What shall I do with a conventional UVRT Test Rig to carry out OVRT Tests and other Tests required for a full model validation

Rainer Klosse, Karsten Küch,
WindGuard Certification GmbH
Oldenburger Str. 65, 26316 Varel, Germany
Email: r.klosse@windguard.de

Friedrich Loh
Testing & Validation PQ/FRT – Wind Energy
GE Renewable Energy
Holsterfeld 16, 48499 Salzbergen, Germany
Email: Friedrich.Loh@ge.com

***Abstract*— Without costly investments in an existing voltage divider based test rig, the spectra of fault characteristics can be extended only by a change of the cable connections. Voltage angle jumps and over voltage ride through (OVRT) tests can be simulated without new main components. Measurements by use this option were carried out at a low voltage test rig to collect a full range data set. As well an application at a medium voltage test rig was investigated. The new set up of the test rig fulfill the requirements of the new German grid codes and gives additional a high number of new measurement results to validate generator models.**

Keywords-component; HVRT, OVRT, LVRT, UVRT, FRT, test unit, rotor displacment angle stability, voltage dip, gird fault, voltage divider, auto transformer, air coils, grid codes, mesurement of impedance, model validation.

I. INTRODUCTION

To get OVRT tests, the draft of the new IEC 61400-21-1 propose an extension of existing test rigs with costly sets of capacitor banks and resistances. This test emulates over voltages as they are occur as well in the grid. But this and other norms and guidelines allows to use as well other possible configurations to simulate this kind of events. In terms of voltage angle jump there often exists the interpretation that this test cannot simulate by use of a passably effort.

II. VOLTAGE ANGLE JUMP

Voltage angle jump during grid faults are rather the rule then the exception [9]. A power generation unit (PGU) needs to be able to handle this kind of fault characteristics. With the now existing guidelines the behavior of the generation unit will not be tested [4], [5], [7]. Standard test rigs were often not used to simulate this kind of faults [1]. A number of new connections were developed to simulate voltage angle displacement together with a change of voltage amplitude. Some are already tested with a low voltage test rig based on voltage divider.

A. Standard Test Procedure

In the middle of the standard under voltage ride through (UVRT) test procedure the amplitude dip is as required generated by the activation of the voltage divider, compare middle of Figure 1. The voltage divider consists at minimum out of two coils for each phase. To get linear test effects often air coils were used. The resulting arrow system for a tree phase symmetrical voltage dip is symbolized as shown in Figure 2. In the standard cases the coils are connected together in one point, here named with "N" or "Neutral". This neutral is usually not connected to the supply system. In medium voltage systems the neutral is often not existing or reachable.

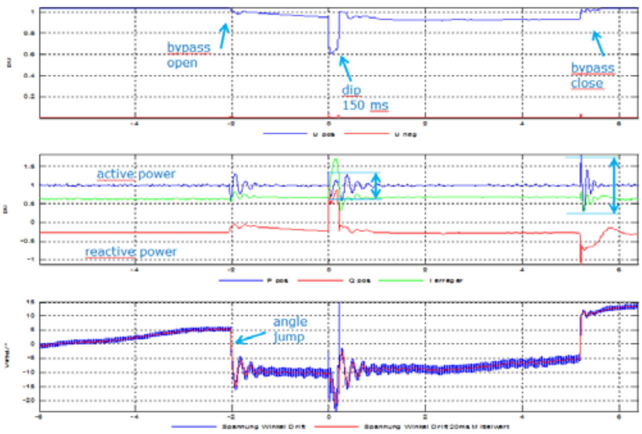

Figure 1: Stradart UVRT Test procedure with dip caused by voltage divider to Neutral and initialization by opening bypass switch.

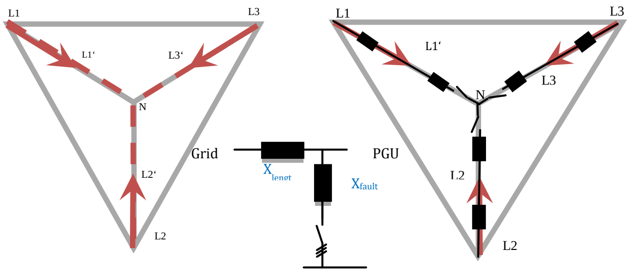

Figure 2: Tree phase symmetrical dip caused by voltage divider to neutral. Left: arrow diargramm; Middel: single line diagram; Right: tree phase connection diagramm.

