Specified documentation, as applicable at the transfer function level (functional, not detailed), concerning the implementation and operating principles of voltage control and Reactive Power control of the Power Generating Facility/generator.
2.4.2	Settings of controllers	
		Preliminary parameters and operating delays set in controllers
2.5	Data required for dynamic modelling	
		Project-specific data or simulation models required for the dynamic modelling in accordance with the Specifications (chapter **15** or **20**)
2.6	Data related to Compliance Testing	
2.6.1	Commissioning plan (section **14.3.1** or **19.3.1**)	
		The detailed commissioning plan, including the Compliance Testing plan, preliminary commissioning instructions provided by the Power Generating Facility supplier and a description of the practical arrangements of the tests for the compliance monitoring of the Specifications shall be submitted to Fingrid for comments.
2.6.2	Preliminary Compliance Testing schedule (section **14.3.1** or **19.3.1**)	
		Preliminary Compliance Testing schedule; subsequent changes to the preliminary schedule shall be reported to the Relevant Network Operator and to Fingrid.
2.6.3	Measurement arrangements (section **14.3.1** or **19.3.1**)	
		Plan of the execution of measurements for the tests related to the Specifications. Data on both fixed measuring equipment and on measuring equipment only used during the Compliance Testing.

Table 6.4. Data required for the acceptance of the compliance monitoring process shall be submitted no later than 3 months after the Compliance Testing related to the Specifications for Power Generating Facilities of Power Classes 2, 3 and 4 (Stage 4).

3	Data to be delivered in stage 4 of the compliance monitoring process of the Specifications
3.1	Changes and further specifications
	Further specifications to the data required in stages 1 and 2 of the compliance monitoring process of the Specifications
3.2	Results of Compliance Testing
	A commissioning report of the tests related to the Specifications and primary results of the Compliance Testing in Numerical format in accordance with the Specifications (section **14.3.3** or **19.3.3**)
3.3	Verified modelling data
	Validated data required for the modelling of dynamic operation, or simulation models (chapter **15** or **20**)
3.4	Final controller settings
	Final reference values and settings of the controllers of Active Power and frequency as well as Active Power and voltage of the Power Generating Facility/generators
3.5	Final protection settings
	Final reference values and settings of the protection of the Power Generating Facility/generators and of the Power Generating Facility connection

Table 6.5. Data to be delivered on all generators of Synchronous Power Generating Modules of Power Classes 2, 3 and 4 as soon as possible but no later than after the selection of the supplier of the main components of the Power Generating Facility (Stage 1).

1	Rated values	
1.1	Rated voltage U_r	[kV]
1.2	Voltage range	[p.u.]
1.3	Apparent power S_r	[MVA]
1.4	Rated capacity P_{max}	[MW]
1.5	Rated current I_r	[A]
1.6	Rated power factor $\cos \phi_r$	
1.7	Rated speed of rotation n	[1/min]
1.8	Nominal excitation voltage U_e	[V]
1.9	Nominal excitation current I_f	[A]
2	Impedances	
2.1	Stator resistance R	[p.u.]
2.2	Direct-axis synchronous reactance X_d	[p.u.]
2.3	Direct-axis synchronous reactance X_d (saturated)	[p.u.]
2.4	Quadrature-axis synchronous reactance X_q	[p.u.]
2.5	Direct-axis transient reactance X_d'	[p.u.]
2.6	Direct-axis transient reactance X_d' (saturated)	[p.u.]
2.7	Quadrature-axis transient reactance X_q'	[p.u.]
2.8	Direct-axis subtransient reactance X_d''	[p.u.]
2.9	Quadrature-axis subtransient reactance X_q''	[p.u.]
2.10	Stator stray reactance X_l	[p.u.]
2.11	Zero phase-sequence reactance X_0	[p.u.]
2.12	Negative phase-sequence reactance X_2	[p.u.]
3	Time constants	
3.1	DC short-circuit time constant T_a	[s]
3.2	Direct-axis transient open circuit time constant T_{do}'	[s]
3.3	Quadrature-axis transient open circuit time constant T_{qo}'	[s]
3.4	Direct-axis subtransient open circuit time constant T_{do}''	[s]
3.5	Quadrature-axis subtransient open circuit time constant T_{qo}''	[s]
3.6	Direct-axis transient short-circuit time constant T_d'	[s]
3.7	Quadrature-axis transient short-circuit time constant T_q'	[s]
3.8	Direct-axis subtransient short-circuit time constant T_d''	[s]
3.9	Quadrature-axis subtransient short-circuit time constant T_q''	[s]
4	Mechanical parameters	
4.1	Stored energy constant (generator + turbine) H	[s]
4.2	Moment of inertia of generator J_g	[kgm²]
4.3	Moment of inertia of each turbine J_{t1}, J_{t2}, J_{t3},....	[kgm²]
4.4	Moment of inertia of exciter (if available) J_{exc}	[kgm²]
4.5	Spring constants between the above-mentioned turbine generator parts K_{t1_t2} , K_{t2_t3} ,..., K_{tx_g} , K_{g_exc}	[Nm/Rad]

7 Derogations

The Power Generating Facility Owner can deviate from the Specifications if the conditions laid down in chapter are met. The Power Generating Facility Owner shall request the a derogation from the Specifications from Fingrid in writing no later than at the procurement stage of the main components of the Power Generating Facility if a need to deviate from the Specifications emerges at that stage. At the same time, the Power Generating Facility Owner shall forward the information on requesting a deviation to the Relevant Network Operator.

Fingrid may grant a derogation of the Specfications if the following conditions are met:

1) the derogation does not compromise the security of supply of the Power System;

2) the deviation from the Specifications does not restrict the transmission capacity of the Power System;

3) the Power Generating Facility does not cause disturbance to the other parties connected to the Power System;

4) the Power Generating Facility supports the operation of the Power System during disturbances and works reliably during and after such situations;

5) the deviation is technically and commercially justified; and

6) the deviation may be granted in the future in a similar situation impartially and without discriminating any future Power Generating Facility projects.

Fingrid grants the requested derogation, grants it with obligatory additional terms, or rejects it. Fingrid is required to provide information on the decision with justification to the Power Generating Facility Owner and to the Relevant Network Operator no later than within 60 working days from receiving of the request. If Fingrid rejects the requested derogation, the Power Generating Facility cannot be connected to the Finnish Power System.

If the Power Generating Facility Owner requests a derogation when the Power Generating Facility is to be connected to the network of a third party, Fingrid shall hear the Relevant Network Operator when Fingrid makes the decision.

8 Measurements and data exchange during the operation of the Power Generating Facility

8.1 Measurements and data exchange of Power Generating Facilities of Power Class 1

The Power Generating Facility Owner shall deliver the real-time power measurement data on Power Generating Facilities of at least 1 MW to Fingrid. The measurement data can be delivered as a producer-specific sum as far as Power Generating Facilities of Power Class 1 are concerned. The measurements shall be available to Fingrid when the Power Generating Facility begins to supply Active Power to the Power System.

The Relevant Network Operator shall deliver or oblige the Power Generating Facility Owner to deliver to Fingrid the real-time measurement data on Power Generating Facilities connected to the electricity network of the Relevant Network Operator.

On the same day when the Power Generating Facility begins to supply Active Power to the Power System, the Power Generating Facility Owner shall inform both the Relevant Network Operator and Fingrid's Main Grid Control Centre of this. The notification shall be made before the supply of Active Power begins.

8.2 Measurements and data exchange of Power Generating Facilities of Power Class 2 and 3

On the same day when and before the Power Generating Facility begins to supply Active Power to the Power System, the Power Generating Facility Owner shall inform both the Relevant Network Operator and Fingrid's Main Grid Control Centre of this.

The Power Generating Facility Owner shall inform Fingrid and the Relevant Network Operator of the contact information of the operator responsible for the operation of the Power Generating Facility, no later than when the Power Generating Facility begins to supply Active Power to the Finnish Power System. The Power Generating Facility Owner is responsible for ensuring that the responsible operator is available 24 hours a day, 7 days a week.

The data exchange and the data to be delivered on Power Generating Facilities connected to Fingrid's grid are agreed upon in the Main Grid Agreement.

The Relevant Network Operator shall deliver or oblige the Power Generating Facility Owner to deliver to Fingrid the real-time measurement data on Power Generating Facilities connected to the electricity network of the Relevant Network Operator.

The Power Generating Facility Owner shall deliver to Fingrid the real-time Active Power and Reactive Power measurement data, hourly energy measurement data, and status data on switching devices concerning Power Generating Facilities of Power Class 2 and 3. The measurements shall be available to Fingrid when the Power Generating Facility begins to supply Active Power to the Power System.

The operator responsible for the operation of the Power Generating Facility shall change the Mode or set value of Active Power control or Reactive Power control of the Power Generating Facility within 15 minutes, if Fingrid's Main Grid Control Centre requests this.

8.3 Measurements and data exchange of Power Generating Facilities of Power Class 4

Power Generating Facilities of Power Class 4 shall fulfil the same requirements concerning measurements and data exchange as Power Generating Facilities of Power Classes 2 and 3, and they shall be equipped with transient fault and swing recorders. This recording system consisting of transient fault and swing recorders allows the recording of the Power Generating Facility functionality and its controllers during disturbance and change situations in the Power System. The recording system shall meet the following requirements:

1) The sampling and recording frequency of the disturbance recorder shall be high (1 kHz or greater). The recording period shall be a few seconds.

2) The sampling frequency of the swing recorder shall be high (1 kHz) and the recording frequency can be low (50 Hz or higher). The recording period shall be a few dozen seconds.

3) The recording systems shall be implemented in such a way that Fingrid has access to the system records no later than within 24 hours from Fingrid's request to the Power Generating Facility Owner.

4) The triggering values of the recording systems with regard to variables related to the VJV Reference Point shall be set in co-operation with Fingrid.

9 VJV Reference Point, Protection, Power quality and Black Start Capability

9.1 Power Generating Facilities of Power Class 1

9.1.1 VJV Reference Point

With Power Generating Facilities of Power Class 1, the VJV Reference Point is at the electric point corresponding to the high-voltage side of an individual generator transformer. The VJV Reference Point is specified by the Relevant Network Operator.

The Power Generating Facility shall be designed in such a way that it fulfils the Specifications imposed on it at the VJV Reference Point or at a point defined by a specific requirement.

9.1.2 Protection settings of Power Generating Facility and Power Generating Facility connection from the viewpoint of Specifications

The Power Generating Facility Owner is responsible for specifying the protection settings of the Power Generating Facility and Power Generating Facility connection in order to guarantee personal and equipment safety and to prevent equipment damage. The protection settings shall be set in such a way that the Power Generating Facility remains connected to the grid during disturbances in the Power System for as long as this is possible within the scope of the technology and operational safety of the Power Generating Facility. The settings shall be based on the capability of the equipment to withstand severe fluctuations in system frequency and in the voltage at the VJV Reference Point.

The Power Generating Facility Owner shall co-ordinate the set values of the protection of the Power Generating Facility and Power Generating Facility connection together with the Relevant Network Operator. If there are discrepancies between the protection settings of the Power Generating Facility or its connection and the Specifications, the protection settings shall be agreed in co-operation between the Power Generating Facility Owner, the Relevant Network Operator and Fingrid.

The Power Generating Facility Owner is responsible for ensuring that the planning of the protection of the Power Generating Facility takes into account the intense short-term changes in the voltages, currents and frequency of the Power System caused by disturbances and faults, and the high-speed automatic reclosing and delayed automatic reclosing commonly used in the restoration of the operation of transmission lines.

The Power Generating Facilities to be connected to the Power System shall be able to withstand intense voltage changes caused by disturbances at the VJV Reference Point in the manner described in chapter 10, and the voltage asymmetry caused by the disturbances at least in accordance with the operating times of the protection of the Power System.

9.1.3 Power quality

The Power Generating Facility Owner is obliged to follow the power quality requirements imposed by the Relevant Network Operator. The Power Generating Facility Owner shall deliver the information and reports (e.g. IEC 61400-21) requested by the Relevant

Network Operator, on the basis of which information and reports the Relevant Network Operator can evaluate the impacts of the Power Generating Facility on the power quality before the Power Generating Facility is connected to the grid.

The Power Generating Facility Owner shall be prepared for the power quality specified by the Relevant Network Operator when the Power Generating Facility Owner designs the Power Generating Facility.

9.2 Power Generating Facilities of Power Classes 2, 3 and 4

Power Generating Facilities of Power Classes 2, 3 and 4 are subject to the same requirements in terms of the protection settings and power quality as Power Generating Facilities of Power Class 1, but the VJV Reference Point is specified in a different manner, and Power Classes 2, 3 and 4 are also subject to a requirement concerning the Black Start Capability.

9.2.1 VJV Reference Point

The VJV Reference Point of a *Synchronous Power Generating Module* is that point at the high-voltage side of a generator transformer of the Power Generating Facility which is electrically closest to the Connection Point of the Synchronous Power Generating Module.

The VJV Reference Point of a *Wind Power Park Module* is that point at the high-voltage side of a Step-up Transformer of the Power Generating Facility which is electrically closest to the Connection Point of the Wind Power Park Module.

The Relevant Network Operator specifies the VJV Reference Point. The Power Generating Facility shall be designed in such a way that it fulfils the Specifications imposed on it at the VJV Reference Point or at some other electric point specified separately per requirement.

9.2.2 Black Start Feature

If a Power Generating Facility to be connected to the Finnish main grid can be equipped with the Black Start Capability at reasonable cost, the Power Generating Facility Owner shall inform Fingrid of this at the preliminary design stage of the Power Generating Facility. The utilisation of the Black Start Capability and the coverage of the related costs are agreed upon separately between Fingrid and the Power Generating Facility Owner.

10 Operation of Power Generating Facility at various voltages and frequencies

10.1 Power System voltages and frequencies

The nominal voltage levels in the Finnish grid are 110 kV, 220 kV and 400 kV. Correspondingly, the design of the connection shall be based on the normal grid Connection Point voltages of 118 kV, 233 kV and 410 kV respectively.

