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

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Title: Developing Digitally Twin Distribution Network Equivalent Models

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Test Objectives
Why is the test needed? What do we expect to find out?
The objective of the proposed project is to perform testing and validation experiments concerning the applicability, feasibility, and efficiency of reduced-order equivalent models for the modelling of modern passive and ADNs. In the framework of the project, four types of equivalents will be tested:

- Conventional static load models, such as the exponential and the polynomial (ZIP) models.
- Dynamic equivalents, such as the first-order exponential recovery model and higher-order equivalents based on variable order transfer functions.
- Models based on difference equations. This type of equivalent consists of static models and difference equations.
- Grey-box models that provide more insight, compared to abovementioned model types, concerning the physical properties of the examined system.

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

- Develop and test the performance of digitally twin DN equivalent models that can effectively mirror the dynamic behavior of all connected network components.
- Investigate the influence of the developed digitally twin DN equivalent models on the dynamic performance of the power system.
- Derive and validate reduced-order dynamic equivalent models, that will serve as digital representations for the physical assets connected to the test facility, under different network operating scenarios via PHIL simulation.

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 different network operating scenarios:

- Voltage and current at each bus in the RTS hosted network as in Fig 1.
- Active power, reactive power, and frequency at each bus in the RTS hosted network as in Fig. 1.
- Voltage and current at LV bus in the hardware side as in Fig. 1.
- Active power, reactive power, and frequency at LV bus in the hardware side as in Fig. 1.

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

The functionality of the digitally twin DN equivalent models that can effectively mirror the dynamic behavior of all connected network components. Special emphasis is given to the investigation of the influence of the developed digitally twin DN equivalent models, which will serve as digital representations for the physical assets connected to the test facility, on the dynamic performance of the power system under different network operating scenarios.

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

Power electronics, electrical distribution systems, power engineering

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

- Real-time digital simulator (RTDS) hosted power network (HV and MV DNs).
- Triphase 15kVA power converter operating in grid-forming and grid-following mode.
- Triphase 90kVA converter interfaced PHIL setup.
- Physical setups including passive load banks, synchronous generators, power signal measurement units in DPSL.

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 of the digitally twin DN equivalent models that can effectively mirror the dynamic behavior of all connected network components. Special emphasis is given to the investigation of the influence of the developed digitally twin DN equivalent models, which will serve as digital representations for the physical assets connected to the test facility, on the dynamic performance of the power system under different network operating scenarios.

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 and current at each bus in the RTS hosted network as in Fig. 1.
- 3-phase active power, reactive power, and frequency at each bus in the RTS hosted network as in Fig. 1.
- 3-phase voltage and current at LV bus in the hardware side as in Fig. 1.
- 3-phase active power, reactive power, and frequency at LV bus in the hardware side as in Fig. 1.

target metrics
Measures required to quantify each identified test criteria

- Phase shift and magnitude distortion of the measured voltage and current signals.
- Relative error and tracking error of the measured power signals.
- 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.

- Relative error and tracking error of the measured power signals.
- Frequency deviation