Test Case 01

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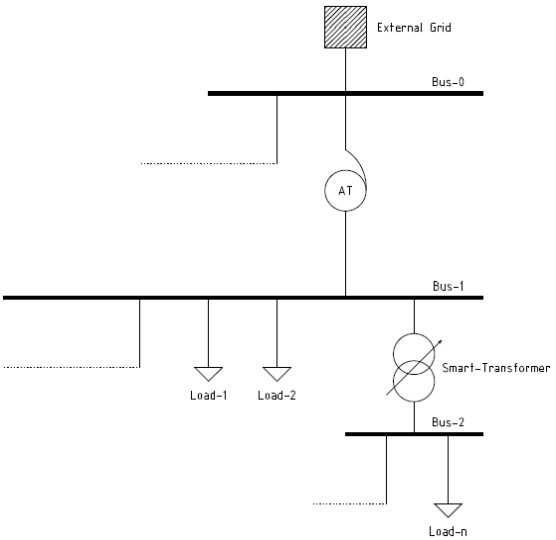
Name of the Test Case	Control of voltage with an on-load tap change controller
Narrative Incl. use case and test objectives.	The aim of this test case is to prove that an on-load tap changer controller “OLTC” is able to regulate the voltage level of the distribution network to the required value as stipulated both by international standards and by the network operator. This regulation would happen when the components connected to its low voltage side or when external anomalies such as the weather disturbing the normal behavior of the grid voltage. Depending on the control strategy, the measured value could come from locally measured values, remotely measured values, or even from end-user (smart meter) measurements.
Function(s) under Investigation (*FuI*) “the referenced specification of a function realized (operationalized) by the object under investigation”	The function under test is the voltage level control
Object under Investigation (*OuI*) "the component(s) (1..n) that are to be qualified by the test”	• OLTC controller • The communication infrastructure between the controller and the RTU. • Flexible loads and sources on the demand side
Domain under Investigation (*DuI*) “the relevant domains or sub-domains of test parameters and connectivity.”	Electric Power System, Communication, Control
Purpose of Investigation *(PoI)* The test purpose in terms of Characterization, Verification, or Validation	Verify if the performance of OLTC controller is adequate to maintain the voltage level within the required limits Characterize the OLTC operating performance in terms of loss reduction and hosting capacity enhancement.
System under Test (*SuT*): Systems, subsystems, components included in the test case or test setup.	The SuT is composed real experimental grid with the follow-ing components: • Generator. • OLTC • Transformers. • automated switchgear with RTUs. • Controllable loads • Communication facilities
Functions under Test (*FuT*) Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.	• OLTC controller regulating the voltage. • Communication of ICT with the RTU. • Interaction of the OLTC with the SuT configuration and conditions. • Loads and generation control.

Test criteria *(TCR)* Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.	The OLTC shall be able to control voltage with the pre-established limits in a predefined time-frame.
Target Metrics *(TM)* Measures required to quantify each identified test criteria	• Voltage (V) on low-voltage side of transformer. • Operation time (s). • Number of TAP position changes.
Variability Attributes *(VA)* controllable or uncontrollable factors and the required variability; ref. to PoI.	• Voltage variation. • Control of loads and generation • Errors in measurement • Errors in Communication • Loss of a line/generator
Quality Attributes *(QA)* threshold levels for test result quality as well as pass/fail criteria.	• Complies with the quality standards, • Maintain voltages within the ±10% specified limit.

Qualification Strategy

The different tests will create situations where there is a significant variability in voltage in the test circuit setup. The PoI will be met when it is verified that the variability is controlled, and the voltage maintained within the limits set out by the corresponding standards.