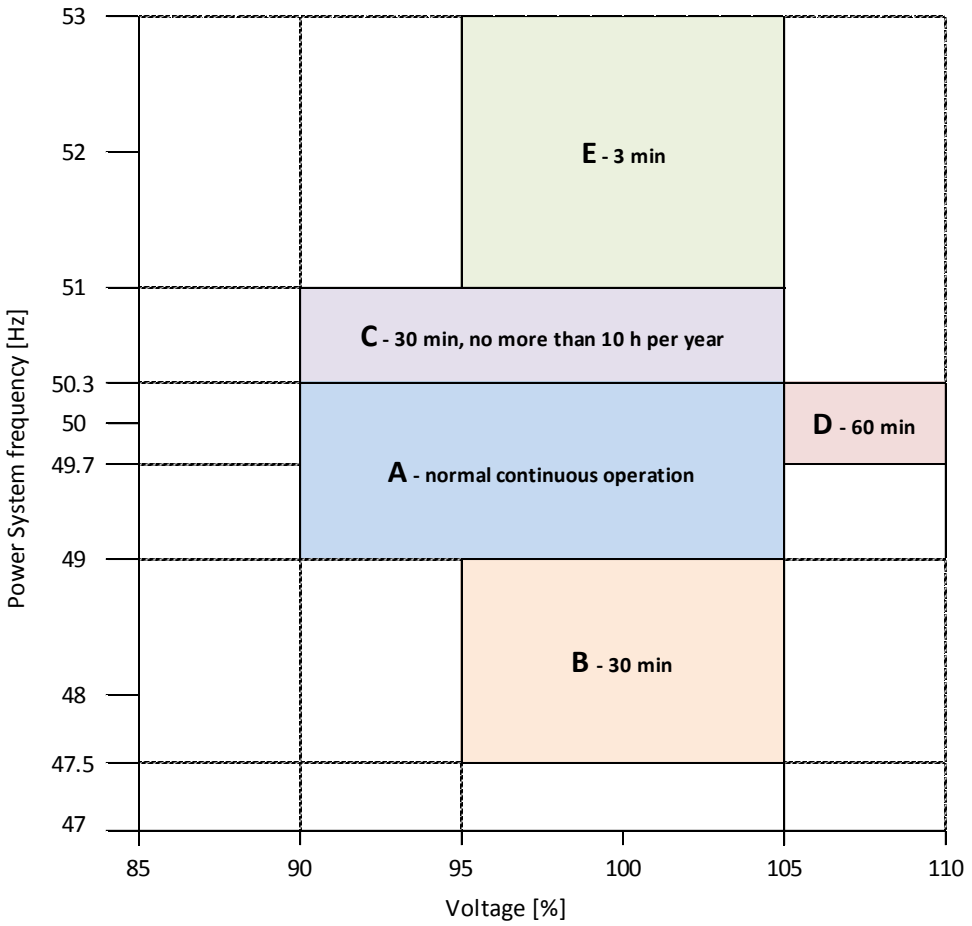
In Fingrid's grid, the voltage fluctuation ranges in a normal situation as well as in disturbance and exceptional situations are as follows: The normal fluctuation range of voltage in a grid with a nominal voltage of 400 kV is 395–420 kV, and in exceptional and disturbance situations the voltage range is 360–420 kV. The normal fluctuation range of voltage in a grid with a nominal voltage of 220 kV is 215–245 kV, and in exceptional and disturbance situations the voltage range is 210–245 kV. The normal fluctuation range of voltage in a grid with a nominal voltage of 110 kV is 105–123 kV, and in exceptional and disturbance situations the voltage range is 100–123 kV. The Normal Operating Voltage (voltage corresponding to the 100% value) at the Connection Point is case dependent and the Power Generating Facility Owner shall always inquire it from the Relevant Network Operator.

The frequency of the Nordic Power System is normally 49.9–50.1 Hz. The frequency of the grid may vary between 49.5–50.5 Hz and exceptionally even between 47.5–53 Hz.

10.2 Operation of Power Generating Facilities of Power Class 1 at various voltages and frequencies

10.2.1 Frequencies and voltages at which Power Generating Facilities of Power Class 1 shall remain connected to the Power System

The Power Generating Facility shall be able to operate continuously and normally when the voltage at the VJV Reference Point is 90–105% and the frequency is 49.0–50.3 Hz. If the voltage, frequency or both at the VJV Reference Point differ from these values, the Power Generating Facility shall remain connected to Power System for at least the periods of time specified in Figure 10.1. The power output of the Power Generating Facility may reduce as presented in the explanations of Figure 10.1.



A:	Normal continuous operation	A decrease in the generation capacity of Active Power or Reactive Power as a result of the voltage and/or frequency of the Power System is not allowed
B:	30 min of continuous operation	A power decrease is allowed in such a way that the maximum permitted decrease at a level of 49 Hz is 0% and at a level of 47.5 Hz 15% (in the frequency range between these, the permitted decrease is determined linearly on the basis of reductions permitted at the borderline frequencies)
C:	30 min of continuous operation for a maximum total of 10 hours annually	A power decrease of 10% is permitted if it does not impose restrictions to continue operation at initial power output when frequency is restored to below 50.3 Hz
D:	60 min of continuous operation	The power is permitted to decrease a maximum of 10% of full power
E:	3 minutes of continuous operation	Rapid power decrease allowed

Outside the above-mentioned operating ranges, operation must continue within the limits allowed by technology, immediate disconnection not permitted

Figure 10.1. The figure shows how long Power Generating Facilities shall remain connected to the grid at various frequencies and voltages at the VJV Reference Point. The 100% voltage of the continuous operating range in the 400 kV grid is always 400 kV. At other voltages, the voltage corresponding to the 100% value shall be inquired from the Relevant Network Operator.

10.2.2 Operation of Power Generating Facilities of Power Class 1 in momentary voltage disturbances

The Power Generating Facilities shall be able to continue operation during and after disturbances in the Power System. Consequently, *Synchronous Power Generating Modules* with their house load operation shall be designed in such a way that they can withstand a momentary voltage fluctuation as shown in Figure 10.2, occurring at the VJV Reference Point, without being disconnected from the grid and without losing their synchronous operation. *Power Generating Facilities connected with a power converter* with their house load operation shall be designed in such a way that they can withstand a momentary voltage fluctuation as shown in Figure 10.2, occurring at the VJV Reference Point, without being disconnected from the grid.

The Power Park Module current injection to the Power System and the dependence of the injected current on the level of voltage of the VJV Reference Point or Turbine Generator during voltage disturbances shall be agreed upon separately with the Relevant Network Operator. A description of the functionality shall be provided as part of the Power Generating Facility data.

After a disturbance, the Power Generating Facility shall be able to operate without being disconnected from the grid during momentary variations in voltage amplitude and phase angle caused by potential local or inter-area electromechanical oscillations following a voltage disturbance.

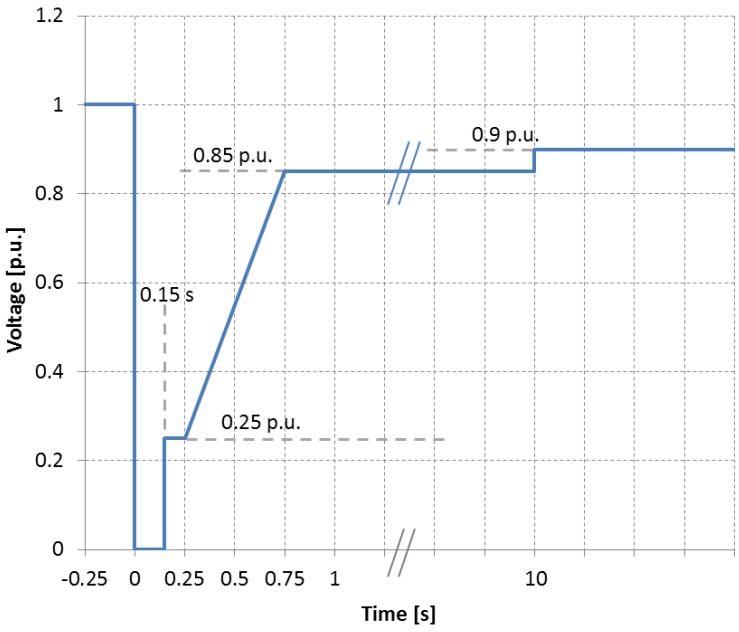


Figure 10.2. Voltage of VJV Reference Point corresponding to a momentary voltage disturbance, during and after which Power Generating Facilities of Power Classes 1, 2 and 3 shall continue to operate normally. The per unit value 1.0 p.u. of voltage is the voltage before the disturbance. The voltage is 0 p.u. for 150 milliseconds.

10.2.3 Operation of Power Generating Facilities of Power Class 1 when the frequency changes

The Power Generating Facility shall be capable of continuing to operate in the normal manner when the rate of change of frequency is less than 2 Hz/s. The Power Generating Facility shall be able to operate for at least 1.25 seconds when the rate of change of frequency is exactly 2 Hz/s. When the rate of change of frequency exceeds 2 Hz/s, the Power Generating Facility may disconnect from the Power System in all other cases except during a momentary voltage disturbance described in chapter 10.2.2.

The measurement of the rate of change of frequency shall not react to the sudden changes in the waveform of voltage caused by disturbances in the system.

10.3 Operation of Power Generating Facilities of Power Classes 2 and 3 at various voltages and frequencies

10.3.1 General requirements

Power Generating Facilities of Power Classes 2 and 3 shall fulfil all the same requirements as Power Generating Facilities of Power Class 1. Moreover, they shall be able to restore Active Power quickly after a momentary voltage disturbance.

After a momentary voltage disturbance in accordance with the definition of Figure 10.2, the Power Generating Facility shall restore the Production Power which preceded the disturbance. This shall take place in 1 second. If the restoration of power takes longer than 1 second, the operation shall be subjected to Fingrid's approval. No permanent Production Power changes are accepted as a result of a voltage disturbance.

If the restoration of Active Power depends on the level of voltage at the VJV Reference Point, the said dependence and a description of its potential impact on power restoration shall be delivered to Fingrid and to the Relevant Network Operator.

10.3.2 Calculation of the operation of the Power Generating Facility during voltage disturbance

A calculation of the operation of the electricity generation installations of the Power Generating Facility during voltage disturbance shall be delivered to the Relevant Network Operator in stage 1 of the compliance monitoring process of the Specifications of the Power Generating Facility. The calculation shall describe the dynamic operation of the Power Generating Facility during voltage disturbances presented in Table 10.1. The restrictions set by the power generation process on electricity generation shall be taken into account in the calculation, but the calculation does not need to describe the entire power generation process.

The voltage disturbance calculation shall be performed with the following assumptions:

- Before the voltage disturbance, the voltage of the VJV Reference Point of the Power Generating Facility is 1 p.u.

- Before the voltage disturbance, the Power Generating Facility does not supply Reactive Power to the VJV Reference Point or take Reactive Power from the VJV Reference Point.
- Before the voltage disturbance, the Automatic Voltage Regulator (AVR) of the Power Generating Facility is in operation.
- When viewed from the VJV Reference Point, an equivalent circuit is made of the Power System. The equivalent circuit contains impedance describing the short circuit power of the Power System and ideal voltage source connected in series.
- The Relevant Network Operator shall notify the short circuit powers to be used in the calculation and presented in Table 10.1 to the Power Generating Facility Owner.
- A description of the model used in the calculation, including the parameters used in the calculation and the block diagram presentations of the control systems, shall be delivered as part of the calculation to the Relevant Network Operator.

Table 10.1. Input data used in the voltage disturbance calculation.

Data	Fault 1	Fault 2
Fault time	150 ms	250 ms
Remaining voltage at the VJV Reference point during the fault	0.0 p.u.	0.25 p.u.
Short circuit current before the fault	Normal	Normal
Short circuit current after the fault	Minimum	Normal

10.4 Operation of Power Generating Facilities of Power Class 4 at various voltages and frequencies

The operation of Power Generating Facilities of Power Class 4 at various voltages and frequencies is subject to the same requirements as Power Generating Facilities of Power Classes 2 and 3, but the operationduring voltage disturbances and the calculation of the operation of the Power Generating Facility during voltage disturbances are different, and they are presented in this section.

10.4.1 Operation of Power Generating Facilities of Power Class 4 in voltage disturbances

The Power Generating Facilities shall be able to continue operation during and after disturbances in the Power System. Consequently, *Synchronous Power Generating Modules* with their house load operation shall be designed in such a way that they can withstand a momentary voltage fluctuation as shown in Figure 10.3, occurring at the VJV Reference Point, without being disconnected from the grid and without losing their synchronous operation. *Power Generating Facilities connected with a power converter* with their house load operation shall be designed in such a way that they can withstand a momentary voltage fluctuation as shown in Figure 10.3, occurring at the VJV Reference Point, without being disconnected from the Power System.

The Power Park Module current injection to the Power System and the dependence of the injected current on the level of voltage of the VJV Reference Point or Turbine Generator during voltage disturbances shall be agreed upon separately with the Relevant Network Operator. A description of the functionality shall be provided as part of the Power Generating Facility data.

After a disturbance, the Power Generating Facility shall be able to operate without being disconnected from the grid during momentary voltage amplitude and phase angle variations caused by potential local or inter-area electromechanical oscillations following a voltage disturbance.

After a momentary voltage disturbance in accordance with the definition of Figure 10.3, the Power Generating Facility shall restore the Production Power which preceded the disturbance. This shall take place in 1 second. If the restoration of power takes longer than 1 second, the operation shall be subjected to Fingrid's approval. No permanent Production Power changes are accepted as a result of a voltage disturbance.

If the restoration of power depends on the level of voltage at the VJV Reference Point, the said dependence and a description of its potential impact on power restoration shall be delivered to Fingrid and to the Relevant Network Operator.

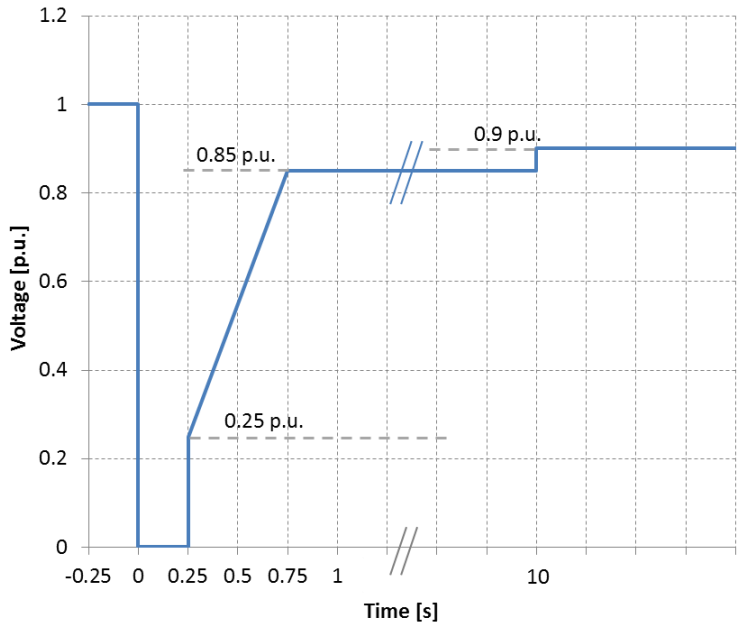


Figure 10.3. Voltage of VJV Reference Point corresponding to a momentary voltage disturbance, during and after which Power Generating Facilities of Power Class 4 shall continue to operate normally. The per unit value 1.0 p.u. of voltage is the voltage before the disturbance. The voltage is 0 p.u. for 250 milliseconds.

