A Fundamental Time-Domain and Linearized Eigenvalue Analysis of Coalesced Power Transmission and *Unbalanced* Distribution Grids using Modelica and the OpenIPSL

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Abstract. This paper present mathematical modeling and implementation in Modelica language of a coalesced electric power transmission and distribution system model. To this end, a newly developed feature in OpenIPSL that allows to amalgamate power transmission and distribution networks at the equation level is described and implemented in Modelica. Mathematical models for three-phase components such as lines and loads are also presented and implemented in Modelica. The models are used to assemble two different, small-scale, sample power systems, and three simulations are performed for each of them in a Modelica-compliant software. Dynamic simulations are carried out to perform comparisons between different modeling approaches for a distribution feeder and among different load characteristics. Each simulation is linearized using a script in ten different time instants and an eigenvalue comparison is performed. The results from all dynamic simulations presented expected results. Voltage behavior observed using positive sequence models and three-phase model with balanced load increase are similar. In addition, results coming from three-phase unbalanced load increase and positive sequence model diverge. The comparison between eigenvalues values corroborates the dynamic simulation results and show that a misused positive-sequence model may lead to wrong conclusions about system stability. The results are meaningful as distribution networks gain relevance due to increasing level of distributed generation being introduced in low-voltage grids. The analyses performed in this paper are easily conducted, showing that Modelica language and compliant software packages may have key role in the development of new computational tools to study complex emerging power systems.

Keywords: Modelica · Power Systems · Hybrid Models · Linearization · Eigenvalues · Transmission Networks · Distribution Networks