(2) test case description: use the following HTD canvas]

Author: Zhiwang Feng

Title: Advanced General Power Theory Inverter Physical Demonstration

Date: 17/03/2023

Test Objectives
Why is the test needed? What do we expect to find out?
The objective of the proposed project is to demonstrate in physical circuits the validity of the GPT control method that has been developed with physics-consistent concept models and the mathematical rigour of linear algebra.

- The experimental demonstrations are expected to show that the delivery loss attributable to a load or source at its Point of Connection (PoC) can be measured by the GPT approach using only measurements at the PoC and for a variety of practical conditions of unbalance and waveform distortion.
- The tests should demonstrate that it is possible to reduce, even eliminate, avoidable loss using a GPT-controlled inverter between PV-, wind-, and battery-sources and the delivery network.
- The test should demonstrate that the practical application of the concepts of reactive power and its derivates cannot define the physical operation of the power system as effectively as the GPT, especially under conditions of unbalance between the wires of the system and distortion of the waveforms, which commonly characterise the conditions at the grid-edges and in isolated grids.

Purpose of Investigation *(PoI)*
The test purposes classified in with terms Characterization, Verification, or Validation

- Investigate the impact of the GPT-controlled converter on the simplified power network hosted in the real-time simulation environment.
- Validate the novel GPT control method regarding its functionality and capabilities in achieving the optimised power flow in electricity distribution networks through dynamically balancing and re-shaping currents in different wires in an electricity distribution network.

Object under Investigation *(OuI)*
"the component(s) (1..n) that are to be qualified by the test"
The following components are to be qualified under the unbalanced and distorting load conditions as tabulated in Table 1 to Table 6:

- Bus voltage and current phase distortion
- Bus voltage and current harmonic distortion
- Power network frequency variation

Function(s) under Investigation *(FuI)*
"the referenced specification of a function realized (operationalized) by the object under investigation"

The functionality and capabilities of the novel GPT control method in achieving the optimised power flow in electricity distribution networks through dynamically balancing and re-shaping currents in different wires in an electricity distribution network.

System under Test *(SuT)*
Systems, subsystems, components included in the test case or test setup.

- A commercial converter manufactured by ArioGenix in South Africa
- GPT controller
- Real-time digital simulator (RTDS) hosted power network
- Triphase 90kVA converter-based PHIL setup
- Physical setups including transmission cable, passive load banks, synchronous generator, Triphase converters, power signal measurement units in DPSL and PNDC

Functions under Test *(FuT)*
Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.

The functionality and capabilities of the novel GPT control method in achieving the optimised power flow in electricity distribution networks through dynamically balancing and re-shaping currents in different wires in an electricity distribution network.

Domain under Investigation *(DuI)*
"the relevant domains or sub-domains of test parameters and connectivity."

Power electronics, electrical distribution systems, power engineering

Test criteria *(TCR)*
Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.

- 3-phase voltage signals at each bus in Figures 1 and 2
- 3-phase current signals at each bus in Figures 1 and 2
- Frequency measurement at each bus in Figures 1 and 2
- Active and reactive power measurement at each bus in Figures 1 and 2
- Evaluation of GPT-based control performance under varying system conditions.

target metrics
Measures required to quantify each identified test criteria

- Phase shift of measured power signals
- Total harmonics distortion of measured power signal
- Frequency deviation

variability attributes
controllable or uncontrollable factors and the required variability; ref. to PoI.
Imbalanced, harmonic distortion, frequency deviation, power factor.

quality attributes
threshold levels for test result quality as well as pass/fail criteria.
Optimised power flow.