10.4.2 Calculation of the operation of the Power Generating Facility during voltage disturbance

A calculation of the operation of the electricity generation installations of the Power Generating Facility during a voltage disturbance shall be delivered to the Relevant Network Operator in stage 1 of the compliance monitoring process of the Specifications of the Power Generating Facility. The calculation does not need to describe the entire power generation process, but the restrictions set by the power generation process on electricity generation shall be taken into account in the calculation. The calculation shall describe the dynamic operation of the Power Generating Facility during the voltage disturbances presented in Table 10.2.

The voltage disturbance calculation shall be performed with the following assumptions:

- Before the voltage disturbance, the voltage of the VJV Reference Point of the Power Generating Facility is 1.0 p.u.
- Before the voltage disturbance, the Power Generating Facility does not supply Reactive Power to the VJV Reference Point or take Reactive Power from the VJV Reference Point.
- Before the voltage disturbance, the Automatic Voltage Regulator (AVR) of the Power Generating Facility is in operation.
- When viewed from the Power Generating Facility, an equivalent circuit is made of the Power System beyond the VJV Reference Point. The equivalent circuit contains impedance describing the short circuit power of the Power System and ideal voltage source connected in series. If the Connection Point of the Power Generating Facility is at the 400 kV voltage level or electrically close to a 400 kV transmission grid, the modelling of the Power System shall be agreed upon with Fingrid.
- The Relevant Network Operator shall notify the short circuit powers to be used in the calculation and presented in Table 10.2 to the Power Generating Facility Owner.
- A description of the model used in the calculation, including the parameters used in the calculation and the block diagram presentations of the control systems, shall be delivered as part of the calculation to the Relevant Network Operator.

Table 10.2. Input data used in the voltage disturbance calculation.

Data	Fault 1	Fault 2
Fault time	150 ms	250 ms
Remaining voltage at the VJV Reference point during the fault	0.0 p.u.	0.0 p.u.
Short circuit current before the fault	Normal	Normal
Short circuit current after the fault	Minimum	Normal

Requirements applicable to Synchronous Power Generating Modules

11 Frequency Control and Active Power control of Synchronous Power Generating Modules

11.1 Frequency Control and Active Power control of Synchronous Power Generating Modules of Power Class 1

The Power Generating Facility shall have the functionalities required by Active Power control, maintaining of power output, and rotation speed control. If the Power Generating Facility characteristics include functionalities related to Active Power control and Frequency Control, Fingrid has the right, if necessary, to utilise these functionalities as described under section 11.2.

11.2 Frequency Control and Active Power control of Synchronous Power Generating Modules of Power Classes 2, 3 and 4

11.2.1 Fingrid's rights during disturbance in the Power System

Fingrid has the right to demand Power Generating Facilities to adjust themselves within the power control features presented in this document, if the Power System cannot be restored to the normal state after a disturbance.

11.2.2 Active Power and start-up time of Power Generating Facility

11.2.2.1 Minimum Output

The Minimum Output of the Power Generating Facility shall be as small as possible. The following Minimum Outputs shall be used as the design basis for the Power Generating Facility:

- hydropower, gas turbine and motor power plants: 10% of Rated Capacity,
- combined heat and power plants and other Power Generating Facilities: 40% of Rated Capacity.

The Minimum Output of the Power Generating Facility and its capability to operate momentarily below its Minimum Output limit shall be reported as part of the data to be delivered.

If the Power Generating Facility consists of several generators and the Minimum Output is not evenly distributed between the generators, the Minimum Outputs of individual generators shall also be reported alongside the Minimum Outputs of the entire Power Generating Facility.

11.2.2.2 Rated Capacity and short-term overloadabillity

The dependence of the Rated Capacity and the short-term overloadability of the Power Generating Facility on external factors, such as the temperature of outdoor air or sea water, shall be reported as part of the data to be delivered.

The control of the Power Generating Facility shall be carried out in such a way that the short-term overloadability of the facility can be utilised effectively. The data related to the short-term overloadablity of the Power Generating Facility shall be reported as part of the data to be delivered.

11.2.2.3 Start-up time

Hydropower, gas turbine and motor power plants shall have ability to start-up and achieve Rated Capacity output in 15 minutes. Estimates of typical starting times to Minimum Output Power and Rated Power shall be reported as part of the data to be delivered.

With combined heat and power plants and other Power Generating Facilities, there are no requirements concerning the start-up time, except for the requirements presented in section 11.2.5 concerning the restoration from house load operation. An estimate of start-up times in the various ready-to-start states of the Power Generating Facility shall be reported as part of the data to be delivered.

11.2.3 Implementation of Frequency Control and Active Power control

11.2.3.1 General controller requirements

The Power Generating Facilities shall be equipped with a turbine controller and associated rotation speed control, with which the Active Power output and the rate of change of Active Power can be adjusted.

The Active Power control of the Power Generating Facility shall allow the setting of the Active Power output manually and the adjustment of the power output on the basis of frequency measurement (Frequency Control) using the turbine controller and potential power plant controller.

Frequency Control shall be implemented in such a way that the Power Generating Facility can automatically contribute to supporting the frequency of the Power System in disturbance situations. Transition to disturbance power control state is executed by a frequency relay or other frequency-sensing equipment. The frequency measurement of Frequency Control shall be carried out in such a way that Frequency Control follows the frequency of the Power System.

If functions or actuators, which filter and average the frequency measurement or functions or actuators which otherwise slow down the measurement or alter its nature, are used in conjunction with the frequency measurement, a description of their impact on the accuracy and delay of the frequency measurement shall be provided as part of the data to be delivered. It shall be possible to bypass the above-mentioned functions or actuators. The bypass shall work in the same way regardless of whether the Power Generating Facility is controlled locally or in remote control.

The Active Power control system of the Power Generating Facility shall be executed in such a way that the inherent dead band of the control is as small as possible.

11.2.3.2 Functionalities of Frequency Control

It shall be possible to set a dead band and linear Droop for Frequency Control. The control shall be implemented so that the control has at least two modes of operation: normal state and disturbance state.

If other modes of operation have been specified for Active Power control and Frequency Control alongside the normal state and disturbance state, Fingrid shall be informed of them and their setting principles.

11.2.3.3 Control parameters to be set

The reference value of Frequency Control shall correspond to the nominal frequency of 50 Hz of the Power System.

It shall be possible to set the Droop of Frequency Control between 2 and 12 per cent in steps of a maximum of 1 percentage point.

It shall be possible to set the dead band of Frequency Control between 0.0 and 1.0 Hz in steps of a maximum of 0.01 Hz.

It shall be possible to set the setting limits of the criteria which define the automatic transition in the modes of operation (normal state, disturbance state) based on the frequency measurement in at least the following limits:

- frequency limits leading to a transition in the modes of operation: ±2 Hz in steps of a maximum of 0.1 Hz,
- delay, after which the transition in the modes of operation takes place: 0–60 s in steps of a maximum of 1 second,
- delay, after which a restoration from the transition in the modes of operation takes place: 0–600 s in steps of a maximum of 1 second.

A separate agreement with Fingrid shall be reached if the automatic transition in the modes of operation of the control is carried out in a manner other than based on the frequency deviation.

11.2.3.4 Accuracy and sensitivity of control

The accuracy of the reference value of Active Power control shall be at least 1 MW.

The sensitivity of Frequency Control shall be at least 10 mHz, and the response time shall be no more than 2 s.

The accuracy and sensitivity of the power control and Frequency Control of the Power Generating Facility shall be verified during the Compliance Testing. A description of these and of the factors affecting them shall be delivered as part of the Power Generating Facility documentation.

11.2.3.5 Transitions between modes of operation

It shall be possible to change, prevent and allow the modes of operation and reference values of the active power control and Frequency Control of the Power Generating Facility. The control of the modes of operation and reference values shall work in the same way regardless of whether the Power Generating Facility is controlled locally or in remote control.

A description of the functionalities which carry out the automatic transitions in the modes of operation of the power control and Frequency Control of the Power Generating Facility shall be delivered as part of the Power Generating Facility documentation.

11.2.4 Rate of change and adjustment range of Active Power

11.2.4.1 Rate of change and adjustment range of Active Power in normal state

The requirements for the rate of change of Active Power have been specified as the highest rate of change of power that shall be achieved in response to a change in the reference value of the Active Power of the generator or the Power Generating Facility.

In a normal operation situation, the rate of change of the power of hydro, gas turbine and motor power plants shall be at least ±40% of the Rated Capacity per minute. It shall be possible to carry out the rate of change of power when the power of the facility is 40–100% of the Rated Capacity. The rate of change of power can be limited to the maximum permitted rate of change of power restricted by the characteristics of the Power Generating Facility in question when the power of the facility is below 40% of the Rated Capacity.

The rate of change of the power of combined heat and power plants as well as Power Generating Facilities other than hydro, gas turbine or motor power plants shall be at least ±5% of the Rated Capacity per minute. It shall be possible to carry out the rate of change of power when the power of the facility is 60–90% of the Rated Capacity. The rate of change of power can be limited to the maximum permitted rate of change of power restricted by the characteristics of the Power Generating Facility in question when the power of the facility is below 60% or above 90% of the Rated Capacity.

11.2.4.2 Rate of change and adjustment range of Active Power in disturbance state

The requirements for the rate of change of Active Power in disturbance state have been specified as response times to a minimum step-like change of 0.5 Hz taking place in the frequency measurement. At least half of the required total change shall be achieved in 5 seconds from the disturbance, and the total change shall be achieved in 30 seconds from the disturbance.

The power change of hydropower, gas turbine and motor power plants shall be at least ±10% of the Rated Capacity in disturbance situations. It shall be possible to carry out the power change when the power output of the plant is 50–100% of the Rated Capacity. The power change can be limited to the maximum permitted power change conforming to the characteristics of the Power Generating Facility when the power output of the facility is below 50%, but in this case the determining factors that limit the power change shall be reported as part of the data to be delivered.

The immediate power change of combined heat and power plants as well as Power Generating Facilities other than hydro, gas turbine or motor power plants shall be at least ±5% of the Rated Capacity in disturbance situations. It shall be possible to carry out the power change when the power output of the facility is 50–90% of the Rated Capacity. The power change can be limited to the maximum permitted power change restricted by the characteristics of the Power Generating Facility in question when the power output of the facility is below 50%, but in this case the determining factors that limit the power change shall be reported as part of the data to be delivered.

11.2.5 House load operation

The Power Generating Facility shall be designed in such a way that it can safely shift to house load operation when the voltages or frequencies of the VJV Reference Point are such that the Power Generating Facility can shift to house load operation by virtue of chapter 10.

Hydropower plants and Reserve Gas Turbine plants shall be designed so that they can operate in house load operation for at least 8 hours. Power Generating Facilities other than hydro and nuclear power plants shall be designed so that they can operate in house load operation for at least 1 hour, but can be restarted and synchronised back to the Power System after this as soon as possible, taking the technical conditions into account; however, within a maximum of 4 hours during the next 12 hours. Nuclear power plants shall operate in house load operation and be available for start-up as prescribed in their safety regulations.

The following descriptions shall be provided as part of the data to be delivered:

1) A description of the House Load of the Power Generating Facility. If the House Load depends on the mode of operation of the Power Generating Facility, the dependence of the House Load on the mode of operation shall be described as part of the documentation to be delivered.

2) A description of how long the facility can operate in house load operation.

3) Information on the delay between remaining in house load operation and synchronisation with the Power System, and on the factors affecting the delay.

12 Reactive Power capacity of Synchronous Power Generating Modules

12.1 Reactive Power capacity of Power Generating Facilities of Power Class 1

The Relevant Network Operator sets the Reactive Power capacity requirement for Power Generating Facilities of Power Class 1.

12.2 Reactive Power capacity of Power Generating Facilities of Power Classes 2, 3 and 4

12.2.1 Dimensioning of generators and generator transformer of Power Generating Facility

The reactances of the generator(s) and generator transformer of the Power Generating Facility shall be as low as is technically and economically feasible so that the Power Generating Facility supports the operation and stability of the Power System as effectively as possible.

12.2.2 Reactive Power capacity required from Power Generating Facility

The generator(s) of the Power Generating Facility shall be able to operate continuously at their Rated Capacity P_{max} when the power factor measured from the generator terminals is 0.95cap–0.9ind. Figure 12.1 illustrates this.

When the generator is operating at power output below the Rated Capacity, it shall be able to generate or consume Reactive Power in accordance with the PQ diagram drawn up with the design voltage and frequency of the generator.

The Power Generating Facility shall be able to limit the rise in the voltage of the VJV Reference Point by consuming Reactive Power from the VJV Reference Point, when the voltage of the VJV Reference Point is higher than the Normal Operating Voltage specified by the Relevant Network Operator. The Power Generating Facility shall be able to limit the decrease in the voltage of the VJV Reference Point by producing Reactive Power to the VJV Reference Point, when the voltage of the VJV Reference Point is lower than the Normal Operating Voltage specified by the Relevant Network Operator.

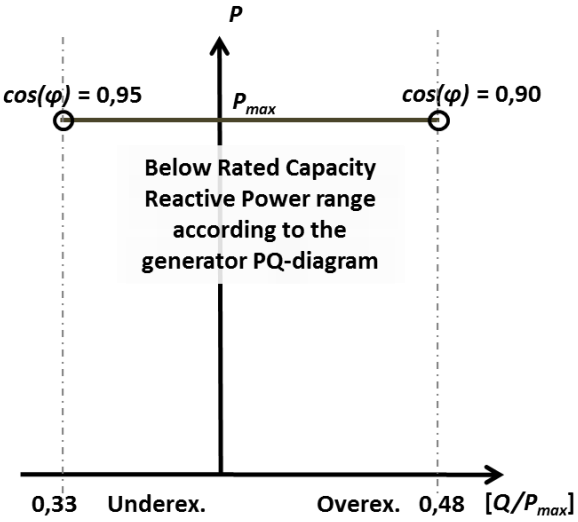


Figure 12.1. Reactive Power capacity required from Synchronous Power Generating Modules.

