Testing procedure and Compliance of Power Generating units and Plants Per Indian Grid Code

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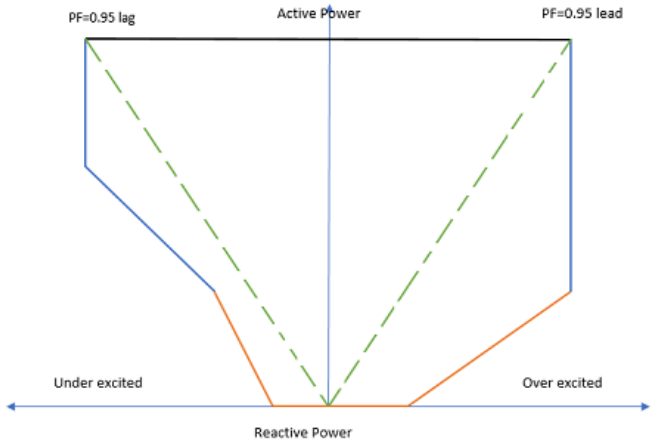
CONTENTS

Introduction

- The penetration of renewable energy in the Indian grid is expected to be high
- MNRE has put a target of 175 GW of renewable energy
- Central Electricity of India has laid down the grid requirements
- Secure operation of Indian electric power grid
- Static and Dynamic requirements
- Requirements are at unit level/ station level
- Measuring Procedure and Certification scheme
- IEC, German grid code and DNVGL service specification

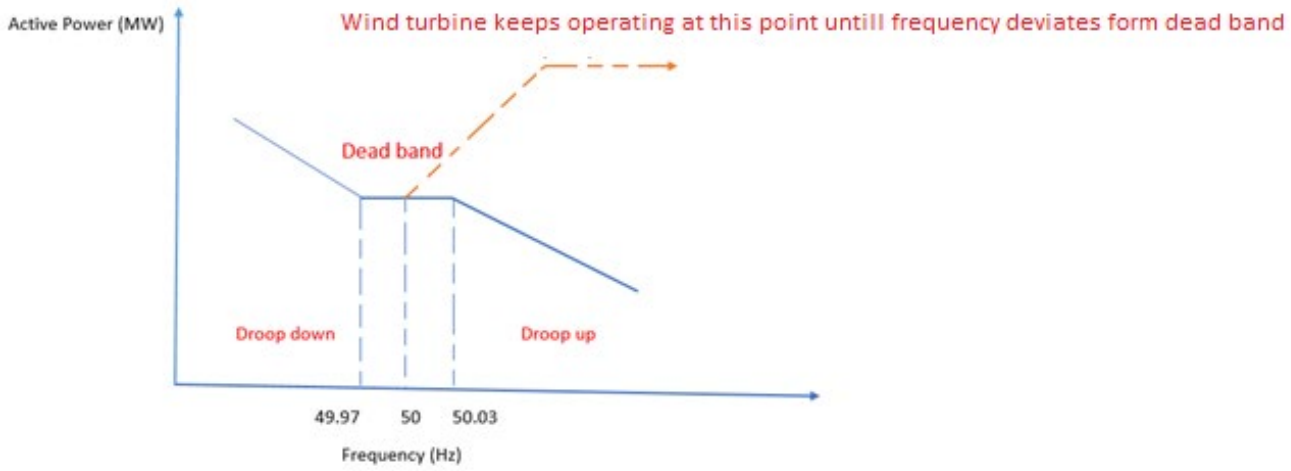
Indian grid code requirements: Overview

- Control behaviour
- **Reactive Power Capability:** *"The Power generating unit shall be capable of supplying dynamically varying reactive power so as to maintain power factor within the limit of 0.95 lag to 0.95 lead" at the POI.*

