<u>YEAR 8 TASK SUMMARY BRIEF</u>

<u>TASK TITLE:</u> UNIFIED MODELING OF INTEGRATED T&D POWER NETWORKS FOR "MAGNIFIED" STABILITY ANALYSIS OF SYSTEMS WITH LARGE PENETRATION OF RES-BASED DER

Project Lead: Luigi Vanfretti
Primary thrust: Modeling
Secondary thrust:

1.1. Abstract

Currently, power systems modeling and simulation methods usually require different tools to analyze different time-scales of system behavior. Phasor-based models are used to study electro-mechanic transient behavior, in which positive-sequence is used to model transmission networks, while three-phase models are used in distribution. Furthermore, wave-based equations are used to model power-electronics-based devices, such as converters used to interface renewable energy resources and energy storage systems to the main grid. In this context, this project aims to implement and assess an integrated modeling framework that unifies, at the equation level, these different modeling philosophies. This framework will be used to study the interaction between transmission, distribution and power-electronic-based devices and their impact in the stability analysis of the entire electric power grid.

1.1. Impacts and Methodology

Analysts develop different modeling strategies and tools to analyze the operation of the electric power system. These strategies and tools are often used in such a manner that each subsystem, i.e. transmission, distribution and power electronic devices, is designed and analyzed independently from other subsystems. However, with the increase of renewable-energy-based distributed generation, along with power-electronic-based devices, their impact cannot be neglected any longer as their dynamic behavior cannot be decoupled from that of the bulk power network, as in the past.

To address this problem, the current work uses a unified modeling approach, integrating transmission, distribution, renewable-based distributed generation and power-electronic devices. In addition, tool-specific simulator interaction is avoided by using the equation-based standardized modeling language *Modelica*. In this context, the proposed integrated modeling framework and associated analysis methods may enable analysts to better understand the dynamics of more complex and integrated power systems.

1.2 Intellectual Merit

The main idea behind this task is to provide the foundation for a new analysis method aimed at providing a "modeling magnifying glass," that would allow the "zooming" into a specific portion of the power network by an analyst. Hence, the granularity of the model's mathematical description could be specified without requiring any co-simulation of two separate models with different modeling tools.

1.2. Related Work

The model for the integration between transmission and distribution systems is based on the work proposed in [1], which was implemented and tested in [2] and [3]. One methodology for the integration between electro-magnetic-based models positive-sequence-modeled systems is presented in [4] and [5]. The modifications proposed in the current work are related to the coupling of the components using an equation-based approach at the model level, thereby decoupling it from any specific simulation tool.

1.3. Future Work

Future work for this task includes:

1. The improvement of the interface between the three-phase-modeled and positive-sequence-modeled systems.
2. The comparison between other interfaces between electro-magnetic and phasor-based models to evaluate the "*modeling magnifying glass*" effect.
3. The study of transient stability in test-systems including different power electronic devices, such as a STATCOM.

1.4. Member Champions & Benefits

This work is not supported by any CURENT member directly, however, Dominion Energy has recognized the potential of this approach to analyze their power systems as the penetration of power electronic-based devices, RES-based distributed generation and energy storage systems will continue to increase. RPI's ALSETLab delivered a 1-week course at Dominion Energy's premises in Richmond where more than 10 engineers were trained in the Modelica language and utilized the approach developed in this task.

1.5. References

[1]. Marinho M. T., and Taranto, G. N., "A hybrid three-phase single-phase power flow formulation". *IEEE Transactions on Power Systems*, *23*(3), 1063-1070, 2008.

[2]. Fernandes, M. de C., de Oliveira, J. G., Vanfretti, L., Baudette, M., Tomim, M.A., "Modeling and simulation of a hybrid single-phase/three-phase system in Modelica". In

[3]. Fernandes, M. de C., Vanfretti, L., de Oliveira, J. G., Baudette, M., "A fundamental time-domain and linearized eigen value analysis of coalesced power transmission and unbalanced distribution grids using Modelica and the OpenIPSL". In International Modelica Conference, Regensburg, Germany, 2019.

[4]. Theodoro, T.S., Tomim, M.A., Barbosa, P.G., de Lima, A.C.S. and Santiago, J., *A Hybrid Simulation Tool for Distributed Generation Integration Studies*, 2018 Power Systems Computation Conference (PSCC), 2018, IEEE.

[5]. Theodoro, T.S., Tomim, M.A., de Lima, A.C.S. and Barbosa, P.G., *A hybrid simulation tool for penetration studies of distributed generation in smartgrids*, 2017 Brazilian Power Electronics Conference (COBEP), 2017, IEEE.