12.2.3 Reactive Power capacity calculation

The Power Generating Facility Owner shall deliver a calculation of the Reactive Power capacity of the Power Generating Facility at the VJV Reference Point to the Relevant Network Operator. The calculation shall be delivered in stage 1 of the compliance monitoring process of the Specifications. The calculation shall demonstrate the capability of the Power Generating Facility to generate and consume Reactive Power at the voltage levels of the VJV Reference Point and at the Active Power output levels of the Power Generating Facility specified in Table 12.1.

If the generator transformer of the Power Generating Facility is equipped with an on-load tap-changer or off-load tap changer, the calculation shall be presented, in addition to the middle position of the on-load tap-changer or off-load tap changer of the generator transformer, also at the extreme positions of the on-load tap-changer or off-load tap changer.

In addition to the Reactive Power capacity specified for the Power Generating Facility in the calculation, the Reactive Power capacity calculation shall present the input data used in the calculation, such as the voltage ranges and Reactive Power capacities of the generators.

The Reactive Power capacity calculation shall take into account, where necessary, the generator and any other Power Generating Facility components that generate and consume Reactive Power. The calculation shall be performed at a frequency of 50 Hz.

Operating points 0.85 p.u. and 0.875 p.u. are momentary at the voltage levels of the VJV Reference Point, and at these operating points the Power Generating Facility shall be able to operate for a minimum of 10 seconds.

Table 12.1. Operating points used in the Reactive Power capacity calculation.

Voltage at VJV Reference point [p.u.]	0.85	0.875	0.9	0.925	0.95	0.975	1.0	1.025	1.05	1.075	1.1
Power output 1	Minimum Output										
Power output 2	P = 0.75 × Pmax										
Power output 3	Rated Capacity										
Operating points 0.85 p.u. and 0.875 p.u. are momentary at the voltage levels of the VJV Reference Point. and at these operating points the Power Generating Facility shall be able to operate for a minimum of 10 seconds.											

If the components of the Power Generating Facility are different from those planned, the calculation related to the Reactive Power capacity of the Power Generating Facility shall be updated and delivered to the Relevant Network Operator.

The Reactive Power capacity of the Power Generating Facility at the VJV Reference Point, specified in the Reactive Power capacity calculation, shall be verified during the Compliance Testing in accordance with the principles described in chapter 14.

12.2.4 Restriction of Reactive Power capacity

The limiters of voltage control of the generator and the Power Generating Facility shall be designed and set so that their operation restricts the capability of the Power Generating Facility to generate and consume Reactive Power as little as possible.

The additional adjustments and limiters of excitation system used for restricting the Reactive Power capacity and the protection related to the operation of excitation shall be co-ordinated so that the Reactive Power capacity of the generator can be utilised efficiently without the risk of the generator being disconnected from the grid.

13 Voltage control of Synchronous Power Generating Modules

13.1 Voltage control of Synchronous Power Generating Modules of Power Class 1

The Power Generating Facility shall be able to operate at a power factor of 1.0 measured at the VJV Reference Point, or alternatively the Power Generating Facility shall be able to support the voltage of the VJV Reference Point by means of its Reactive Power capacity, as follows:

- The Power Generating Facility generates Reactive Power to the Power System when the voltage of the VJV Reference Point decreases.
- The Power Generating Facility consumes Reactive Power from the Power System when the voltage of the VJV Reference Point increases.

13.2 Voltage control of Synchronous Power Generating Modules of Power Classes 2 and 3

13.2.1 Operation and method of voltage control

The generators of the Power Generating Facility shall have constant voltage control for the Terminal Voltage of the Generator. The control shall be carried out so that the control operates continuously and so that the changes in Reactive Power at the VJV Reference Point as a result of the control take place steplessly.

The control shall enable the utilisation of the Reactive Power capacity of the Power Generating Facility specified in chapter 12 when the Power Generating Facility generates Active Power to the Power System. The functioning of the control shall not be disturbed by changes in the voltage and frequency of the grid or by momentary voltage disturbances.

The primary method of generator voltage control is the constant voltage control of the Terminal Voltage of the Generator. If, for the needs of regional or local voltage control or for other corresponding reasons related to the operation of the Power System, it is justified to use another control method or higher facility-level control, the control shall be able to respond, wherever necessary, to voltage changes in the same manner as the constant voltage control of the Terminal Voltage of the Generator. The use of a method other than constant voltage control as the primary voltage control method of the Power Generating Facility shall be agreed separately with the Relevant Network Operator and Fingrid.

Any transitions in the Mode and operating point of the control shall take place without sudden and significant changes or repeated and significant oscillations in the Active Power or Reactive Power generated by the Power Generating Facility.

13.2.2 Automatic Voltage Regulator of generator

In order to safeguard the system security of the Power System, the Automatic Voltage Regulator shall have two channels. Both channels shall have automatic constant voltage control of the Terminal Voltage of the Generator, and constant current control of the

excitation current as its back-up system. (The latter is also known as manual control of the excitation current.)

The Automatic Voltage Regulator shall be designed so that its ceiling voltage is at least twice the excitation voltage corresponding to the design load of the generator with static excitation and at least 1.6 times that with brushless excitation[1]; however, taking into account all the other requirements set on voltage control. It shall be possible to maintain the ceiling voltage for at least 10 seconds.

When the reference value of the Automatic Voltage Regulator of a generator which is in no-load operation and disconnected from the grid is changed in step upwards from 95 per cent to 105 per cent, the step response shall be as follows:

1) With static excitation, the rise time of the step response from zero to 90 per cent of the total change in the Terminal Voltage shall be 0.2–0.3 seconds,

2) With brushless excitation, the rise time of the step response from zero to 90 per cent of the total change in the Terminal Voltage shall be 0.2–0.5 seconds.

When the reference value of the Automatic Voltage Regulator of a generator which is in no-load operation and disconnected from the grid is changed in step downwards from 105 per cent to 95 per cent, the step response shall be as follows:

1) With static excitation, the rise time of the step response from zero to 90 per cent of the total change in the Terminal Voltage shall be 0.2–0.3 seconds,

2) With brushless excitation, the rise time of the step response from zero to 90 per cent of the total change in the Terminal Voltage shall be 0.2–0.8 seconds.

The Automatic Voltage Regulator shall be set so that the step response does not oscillate. The above-specified step responses may exceed by a maximum of 15 per cent of the measured total change in the Terminal Voltage.

13.2.3 Modes and functionalities of the Automatic Voltage Regulator of generator

The Automatic Voltage Regulator shall operate with the constant voltage control of the Terminal Voltage of the Generator. Moreover, the Automatic Voltage Regulator may have other Modes such as constant Reactive Power control or constant power factor control.

The control system shall include, in addition to the Automatic Voltage Regulator and potential additional stabiliser, also functionalities which protect the generator from overloading.

It shall be possible to set the reference value of constant voltage control in maximum steps of 0.01 p.u in accordance with the limit values specified for the voltage of the generator (continuous operation) .

[1] While at the rated load, the generator produces as much Active Power as what its Rated Capacity is, and as much Reactive Power as what its Reactive Power capacity is.

The Slope of voltage control shall be linear, and it shall be possible to set it within a range of 1 to 10 per cent in maximum steps of 1 percentage point. The set value can be set as positive or negative.

If the Power Generating Facility has constant Reactive Power control, it shall be possible to set the set value in maximum steps of 1 Mvar.

13.2.4 Changes in the Modes of Automatic Voltage Regulator

The Modes and set values of the Automatic Voltage Regulator shall work in the same way regardless of whether the Power Generating Facility is controlled locally or in remote control.

13.2.5 Protection and limiters related to the functioning of Automatic Voltage Regulator and excitation

The current limiters of the generator shall have inverse time characteristics so that the overload range of the Automatic Voltage Regulator of the generator can be utilised in various operation situations.

The functioning of the limiters shall control, in as direct and delay-free manner as possible, the functioning of the Automatic Voltage Regulator in order to avoid potential intense overvoltages or undervoltages at the VJV Reference Point of the Power Generating Facility.

The functioning of the limiter of underexcitation shall be co-ordinated with the current limiters (stator, rotor, excitation) as well as with loss of excitation (LOE) and potential power system stabiliser (PSS).

The functioning of the limiter of overexcitation shall be co-ordinated with the current limiters as well as with overvoltage protection (stator, rotor, excitation) and potential power system stabiliser (PSS).

13.2.6 Other components contributing to the voltage control and Reactive Power control of the Power Generating Facility

If separate compensation devices implemented as part of the Power Generating Facility are utilised in order to achieve the Reactive Power capacity requirement, the functioning of such devices shall be co-ordinated with the functioning of the controllers of the generators of the Power Generating Facility.

13.3 Voltage control of Power Generating Facilities of Power Class 4

Power Generating Facilities of Power Class 4 shall fulfil the same requirements as Power Generating Facilities of Power Classes 2 and 3. Moreover, the generators of Power Generating Facilities of Power Class 4 shall have power system stabilisers (PSS).

The structure of the power system stabiliser shall be such that the stabiliser can be tuned to damp the oscillations between the generator and the Power System at frequencies of 0.2–2.0 Hz. The power system stabiliser shall be tuned to improve the damping of the local oscillation frequency between the Power Generating Facility and the Power System.

The power system stabiliser shall not amplify inter-area oscillations of 0.3 Hz. The tuning of the power system stabiliser for the damping of system-frequency oscillations shall be agreed upon separately with Fingrid.

It shall be possible to disconnect the power system stabiliser, and it shall be possible to limit the magnitude of the stabilisation signal by means of limiters with adjustable settings.

The functioning of the power system stabiliser in accordance with the Specifications shall be verified during the Compliance Testing.

14 Compliance Testing of Synchronous Power Generating Modules

14.1 Shared requirements for the Compliance Testing of all Synchronous Power Generating Modules

It is the responsibility of the Power Generating Facility Owner to verify that the Power Generating Facility operates in accordance with the Specifications imposed on it. The Power Generating Facility Owner is responsible for the costs related to compliance monitoring. Compliance with the Specifications shall primarily be verified by means of Compliance Testing carried out in conjunction with the commissioning of the Power Generating Facility.

14.2 Compliance Testing of Synchronous Power Generating Modules of Power Class 1

The Power Generating Facility Owner shall deliver minutes of commissioning of the Compliance Testing to the Relevant Network Operator. The minutes shall comprise the documentation of the variables validated by means of measurements and the time of the measurements.

It is the responsibility of the Power Generating Facility Owner to verify by Compliance Testing that the following characteristics of a Synchronous Power Generating Facility of Power Class 1 conform to the Specifications:

1) impact of the starting and stopping of the Power Generating Facility on the voltage level at the VJV Reference Point,

2) Rated Capacity of the Power Generating Facility,

3) Reactive Power capacity of the Power Generating Facility,

4) functioning of voltage control or Reactive Power control, if the Relevant Network Operator requires this, and

5) power quality.

Even though Compliance Testing is the primary compliance monitoring method, the commissioning measurements for items 2, 3 and 5 can be replaced by a type test report or a corresponding document verifying the functionality, if the execution of the tests related to those items is not possible for example due to circumstances influencing generation or the operation situation of the Power System.

14.3 Compliance Testing of Synchronous Power Generating Modules of Power Classes 2 and 3

14.3.1 Compliance Testing plans, measurements and data exchange

The Compliance Testing shall be carried out in co-operation between the Power Generating Facility Owner, the Relevant Network Operator, and Fingrid. Fingrid's representatives have the right to participate in all Compliance Testing.

The Power Generating Facility Owner shall draw up a Compliance Testing plan for the specific Power Generating Facility. The plan shall cover the testing of the functionalities specified in the Specifications at least in the scope described in this section. The Power Generating Facility Owner shall deliver the Compliance Testing plan, preliminary commissioning instructions and a description of the practical arrangements of the tests. The description of the practical arrangements shall cover at least the measurement arrangements, responsible persons, and preliminary schedule. The documents shall be delivered to the Relevant Network Operator no later than 3 months before the planned start of the Compliance Testing.

In conjunction with the drawing up and delivery of the Compliance Test plans, the Power Generating Facility Owner shall appoint on a meeting between the Power Generating Facility Owner, the Relevant Network Operator, and Fingrid. The meeting shall take place no later than 2 months before the Compliance Testing. In the meeting, the Power Generating Facility Owner shall agree on the final Compliance Testing plan and on the schedule and practical arrangements of the Compliance Testing with the Relevant Network Operator and Fingrid. If the above-mentioned parties agree that a meeting will not be held, the data exchange concerning the issues to be agreed shall be arranged in some other way. Each of the above-mentioned parties shall appoint at least one contact person for the Compliance Testing.

As the transmission system operator, Fingrid has the right to cancel or change the schedule of the Compliance Testing if the execution of the tests at the planned time is not possible due to the operation situation of the Power System. The Relevant Network Operator has a corresponding right with regard to the operation situation of its own electricity network. The cancellation or schedule change may be caused by factors such as circumstances related to the operation of Power Generating Facilities or the operation situation of the local electricity network and Power System. If the timing of the Compliance Testing needs to be changed, the Power Generating Facility Owner shall agree on a new schedule with the Relevant Network Operator and Fingrid.

At least the below variables shall be measured and recorded in all Compliance Testing at a minimum recording frequency of 50 Hz:

- Terminal Voltage of the Generator,
- excitation voltage of the generator or its excation system,
- frequency of the generator,
- excitation current of the generator or its excation system,
- Active Power of the generator, and
- Reactive Power of the generator.

Moreover, the reference value of the variable adjusted in the Compliance Testing and the changes in the reference value shall be recorded.

The Compliance Testing shall be planned so that the correspondence between the actual operation of the Power Generating Facility and the dynamics modelling data can be demonstrated by means of calculations.

14.3.2 Substituting the Compliance Testing

If the Compliance Testing cannot be performed for example due to the operational situation of the Power System, the Power Generating Facility Owner shall agree separately with Fingrid and the Relevant Network Operator on substituting the Compliance Testing. Fingrid will determine whether any Compliance Testing can be replaced with one of the following methods:

1) certificates given by accredited laboratories, or equivalent detailed test reports of the Turbine Generators,

2) continuous follow-up,

3) simulation examinations carried out by utilising verified simulation models.

14.3.3 Documentation and acceptance of Compliance Testing

It is the responsibility of the Power Generating Facility Owner to document the Compliance Testing and its results in the commissioning report. The Power Generating Facility Owner shall deliver the commissioning report as an electronic document and the results of the Compliance Testing in Numerical format to the Relevant Network Operator in the scope specified under section 15.2.2.

The Power Generating Facility Owner shall agree separately with the Relevant Network Operator on the timing of tests of Power Generating Facility projects which proceed in stages, described in section 5.3.