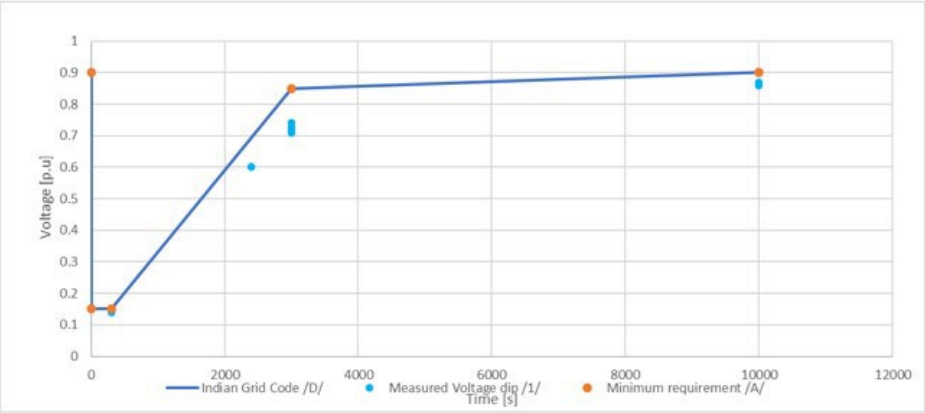


- **Frequency withstanding capability:** *Power generating stations shall be capable of remaining connected to the network and operate within the frequency range of 47.5 Hz to 52 Hz.*
- *In addition, they should be able to deliver rated power in the frequency range of 49.5 to 50.5 Hz, subject to availability of the primary energy source (i.e. wind speed or solar radiation). This performance shall be also achieved with a voltage variation of up to ± 5 %.*

- **Active Power Set Point Control:** *Control active power injection in accordance with a set point*
- **Frequency Droop Control:** *Generating stations with installed capacity of more than 10 MW connected at voltage levels of 33 kV and above shall have governors or frequency controllers typically within the units.*
- *Units need to show the ability to operate at a droop of 3 to 6% and a dead band not exceeding ±0.03 Hz:*
- *Provided that for frequency deviations in excess of 0.3 Hz, the Generating Station shall have the facility to provide an immediate (within 1 second) real power primary frequency response of at least 10% of the maximum active power capacity available at the moment of occurrence.*

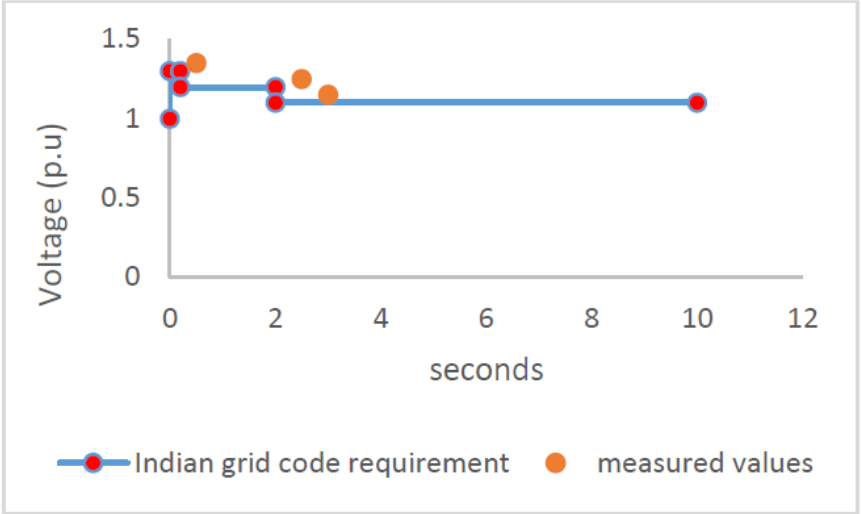


- **Ramp Rate Control:** *The generating stations with installed capacity of more than 10 MW connected at voltage levels of 33 kV and above shall be equipped with the facility for controlling the rate of change of power output at a rate not more than ± 10% per minute.*
- **Fault Ride-Through behaviour (FRT):** Fault Ride-Through (FRT) is the ability of a generating unit or station to remain connected to the grid when there is a short dip or swell in voltage due to a short-circuit somewhere in the grid (UVRT & OVRT).
- *The generating station connected to the grid, shall remain connected when voltage at the interconnection point on any or all phases dips up to the level depicted below in figure provided that a) during the voltage dip, the supply of reactive power has first priority b) supply of active power has second priority and the active power preferably be maintained during voltage dips c) active power be restored to at least 90% of the pre-fault level within 1 sec of restoration of voltage.*



- *According to the Indian grid code, the generating station connected to the grid, shall remain connected when voltage at the interconnection point, on any or all phases (symmetrical or asymmetrical overvoltage conditions) rises above the specified values given below for specified durations as shown in Table below*

over voltage V at POI (pu)	minimum time to remain connected
V > 1.30	0 seconds (instantaneous trip)
1.30 ⩾ V > 1.20	0.2 seconds
1.20 ⩾ V > 1.10	2 seconds
1.10 ≥ V	continuous



