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A DEVS BASED MODELING ARCHITECTURE OF ELECTRICAL POWER SYSTEMS

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ABSTRACT

Recurrent energy planning issues cited in the literature are (1) the growth in demand for energy, (2) the challenge of diversity in energy supply and (3) the concern about energy security and environmental constraints, particularly the challenge of climate change (Safi et al. 2012). Decision-makers in the power system infrastructure domain have to deal with physical and financial constraints as well as uncertainties related to renewables, costs, etc. (Van Dam 2009). In this research, *Spark!*, an energy system simulation model developed on a DEVS (Discrete Event System Specification) platform, offers a realistic representation of large scale power grids. The model captures the intermittence of renewables, constraints of conventional generation resources, geographical and climate information, the transmission capacities, and offers flexible time resolution.

1 INTRODUCTION

Power system infrastructures must, at all time, match supply and demand, at all locations across the network. However, reliably maintaining this balance can become increasingly difficult, considering the growing penetration of renewable energy sources. Two major changes need to be addressed: (1) adjustment in power flow patterns, which would potentially cause grid congestions and the need for large grid reinforcement, and (2) increase in variability in power generation, which would likely require balancing through energy storage systems, or increased power trading between different zones (Svendsen and Spro 2016).

All these changes make the medium to long term planning quite complicated. May it be expansion or operational planning, challenges related to high renewable penetration necessitate accurate modeling, at the rick of compromising economic wellbeing of utility companies and society, in general.

2 MODEL FORMALISM

This research formally sets forth an architecture for *Spark!*. The model is designed on the premise that complex systems, like Power systems, can be modeled in a modular and layered fashion, in which systems specification can be built on top of previously verified components (Concepcion and Zeigler 1988). Functionally, a power system can be divided into load centers, generation system, transmission system, and generator dispatch and commitment systems. Generation system refers to generating or storage units, producing electricity. Transmission system refers to transmission lines, carrying electricity from distant sources to load centers. Load center refers to electricity demands from the population. Generator commitment system helps determine the schedule of generating units (when to turn them ON/OFF), over a time horizon, taking into account operating constraints (Tahanan et al. 2015). This activity is referred to as the unit commitment problem. Generator dispatch system helps identify the optimal use of a number of electricity generation facilities, in the least costly and environmentally damaging manner. These functional

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delineations present a strong case for system components to be built independently, providing the capacity, to not only perform analysis at the individual level, but also at the system level.

The DEVS formalism is most appropriate to build *Spark!*, as it offers both modularity and hierarchy (Zeigler 1976). Modularity is the ability for a system to be broken down into modules, here power system components, able to effectively communicate together via information exchange and collaborate for a specific purpose. Hierarchy suggests a multi-layer structure of the system, depicting the different levels at which the system operations are implemented (Huang et al. 2012). The model is coded in Python.

3 MODEL ARCHITECTURE

Each of these module (*generators*, *transmission lines*, *loads*, *dispatchers*, *unit commitment* and *storage*) is modeled as an *atomic* DEVS model. Their behavior change not only due to internal mechanism but also to external inputs. The *generators*, *loads*, *dispatchers*, and *storage* models are located at the *zone layer* of the system. The connections between *generators*, *loads*, *storage* models and *dispatcher* model form the *zone* model, which is built as a *coupled* DEVS model. At this level, system balance is sought locally, and eventual power excess or deficit is determined. The connections between the *zone*, *transmission lines* and *unit commitment* models form the *inter-zone* model, which is also a *coupled* DEVS model. This model is located at the *inter-zone layer* of the system. At this level, balance is sought throughout the network, and *zone* models can decide whether to trade with others or not.

Using this architecture, we can formally specify the roles of- and relationships between- each module. We can also capture the different activities taking place at each layer of the system. The model can thus be detailed enough to capture the (1) technical requirements of each component and (2) architectural features of the grid.

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