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Modeling and Simulation of Renewable Energy Sources in Smart Grid Using DEVS Formalism

Moath Jarrah[a]

[a]*Department of Computer Engineering, Jordan University of Science and Technology, Irbid 22110, Jordan*

Abstract

Because of safety, economical, and environmental reasons, the community of power systems is being working on developing a new and clean power grid, the smart grid. Smart grid infrastructure brings together renewable energy sources with information technology domain to find optimal and clean power generation, storage, and consumption. The first step in designing an intelligent power and data infrastructure, is to model and simulate the different components of smart grid in order to make accurate design decisions. In this paper, a modeling and simulation approach in the Discrete EVent System Specification (DEVS) environment is proposed. The approach models four main components in smart grid which are: photovoltaic arrays, wind turbines, storage devices, and load demand. Also, other components are being developed as well and will be discussed. Real wind speed and solar radiation profiles were used in the simulation. The tool results of the maximum amount of stored power and the power shortage are used to help the power system designer at a specific location in making decisions on the capacities needed for photovoltaic arrays, wind turbines, and storage.

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Keywords: DEVS formalism, smart grid, renewable energy, automatic decision;

1. Introduction

The energy sector plays a vital role in today's industrial and scientific development. The main energy sources that are currently being used around the world are based on fuel and nuclear reactors. Chernobyl and Fukushima Daiichi nuclear catastrophes that occurred in 1986 and 2011 respectively, has awakened power systems designers of safety problems. This has urged countries like Italy and Germany to abandon nuclear power plant. Germany, Europe's biggest economy, has announced to entirely shut down nuclear power plants by 2022[1]. In addition, global warming has become a crisis causing governments to control CO2 emissions by setting rules on using fossil foil sources. These

* Moath Jarrah. Tel.: +962-7777-68027.
E-mail address: mjarrah@just.edu.jo

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economical and political crises urged scientists to develop a new safe and sustainable energy resources. Hence, smart grid concept has been proposed and power companies have started building new infrastructures for renewable energy.

Smart grid power systems integrate clean energy sources (solar panels and wind turbines) on a large scale to generate power whenever wind speed and solar radiation are available. Since, these are not available all the time, storing excess power in storage batteries (hydrogen, super-capacitors, electrical vehicles) is very critical to the success of deploying such systems. Many optimality efforts in generation, storage, and consumption have published such in [2,3,4,5,6].

The cost of setting up the green energy of solar photovoltaics (PV) and wind turbines is high. However, after setting up the hybrid energy system, the cost of maintaining it is very little and very efficient on the long run. Since the sunlight and wind varies, some other forms of energy resources (such as gas, petroleum, hydrogen, bio-fuels) can be used at low periods to avoid blackouts. Using this model, the dependency on petroleum and gas is reduced significantly [7].

In this effort, the objective is to build a modeling and simulation (M&S) environment using the Discrete EVent System Specification (DEVS) formalism for smart grid. This tool models the main components of the system such as: photovoltaic arrays, wind turbines, storage, load demand, and vehicle-to-grid. The motivation behind building the M&S environment is to help power system designers in making decisions of the smart grid system before actually setting it up. Some decisions are, but not limited to: number and type of solar PVs, wind turbines, number of storage elements, number of coordinators, number of grids or microgrids, decision making policies, best estimate for other energy resources.

This work aims to build the environment using a modular design. Real data profiles of wind speed and solar radiation in Jordan are used as inputs to the simulation environment in order to predict future trends and be proactive in making decisions. For example, when there is an excess in the solar power generation during noon times, the system should be automated to save this extra power so it can be used later to efficiently balance different times of power loads.

2. Smart Grid Characteristics

Smart grid infrastructures include power transmission lines, data communication media (wired and wireless), and smart meters to collect statistics that are needed in optimization techniques. Two-way communication of data and statistics are done between the different controllers and components of the smart grid [8 9]. The main communication networks in smart grid systems according to their scope and area of coverage are: Home Area Network (HAN), Neighborhood Area Network (NAN), and Wide Area Network (WAN) [10].
Power generators in smart grid include wind turbines, photovoltaic arrays, gas, and fuel. Smart grid also comes with storage devices such as electrical vehicles, hydrogen storage, and super-capacitors. In this paper, models are used to address the main power components. One of the challenges is that residential and business areas have a stochastic growth by nature. This puts a challenge in modeling the load demands as it varies continuously in time. To tackle this challenge, a modular design is implemented in this paper, where adding and removing load models are flexible. As a result, the simulation helps designers to expand the system to meet the future demands before they occur. Four components of the smart grid are used which are:

1. Generation (hybrid including solar and wind)
2. Storage (to store extra power)
3. Consumers (residential and business power demands)
4. Coordinator (for decision making to fulfil power demands and implement optimization solutions)

3. Modeling and Simulation Components

This section provides a brief overview about DEVS models and how the smart grid modeling and simulation environment is implemented in a modular approach.