2. Test case description

ERIGrid Test Description Canvas

Title: unified Infrastructure-as-a-Service platform for Distributed co-simulation of networked Microgrids

Author: Nauman Beg
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Test Objectives
The primary objective of tests is to identify the scope of application of the developed IaaS platform under various grid scenarios in a lab test environment of a distribution grid (microgrid). The conducted tests are relevant for benchmarking the performance of the platform as a modeling toolset for dynamic studies in cyber-physical power systems (CPPS).

Why is the test needed? What do we expect to find out?

Purpose of Investigation *(PoI)*
The core purpose of investigation is summarized below:
- Characterize rapid modeling of heterogenous components in the platform
- Functionality tests to validate integration of new components
- Latency tests to study the relevance for quasi-dynamic studies in CPPS.

The test purposes classified in with terms *Characterization*, *Verification*, or *Validation*

Object under Investigation (*OuI*)
The following components of the platform are to be qualified by the tests:
- Simulator agents in the platform
- Remote web services in the platform
- Communication interface between simulator agents and the remote web-services

"the component(s) (1..n) that are to be qualified by the test"

Function(s) under Investigation (*FuI*)
The functions specified by individual OuI under investigation are as follows:
- Methods described for individual simulation components in the agents
- Methods described for individual hardware components in the agents
- Degree of abstraction of heterogenous communication interfaces using web-services

"the referenced specification of a function realized (operationalized) by the object under investigation"

Domain under Investigation (*DuI*)
The developed framework is proposed as a toolset for modeling, testing and analyzing large scale cyber-physical power systems. The test parameters are suited for analyzing ancillary grid services (control reserves) in distribution grids.

"the relevant domains or sub-domains of test parameters and connectivity."

System under Test (*SuT*)
The following on-site and remote assets are included in the test-case:

Simulation assets:
- Powerfactory for grid simulation (on-site)
- IaaS Platform in python (on-site)
- Hardware-in-the-loop models (on-site)

Hardware assets:
- Grid emulator (on-site)/
- PV system / emulator (on-site)
- EV system / emulator (on-site)
- Household emulation (on-site / remote)

Systems, subsystems, components included in the test case or test setup.

Functions under Test (*FuT*)
Three core functional components in OuI relevant for the operation of the SuT are tested:
- Accuracy of Digital twins using composite modeling in SuT over OuI
- Accuracy of Hardware twins in SuT over OuI
- Round-trip delay in OuI

Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.

Test criteria *(TCR)*
- Modelling accuracy of rapid prototyping characterized by Digital and Hardware twins in the SuT.
- Benchmarking of SuT response to control commands with monolithic implementation
- Definition and calculation of round-trip-delay in context of dynamic studies in CPPS

Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.

target metrics
- Quantization error between digital and hardware twins for different data exchange rate (co-simulation timesteps)
- Qualitative comparison between dynamic response of various assets in SuT
- Latency overhead of the OuI

Measures required to quantify each identified test criteria

variability attributes
controllable or uncontrollable factors and the required variability; ref. to PoI.
- Observability and controllability of the individual assets in SuT
- Round-trip-delay of the OuI
  - Variability over different co-simulation time steps (controllable)
  - Variability due to network congestion (uncontrollable)

quality attributes
- Successful integration of components in SuT as a Pass / fail criterion
- Error threshold of Digital twins < 5-6%
- Latency overhead of OuI relative to network latency = specific to application

threshold levels for test result quality as well as pass/fail criteria.

TITLE: unified Infrastructure-as-a-Service platform for Distributed co-simulation of networked power system

AUTHOR: Nauman Beg
DATE: 15.11.2024

Object under Investigation (*OuI*)

The following components of the platform are to be qualified by the tests:

- Simulator agents in the platform
- Remote web services in the platform
- Debug environment in the platform
- Communication interfaces in the platform

Function(s) under Investigation (*FuI*)

The functions specified by individual OuI under investigation are as follows:

- Methods described for individual simulation components in the agents
- Methods described for individual hardware components in the agents
- Debug environment for validation of implemented methods
- Robustness with heterogenous communication interfaces over web-services

Domain under Investigation (*DuI*):

The developed framework is proposed as a toolset for modeling, testing and analyzing large scale cyber-physical power systems under constrained lab environments. The framework relies on inherent lab coupling methods for distributed grid simulation studies. The test parameters are suited for quasi-dynamic studies in distribution grids using co-simulations

Target metrics (*TM*)

- Co-relation between quality of communication link and data exchange rate between OuI components in SuT
- Qualitative comparison between dynamic response of various assets in SuT
- Individual latencies in SuT modeled over OuI

Test Objectives

The primary objective of tests is to integrate heterogenous range of distributed systems into the existing IaaS platform in a lab test environment of a distribution grid. The conducted tests are relevant for benchmarking the performance of the platform and ease-of-modeling of wide spectrum of power system components for simulation studies in cyber-physical power systems (CPPS).

Purpose of Investigation *(PoI)*

The core purpose of investigation is summarized below:

- Characterize rapid modeling of heterogenous components in the platform
- Functionality tests to validate integration of distributed components
- Tests validation under controlled degree of randomness in communication interfaces

Test criteria *(TCR)*

- Modelling accuracy of rapid prototyping characterized by Digital and Hardware twins in the SuT
- Characterization of individual latencies in OuI on the accuracy of SuT.
- Resilience in OuI prone to communication constrains in SuT.

Quality attributes *(QA)*

- Successful integration of components in SuT as a Pass / fail criterion
- Steady state error threshold of Digital twins < 5%
- Dynamic response of components in SuT over OuI with latencies (test specific)

System under Test (*SuT*)

The following on-site and remote assets are included in the test-case:

Simulation assets:

- IaaS Platform in python (on-site)
- Powerfactory for grid simulation (on-site)
- Matlab for Simulation-in-the-loop (SiL) models (on-site)

Hardware assets:

- Grid emulator (on-site)
- Load emulator (on-site)
- Smart home assets (remote)
- 5G communication link (on-site)

Systems, subsystems, components included in the test case or test setup

Functions under Test (*FuT*)

Three core functional components in OuI relevant for the operation of the SuT are tested:

- Accuracy of Digital twins using composite modeling for distributed assets in SuT over OuI
- Accuracy of Hardware twins in SuT over OuI
- Round-trip delays in SuT modeled with FUI in OuI

Variability attributes *(VA)*

- Simulation resolution of the individual assets in SuT
- Co-simulation resolution in OuI to characterize digital twins in SuT
- Delays in OuI
  - Variability over different co-simulation time steps (controllable)
  - Variability over quality of communication link (partial controllable)
  - Variability due to network congestion (uncontrollable)