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Specific study requirements for power park modules related to risk of subsynchronous oscillations

1 Introduction

This document defines specific study requirements for type D power park modules (converter-connected power plants) connected in the vicinity of Fingrid's series compensated network. The requirements are set according to the specific study requirements defined in Grid Code Specifications for Power Generating Facilities (VJV2018, Chapter 5, [1]). The Connectee shall request from Fingrid the assessment of a need for specific study well in advance so that the requirements are considered in design and procurement of equipment.

This document supersedes the previous version of the same requirement specification, published originally on 7th of January 7, 2021. The requirements apply to projects for which Fingrid has not yet carried out an assessment of the specific study requirements. The specific study requirements are always assessed separately for each power plant meaning that the applicable requirements can be specified further if necessary.

During years 2020-2021, Fingrid has studied subsynchronous interaction (SSO, Subsyncronous oscillations) within frequency range of 5-45Hz occurring in converter-connected power plants in the vicinity of a series compensated network. According to the results of the study, converter-connected power plants connecting in the vicinity of a series compensated network may interact with the series compensated network resulting to a high amplitude subsynchronous oscillations. Fingrid has published a technical white paper in English on this topic on its website [2].

When unmitigated, subsynchronous interaction between a power plant and a series compensated network may result in significant subsynchronous currents and voltages. Subsynchronous interaction must be taken into account in the design and construction of a power plant to prevent the phenomenon from causing repeated short-term unavailability, as the protection system operates, or significant unavailability, due to equipment failure. The objectives of these requirements are as follows:

- to ensure effective protection for power plants against subsynchronous currents and voltages,
- to minimise the risk of subsynchronous interaction in the various operational states of a transmission grid, including transmission outages as well as typical disturbances and faults,

to ensure that necessary simulation modelling and measurement data of the power plant is available.

The measures mentioned above improve the availability of power plants and maintain system security and transmission reliability of the entire power system.

The study carried out by Fingrid [2] in particular focuses on wind power plants. The connected devices in other types of power park modules may also utilise similar technology, which means this requirement is set for all type D power park modules connected in the vicinity of Fingrid's series compensated network.

2 Scope of application for the requirements

The requirements for the measures required to account for subsynchronous interaction are divided into protection, modelling, attenuation, and instrumentation requirements.

The requirements are set for all type D power park modules connected in the vicinity of Fingrid's series compensated network. The scope of the applicable requirements depends on the rated capacity (P_{max}) of the power plant. The requirements apply if the connection point or the connection point of the connecting network of the power plant is located within the area marked in yellow in Figure 1. The boundary of the area is indicative and applicability of the requirements at boundaries will be studied for given connection point on case by case basis.

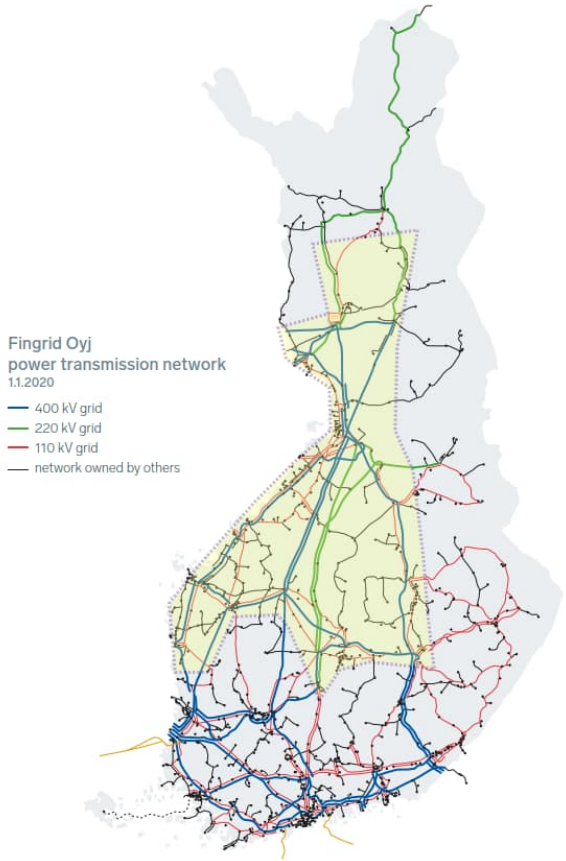

Figure 1. The requirements are applicable if the connection point of the power plant or the connection point of the connection network of the power plant is located in the area marked with yellow in Figure 1. The boundary of the area is indicative and applicability of the requirements at boundaries will be studied for given connection point on case by case basis.