It is the responsibility of the Relevant Network Operator to confirm the fulfilment of the compliance monitoring obligation related to the Specifications in terms of the Compliance Testing based on the following four sectors:

1) The preparation, planning and data exchange of the tests have been carried out in accordance with the Specifications.

2) The tests have been carried out in accordance with the scope of the Specifications.

3) The operation of the Power Generating Facility verified by the tests is in accordance with the Specifications and with the data provided on the Power Generating Facility.

4) A commissioning report and measurement data in Numerical format have been delivered of the tests related to the Specifications in accordance with the Specifications (section 15.2.2).

14.3.4 Functions to be verified in Compliance Testing

The Compliance Testing shall verify the following issues:

1) The operation of the Power Generating Facility at the Minimum Output is in accordance with the Specifications (section 11.2.2.1).

2) The actual Reactive Power Capacity of the Power Generating Facility is in accordance with the Specifications (section 12.2.2) and corresponds to that specified in the Reactive Power Capacity calculation (section 12.2.3).The capability of the Power Generating Facility to generate inductive and capacitive Reactive Power shall be verified while the Power Generating Facility is operating at its Rated Capacity (P_{max}) and, in addition to the Rated Capacity, at at least two Active Power generation levels, for which the highest inductive and capacitive Reactive Power have been specified in the Reactive Power capacity calculation.

3) The following issues shall be verified of the operation of Reactive Power control and voltage control of the generator:

   a. The functioning and characteristics of the excitation of the generator are in accordance with the Specifications (section 13.2.2).

   b. The functioning, setting features and characteristics of the constant voltage control of the generator are in accordance with the Specifications (sections 13.2.1 and 13.2.3).

   c. The functioning of the underexcitation limiter of the voltage control of the generator is in accordance with the Specifications (section 13.2.5).

   d. The functioning of the overexcitation limiter of the voltage control of the generator is in accordance with the Specifications (section 13.2.5).

4) The capability of the Power Generating Facility to contribute to the Active Power control and Frequency Control of the Power System in conjunction with major step-like and ramp-like frequency changes shall be in accordance with the Specifications (section 11.2.3). During the tests, the Active Power generation of the Power Generating Facility shall be at least 30 per cent of the Rated Capacity of the Power Generating Facility. Correspondingly, the control range of Frequency Control shall be at least ±10 per cent of the Rated Capacity of the Power Generating Facility. The tests shall indicate at the least the following dynamic characteristics related to the Active Power control capability and Frequency Control capability of the Power Generating Facility:

   a. The characteristics of fast (of a few seconds) response of Frequency Control shall be verified. The response characteristics shall be verified by using a test signal, as a result of which Frequency Control controls the Active Power of the Power Generating Facility utilising all the Frequency Control capacity set for the Power Generating Facility. The response characteristics shall be verified by using either the highest available setting of the limiter of the rate of change of Active Power or a setting that is typical for the operation situation.

   b. The characteristics of slow (of a few dozen seconds) response of Frequency Control shall be verified. The response characteristics shall be verified by using a test signal, as a result of which Frequency Control controls the Active Power of the Power Generating Facility utilising all the Frequency Control capacity set for the Power Generating Facility. The response characteristics shall be verified by using at least one setting of the limiter of the rate of change of Active Power typical for the operation situation.

c. It shall be verified that the implementation and setting options of the Droop and dead band of the control are in accordance with the Specifications.

5) The control of Active Power and the rate of change of Active Power of the Power Generating Facility shall be in accordance with the Specifications (section 11.2.4).

6) The Power Generating Facility can shift to house load operation and operate in house load in accordance with the Specifications. In the test, the Power Generating Facility shall shift to house load operation from the Rated Capacity of the Power Generating Facility (section 11.2.5).

7) During a momentary voltage disturbance and after a voltage disturbance, the Power Generating Facility shall operate in accordance with the Specifications (sections 10.2.2 or 10.4.1).

14.4 Compliance Testing of Synchronous Power Generating Modules of Power Class 4

The Compliance Testing of Power Generating Facilities of Power Class 4 is subject to the same requirements as Power Classes 2 and 3. In addition, the Compliance Testing of Power Generating Facilities of Power Class 4 shall verify the functioning and characteristics of the power system stabiliser (PSS) of the voltage control of the generator. The Compliance Testing of the power system stabiliser shall verify the response of the controller to electromechanical oscillations. These are verified, because they have an impact on the transmission capacity of the grid and on the assessment of the transmission capacity. The tests shall verify the functioning of the generator in accordance with the Specifications (section 13.3) both while the power system stabiliser is in operation and while it is out of operation.

The detailed content and scope of the Compliance Testing of the power system stabiliser shall be agreed separately with Fingrid and with the Relevant Network Operator. The Compliance Testing shall cover the following issues:

1) The tests shall be carried out at the Rated Capacity and at at least one Active Power level which is different from it.

2) The response of the controllers of the Power Generating Facility within the frequency range of system-frequency oscillations shall be verified in the Compliance Testing. This can be done by changing the system switching situation or by feeding a separate signal, which imitates the oscillation, to the Power Generating Facility controllers (test signal injection).

3) The functioning of the Power Generating Facility and its controller shall be recorded extensively in Numerical format using measurement equipment with a sufficient sampling frequency for the analysis of the response of the controller.

15 Modelling requirements applicable to Synchronous Power Generating Modules

15.1 Modelling requirements concerning Synchronous Power Generating Modules of Power Class 1

Synchronous Power Generating Modules of Power Class 1 are not subject to modelling requirements.

15.2 Modelling requirements concerning Synchronous Power Generating Modules of Power Classes 2 and 3

15.2.1 Functional requirements of dynamics modelling data

The data to be delivered for the dynamics modelling shall enable the modelling of the interaction between the Turbine Generator of the Power Generating Facility and the Power System, taking into account the response of the Turbine Generator of the Power Generating Facility and its impact on the following issues:

1) changes in the voltage amplitude and in its phase angle in conjunction with electromechanical transients,

2) electromechanical oscillations related to angle stability at frequencies 0.2–2 Hz following small and large signal disturbancies,

3) high-speed (10 ms – 10 s) transients related to voltage stability. These shall take into account the operation of the facility in conjunction with momentary voltage disturbances, and the dependence of the recovery of Active Power and the Reactive Power capacity on voltage.

15.2.2 Requirements concerning the verification and documentation of the modelling data

The data to be delivered for the dynamics modelling shall be verified by comparing the modelling data, using the modelling results obtained, to the results of the Compliance Testing of the Power Generating Facility.

The verification obligation of modelling data applies to Power Generating Facilities in the scope presented in Tables 15.1 and 15.2. If a Power Generating Facility has several mutually similar units, the correctness of the modelling data can be verified using the recordings for a single unit.

The data to be delivered for dynamics modelling shall be documented. The data shall be delivered as electronic documents to the Relevant Network Operator. The documents to be submitted shall be clear and unambiguous in terms of their layout and structure. The documentation shall cover the following main issues:

1) Dynamics modelling data:

   a) block diagram level description of the Active Power control, Reactive Power control and voltage control of the generators,

b) project-specific parameters suited to the block diagram level description, taking into account the requirements laid down in section 15.2.1.

2) Results of verification of modelling data:

a) report of the verification of modelling data,

b) comparison of the modelling results and the results of the Compliance Testing in the scope presented in Table 15.1,

c) measurement results of the Compliance Testing in Numerical format in the scope presented in Table 15.2 in so far as Table 15.1 obliges verification,

d) account of potential differences between the modelling results and the results of the Compliance Testing.

Table 15.1. Verification obligation of modelling data on Synchronous Power Generating Modules by various power classes.

Item to be verified	Power Class 2	Power Class 3	Power Class 4
Step response of generator voltage (both the increase and decrease of voltage)	X	X	X
Slope of voltage control at two different Slope set values		X	X
Functioning of power system stabiliser (PSS)			X
Functioning of overexcitation limiter			X
Functioning of underexcitation limiter			X
Fault ride-through test *)			X

*) If a fault ride-through test for the Power Generating Facility is not carried out, the functioning of the Power Generating Facility in a momentary voltage disturbance shall be indicated by means of modelling calculations.

Table 15.2. Measurement data on Compliance Testing to be delivered in Numerical format, to which measurement data the results calculated using the modelling data is compared.

Item to be verified	U_{gen}	U_f or U_{ef}	f_{gen}	I_f or I_{ef}	P_{gen}	Q_{gen}	Signals
Step response of generator voltage (both the increase and decrease of voltage)	X	X	X	X			
Slope of voltage control at two different Slope set values	X	X	X	X	X	X	
Functioning of power system stabiliser (PSS)	X	X	X	X	X	X	PSS input and output signals
Functioning of overexcitation limiter	X	X	X	X	X	X	Output signal of limiter
Functioning of underexcitation limiter	X	X	X	X	X	X	Output signal of limiter
Fault ride-through test	To be agreed individually in each case. If a fault ride-through test for the Power Generating Facility is not carried out, the functioning of the Power Generating Facility in a local fault shall be indicated by means of simulation calculations.						

U_{gen}	Terminal Voltage of Generator
U_{ef}	excitation voltage of excitation system
U_f	excitation voltage of generator
f_{gen}	frequency of generator
I_{ef}	excitation current of excitation system
I_f	excitation current of generator
P_{gen}	Active Power of generator
Q_{gen}	Reactive Power of generator

15.2.3 Specific study requirements

If conducting the specific studies requires utilising calculation programs applicable to electromagnetic transients, the simulation models of the Power Generating Facility used in the simulation shall be delivered to Fingrid as part of the final report of the specific study. The said simulation model shall be updated after the Compliance Testing and delivered to Fingrid as part of the final documentation of the Power Generating Facility.

15.2.4 Requirements for the simulation models of compensation devices

The simulation models of compensation devices related to the Power Generating Facility project shall be agreed upon separately with Fingrid.

15.3 Modelling requirements concerning Synchronous Power Generating Facilities of Power Class 4

Power Generating Facilities of Power Class 4 shall fulfil all the same requirements as Power Generating Facilities of Power Classes 2 and 3. Moreover, it shall be possible to freely change that modelling data which enables the implementation of the dynamics simulation model so that the response of the controllers can be changed either by changing the control parameters or by changing the parameters of higher-level

controllers, such as power system stabiliser or damping control. The analysis of the response of the controller shall be carried out in close co-operation between the Power Generating Facility Owner and Fingrid in order to obtain a realistic estimate of the impact of the Power Generating Facility on the transmission capacity of the Power System.

Requirements applicable to Wind Power Park Modules

16 Frequency Control and Active Power control of Wind Power Park Modules

16.1 Frequency Control and Active Power control of Wind Power Park Modules of Power Class 1

Wind Power Park Modules of Power Class 1 are not subject to requirements related to Frequency Control or Active Power control. If the Power Generating Facility characteristics include functionalities related to Active Power control and Frequency Control, Fingrid has the right, if necessary, to utilise these functionalities as described under section 16.2.

16.2 Frequency Control and Active Power control of Wind Power Park Modules of Power Classes 2, 3 and 4

16.2.1 Fingrid's rights during disturbance in the Power System

Fingrid has the right to demand Power Generating Facilities to adjust themselves within the power control characteristics presented in this document, if the Power System cannot be restored to the normal state after a disturbance.

16.2.2 Active Power, start-up, and house load operation of Power Generating Facility

16.2.2.1 Minimum Output

The Minimum Output of the Power Generating Facility and its capability to operate momentarily below its Minimum Output shall be reported as part of the data to be delivered. The Minimum Output of the Power Generating Facility shall be no more than 10 per cent of the Rated Capacity of the Power Generating Facility.

If the Power Generating Facility consists of several units and the Minimum Output is not evenly distributed between the generators/units, the Minimum Outputs of individual generators shall also be reported as part of the data to be delivered alongside the Minimum Output of the entire Power Generating Facility.

16.2.2.2 Rated Capacity

The dependence of the power generation of the Wind Power Park Module on wind velocity and potential other dependences (such as on temperature) shall be reported as part of the data to be delivered.

If the Power Generating Facility consists of several units and the Rated Capacity is not evenly distributed between the generators/units, the Rated Capacities of individual generators shall also be reported as part of the data to be delivered alongside the Rated Capacity of the entire Power Generating Facility.

The data related to the overload capacity of the Power Generating Facility shall be reported as part of the data to be delivered.

16.2.2.3 Start-up of Power Generating Facility

The connection of the Wind Power Park Module to the Power System shall not cause a change in excess of 3 per cent in the voltage of the VJV Reference Point of the Power Generating Facility.

The need to limit the Active Power rate of change during the start-up of the Wind Power Park Module shall be agreed separately with the Relevant Network Operator.

16.2.2.4 House Load

The House Load Power of the Power Generating Facility shall be reported as part of the data to be delivered.

16.2.3 Implementation of Frequency Control and Active Power control

16.2.3.1 General controller requirements

The Power Generating Facilities shall be equipped with devices with which the Active Power and the rate of change of Active Power can be adjusted.

The Active Power control of the Power Generating Facility shall allow the setting the reference of Active Power manually and the adjustment of the Active Power on the basis of frequency measurement (Frequency Control).

16.2.3.2 Functionalities of Frequency Control

Frequency Control shall function proportionally to the frequency deviation, in other words the control system shall have adjustable linear Droop of Frequency Control.

It shall be possible to control the active power of the Power Generating Facility so that as a result of the functioning of Frequency Control, the Power Generating Facility can increase or decrease its power generation based on the frequency variation.

It shall be possible to specify a power range for Frequency Control, at which power range the Power Generating Facility can adjust the Active Power generated by the Power Generating Facility.

It shall be possible to set a dead band for the control.

16.2.3.3 Control parameters to be set

It shall be possible to set the Droop of Frequency Control between 2 and 12 per cent in steps of a maximum of 1 percentage point.

The power range to be specified for Frequency Control shall correspond to the Rated Capacity ((0–100%) × P_{max}) of the Power Generating Facility, and it shall be possible to set it in steps of 1 MW.

It shall be possible to specify the power range for Frequency Control separately into a direction increasing the power output and to a direction decreasing the power output; in other words, it shall be possible to specify the range as asymmetrical.

It shall be possible to specify the dead band of Frequency Control between 0.01 and 1 Hz in steps of a maximum of 10 mHz.

16.2.4 Curtailment of Active Power

It shall be possible to curtail the upper limit of Active Power generation so that it shall be possible to specify a value smaller than the Rated Capacity for the highest permitted level of Active Power of the Power Generating Facility.

The functioning of the upper limit set shall ensure that the Active Power generation, which is measured as 10 second averages, does not exceed the specified level.

