Chapter

Applications of Multi-Agent System in Power System Engineering

G.S. Satheesh Kumar and S. Tamil Selvi

Abstract

Power system needs a continuous upgrade to overcome the challenges like distributed control, self-healing, power quality, demand side management and integration of renewable system. At present, power system needs an advance and intelligent technology to perform various system level tasks. Centralized control of the system has efficient operation during integration of the renewable resources and lag of communication between the stations. Smart grid provides the intelligent and efficient power management system. Upgrade of present power system with multi-agent system (MAS) provides the solution for most of the power system issues. More number of MAS are used in the power system network based on acquires of the system. MAS are communicating with each other for the more acquired result. Better implantation of MAS can achieved by providing the high speed and secured communication protocol. In this chapter, we discussed about the MAS fundamental architecture and intelligent controller design tools and case study of real time tariff management using MAS.

Keywords: multi-agent system, power system, self-healing, MAS platform centralized control, decentralized control

1. Introduction

Nature has various forms of energy that exist in the world, among these electrical energy is very important. The modern world is mainly depending on electrical energy. Electricity is an important part of the day-to-day life of every human. Energy is the basic need for the development of any country. Availability of the energy in various forms depends on the geographical location of the country. Demand for energy is increasing rapidly due to industrialization and modernization. The energy availability in the world is decreasing gradually. Energy that is developed and supplied all comes under power system engineering. This will consist of power generation, transmission, distribution and analysis. The main drawback in the present power system is inefficiency due to lack of infrastructure [1, 2].

One of the highly risk system is known as power system. The analysis of the system in different conditions at the real time is more important for the smooth operation of the system. Error information costs the shutdown of the whole system. Implementing the sophisticated controls in all the levels improves the economy and reliability in the system. For this, detailed study about the operation, control, analysis and interconnection of the system is essential [3–5].

Power system is responsible for maintaining the adequate level of power in the network by adding or removing the power generation units in the network. It also supplies the power uniformly to the loads with high quality at any time. In past decade, the power system uses the low-level AC transmission lines which have low efficiency. Now the power system networks are developed to support the high-voltage AC transmission. This improves the efficiency of the system and derives many number of loads, also high-voltage direct current (HVDC) system is developed to reduce the transmission loss and conductor cost. Implementing power system network with closed loop system will improve the efficiency of the system and also reduce the power outage. Fast growing power system structure needs and high responsible intelligent and self-healing system to upgrades the system for future world.

The scientific community is not only searching for next generation computing but also searching for next breed of processing machines. This should be smaller, faster and more potent to process more data in a short span of time. To develop such kind of machines, one needs to consider the following points: (1) theories that explain what intelligence is, how it processes imprecise information and stores, recalls, associates, correlates, infers and extract precious values, (2) technology with a small amount of circuitry to process vast amount of imprecise information in a very short time and provide precisions, and (3) architecture that encompasses the new theories and technologies [6, 7].

2. What is multi-agent system?

It is related to the computer with intelligence programming. Various definitions for agent are available based on their environment and how it is used. An advantage of using agent is its flexibility in all types of environment and autonomy. Complex system control and monitoring can be done using intelligent controllers. Agent is a fully referred as software and it mainly depend on the environment. Agent is used in the power system, it known as power system environment are agent may be a part of an environment like sensors, relay, etc.

The agent is mainly interconnected between the hardware and software components. The agents will take the decision based on the signals received from the work environment. More numbers of agents are used in the network for the efficient operation and hence it is named as multi-agent system (MAS). Basic property of the MA is not varied but depends on the location. For example, in a power system use MA in substation and control center is same, only the program that feed in the MA depends on the location. The function of the MA related with the other MA system connected in the network. Autonomy places a major role in the MA for the real time decision making it performed based the present and future data analysis. MA data are stored and is shared through the network for the references of MAS [8–12].

3. MAS design

3.1 Introduction

Present power systems are espoused with the centralized control it leads to delay of the operation, reliability, power management and control. Utilization of renewable energy and energy management needs advanced technology with autonomous control and operation.

A smart grid is a hope to efficiently control and operate the future power system. The centralized grid required communication between hardware and software protocol. Nowadays, grid is automated through the exchange of control signals and status of the grid. Monitoring and controlling purpose automated technology agents used this so-called multi-agent system (MAS). It is one of the sound technologies to implement into the present grid. In this approach, a number of agents are interlinked together to obtain the objective of the complex system. The main function of the MAS in function autonomously and take the decision locally while a grid suffers from the unexpected operating condition. Implementation of MAS technology into the power system is due to lake of awareness. A major application of the MAS is to integrate renewable resources into the power grid in an efficient and controllable way. In this chapter organizing as follows, deals with MAS structure, intelligent technology and the implementation related to this work.

