FINGRID

Guidance on ESCR values and voltage control tuning of converter connected generation

19.9.2023

Change log

Date	Version	Changes
25.03.2022	0.9	Draft
19.04.2022	0.91	A change in definition of the bus where $ESCR_{HV}$ value is calculated. The value is calculated at the bus where voltage is measured for voltage control. An addition to voltage control tuning step 3 for voltage set point change.
01.06.2022	1.0	Desirable rise time changed from 1.0 s to 0.5-1.0 s.
1.2.2023	2.0	Document re-structured. Voltage controller tuning principle changed from power plant controller Vref change to voltage change in PCC. Added a requirement to include two different control tunings: a) 1.0±0.1s, b) 10±1s. Clarified the process with stability studies. Changed terminology from $ESCR_{HV}$ to VCSCR. Test requirements added. Added reference to Fingrid's modelling instruction and white paper on ESCR.
19.9.2023	2.1	Tuning of voltage control instructions is updated in section 3.1.(1). Background network impedance Z_{SMIB} is delivered as physical value.

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1 Purpose

This instruction describes procedure for voltage control (re)tuning and stability studies of converter connected plants.

2 Introduction

In the Finnish transmission system, amount of converter connected generation is increasing rapidly in certain areas. This poses a challenge on the tuning of the control functions since converter connected plants are affecting each other. The phenomenon becomes visible especially in areas where the proportional amount of synchronous machines in the generation mix is low. If the converter connected power generating facility or battery energy storage (hereafter “plant”) is located to an area where large number of converters already exist, (re)tuning of plant voltage control and possibly other additional stability studies are required to ensure appropriate response and stable operation of the plant in normal operation as well as during contingencies.

Traditionally, the short circuit ratio (SCR) has been the metric to evaluate the capability of a generator to operate in the connection point. However, the SCR value does not consider other converter connected plants which “share” the short-circuit power of the grid. One way to evaluate “shared” SCR between converter connected plants is equivalent short circuit ratio (ESCR). ESCR is defined in the CIGRÉ publication. [1] Fingrid has also published a White Paper document, [2], which provides additional information on the topic.

Fingrid (vikavirrat@fingrid.fi) delivers two types of ESCR based values for the customers, “VCSCR” value and “$ESCR_{MV}$” value.

- VCSCR (Voltage Controller Short-Circuit Ratio, called as $ESCR_{HV}$ in earlier revisions of this document) value is calculated at the high voltage bus, where voltage is measured for the voltage controller (either bus PCC WPP or HV BUS 1 in the Figure 1). VCSCR value is calculated in N-0 situation, that is, for intact grid. VCSCR value is used for voltage controller tuning as described in Chapter 3.

- $ESCR_{MV}$ value is calculated at the medium voltage level (MV BUS 1 in the Figure 1). $ESCR_{MV}$ value is calculated in N-1 situation (after a fault) where the ESCR is at the lowest. This value is for evaluating the stability of the plant as described in Chapter 4.

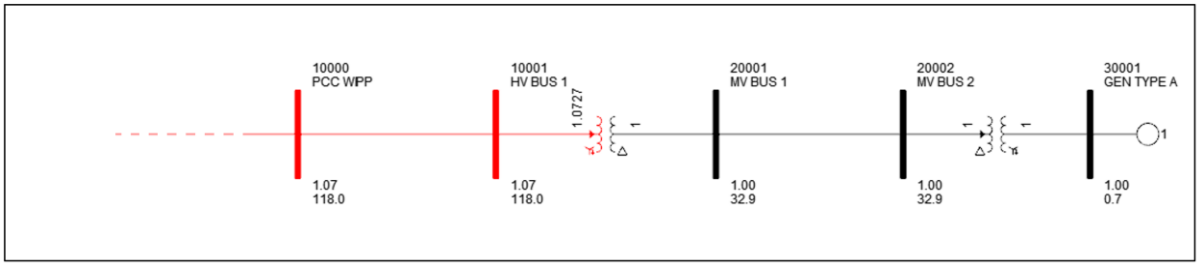

FIGURE 1 SIMPLIFIED SINGLE LINE DIAGRAM OF A CONVERTER CONNECTED PLANT.