The requirements apply to converter-connected power plants as follows:

1. Protection requirements

   The protection requirements are set for all type D power park modules connected in the vicinity of Fingrid's series compensated network.

2. Modelling requirements

   The modelling requirements are set for all type D power park modules connected in the vicinity of Fingrid's series compensated network.

   For full-converter (FC) power plants of less than 60MW of rated capacity, the results of dynamic impedance scanning (section 3.2.2.3) are not required.

3. Damping requirements

   The requirements for damping are set for all type D power park modules of more than 60 MW of rated capacity and connected in the vicinity of Fingrid's series compensated network.

   In addition to this, all type D power park modules having double-fed induction generators (DFIG) shall be equipped with damping controls. Tuning of the damping controls will be done based on the passive impedance profiles of the connection point delivered by Fingrid.

4. Instrumentation requirements

   The requirements for instrumentation are set for all type D power park modules of more than 60 MW of rated capacity and connected in the vicinity of Fingrid's series compensated network.

3 Requirements

3.1 Protection requirements

The power plant must be protected against any subsynchronous interaction possibly emerging between the power plant and series compensated network to avoid damage to the equipment.

The protection must be able to reliably detect the subsynchronous frequency components present in the voltage and current. The protection must operate selectively in relation to the other protection of the power plant and the grid.

The protection can be implemented on the main transformer level or separately at each converter-connected unit of the power plant. For wind power plants, this means implementation at park level or at turbine level. If the protection will be implemented on

the main transformer level and there are several transformers, separate transformers shall have different protection settings (time selectivity).

The Connectee defines the setting values of the protection, taking into account the dimensioning of the power plant components, such as converters, transformers, surge arresters and auxiliary equipment, as well as the requirements of VJV2018 for the operation of the power plant, e.g. within the frequency-voltage operating range (VJV2018 / Fig. 10.5) and during a voltage disturbance (10.5.2). The protection must not malfunction, for example in a low-frequency situation where the system's fundamental frequency falls in the range of 47.5 to 50 Hz, where the power plant is required to remain connected to the grid.

Fingrid recommends that following principles are being followed in the technical implementation of the protection:

- The subsynchronous components are filtered from the measurement with a bandpass filter with a high-pass frequency of 5-7 Hz and a low-pass frequency of 42-45 Hz.
- The operation of the protection is based on the amplitude of the filtered subsynchronous currents and voltages, which determines the operation time of the protection.
    - Primarily the operating time is determined on the basis of the inverse time operating curve (higher amplitude, shorter operating delay) with the shortest settable operating time not exceeding 500 ms.
    - An alternative to inverse time operation is to implement at least three protection steps based on a definite time setting. The operating time range of the protection stages is at minimum 500 ms to 60 s.

Protection settings - such as operating times and filter cut-off frequencies - must be changeable afterwards. Fingrid recommends that the settings can be changed remotely.

The operation of the protection shall be verified by a type test report produced in factory tests or equivalent test conditions. Instructions for the type test shall be prepared and approved by Fingrid before the test is performed. The device test performed for protection shall be repeated with the project-specific PSCAD model according to chapter 3.2.2.

A converter-connected power plant can be partially or completely exempted from the protection requirements described above if the Connectee is able to demonstrate that the power plant does not participate in the subsynchronous interaction in a manner that impairs the system security of the power system. However, a possible exemption does not relieve the Connectee of its responsibility to protect its assets against possible power quality deviations at the connection point.

Functioning of the protection must be verified by a type test report recorded at factory testing or similar test conditions.

3.2 Simulation modelling requirements

The power generating facility owner must provide Fingrid with a simulation model and calculation results as early as possible and no later than six months before the planned commissioning of the power plant (first converter-connected unit connected to grid).

3.2.1 Requirements for the simulation model

A PSCAD model including the project-specific plant control and protection systems must be provided for the power plant. The model must be sufficiently detailed to enable realistic replication of the power plant's operation in the subsynchronous frequency range. A scalable aggregated model is permitted.