It shall be possible to restrict the rate of the power change taking place in conjunction with the curtailment of Active Power, for example in the manner described in section 16.2.5 or in a corresponding manner.

The setting of the upper limit shall be made at a minimum accuracy of 1 MW within a range limited by the Minimum Output and Rated Capacity of the generator.

16.2.5 Restriction of rate of change of Active Power

It shall be possible to restrict the rate of change of the Active Power generation of the Power Generating Facility and its generators.

When the power increases, it shall be possible to restrict the rate of change both in a case where the reference value of the Active Power limiter is changed and in a situation where the Active Power generation of the Power Generating Facility increases as the wind velocity increases.

If the wind velocity decreases rapidly, there is no need to restrict the rate of change of Active Power. It shall be possible to restrict the rate of change of power if the reference value of the Active Power limiter is decreased.

A description of the implementation method of the functionality shall be delivered as part of the Power Generating Facility documentation.

It shall be possible to specify the reference value of the rate of change of power at least within a range where the minimum value is 10 per cent of the Rated Capacity per minute and the maximum value is 100 per cent of the Rated Capacity per minute ($0.1 \times P_{max}$/min...$1.0 \times P_{max}$/min). The smallest change in the reference value shall be at least 1 megawatt per minute.

It shall be possible to specify the rate of change reference values, which restrict the increase and decrease of power, separately.

16.2.6 Rapid downward control of Active Power

It shall be possible to control the Active Power generation of the Power Generating Facility down from 100 per cent to 20 per cent of the Rated Capacity in less than 5 seconds.

It shall be possible to restore the Active Power within a short period of time after downward control.

It is not necessary to implement the rapid downward control as a function of its own if it can be implemented by utilising the other functionalities of the power control system of the Wind Power Park Module.

16.2.7 Changes between the Modes of Active Power control and Frequency Control

A change in the Mode of Active Power control and Frequency Control shall not cause a major sudden variation in the Active Power or Reactive Power generated by the Power Generating Facility.

It shall be possible to change, prevent and allow the Modes and set values of the Active Power control and Frequency Control of the Power Generating Facility. The control of the Modes and set values shall work in the same way regardless of whether the Power Generating Facility is controlled locally or in remote control.

16.2.8 Accuracy and sensitivity of control

The accuracy of the reference value of Active Power control shall be at least 1 MW.

The sensitivity of Frequency Control shall be at least 10 mHz, and the response time shall be no more than 2 s.

The accuracy and sensitivity of the power control and Frequency Control of the Power Generating Facility shall be verified during the Compliance Testing. A description of these and of the factors affecting them shall be delivered as part of the Power Generating Facility documentation.

16.2.9 Interrupting the generation of Active Power due to high wind

The Wind Turbine Generators of the Wind Power Park Module shall not stop simultaneously due to high wind velocity. The stopping shall be graded, and the grading shall be based on the capability of the Wind Turbine Generators to operate safely in high wind.

The implementation of the gradation of the automatic stopping of a Wind Turbine Generator in terms of wind velocities which are critical in order to ensure functional safety and in terms of related delays shall be documented and delivered as part of the Power Generating Facility documentation. The documentation shall also contain a description of the principles relating to continue generation after an interruption due to high wind velocities.

16.2.10 Restarting of generation after disconnection from the grid

The automatic start-up of electricity generation by the Power Generating Facility after disconnection from the grid shall be agreed upon separately with the Relevant Network Operator.

If the restarting of generation by the Power Generating Facility after disconnection from the grid involves restrictions related to the operation and implementation of the Power Generating Facility, a description of the restrictions shall be delivered as part of the Power Generating Facility documentation.

17 Reactive Power Capacity of Wind Power Park Modules

17.1 Reactive Power Capacity of Wind Power Park Modules of Power Class 1

The Relevant Network Operator sets the Reactive Power capacity requirement for Wind Power Park Modules of Power Class 1.

17.2 Reactive Power Capacity of Wind Power Park Modules of Power Class 2

17.2.1 Reactive Power capacity requirement

When the power output of the Power Generating Facility is between the Minimum Output and the Rated Capacity, the Power Generating Facility shall be able to generate and consume Reactive Power (Q) the amount that the Power Generating Facility produces while operating at the Rated Capacity (P_{max}), overexcited or underexcited with a power factor of 0.995. Figure 17.1a) shows this Reactive Power capacity range.

The Reactive Power measured at the VJV Reference Point shall be, as shown in Figure 17.1b):

- 0–0.1 [Q/P_{max}] overexcited, when the voltage of the VJV Reference Point is 0.90–1.00 p.u.
- 0–0.1 [Q/P_{max}] underexcited, when the voltage of the VJV Reference Point is 1.00–1.05 p.u.

The Power Generating Facility is not required to generate Reactive Power below the Minimum Output.

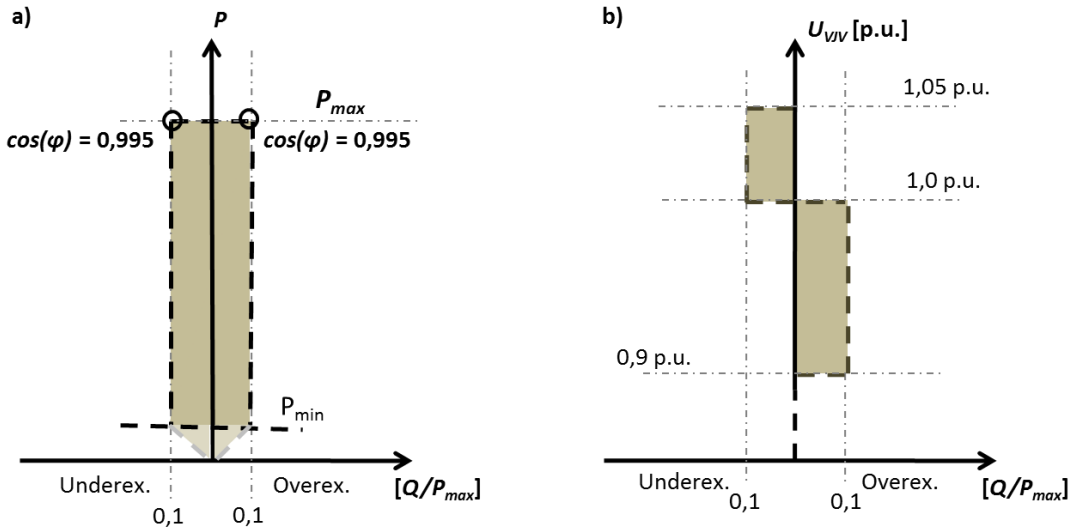


Figure 17.1. Reactive Power capacity requirements as a function of Active Power and voltage of VJV Reference Point for Wind Power Park Modules of Power Class 2. In the figure, a voltage of 1.0 p.u. corresponds to the Normal Operating Voltage specified by the Relevant Network Operator.

17.2.2 Components utilised to achieve the Reactive Power capacity requirement

Reactive Power capacity does not need to be reserved in wind turbines only, but it can be reserved in one or more separate adjustable Reactive Power compensation devices, which have been connected to the Power System to the VJV Reference Point of the Power Generating Facility or beyond it to be part of the other Power Generating Facility equipment.

The functioning of components utilised so as to achieve the Reactive Power capacity requirement shall be co-ordinated with the functioning of the other Power Generating Facility components that control voltage, in such a manner that the Reactive Power control requirements and voltage control requirements laid down for the Power Generating Facility under section 18 are fulfilled.

The testing, documentation and simulation requirements of devices used so as to fulfil the Reactive Power capacity requirement of the Power Generating Facility shall be agreed upon separately with the Relevant Network Operator in accordance with the compliance monitoring process of the Specifications.

17.2.3 Reactive Power capacity calculation

The Power Generating Facility Owner shall deliver a calculation of the Reactive Power capacity of the Power Generating Facility at the VJV Reference Point to the Relevant Network Operator. The calculation shall be delivered in stage 1 of the compliance monitoring process of the Specifications. The calculation shall demonstrate the capability of the Power Generating Facility to generate and consume Reactive Power at the voltage levels of the VJV Reference Point and at the Active Power levels of the Power Generating Facility specified in Table 17.1.

If the Step-up Transformer of the Power Generating Facility is equipped with an on-load tap-changer or off-load tap changer, the calculation shall be presented, in addition to the middle position of the on-load tap-changer or off-load tap changer of the Step-up Transformer, also at the extreme positions of the on-load tap-changer or off-load tap changer.

In addition to the Reactive Power capacity specified for the Power Generating Facility in the calculation, the Reactive Power capacity calculation shall present the input data used in the calculation, such as the voltage ranges and Reactive Power capacities of the generators.

The Reactive Power capacity calculation shall consider, as necessary, the generators and any other Power Generating Facility components that generate and consume Reactive Power.

Operating points 0.85 p.u. and 0.875 p.u. are momentary at the voltage levels of the VJV Reference Point, and at these operating points the Power Generating Facility shall be able to operate for a minimum of 10 seconds.

Table 17.1. Operating points used in the Reactive Power capacity calculation.

Voltage at VJV Reference point [p.u.]	0.85	0.875	0.9	0.925	0.95	0.975	1.0	1.025	1.05	1.075	1.1
Power output 1	Minimum Output										
Power output 2	P = 0.50 × Pmax										
Power output 3	Rated Capacity										
Operating points 0.85 p.u. and 0.875 p.u. are momentary at the voltage levels of the VJV Reference Point. and at these operating points the Power Generating Facility shall be able to operate for a minimum of 10 seconds.											

If the final implementation of the components of the Power Generating Facility is different from that planned, the report related to the Reactive Power capacity of the Power Generating Facility shall be updated and delivered to the Relevant Network Operator.

The Reactive Power capacity of the Power Generating Facility at the VJV Reference Point, specified in the Reactive Power capacity calculation, shall be verified in conjunction with the verification of compliance in accordance with the principles described in chapter 19.

17.2.4 Restriction of Reactive Power capacity

When operating outside the limit values specified in section 17.2.1, the Reactive Power generation capacity of the Power Generating Facility and its generator shall be in accordance with that indicated in the Reactive Power capacity calculation.

The protection related to the operation of current limiters (or equivalent equipment) used in the Power Generating Facility shall be co-ordinated so that the available Reactive Power capacity can be utilised efficiently without the risk of the Power Generating Facility disconnecting from the Power System.

17.3 Reactive Power Capacity of Wind Power Park Modules of Power Classes 3 and 4

Wind Power Park Modules of Power Classes 3 and 4 shall fulfil the requirements for Power Class 2 in other respects, except that the Reactive Power capacity requirement, which is described in this section, is different.

The Power Generating Facility shall be able to generate and consume Reactive Power (Q) within the operating range limited by its Minimum Output and Rated Capacity, overexcited or underexcited with a power factor of 0.95. Figure 17.2a) shows this Reactive Power capacity range.

The Reactive Power measured at the VJV Reference Point shall be, as shown in Figure 17.2b):

- 0–0.33 [Q/P_{max}] overexcited, when the voltage of the VJV Reference Point is 0.90–1.00 p.u.
- 0–0.33 [Q/P_{max}] underexcited, when the voltage of the VJV Reference Point is 1.00–1.05 p.u.

The Power Generating Facility is not required to generate Reactive Power below the Minimum Output.

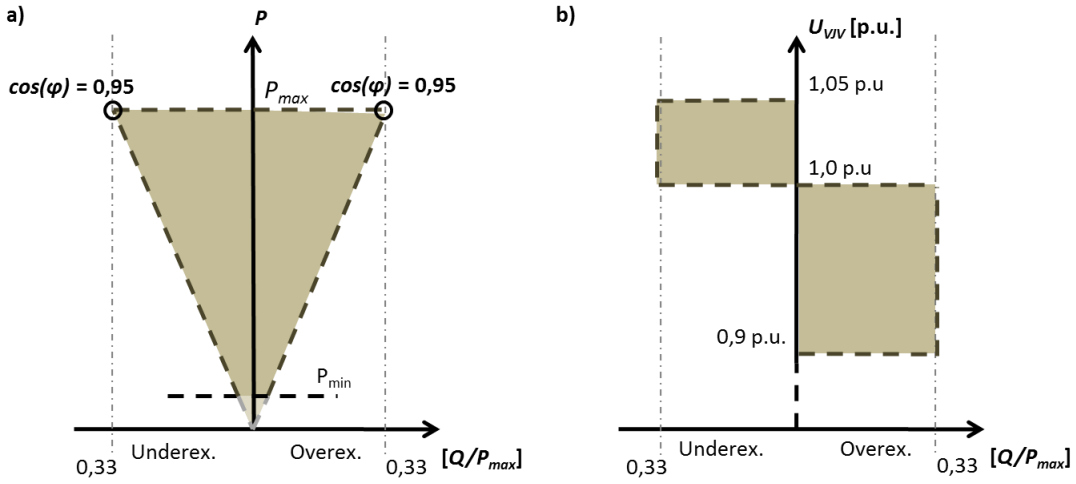


Figure 17.2. Reactive Power capacity requirements as a function of Active Power and voltage of VJV Reference Point for Wind Power Park Modules of Power Classes 3 and 4. In the figure, a voltage of 1.0 p.u. corresponds to the Normal Operating Voltage specified by the Relevant Network Operator.

18 Voltage control and Reactive Power control of Wind Power Park Module

18.1 Voltage control and Reactive Power control of Wind Power Park Modules of Power Class 1

The Power Generating Facility shall be able to operate at a power factor of 1.0 measured at the VJV Reference Point, or alternatively the Power Generating Facility shall be able to support the voltage of the VJV Reference Point by means of its Reactive Power capacity, as follows:

- The Power Generating Facility generates Reactive Power to the Power System when the voltage of the VJV Reference Point decreases.
- The Power Generating Facility consumes Reactive Power from the Power System when the voltage of the VJV Reference Point increases.

18.2 Voltage control and Reactive Power control of Wind Power Park Modules of Power Classes 2 and 3

18.2.1 Functionalities of voltage control and Reactive Power control

The Power Generating Facilities shall have automatic Reactive Power control and voltage control. The control shall be carried out so that the control operates continuously and the changes in Reactive Power at the VJV Reference Point as a result of the control take place steplessly.

Reactive Power control shall enable the utilisation of the Reactive Power capacity of the Power Generating Facility in the manner described in chapter 17. The functioning of the control shall not be disturbed by changes in the voltage and frequency of the Power System or by momentary voltage disturbances.

The Reactive Power control and voltage control of Power Generating Facilities shall have the following Modes:

1) constant Reactive Power control,
2) constant power factor control, and
3) constant voltage control.