3 Requirements for tuning of the voltage control

3.1 Tuning of voltage control using VCSCR value

The voltage control of the plant shall be tuned as follows:

1. Create a single machine infinite bus (SMIB) system, with background network defined by VCSCR value. Fingrid delivers VCSCR defined background network impedance Z_{SMIB} as physical value.
2. If point of measurement (PoM) and point of common coupling (PCC) are not in same bus it must be noted that *VCSCR* defined short circuit level must be in the bus where it is given. Example of this situation is given in Figure 2. In this case the connection line must be included in the model. The impedance of connection line must be subtracted from the Z_{SMIB} to calculate background network impedance Z_{th}.
3. Use maximum active power P_{max} for the generator. In case of extremely low VCSCR, unstable operation may occur and consequently the tuning principles shall be discussed with Fingrid.
4. Define two separate sets of control parameters to achieve following rise times (0-90%):
    a. 1.0±0.1 seconds,
    b. 10±1 seconds.

- The rise time shall be achieved by changing the voltage at PCC for ±2 % (**not** by changing the voltage reference Vref of the controller). The voltage change can be simulated i.e. by switching a shunt reactor in the PCC.
- The rise time requirement will supersede the requirement given in VJV2018 section 18.2.2.
- As before, the overshoot in the step response shall not be more than 15 per cent of the measured total change in reactive power. The response shall settle to its target level within 5 seconds from the stepwise excitation. When steady-state stability is achieved, the actual value of reactive power shall deviate by no more than ±5% of the reactive power target value, up to a maximum of ±1 Mvar.
- Tuning is performed with default slope (reactive droop) value used in the plant, which is normally 4 %. Alternative tuning for slope value of 2% is not required and can be excluded from the constant voltage performance calculation required in VJV2018 section 18.2.2.1.

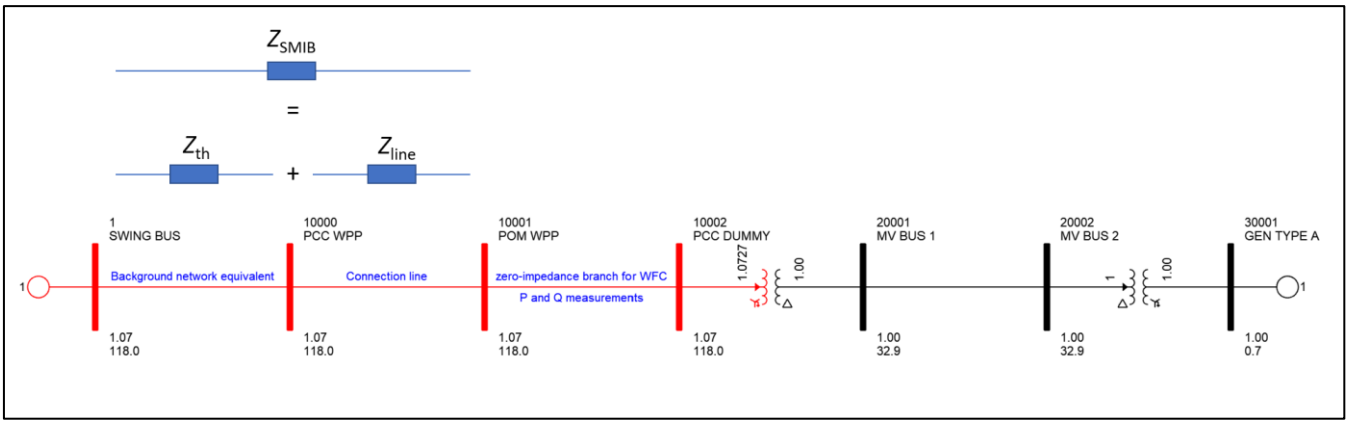

FIGURE 2 EXAMPLE TOPOLOGY OF A CASE WITH DIFFERENT POM AND PCC BUSES.

3.2 Reporting and model delivery

A written report of the tuning shall be delivered to Fingrid. The report shall include

- basic data of the power plant
- overview of the used simulation model and relevant tuning parameters
- used grid data and ESCR/VCSCR values used as a basis of the tuning
- Graphs for simulated voltage changes in time domain (voltage, current, active power and reactive power at PCC)
- tabulated values of achieved rise times

An updated PSS/E model shall be delivered along with the report to Fingrid. The model shall be compatible with PSS/E version 35. The model shall fulfil Fingrid's modelling requirements, [3]. If a PSS/E model of the plant has already been delivered to Fingrid, existing model can be used but compatibility with PSS/E version 35 must be ensured.