Single agent system denotes, it communicates particularly to one device for control and monitoring purpose. It will not help to achieve the entire goal of the systems. MAS has more numbers of agents working together to achieve the common goal by means of effective communication, coordination and cooperation between the agents.

3.2 Multi-agent system

In a present power system, effective communication and control were done using supervisory control and Data Acquisition System (SCADA) as a centralized system. SCADA did not allow any autonomous function of the device. Command and control signals are sending by the SCADA, it leads to absences of real-time performance. Multi-agent system is overcoming the drawback of the existing system. It provides distributed control over the system. Intelligent electronics devices or software is used as a control agent. This will have the rights to take the decision based on the environment condition [13–17].

Each agent has set goals to perform at a specified time period. Agents are classified into many types based on the operation namely control agent, distributed agents, monitoring agent, centralized control agent, date base agent, etc.

3.3 Structure of multi-agent system (MAS)

Integration of hardware and software was done by the multi-agent system. An agent may be hardware or software based on the operating condition. Every agent has its own set of goals. In a complex power system, a number of agents used at different levels with its own set of goal. Collectively, the objective of the agents is to implement the smart grid technology into the power system. The agent may be hardware or software interlaced with an operating condition and able to perform autonomously. Characteristics of agents are reactivity, pro-activity and social ability. **Figure 1** shows the basic structure of MAS [18].

The complex power system problems are cracked into small problems. These small problems are handled by individual MAS. This will reduce the complexity of the system easy to identify and isolate the system. MAS have the right to take the decision individually, no need to wait to get the signal from the control center. An agent can communicate with the nearby agent about its task completion status and provide information about some nearby agents and its status. Coordination and cooperation between the MAS are very essential for the intelligent operation of the system to achieve the overall goal. Coordination is need between the MAS for effective exchange of the information at a real-time to obtain the overall objective

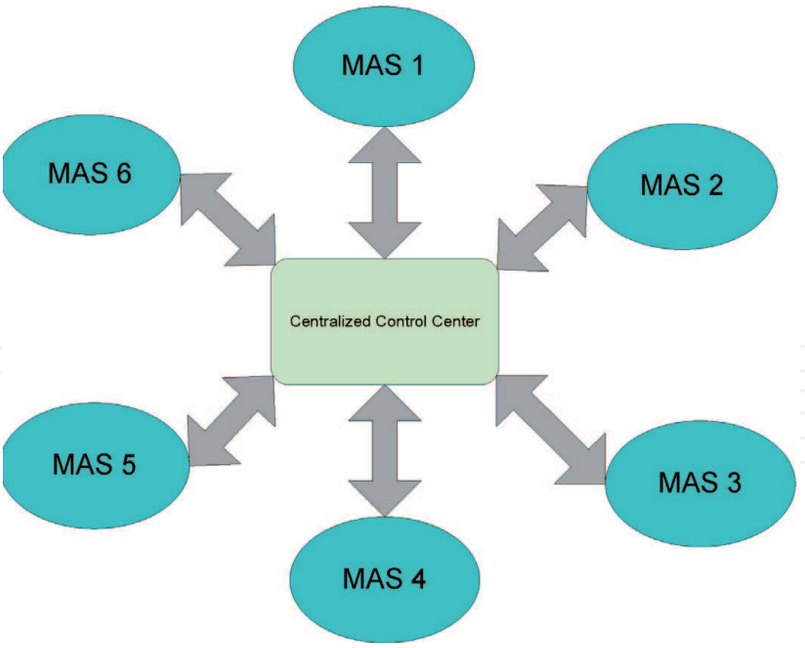

Figure 1.
Structure of MAS.

of the system. Cooperation in this agent has the right to reject, accept and defend the signal from the other agents. In this regard, cooperation is a very critical thing in MAS function.

The agents can communicate about status and goal achievement. This supports other agents to obtain the goal in the fastest way. Throughout the operation, common commanding language is used for communication.

3.4 Features of a multi- agent

- An agent can perform partly with the environment like it has information about the current bus systems voltage level and a voltage level of the generation bus. Decisions are taken in the consideration of other bus parameters also (autonomous and decision making).

- An agent has a facility for communicating nearby agent through high-speed communication network to interchange their real-time data. For example, the current power generation cost are collected from the center control agent, based on this information, the consumer can change their load pattern (coordination and cooperation).

- An agent has the decision making capability for certain level. Based on the resources date available with the agent, it will perform independently to obtain the objective. If anyone of the generation is failed, agent will take the decision to give reliable supply based on the real-time data available to end user (self-healing).

3.5 Multi-agent system in power system

Power system needs to reward with upcoming technology to operate the grid professionally. The power system has a huge network with a high sense of risk in the control and operation. The areas include generation control, monitoring, fault location, overload and surplus power generation, etc. It needs a more sensible

operation. These high-risk factors are addressed by the MAS without disturbing the reliability of the system.