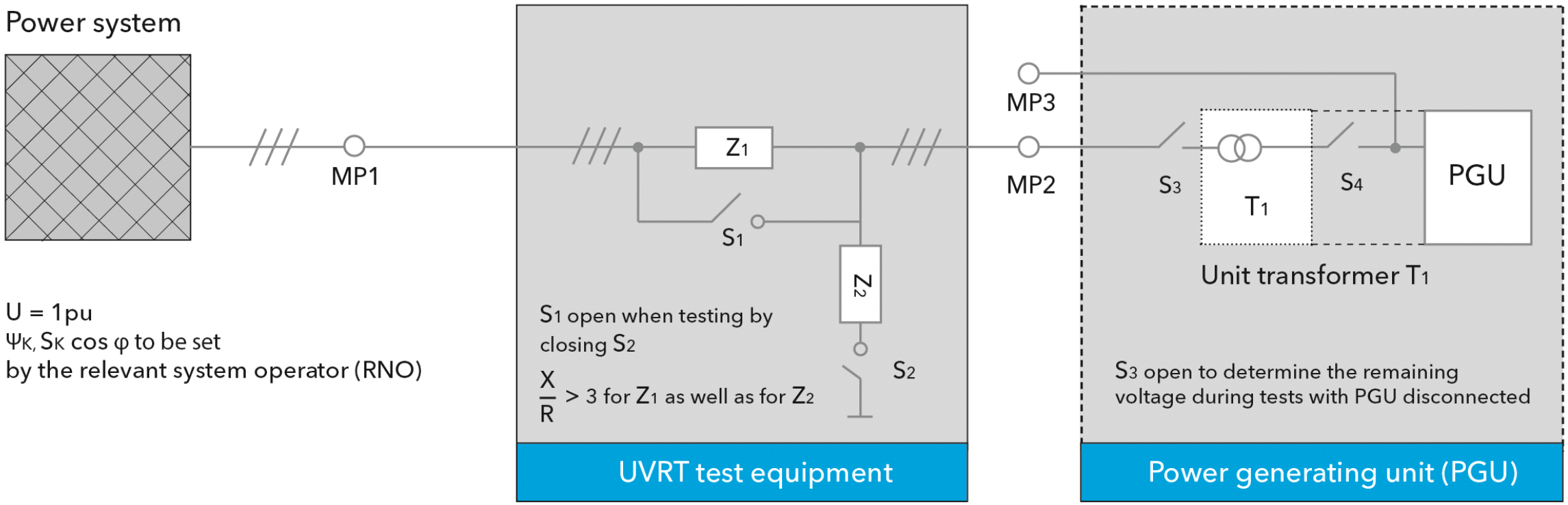
- **Short Circuit ratio:** The generating stations shall have a short circuit ratio not less than 5 at the interconnection point where the generating station is proposed to be connected.
- **Power quality**
- *harmonic current injections from a generating station shall not exceed the limits specified by the Institute of Electrical and Electronics Engineers (IEEE) Standard 519.*
- *The Generating station shall not inject DC current greater than 0.5 % of the full rated output at the interconnection point.*
- *The generating station shall not introduce flicker beyond the limits specified in IEC 61000.*

Testing Procedure

- Testing, measuring recording and post processing of the measured values.
- DNVGL-ST-0125, FGW TR-3