By studying the example of Figure 1 the reset of the test unit is as well interesting for characterizing the device under test (DUT) that maybe representing the PGU. By closing the bypass of the length impedance the active power fluctuation is higher as during the dip of the amplitude. Reason for the fluctuation is the displacement or jump of the tree phase system in fore wards direction. During this moment the grid impedance change form a mainly inductive behavior out of the dominant inductance of the test unit in to a grid impedance were the active part of the impedance gets back to a significant role. The principal one phase main connection diagramm and the 3-phase change of the arrow system is illustrate in Figure 3. The amount of angle displacement is highly dependent on the infeed of the PGU. At no load situation or for PGU which are small comparing the test unit no or no relevant vector jump can be observed.

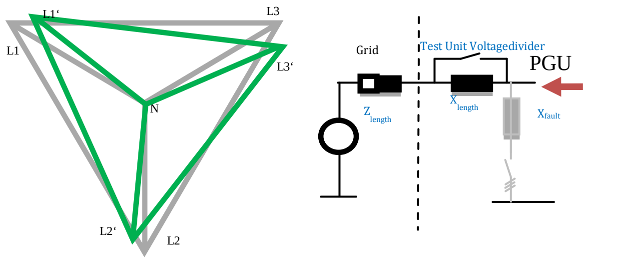

Figure 3: Initialisation of voltage divideer, phase shift depending on to Neutral, left arrow diargramm, middel single line diagram, right tree phase connection diagramm.

During the simulation of two phase faults the phase voltages of only two phases are connected via at minimum four inductances together. The arrow diagram of Figure 4 shows the different to the arrow system of the Figure 3. At booth diagrams it can be observed that the numbers of switches can be reduced of one less contact.

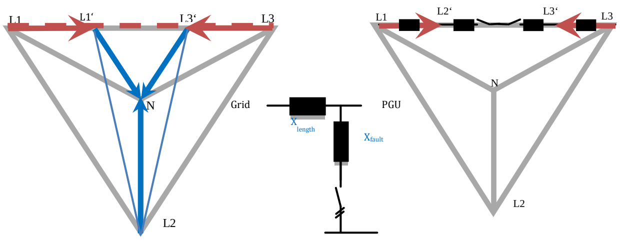

Figure 4: Dip caused by voltage divideer phase to phase, left arrow diargramm, middel single line diagram, right tree phase connection diagramm.

B. *Vectorjump by us of us of an complex inductanc network*

Target of a unit test is to simulate additional to a voltage dip at the same time as well an angle dip. One possibility is to use a coil network as shown in Figure 5. There it can be observed that each of the tree switching units is required and each phase of the switch gear open the line to line voltage. Similar to the standard voltage divider before and after the dip, the overall inductance should be low enough that the DUT is not disturbed too much. By starting the dip no situation of not connecting of the DUT should be occur. During the dip enough current has to flow that the voltage in the network is not too much influenced by the DUT.

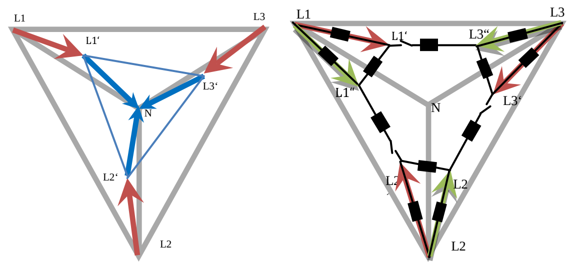

Figure 5: Dip with 3 phase shift caused by voltage divideer; left arrow diargramm, right tree phase connection diagramm.

Depending on the connection points of the DUT a three phase shifting of the voltage can be simulated in pre (L1", L2", L3") or in post (L1', L2', L3') direction. By combining the pre and post direction connection points a lot of nonsymmetrical dips can be simulated. It has to notice that the angle displacement occur as well by no infeed of current from the DUT.

Measurement at a low voltage test unit shows the functionality of the simulation procedure, compare Figure 6. The upper time series shows the 3-phase-to-phase voltages and as well the symmetrical component of the voltage. The middle time series shows the instantaneous voltages. The bottom time series shows the 3-phase-voltage-angle as a moving average over 20 ms and the calculated frequency as a moving average over 60 ms. The significant steps of the frequency is resulting out of the distortions during the dip and the moving average algorithm.