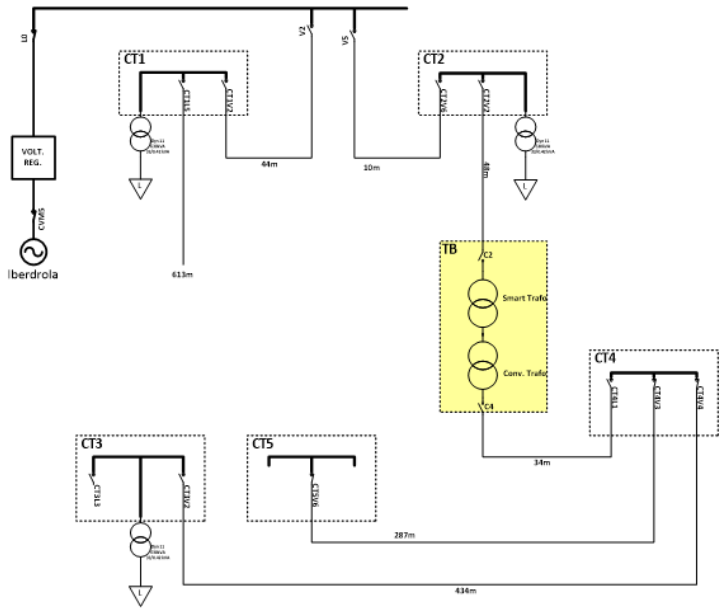
Test Specification 01.01

Reference to Test Case	*01*
Title of Test	***Control of voltage with an on-load tap change controller***
Test Rationale	Verify that an on-load tap changer controller "OLTC" is able to regulate the voltage level of the distribution network to the required value as stipulated both by international standards and by the network operator
Specific Test System (graphical)	 Grid voltage levels may be defined in specific cases, but the MV range expected is 0-36Kv.

Target measures	• *Voltage (V).* • *Operation time (s).* • *TAP position* • *Number of TAP position changes*
Input and output parameters	**Inputs**: • Voltage (V) • TAP position • TAP direction (up/down) **Outputs**: • Voltage (V) • Operation time (s) • TAP position **Other:** • Number of TAP position changes • Operation delay time (s)
Test Design	• Initialization of system (network, OLTC controller) • Measurement of input parameters • Calculation of optimal TAP position • Output of optimal set points to voltage regulator • Repeat
Initial system state	• System in steady-state at nominal grid voltage • OLTC controller in ready state • Communications established
Evolution of system state and test signals	*Voltage signals monitored from start of experiment. Disturbances on the network are stabilized by changing tap position to return grid voltage level to within permitted grid voltage limits..*
Other parameters	*n/a*
Temporal resolution	*1ms*
Source of uncertainty	*Communication delays, power supply fluctuations*
Suspension criteria / Stopping criteria	*Uncontrollable abnormal system conditions, communications failures*

Mapping to Research Infrastructure

Experiment Specification 01.01.01

Reference to Test Specification	*01*
Title of Experiment	Control of voltage with an on-load tap change controller
Research Infrastructure	UDEX
Experiment Realisation	The combination of the OLTC and the conventional transformer is called a "smart-transformer". The test is carried out with real components in a real network with no simulation required. During the test, drops and overvoltages would be applied by instantaneously connecting and disconnecting parts of the grid components where the smart-transformer is connected, while at its output the physical quantities would be measured to check that they comply with the required setpoint previously configured.
Experiment Setup (concrete lab equipment)	 Specific lab equipment includes: • Medium voltage distribution network cable infrastructure • Generator. • OLTC • Transformers. • Automated switchgear with RTUs. • Controllable loads • Communication facilities
Experimental Design and Justification	*The experiment requires the use of a real controllable network environment and so justifies the use of the UDEX infrastructure. The open possibilities of different grid voltages ranging from 0-36KV to demonstrate the objectives set out for this experiment, with a flexibility in the grid configuration providing flexibility in the load and generation characteristics requires a laboratory infrastructure such as the UDEX.*
Precision of equipment and measurement uncertainty	System uncertainty <5%
Storage of experiment data	*Experimental data is collated locally in files for posterior analysis if required.*