The control range of Reactive Power control and voltage control shall correspond to the actual Reactive Power capacity of the Power Generating Facility. The Reactive Power capacity shall not be artificially limited. The basic operation of limiters implemented in order to guarantee the electrical strength of the Power Generating Facility components shall be described as part of the Power Generating Facility documentation to be delivered.

The Reactive Power control functions and voltage control functions shall be able to keep the Reactive Power generation of the Power Generating Facility within the reference value of the control function. The accuracy of the Reactive Power control functions and voltage control functions shall be verified during the Compliance Testing. The response of

the control functions to stepwise changes and to continuous variation in the voltage of the Power System shall be stable, and the control functions to be carried out as a result of the changes shall not lead to repeated or poorly damping oscillations in the Reactive Power or Active Power of the facility.

If the Wind Turbine Generator and/or Wind Power Park Module is operating below its Minimum Output (P_{min}), the Wind Power Park Module does not have an obligation, from the viewpoint of the Specifications, to control the voltage or Reactive Power of the VJV Reference Point.

18.2.2 Constant Reactive Power control

The Power Generating Facility shall be able to operate at constant Reactive Power control so that the control can be used for controlling directly the Reactive Power fed to the VJV Reference Point and the Reactive Power taken from the VJV Reference Point.

It shall be possible to set the reference value of constant Reactive Power control for Reactive Power at the VJV Reference Point in maximum steps of 1 Mvar. The setting range of the reference value shall correspond to the actual Reactive Power capacity of the Power Generating Facility.

18.2.3 Constant power factor control

The Power Generating Facility shall be able to operate at constant power factor control so that the control can be used for controlling directly the power factor of the VJV Reference Point, i.e. the Reactive Power fed to the VJV Reference Point and the Reactive Power taken from the VJV Reference Point as a function of the Active Power generated by the Power Generating Facility.

It shall be possible to set the reference value of constant power factor control for the power factor in maximum steps of 0.01 between 0.95ind–0.95cap or in a broader range.

18.2.4 Constant voltage control

The Power Generating Facility shall be able to operate at constant voltage control so that the control can be used, considering the Slope, for controlling directly the voltage of the VJV Reference Point.

It shall be possible to set the reference value of constant voltage control for the voltage in accordance with the limit values specified for the voltage of the VJV Reference Point (continuous operation) in the Specifications in maximum steps of 0.01 p.u.

The Slope of voltage control shall be linear, and it shall be possible to set it within a range of 1 to 10 per cent in maximum steps of 1 percentage point. The reference value can be set as positive or negative depending on the implementation of the voltage control of the Power Generating Facility.

When the stepwise change in the voltage of the VJV Reference Point is below 0.05 p.u., the response of constant voltage control shall be as follows:

1) the rise time of the Reactive Power response from 0 to 90 per cent of the measured total change in Reactive Power shall not be more than 1 second,

2) the exceeding verified in the step response shall not be more than 15 per cent of the measured total change in Reactive Power,

3) the response shall settle to its target level within 3 seconds from the stepwise excitation.

18.2.5 Changes in the Modes and reference values of voltage control and Reactive Power control

Any transitions in the Mode and operating point of the control shall take place without sudden significant changes (no more than 1 per cent of the Rated Capacity) or repeated, significant oscillations in the Active Power or Reactive Power produced by the Power Generating Facility. The Mode transition shall take place within a predetermined period of time after the Mode transition is requested from the Wind Power Park Module.

The Modes and reference values of the voltage control shall work in the same way regardless of whether the Power Generating Facility is controlled locally or in remote control.

18.2.6 Protection and limiters related to the functioning of voltage control

When the voltage of the Connection Point of the Power Generating Facility is high, the functioning of the limiters shall control, in as direct and delay-free manner as possible, the functioning of the voltage control in order to avoid intense overvoltages.

18.2.7 Other components contributing to voltage control and Reactive Power control

If separate compensation devices implemented as part of the Power Generating Facility are utilised in order to achieve the Reactive Power capacity requirement, the functioning of such devices shall be co-ordinated with the functioning of the controllers of the Wind Turbine Generators so as to fulfil the other requirements laid down in this chapter 18. Moreover, the need to co-ordinate the functioning of the devices with the other components contributing to the control of voltage in the Power System shall be agreed upon separately with the Relevant Network Operator.

18.3 Voltage control and Reactive Power control of Wind Power Park Modules of Power Class 4

Wind Power Park Modules of Power Class 4 shall fulfil all the same requirements as Wind Power Park Modules of Power Classes 2 and 3, and Wind Power Park Modules of Power Class 4 are also subject to additional requirements concerning the impacts of Reactive Power control and voltage control on electromechanical oscillations.

In the tuning of Reactive Power control and voltage control, the potential impact of the functioning of the controller on the dynamics of the Power System shall be taken into account.

The analysis of the response of voltage control and Reactive Power control shall be carried out in close co-operation between the Power Generating Facility Owner, the Relevant Network Operator and Fingrid in order to be able to specify the impact of the Wind Power Park Module on the transmission capacity of the Power System so that it supports the functioning of the Power System as well as possible.

If the response of the normal control functions of the Power Generating Facility to electromechanical oscillations deteriorates the transmission capacity of the Power System irrespective of the implementation and set values of the controls, the impact of the response of the control of the Power Generating Facility on the oscillations shall be improved by means of additional control functions, such as functionalities corresponding to power system stabiliser (PSS) or power oscillation damping (POD).

The details related to the control settings shall be documented comprehensively and delivered as part of the data to be provided.

The functioning of the control shall be verified during the Compliance Testing.

19 Compliance Testing of Wind Power Park Modules

19.1 Shared requirements for the Compliance Testing of all Wind Power Park Modules

It is the responsibility of the Power Generating Facility Owner to verify that the Power Generating Facility operates in accordance with the Specifications imposed on it. The Power Generating Facility Owner is responsible for the costs related to compliance monitoring. Compliance with the Specifications shall primarily be verified by means of Compliance Testing carried out in conjunction with the commissioning of the Power Generating Facility.

19.2 Compliance Testing of Wind Power Park Modules of Power Class 1

The Power Generating Facility Owner shall deliver minutes of commissioning of the Compliance Testing to the Relevant Network Operator. The minutes shall comprise the documentation of the variables validated by means of measurements and the time of the measurements.

It is the responsibility of the Power Generating Facility Owner to verify by Compliance Testing that the following characteristics of a Wind Power Park Module of Power Class 1 conform to the Specifications:

1) impact of the starting and stopping of the Power Generating Facility on the voltage level at the VJV Reference Point,

2) Rated Capacity of the Power Generating Facility,

3) Reactive Power capacity in accordance with the Specifications,

4) functioning of voltage control or Reactive Power control, if the Relevant Network Operator requires this, and

5) power quality.

Even though Compliance Testing is the primary compliance monitoring method, the commissioning measurements for items 2, 3 and 5 can be replaced by a type test report or a corresponding document verifying the functionality, if the execution of the tests related to those items is not possible for example due to circumstances influencing generation or the operation situation of the Power System.

19.3 Compliance Testing of Wind Power Park Modules of Power Classes 2, 3 and 4

19.3.1 Compliance Testing plans, measurements and data exchange

The Compliance Testing shall be carried out in co-operation between the Power Generating Facility Owner, the Relevant Network Operator, and Fingrid. Fingrid's representatives have the right to participate in all Compliance Testing.

The Power Generating Facility Owner shall draw up a Compliance Testing plan for the specific Power Generating Facility. The plan shall cover the testing of the functionalities specified in the Specifications at least in the scope described in this section. The Power Generating Facility Owner shall deliver the Compliance Testing plan, preliminary

commissioning instructions and a description of the practical arrangements of the tests. The description of the practical arrangements shall cover at least the measurement arrangements, responsible persons, and preliminary schedule. The documents shall be delivered to the Relevant Network Operator no later than 3 months before the planned start of the Compliance Testing.

In conjunction with the drawing up and delivery of the Compliance Test plans, the Power Generating Facility Owner shall appoint on a meeting between the Power Generating Facility Owner, the Relevant Network Operator, and Fingrid. The meeting shall take place no later than 2 months before the Compliance Testing. In the meeting, the Power Generating Facility Owner shall agree on the final Compliance Testing plan and on the schedule and practical arrangements of the Compliance Testing with the Relevant Network Operator and Fingrid. If the above-mentioned parties agree that a meeting will not be held, the data exchange concerning the issues to be agreed shall be arranged in some other way. Each of the above-mentioned parties shall appoint at least one contact person for the Compliance Testing.

As the transmission system operator, Fingrid has the right to cancel or change the schedule of the Compliance Testing if the execution of the tests at the planned time is not possible due to the operation situation of the Power System. The Relevant Network Operator has a corresponding right with regard to the operation situation of its own electricity network. The cancellation or schedule change may be caused by factors such as circumstances related to the operation of Power Generating Facilities or the operation situation of the local electricity network and Power System. If the timing of the Compliance Testing needs to be changed, the Power Generating Facility Owner shall agree on a new schedule with the Relevant Network Operator and Fingrid.

At least the below variables shall be measured and recorded in all Compliance Testing at a minimum recording frequency of 50 Hz:

- Active Power of Power Generating Facility,
- Reactive Power of Power Generating Facility,
- voltage at VJV Reference Point,
- frequency at VJV Reference Point.

Moreover, the reference value of the variable adjusted in the Compliance Testing and the changes of the reference value shall be recorded.

The Compliance Testing shall be planned so that the correspondence of the actual operation of the Power Generating Facility and the dynamic modelling data can be demonstrated by means of calculations.

19.3.2 Substituting the Compliance Testing

If the Compliance Testing cannot be performed for example due to the operational situation of the Power System, the Power Generating Facility Owner shall agree separately with Fingrid and the Relevant Network Operator on substituting the Compliance Testing. Fingrid will determine whether any Compliance Testing can be replaced with one of the following methods:

1) certificates given by accredited laboratories, or equivalent detailed test reports of the Turbine Generators,

2) continuous follow-up,

3) simulation examinations carried out by utilising verified simulation models.

19.3.3 Documentation and acceptance of Compliance Testing

It is the responsibility of the Power Generating Facility Owner to document the Compliance Testing and its results in the commissioning report. The Power Generating Facility Owner shall deliver the commissioning report as an electronic document and the results of the Compliance Testing in Numerical format to the Relevant Network Operator in the scope specified under section 20.2.5.

The Power Generating Facility Owner shall agree separately with the Relevant Network Operator on the timing of tests of Power Generating Facility projects which proceed in stages, described in section 5.3.

It is the responsibility of the Relevant Network Operator to confirm the fulfilment of the compliance monitoring obligation related to the Specifications in terms of the Compliance Testing based on the following four sectors:

1) The preparation, planning and data exchange of the tests have been carried out in accordance with the Specifications.

2) The tests have been carried out in accordance with the scope of the Specifications.

3) The operation of the Power Generating Facility verified by the tests is in accordance with the Specifications and with the data provided on the Power Generating Facility.

4) A commissioning report and measurement data in Numerical format have been delivered of the tests related to the Specifications in accordance with the Specifications (section 20.2.5).

19.3.4 Functions to be verified in Compliance Testing

The Compliance Testing shall verify the following functions:

1) Operation of the Wind Power Park Module at Minimum Output for 15 minutes.

2) The starting sequences of the Wind Power Park Module are in accordance with the Specifications (section 16.2.2.3).

3) The capability of the Wind Power Park Module to generate Reactive Power to the Power System is in accordance with the Specifications (chapter 17). The test shall demonstrate that the actual Reactive Power capacity of the Wind Power Park Module conforms to the capacity indicated in the Reactive Power capacity calculation. The Reactive Power capacity test shall demonstrate the operation of the Wind Power Park

Module in accordance with the Specifications for 15 minutes in at least 6 operating points:

a) the highest possible Reactive Power of the Wind Power Park Module at the capacitive power factor when the Active Power generation is at least 50 per cent of the Rated Capacity of the facility,

b) the highest possible Reactive Power of the Wind Power Park Module at the inductive power factor when the Active Power generation is at least 50 per cent of the Rated Capacity of the facility,

c) the highest possible Reactive Power of the Wind Power Park Module at the capacitive power factor when the Active Power generation is 20–40 per cent of the Rated Capacity of the facility,

d) the highest possible Reactive Power of the Wind Power Park Module at the inductive power factor when the Active Power generation is 20–40 per cent of the Rated Capacity of the facility,

e) the highest possible Reactive Power of the Wind Power Park Module at the capacitive power factor when the Wind Power Park Module is operating at the Minimum Output,

f) the highest possible Reactive Power of the Wind Power Park Module at the inductive power factor when the Wind Power Park Module is operating at the Minimum Output.

4) The functioning and implementation of the constant Reactive Power control of the Wind Power Park Module are in accordance with the Specifications (section 18.2.2).

5) The functioning and implementation of the constant power factor control of the Wind Power Park Module are in accordance with the Specifications (section 18.2.3).

6) The functioning and implementation of the constant voltage control of the Wind Power Park Module are in accordance with the Specifications (section 18.2.4). The compliance monitoring shall cover at least the following sectors:

a) The verification of the characteristics of the response time and the response of constant voltage control to a stepwise change taking place in the actual value signal of voltage going to voltage control. The response shall be determined at the voltage control Slope values of 0.02 and 0.08 p.u. At each Slope value, a test shall be carried out with the following stepwise changes in the actual value of voltage: +0.01, −0.01, +0.02, −0.02 p.u. In other words, 8 tests will be needed. The step response tests of constant voltage control shall be conducted either by feeding a stepwise test signal to voltage control or by changing the voltage of the VJV Reference Point in steps by using for example Reactive Power compensation devices or on-load tap changers.

b) The response of constant voltage control to changes in the reference value of voltage.

7) The tests shall demonstrate the functioning of the Wind Power Park Module in accordance with the Specifications during a transition in the Modes of voltage control of the Wind Power Park Module (section 18.2.6).

8) The Compliance Testing shall verify the capability of the Wind Power Park Module to limit Active Power generation as follows:

    a) limitation of power to a level which corresponds to the Minimum Output of the available Wind Power Generators,

    b) limitation of power to a level which corresponds to 30 per cent of the Rated Capacity of the available Wind Power Generators,

    c) limitation of power to a level which corresponds to 50 per cent of the Rated Capacity of the available Wind Power Generators.

9) Functioning of the Active Power limiters (section 16.2.4) and limiters of the rate of change of Active Power (section 16.2.5) of the Wind Power Park Module in accordance with the Specifications. The compliance monitoring shall be performed in both power change directions using at least two different rate of change values.