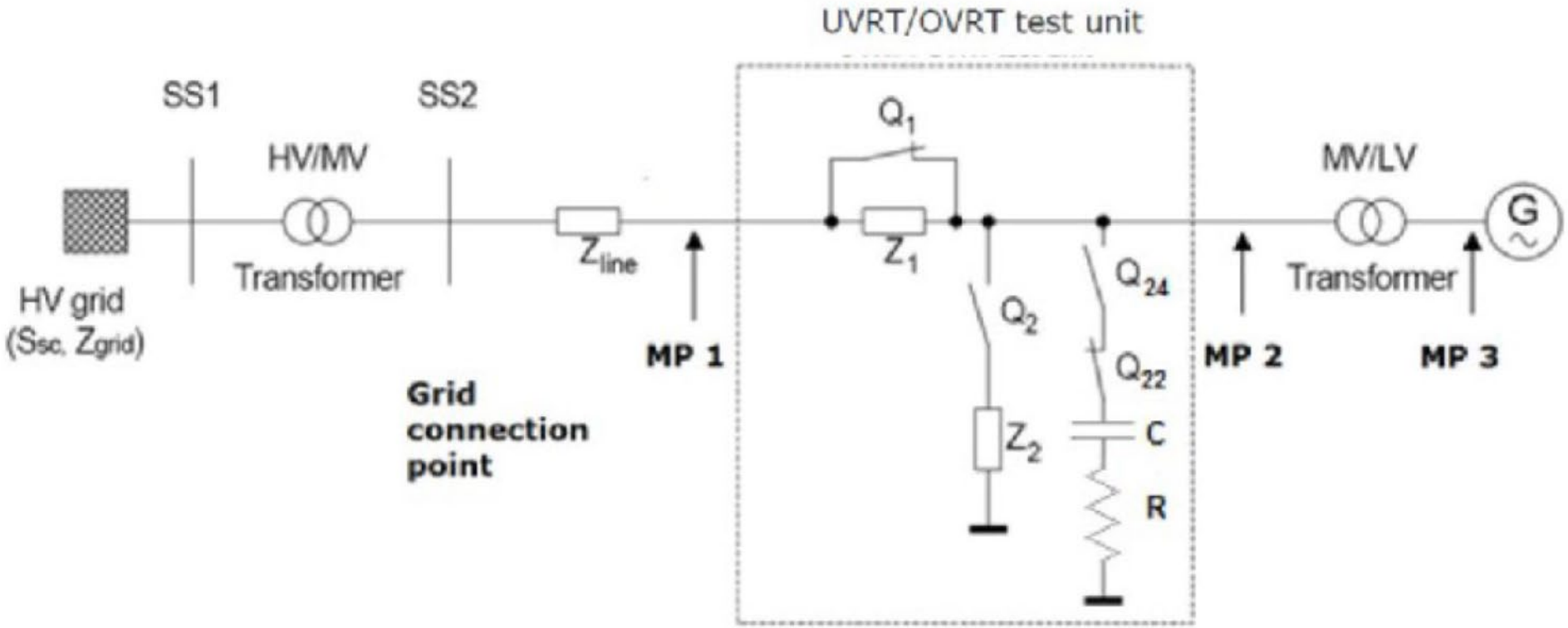
FRT testing procedure

- UVRT test



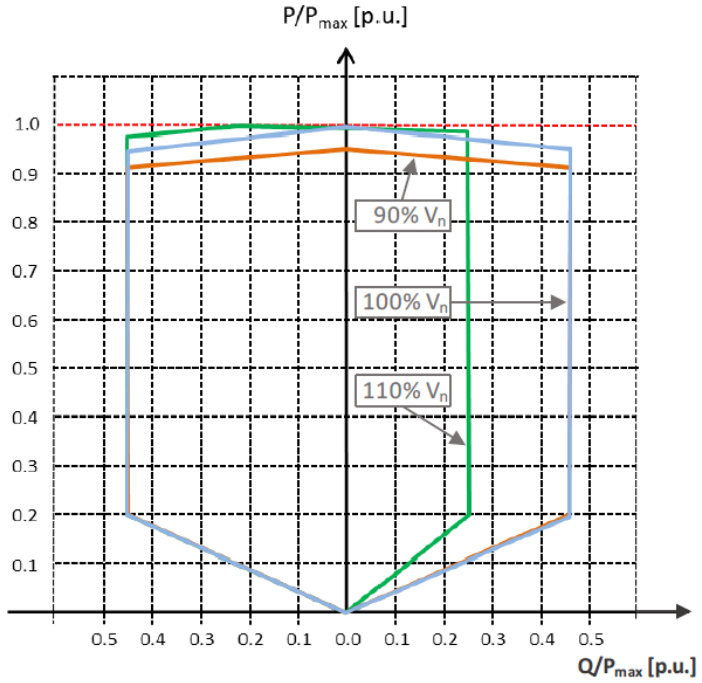
- The test shall be done for 3-phase and 2-phase and for partial (between 0.1 P_n and 0.3 P_n) and full load (above 0.9 P_n)
- Four different voltage levels are tested accordingly as a) small voltage dip test b) medium voltage dip test c) large voltage dip test d) long duration dip test.
- **Criteria for successful testing*:***
- If the unit is regularly online 10 seconds after the test is over (standard production mode).
- If the unit did not disconnect during 2 consecutive tests (2 durations (t1 and t2) or (t2 and t2)) within one category.

- OVRT test


UVRT/OVRT test unit
SS1
SS2
HV/MV
MV/LV
HV grid
(Ssc, Zgrid)
Transformer
Transformer
Zline
Q1
Z1
Q2
Z2
Q24
Q22
C
R
G
MP 1
MP 2
MP 3
Grid
connection
point

Reactive Power Capability testing

- The aim of this measurement is to determine the under- and overexcited reactive power capability
- The PGU is in operating mode.
- The maximum overexcited and underexcited reactive power must be determined for each 10% active power bin.
- 1-minute mean values must be recorded for each of the two measurement points of a power bin.