The scope of the power plant model must be modelled as follows:

1. Park controller modelling, including the park control and regulation systems.
2. Turbine(module unit) model, including the turbine control and protection systems.
3. The internal electrical network of the power plant, including the main transformer, turbine (module unit) transformers, and the cabling between the above-mentioned components as an aggregated component.
4. The electric network between the power plant connection point and the main transformer.
5. Any ancillary equipment that may significantly affect the operation of the power plant, such as mechanically switched capacitors (MSCs) or reactors (MSRs), and their control logic.

Fingrid will provide the short-circuit currents and impedances, equivalent short-circuit ratio (ESCR) and passive impedance profile at subsynchronous frequency band at the connection point for modelling.

3.2.2 Required modelling analyses

Following studies shall be carried out using the PSCAD model of the power plant:

1. The simulations describing the overall compliance of the power plant model (voltage response step response, short-term fault test, reactive power capacity and any additional plant-specific adjustments) listed in Table 20.1 of VJV2018, [1],
2. Repetition of the device test performed for SSO protection in section 3.1 to demonstrate similar operation as witnessed during the test

and

3. A dynamic impedance scan which represents the frequency response of the power plant in the subsynchronous frequency range. When carrying out the impedance scan, the voltage control of the power plant must be operational and

tuned according to the requirements. The scan must cover the five different operation points of the PQ diagram:

- P = P_{max}; Q = 0.33 [Q/P_{max}]
- P = P_{max}; Q = –0.33 [Q/P_{max}]
- P = P_{min}; Q = Q_{max}
- P = P_{min}; Q = Q_{min}
- P = P_{min}; Q = 0 [*pu*]

3.3 Damping analysis and requirements

Fingrid will estimate the subsynchronous interaction between the power plant and grid components using the PSCAD model and the impedance scan provided by the power generating facility owner (Chapter 3.2). In the assessment, the results of the impedance scan carried out by the Connectee will be compared with the results of the grid impedance scan carried out by Fingrid. The comparison will account for the present and for the future grid model in various operational situations and outage contingencies.

If the analysis shows that the power plant may engage in subsynchronous interaction in a single frequency range or several frequency ranges, a re-tuning of the power plant control system will be required to minimise the interaction. Once the re-tuning is completed, the Connectee must provide Fingrid with updated impedance profiles and a new PSCAD model. Based on the delivered information, Fingrid will reassess the power plant's subsynchronous interaction.

Undamped subsynchronous interaction, during normal operation and congestion conditions, will result in repeated short-term unavailability of the power plant, as the protection system operates, or in significant unavailability, due to equipment failure. If subsynchronous interaction cannot be damped by tuning the damping controller of the power plant control system, adequate damping must be achieved by modifying or upgrading the power plant engineering design.

3.4 Instrumentation requirements

The power plant must be equipped with a continuous measuring system that meets the following requirements:

- The measuring equipment must measure and record the instantaneous values of voltage and current of each phase at the connection point or at the high-voltage side of the main transformer closest to the connection point.
- The sample rate and recording rate of the measuring device must be no less than 1 kHz.
- The measurement records must be stored at least for 60 days.

Alternatively, a triggered measuring system may be used instead of continuous measuring, provided that the triggered measuring system meets the following criteria in addition to the requirements stated above:

- Pre + post fault trigger time no less than 30 + 30 seconds.
- The measuring device must be triggered when:
  - the instantaneous voltage is lower than 0.95 pu or higher than 1.05 pu,
  - the instantaneous current is higher than 1.10 pu,
  - the protective relay operates.

Furthermore, an additional measurement is recommended to trigger an alarm when the subsynchronous current level exceeds a pre-set value.

References

[1] Grid Code Specifications for Power Generating Facilities, VJV2018

(URL: https://www.fingrid.fi/globalassets/dokumentit/en/customers/grid-connection/grid-code-specifications-for-power-generating-facilities-vjv2018-.pdf

[2] Subsynchronous Oscillation Risks of Wind Power Plants Connecting to Finnish Series Compensated Network

(URL: https://www.fingrid.fi/globalassets/dokumentit/fi/palvelut/kulutuksen-ja-tuotannon-liittaminen-kantaverkkoon/subsynchronous-oscillation-risk-of-wpps-connecting-to-finnish-series-compensated-network-white-paper.pdf)