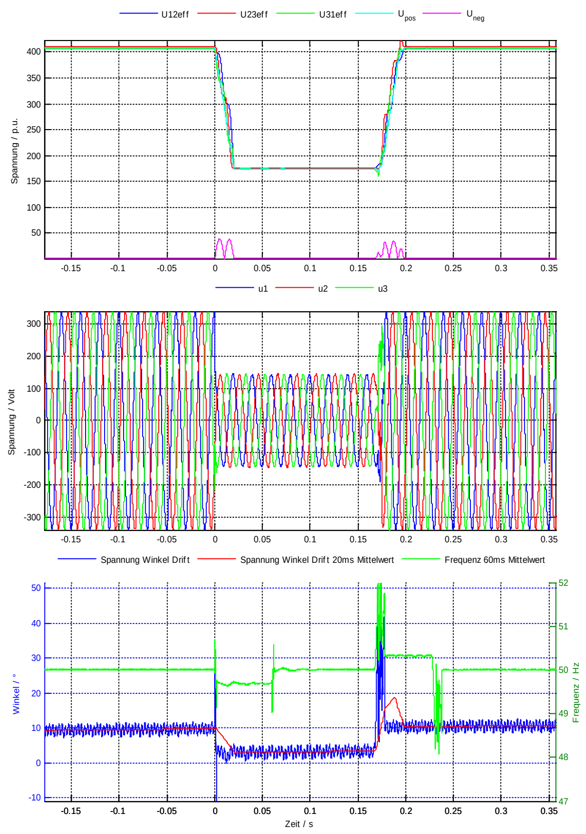

Figure 6: Symmetrical 3 phase amplitude dip together with phase angle shift. Uepper time series: Effective voltages; Middel time series: Instantaneos voltages; Bottom time series: 3-phase voltage angle and frequency.

III. OVER VOLTAGE RIDE THROUG

Real tests of the OVRT capability of power generation units are required in more and more grid codes. But to fit up test rigs to be able to do such tests can come quite expensive. Common voltage based test rigs can be used easily upgrade in case there coils are equipped with more than two connections of the windings. In this case the coils can be used as auto transformers to generate over voltage. This can be done as well with air coils. These auto transformers have a very small main inductance. As well the numbers of possible transformation ratios are limited. To reduce the short circuit current across the main inductance, other short circuit impedances can be used. This impedances can be used to adjust the value of the over voltage.

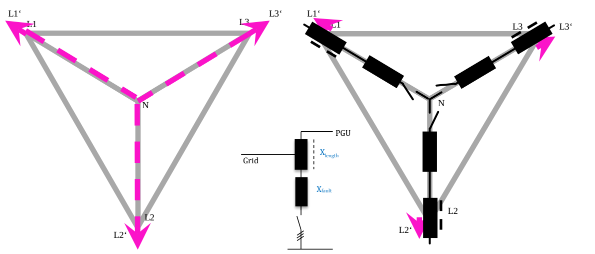

Figure 7: Generating overfoltage by use one set of coils as auto transformer. Left: Arrow diargramm; Middel: Single line diagram; Right: Tree phase connection diagramm.

Over Voltage Ride Trough (OVRT) tests at no load were carried out at low and medium voltage test rigs. Out of this, it can be observed that the construction of the coils have a significant influence in to the range of overvoltage which can be reached. But never the less, the recorded 110 % OVRT were reached in one example as shown in Figure 8.

