TITLE: Grid Interconnection protocols for Largely Dispersed minigrids/microgrids (*Multigridcon*)	**AUTHOR: Dr. Chandrasekhar Perumalla and MR. Amit Gupta** **DATE: 22.08.2022**

Object under Investigation (*OuI*)

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

- Define reference mini-grids and reference decentralized control schemes for energy management in the context of rural India electrification.
- Develop sequential control strategies for seamless interconnection of microgrids and transition from islanded to grid connected mode and vice-versa for the selected reference control schemes.
- Numerical validation of the connecting/disconnecting strategies for power system consisting of several microgrids (e.g. > 10) with focus on stability and power quality.
- Experimental validation of the connecting/disconnecting strategies for a few microgrids (e.g. < 5) in the Laboratory combining physical power converters and real-time simulations.

Function(s) under Investigation (*FuI*)

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

Test Objectives

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

The policy and regulatory aspects of mini-grids and their interconnection protocols are yet to be defined clearly, if not completely. Such protocols on grid integration and islanded operation as well as interconnection of mini-grids are highly dependent on the grid type, location and specific combination of energy sources. The present protocols are not comprehensive enough and do not cover sufficiently the needs for interconnection of multiple mini-grids. Moreover, the lack of clear integration protocols for the mini-grids is resulting in stranded and abandoned assets when the main grid is extended to the area. This project aims to address the gap in guidelines and protocols for connection of multiple mini-grids between each other.

In this connection, the proposed test(s) have following objectives

- Validate the proposed interconnection scheme along with its specifications when interfacing the (reference) microgrid with the existing system
- Validate the developed control scheme along with its reference protocols for interconnection of two or more micro/minigrids, based on laboratory infrastructure
- Adapt the interconnection protocols and control schemes from test results for better performance, if required.

System under Test (*SuT*)

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

A subsystem with heterogeneous generating sources forming microgrids/minigrids which are electrically isolated with a provision to interconnect based on the compliance with the defined protocol with the help of a developed controller and associated subsystems, including protection.

A subsystem forming a micro/minigrid which is isolated from main grid with a provision to interconnect based on the compliance with the defined protocol with the help of a developed controller and associated subsystems, including protection.

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Interconnection protocols for integrated operation of multiple minigrids with heterogeneous sources and loads.
Interconnection protocols for integrated operation of microgrids with different types of sources with grid
Performance of the controller for the above two functions.

Domain under Investigation (DuI):
“The relevant domains of test parameters and connectivity”

Electrical Power System; Energy System – Smart Grid
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Purpose of Investigation (PoI)
The test purposes classified in with terms Characterization, Verification, or Validation

Validating the proposed interconnection protocols along with developed controller for integrated and sustained operation of multiple mini/microgrids as well as integrated operation with grid.
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Functions under Test (FuT)
Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT

Stable and Sustained operation of microgrid islanded mode
Stable and satisfactory transition from islanded mode to interconnection mode
Stable and sustained operation of mini/microgrid in Interconnection mode
Achieving the desired power flows along with other stability parameters

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Target metrics (TM)
Measures retrievable from SuT required to quantify each of the identified test criteria

Smooth transition from island mode to interconnection mode, both for grid interconnection and for interconnection of multiple mini/microgrids is the prime objective of the test which can be quantified by measuring

Inrush currents,
Operating voltages,

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

Developing Test setups as per SuT
Validating the protocols and developed controllers as mentioned in “Test Objectives”.
If required, adapting the proposed protocols and/or developed controller such that satisfactory and stable interconnection will takes place.
Achieving a seamless transition between island mode to interconnection mode in terms of zero inrush currents, stable interconnection voltages and inter/intra microgrid power flows and other stability parameters.

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Variability attributes (VA)
Identify relevant controllable or uncontrollable factors of the SuT and their required variability; refer to PoI

It is expected that the microgrid consists of heterogenous sources and can be operated in islanded mode. However, the type of sources and their share can be variable.
As it is expected to validate the interconnection of microgrid with gird, the grid can be a distribution grid. However, it should be sufficiently

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• Inter and Intra microgrid power flows and • other parameters which can confirm the stable and sustainable interconnection.	**Quality attributes** *(QA)* Threshold levels for test result quality as well as pass/fail criteria ➢ The primary threshold levels would be as per IEEE/EU-Norway/CEA protocols ➢ Adaption of the protocol will be done as per laboratory setup available/to be established ➢ The proposed protocol should take care of the satisfactory and stable interconnected operation of microgrids or interconnected operation of microgrid with grid, which ever may be the case, with the help of the developed controller, rather than activating the protection system frequently.	strong grid representing the practical scenario so that seamless integration is achievable ➢ There should be provision for island as well as interconnection operation of heterogeneous mini/microgrids as when required as per defined protocols and developed controller. However, there is no specific size requirements but they should be of comparable size. ➢ The control platform should be able to execute the protocol defined within the variable operational limits of equipment associated.