If a PSCAD model has been required from the plant, the PSCAD model shall be updated and results of the step response test shall be included in the tuning report. The model shall fulfil Fingrid's modelling requirements, [3].

3.3 Confirmation of tuning by Fingrid

After receiving the report and the simulation model(s), Fingrid will check the tuning of the plant voltage control using a wide area model which includes parallel wind power plants and background network. Consequently, Fingrid will confirm whether the tuning parameters can be used on site.

3.4 Site test

After Fingrid has confirmed the controller parameters, they can be updated to the plant controller on site. After new re-parametrization, following step response test shall be performed:

1. Following voltage changes are performed by stepping the voltage reference of the plant controller: +1%, -1%, +2%, -2%. The test is performed with 4% slope value (or using site-specific value other than 4%).

2. Additionally, if specifically requested by Fingrid, the tap changer of the 400/110kV transformer at the nearest Fingrid substation is stepped up and down or a tertiary shunt reactor is switched on and off to determine the response of the plant to grid voltage change. In order to perform the test, Fingrid Main Grid Control Centre (Kantaverkkokeskus) has to be contacted (+358 (0)30 395 4300).

The test(s) can be performed at an active power level which does not limit the reactive power response resulting from the voltage change (+/-2%).

The test(s) will cover the *constant voltage control* test required in VJV2018 section 19.3.4.(5). Separate test with slope setting of 2% is not required.

The test arrangements and date for the test will be agreed with Fingrid and possible grid owner.

After the test, parameters (a) for 1.0±0.1 sec rise time shall be left in operation. Parameter set (b) for 10±1 sec rise time shall be taken into use only as per request by Fingrid.

The tests shall be

- recorded using recording frequency of ≥50 Hz. Recorded data is delivered to Fingrid in editable format (.csv, .xls(x)). Existing on-site fault recorder (e.g. power analyzer or protection relay) can be used to record the tests.

- reported as described in section 3.2. Contrary to the original requirement of VJV2018 section 20.1.5.(6b) and Table 20.1, verification of the simulation model against measured step response is not required.

4 Stability studies

Tuning of the plant voltage control based on VCSCR value and the procedure described in Chapter 3 is expected to ensure appropriate operation of the voltage control during normal operation in intact grid (N-0). In addition to this, stable operation has to be maintained during different contingencies including switching sequences and faults. The severity of these conditions is described by the $ESCR_{MV}$ value. It should be noted that while operating under $ESCR_{MV}$ conditions, the plant voltage control does not have to meet the response time requirements presented in Chapter 3.

The stability studies under $ESCR_{MV}$ conditions are performed by Fingrid using the aforementioned VCSCR tuned simulation models delivered by the Connectee (plant owner). In the studies, the plant is operated as a part of a wide area grid model in parallel with other plants. Typically, the studies require participation of the equipment manufacturers (OEMs) if support for modelling, parameter adjustments

and additional information are needed. The Connectee is responsible for arranging required OEM support for the studies.

Stability assessment at very low $ESCR_{MV}$ requires EMT studies with PSCAD model as the PSS/E models are not suitable for simulating low-level controller stability which becomes then relevant. Consequently, Fingrid can evaluate the overall stability of the plant only if a PSCAD model has been delivered.

For now, a PSCAD model has to be delivered for all new type D (acc. to grid code VJV2018) plants. Existing plants, for which retuning of voltage control is requested by Fingrid, are not required to deliver PSCAD models yet this is highly recommended as it enables comprehensive stability studies which aim to ensure safe operation and high availability of the plant in the future.

5 References

[1] CIGRÉ Working Group B4.62. TB 671: Connection of wind farms to weak AC networks. Technical report, CIGRÉ, 2016

[2] Fingrid Oyj, “White Paper: Utilizing Equivalent Short-Circuit Ratio (ESCR) approach for assessing the slow converter driven stability and tuning the voltage controllers” [Online]. Available: https://www.fingrid.fi/globalassets/dokumentit/fi/palvelut/kulutuksen-ja-tuotannon-liittaminen-kantaverkkoon/white-paper-on-escr.pdf

[3] Fingrid Oyj, “Modelling instruction for PSS/E and PSCAD models”, 5 May 2022. [Online]. Available: https://www.fingrid.fi/globalassets/dokumentit/fi/palvelut/kulutuksen-ja-tuotannon-liittaminen-kantaverkkoon/modelling-instruction-for-psse-and-pscad-models.pdf.