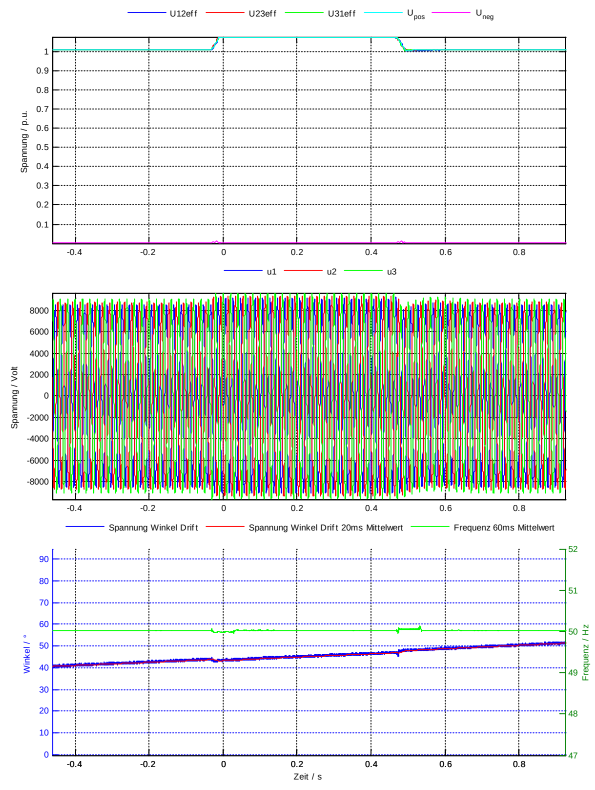

Figure 8: No load symmetrical 3 phase OVRT dip. Uepper time series: Effective voltages; Middel time series: Instantaneos voltages; Bottom time series: 3-phase voltage angle and frequency.

Coils which were produce only for an Under Voltage Ride Through (UVRT) test unit have an unpredictable transmission ratio for to use for an auto transformer. In case to build up a new test device this can be consider from the beginning to get more specify behavior. As well this autotransformer based on an air coil is a bit unpredictable for the resulting grid impedance from the view of the DUT. This impedance is necessary for the model validation of the DUT. This problem can be observed by measurement of the impedance during fault simulation. In these cases usually the fluctuating current of the DUT influences the voltage at the terminals of the DUT. With this information a grid impedance can be calculated to find the impedance by use of the minimum mean square rout deviation. Then a short circuit power can be calculated before and after the fault and during the fault, compare [1].

IV. SUMMARY

A lot of different combination of coils were try out to get vector jumps at the terminal of DUT. These kind of measurements are out of the requirements of the now existing guidelines. This test can be used to verifying the rotor displacement angle stability of the DUT during fault situation.

OVRT measurements are already part of new grid codes. These measurements can be performed in a small range with already existing UVRT test units in case the coils have at least a third connection and have a high enough transmission ratio between the two part of windings. The impedance of such setup can be teste by use of the minimum mean square rout deviation of the function between current and voltage during high load tests.

V. Outlook

Still under estimation is to precise the estimation of the grid impedance. As well a lot of switching combination were not tested jet. Especially the combination of vector jump, unsymmetrical fault, over voltage and use of the autotransformer effect opens a wide range of possibilities.

VI. Acknowledgment

This estimation was added on the research project "Allfred" subsidized by the Project Management Juelich and the German Federal Ministry of Economics Affairs and Energy as well as the Federal Environment Agency for funding (project number 0325721).

VII. References

[1] Rainer Klosse, Karsten Kuech, Joerg Jahn, Julius Gerdes Improvement of PGU Simulation Models based on FRT Test Rig with adjustable Voltage Vector and Short-Circuit Power 14th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well Transmission Networks for Offshore Wind Power Plans, Paper 133, Brüssel 10/2015

[2] Rainer Klosse, High-Voltage-Ride-Through Test System based on Transformer Switching, 12th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well Transmission Networks for Offshore Wind Power Plans, Paper 1173, London 10/2013

[3] Rainer Klosse, Fritz Santjer; Fault Ride Through Test based on Transformer Switching, 8th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well Transmission Networks for Offshore Wind Power Plans, Paper 82, Bremen 10/2009

[4] Fördergesellschaft Windenergie und andere Erneuerbaren Energien, FGW e.V., Technical Guidelines for Power Generating Units, Part 3: "Determining the Electrical Properties of Power Generating Units connected to Medium-, High- and Extra-High-Voltage Grids", TR3, Rev. 24, 01.03.2016.

[5] IEC 61400-21:2008, Wind turbines - Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines, 2nd ed., 2008.

[6] Verband der Elektrotechnik, Elektronik, Informationstechnik e. V. (VDE), VDE-AR-N 4120, Technische Bedingungen für den Anschluss und Betrieb von Kundenanlagen an das Hochspanungsnetz (TAB Hochspannung), Berlin, Germany: VDE-Verlag, 2015

[7] IEC CD 61400-21-1 Ed. 1, "Wind turbine generator systems – Part 21: Measurement and assessment of electrical characteristics – Wind turbines" Date of circulation 2014-07-11

[8] IEC 61400-27-1 Wind turbine generator systems – Part 27/FDIS Draft: Electrical simulation modules – Wind turbines and draft version 9.1 from 10.09.2015

[9] Emilio Gómez-Lázaro, Juan Alvaro Fuentes, Angel Molina-García, and Miguel Cañas-Carretón; Characterization and Visualization of Voltage Dips in Wind Power Installations; IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 24, NO. 4, OCTOBER 2009