Frequency withstanding capability:

- The system frequency is not constant
- The units as well as the plants need to be capable of being operated continuously or for certain durations within a specified frequency range specified by the grid codes.
- This assessment is usually based on manufacturer declarations proving the requested ability.

Active Power Set Point Control

- The aim of this test is to determine the response of the unit to different reference commands regarding the static error, the rise time and the settling time of active power, for both steady-state conditions and under dynamic response conditions.
- Static error: A reference value shall request active power reduction from 1.00 p.u. to 0.20 p.u. in steps of 0.20 p.u. with at least a 2-minute operation
- Dynamic error: The test for dynamic response shall be carried out by a step with a minimum step size of 0.4 p.u. of the nominal active power.

Frequency droop control

- Changing parameters in the unit control system:
- The test can be carried out by adjusting the frequency rating value in the control software on the unit.
- This can be achieved for example, by changing the rated frequency from 50 Hz to 48.80 Hz in the control system to simulate a 1.2 Hz increase in grid frequency.
- Grid Simulator:
- The function can be tested via a grid simulator on the control system or a test bench.
- This test can only be carried out with the unit stopped.
- When the unit is stopped, output of the control system can be recorded, and compliance can be shown in a suitable form.
- The test can be carried out with unit running if the safety of the unit is guaranteed by using a separate grid protection unit.

Ramp rate control:

- The aim of this measurement is to show the capability of the unit to follow given active power gradients, with positive and negative ramp rate limitations, during the following operational states:
- start-up, normal stop and start up after grid disconnection; normal operation (with positive and negative ramp rate).
- At the beginning of the test, the unit shall be operated in normal operation mode.
- The active power of the unit can be set to an adequate start value above 0.5 p.u. of the nominal active power.
- Then the following two tests with different ramp rates shall be performed.
- Test 1 (slow ramp rate), e.g. +/- 10 % P_n/minute.
- Test 2 (fast ramp rate), e.g. +/- 2 % P_n/s.
- The test shall be carried out with at least P = 0.2 p.u. of the nominal active power between each reference value (power steps).

Power Quality

- **Harmonic measurements**:
- The CEA guidelines for the harmonic measurement refers to the standard IEEE 519. The instruments used for assessing harmonic levels shall comply with specifications of IEC 6100-4-7 & IEC 61000-4-30.
- **Flicker measurements:** The CEA guidelines for the flicker measurement refers to the standard IEC 61000 series of standards which in turn refers to IEC 61000-3-7

Certification Procedure and Compliance

- Measurement report from an accredited measurement shall be submitted to a Certification body
- The certification body shall assess the measurement report, evaluate its compliance with the CEA grid code
- issue a statement of compliance for each requirement and issue a type certificate for GCC if all the requirements at unit level are met
- The certification body validates the simulation model against measurement results as obtained from type tests at unit level
- After simulations are performed the certification body shall issue a project certificate for GCC, if the requirements at station/plant level are met.

FRT assessment

The success criteria for the UVRT requirement for India are: a) that reactive current shall be injected during the fault, b) active power is maintained, and c) active power is recovered postfault to 90% of the prefault value within one second after restoration of voltage. In some cases, the active current can be reduced to increase the reactive current for supporting the voltage recovery.

For the OVRT behaviour, the generation station shall stay connected to the grid during a voltage rise

the protection systems shall be taken into account as well.

Control behaviour & Power quality assessment

- For the frequency withstand ability the capability of the unit to operate within the specified frequency range shall be verified
- For the evaluation of the operability of the plant with decreased or increased grid frequency the protection settings at the POI shall be assessed according to the requirements of the relevant grid code.
- For the frequency droop control the assessment shall be made on unit level. For assessment on plant level each unit and the relevant plant control shall be assessed
- For units the reactive power capability shall be measured under rated voltage conditions
- For the withstand capability regarding the voltage range the assessment is based on manufacturer declarations.
- For stations the capability at POI shall be determined with complex load flow calculations

- For the power quality assessment, the certification body assess the measurement report for the harmonic, DC current injection and flicker. The certification report properly documents all observations and gives comments. Any deviation from the limits which adversely affect the grid performance would be conveyed to the customer and in such case no certificate would be issued.

Conclusions

- The requirements of the Indian grid code
- The testing is usually according to international standards like IEC 61400-21, FGW TR-3 etc
- Contains the efficient assessment and interpretation of the results to ensure that the CEA requirements are fulfilled
- For the compliance certification DNVGL-SE- 0124 shall be used together with the CEA

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