10) The stopping of the Wind Power Park Module in high wind conditions takes place in a controlled manner, when the wind velocity exceeds the limit value for the maximum wind velocity of the Wind Power Park Module (section 16.2.9).

11) The rapid downward control of the Active Power of the Wind Power Park Module is in accordance with the Specifications (section 16.2.6).

12) The capability of the Power Generating Facility to contribute to the Active Power control and Frequency Control of the Power System in conjunction with major step-like and ramp-like frequency changes shall be in accordance with the Specifications (section 16.2.3). During the tests, the Active Power generation of the Power Generating Facility shall be at least 30 per cent of the Rated Capacity of the Power Generating Facility. Correspondingly, the control range of Frequency Control shall be at least ±10 per cent of the Rated Capacity of the Power Generating Facility. The tests shall indicate at the least the following characteristics related to the Active Power control capability and Frequency Control capability of the Power Generating Facility:

    a) The characteristics of fast response of Frequency Control shall be verified. The response characteristics shall be verified by using a fast test signal (frequency change in a few seconds), as a result of which Frequency Control controls the Active Power of the Power Generating Facility utilising all the Frequency Control capacity set for the Power Generating Facility. The response characteristics shall be verified by using at least the highest available setting of the limiter of the rate of change of Active Power and a setting that is typical for the operation situation.

    b) The characteristics of slow response of Frequency Control shall be verified. The response characteristics shall be verified by using a slow test signal (frequency change in a few dozen seconds), as a result of which Frequency Control controls the Active Power of the Power Generating Facility utilising all

the Frequency Control capacity set for the Power Generating Facility. The response characteristics shall be verified by using at least one setting of the limiter of the rate of change of Active Power typical for the operation situation.

c) It shall be verified that the implementation and setting options of the Droop and dead band of the control are in accordance with the Specifications.

13) The tests shall demonstrate the functioning of the Wind Power Park Module in accordance with the Specifications during a transition in the Modes of Active Power control of the Wind Power Park Module (section 16.2.7).

14) The impact of the Wind Power Park Module on the power quality is in accordance with the Specifications (section 9.1.3).

15) During a momentary voltage disturbance and after a voltage disturbance, the Wind Power Park Module shall operate in accordance with the Specifications (sections 10.2.2 or 10.4.1).

20 Modelling requirements applicable to Wind Power Park Modules

20.1 Modelling requirements concerning Wind Power Park Modules of Power Class 1

Wind Power Park Modules of Power Class 1 are not subject to modelling requirements.

20.2 Modelling requirements concerning Wind Power Park Modules of Power Classes 2 and 3

20.2.1 General simulation model requirements

The simulation models to be supplied of Wind Power Park Modules shall reproduce the main functionalities and characteristics of the Wind Power Park Module realistically.

The simulation models shall be delivered either as a model compatible with the calculation software specified by Fingrid or as detailed block diagram level descriptions, with the set values. The models can be replaced by block diagram models and parameter listings made using other calculation software, if the data to be provided is sufficiently accurate for the implementation of a corresponding calculation model in the calculation software specified by Fingrid.

20.2.2 Aggregation of Power Generating Facility for the simulation model

The power flow simulation models, fault current simulation models and dynamics simulation models of each Power Generating Facility shall be delivered as an entity compiled into a single equivalent generator. The model shall cover – alongside the equivalent generator – the transformers needed to connect the generator and the Power Generating Facility to the Power System. The aggregation requirement does not apply to the simulation models of section 20.2.6 for the simulation of electromagnetic transients.

20.2.3 Requirements concerning power flow and fault current simulation

The power flow simulation model and fault current simulation model shall reproduce, within the voltage and frequency operating range conforming to the Specifications, the impact of the Power Generating Facility on the following issues:

1) power flow of the Power System, considering potential dependences for example between the Production Power and the voltage of the VJV Reference Point,

2) voltage profile of the Power System, considering the different Modes and constraints of voltage control as well as potential compensation equipment,

3) fault currents.

If the simulation model cannot reproduce some of the characteristics of the operation of the Power Generating Facility, such as the dependence of power on the voltage of the VJV Reference Point or the current fed by the Power Generating Facility in conjunction with fault current simulation, the actual behaviour of the facility in terms of such discrepancies as compared to the behaviour disclosed by the simulation model shall be documented and delivered as part of the documentation of the simulation model.

20.2.4 Requirements concerning the dynamics simulation of Wind Power Park Modules

The model intended for dynamics simulation shall reproduce the operation of the Power Generating Facility within the voltage and frequency operating range in accordance with the Specifications, taking into account the response and impact of the Power Generating Facility on the following issues:

1) changes in the voltage amplitude and in its phase angle in conjunction with electromechanical transients,

2) electromechanical oscillations related to angle stability at frequencies 0.2–2 Hz following small and large signal disturbances,

3) high-speed (10 ms – 10 s) transients related to voltage stability. These shall take into account the operation of the facility in conjunction with momentary voltage disturbances, and the dependence of the recovery of Active Power and the Reactive Power capacity on voltage.

20.2.5 Requirements concerning the verification and documentation of the simulation data

The data to be delivered for the simulation calculation shall be verified by comparing the simulation data, using the simulation results obtained, to the results of the Compliance Testing of the Power Generating Facility. The verification obligation of simulation data applies to Power Generating Facilities in the scope presented in Tables 20.1 and 20.2.

The data to be delivered for the simulation calculation shall be documented. The documentation shall be delivered as electronic documents to the Relevant Network Operator. The documents to be submitted shall be clear and unambiguous in terms of their layout and structure. The documentation shall cover the following main issues:

1) Data on the simulation model of the Wind Power Park Module:

    a) block diagram level description of the Frequency Control, Active Power control, voltage control system of the Power Generating Facility and the power generating units as well as of other potential Power Generating Facility controls that have significance in terms of the Specifications,

    b) project-specific parameters suited to the block diagram level description, taking into account the requirements laid down in sections 20.2.3 and 20.2.4.

    c) instructions for the use and maintenance of the simulation model.

2) Results of the verification of the simulation model of the Wind Power Park Module:

    a) report of the verification of the model,

    b) comparison of the simulation results and the results of the Compliance Testing in the scope presented in Table 20.1,

c) measurement results of the Compliance Testing in Numerical format in the scope presented in Table 20.2 in so far as Table 20.1 obliges verification,

d) account of potential differences between the simulation results and the results of the Compliance Testing.

Table 20.1. Verification obligation of simulation data on Wind Power Park Modules by various power classes.

Item to be verified	Power Class 2	Power Class 3	Power Class 4
Step response of voltage control (both the increase and decrease of voltage)	X	X	X
Slope of voltage control at two different Slope set values		X	X
Reactive Power capacity and the functioning of limiters that restrict the capacity		X	X
Fault ride-through test *)	X	X	X

*) If a fault ride-through test for the Power Generating Facility is not carried out, the functioning of the Power Generating Facility in a momentary voltage disturbance shall be indicated by means of simulation calculations.

Table 20.2. Measurement data on Compliance Testing to be delivered in Numerical format, to which measurement data the results calculated using the simulation data is compared.

Item to be verified	U_{VJV}	P_{VJV}	Q_{VJV}	Signals
Step response of voltage control (both the increase and decrease of voltage)	X	X	X	
Slope of voltage control at two different Slope set values	X	X	X	
Reactive Power capacity and the functioning of limiters that restrict the capacity	X	X	X	To be agreed individually in each case
Fault ride-through test	To be agreed individually in each case. If a fault ride-through test for the Power Generating Facility is not carried out, the functioning of the Power Generating Facility in a local fault shall be indicated by means of simulation calculations.			
U_{VJV} voltage of VJV Reference Point P_{VJV} Active Power of Power Generating Facility measured at the VJV Reference Point Q_{VJV} Reactive Power of Power Generating Facility measured at the VJV Reference Point				

20.2.6 Specific study requirements

If conducting the specific studies requires utilising calculation programs applicable to electromagnetic transients, the simulation models of the Power Generating Facility used in the simulation shall be delivered to Fingrid as part of the final report of the specific study. The said simulation model shall be updated after the Compliance Testing and delivered to Fingrid as part of the final documentation of the Power Generating Facility.

20.2.7 Requirements for the simulation models of compensation devices

The simulation models of compensation devices related to the Power Generating Facility project shall be agreed upon separately with Fingrid.

20.3 Simulation modeling requirements concerning Wind Power Park Modules of Power Class 4

Wind Power Park Modules of Power Class 4 shall fulfil all the same requirements as Power Generating Facilities of Power Classes 2 and 3. Moreover, it shall be possible to freely change that modelling data which enables the dynamics simulation model or the implementation of the dynamics simulation model so that the response of the controllers can be changed either by changing the control parameters or by changing the parameters of higher-level controllers, such as power system stabiliser or damping control. The analysis of the response of the controller shall be carried out in close co-operation between the Power Generating Facility Owner, the Relevant Network Operator and Fingrid in order to obtain a realistic estimate of the impact of the Power Generating Facility on the transmission capacity of the Power System.

21 Appendix A: Compliance monitoring process of Specifications during a Power Generating Facility project

21.1 Summary, and basic details of Power Generating Facility

Compliance monitoring and fulfilment of VJV2013 Specifications concerning of Power Classes 2, 3 and 4

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Specifications concerning Power Generating Facility	VJV2013
Production type	
Rated capacity	
Type of Turbine Generator(s)	
Location and VJV Reference point	
Commissioning	
VJV2013 process status	

Situation 2013-11-21	**Not started**	**Started**	**Shall be specified/ corrected**	**Accepted**	**Comments**
Requested and granted deviations from VJV2013 Specifications	X				
Specification of VJV Reference Point	X				
Delivery of general Power Generating Facility data	X				
Delivery of project-specific Power Generating Facility data	X				
Planning of Compliance Testing	X				
Accepted performance of Compliance Testing, and documentation of Compliance Testing	X				
Acceptance of the compliance monitoring process of the Specifications	X				
Compliance monitoring process of VJV2013 Specifications	Compliance monitoring and documentation obligation concerning the VJV2013 Specifications has not been fulfilled, process in progress				

21.2 Stage 1: Delivery of general Power Generating Facility data, determination of VJV Reference Point, and handling of potential deviations

	Data to be delivered	A request for a report related to the VJV2013 Specifications has been sent	Data related to the VJV2013 Specifications has been successfully delivered	Status of data exchange related to potential deviations and/or the Specifications	Comments
1	Basic data, structure and location of Power Generating Facility			Accepted	
2	Reactive Power capacity calculation			Accepted	
3	Technical details of Turbine Generators			Accepted	
4	Active Power control and Frequency Control			Accepted	
5	Reactive Power control and voltage control			Accepted	
6	Frequency operating range and voltage operating range			Accepted	
7	Calculation of the operation of the Power Generating Facility during momentary voltage disturbance, and potential reports of factory testing			Accepted	
8	Description of the fault current injection of the Power Generating Facility during voltage disturbance, and power restoration after voltage disturbance			Accepted	
9	Data on the transformers and main components of the Power Generating Facility			Accepted	
10	General data or simulation models required for the modelling of the operation of the Power Generating Facility			Accepted	
11	Required specific studies related to the Specifications			Accepted	
12	Real-time measurement data			Accepted	
13	Preliminary schedule of Power Generating Facility project			Accepted	
	Status of stage 1		Accepted		

21.3 Stage 2: Supplementing of project-specific Power Generating Facility data, and planning of Compliance Testing

Data to be delivered		A request for a report related to the VJV2013 Specifications has been sent by Fingrid	A request for a report related to the VJV2013 Specifications has been accepted	Status of data exchange related to potential deviations and/or the Specifications	Comments
1	Further specifications to the data presented in stage 1			In progress	
2	Protection settings of Power Generating Facility			In progress	
3	Power quality			In progress	
4	Project-specific data on Active Power control and Frequency Control			In progress	
5	Project-specific data on Reactive Power control and voltage control			In progress	
6	Project-specific data or simulation models required by the modelling of dynamic operation			In progress	
7	Preliminary commissioning schedule and commissioning programme			In progress	
Status of stage 2			**In progress**		

21.4 Stage 3: Accepted execution of Compliance Testing, and documentation of Compliance Testing

21.4.1 Synchronous Power Generating Facilities

	Test	Availability of functionality has been verified	Operation in accordance with the Specifications has been verified	Status	Comments
1	Operation at Minimum Output			Must be renewed	
2	Reactive Power capacity			Must be renewed	
3	Step response of voltage control of generator			Must be renewed	
4	Constant voltage control			Must be renewed	
5	Functioning of underexcitation limiter			Must be renewed	
6	Functioning of overexcitation limiter			Must be renewed	
7	Functioning of power system stabiliser (PSS)			Must be renewed	
8	Response of Frequency Control to normal frequency fluctuation			Must be renewed	
9	Response of Frequency Control to step-like and ramp-like changes			Must be renewed	
10	Dead band of Frequency Control			Must be renewed	
11	Transitions in the modes of power control and Frequency Control			Must be renewed	
12	Restriction and rate of change of power			Must be renewed	
13	Transition to house load operation, remaining in house load operation			Must be renewed	
14	Fault ride-through			Must be renewed	
	Status of stage 3	**Must be renewed**			

21.4.2 Wind Power Park Modules

	Test	Availability of functionality has been verified	Operation in accordance with the Specifications has been verified	Status	Comments
1	Operation at Minimum Capacity			Must be renewed	
2	Start-up of Power Generating Facility			Must be renewed	
3	Reactive Power capacity			Must be renewed	
4	Constant Reactive Power control			Must be renewed	
5	Constant power factor control			Must be renewed	
6	Constant voltage control			Must be renewed	
7	Transitions between Control Modes			Must be renewed	
8	Active power curtailment			Must be renewed	
9	Restriction of rate of change of active power			Must be renewed	
10	High wind operation			Must be renewed	
11	Rapid downward control of active power			Must be renewed	
12	Frequency Control			Must be renewed	
13	Transitions between Control Modes			Must be renewed	
14	Power quality			Must be renewed	
15	Fault ride-through			Must be renewed	
	Status of stage 3	**Must be renewed**			

21.5 Stage 4: Acceptance of the compliance monitoring process of the Specifications

VJV2013 sub-entity, and data to be delivered in stage 4	Action started	Action performed in an accepted manner	Status	Comments
Further specifications to the data presented in stages 1 and 2				
Stage 1				
Stage 2				
Stage 3				
Commissioning report and required results in Numerical format				
Validated modelling data or simulation models needed in modelling of the Power Generating Facility				
Final set values of controllers of Power Generating Facility/generators				
Final set values of protection of Power Generating Facility/generators				
Compliance monitoring	**Accepted**			