The present structure of the system falls under the inefficient operation due to the aging of the power system devices like circuit breakers, switching devices and transformer. Replacement of the entire system leads to huge investment. The smart grid with intelligent devices provides the solution to avoid the huge investment by adaptability with present system devices with slide modifications. **Figure 2** shows the smart grid structure [19, 20].

Computational intelligence is required in the smart grid in all levels for better operations. The fuzzy logic, neural networks and other intelligent technology are necessary for the implementation. The sensor devices are more sensible and it will decide the entire system efficiency during real-time operation. Intelligent operation of the system is based on the received from the sensor to control center. Malfunctioning of the sensor causes the entire system failure. The devices receive a number of dates from the sensor devices at a periodic interval of time from generation to end users. The devices also know the normal and up normal operations of the sensor data based on the reference value to avoid the uncertainty of the system.

The wireless communication between the devices also places the main role for the smart grid. Advanced communication technology with high-security date transfer is essential to avoid the cyberattack. Wrong information from the remote center leads the system under the block out condition.

3.6 Use of fuzzy in power system

Fuzzy mathematics is adopted in all traditional mathematical area. Implementation of Fuzzy in to power system provides better results. Fuzzy logic plays a vital role in the engineering area and also commercial market. This provides

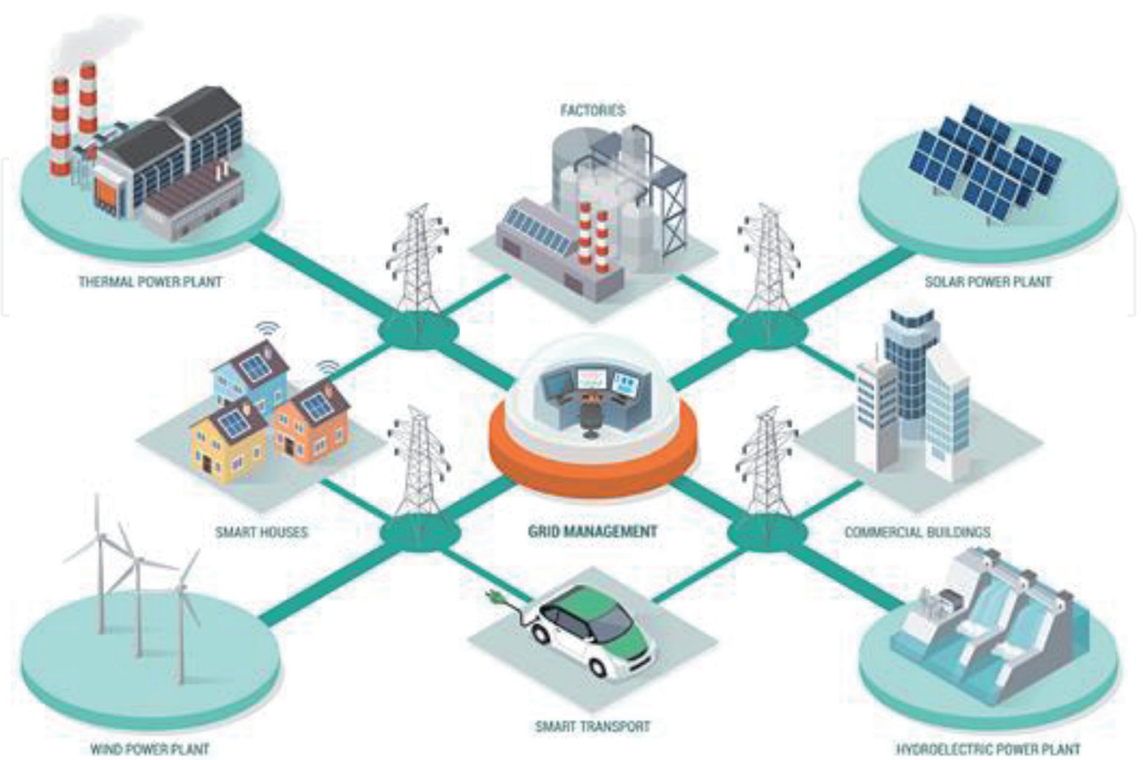

Figure 2.
Smart grid structures.

a user friendly approach for the consumer with sophisticated decision and control problems. Some of the features and capability of fuzzy set approaches are

- Integration between logical and numerical methods.
- Models for soft constraints.
- Models for resolving multiple conflicting objectives.
- Strong mathematical foundation for manipulation of the above representations.

Improbability is developed in many ways in power systems problems. This can be modeled using the fuzzy. Independent problem arise in the knowledge of the system. This problems need to be addressed to achieve the goal of the system. The ways of uncertainty in the system is caused due to models of the system and constraints and objectives arise from the decision-making process.

Fuzzy sets have to be applied for many power system application like Contingency analysis, diagnosis/monitoring, distribution planning, load frequency control, generator maintenance scheduling, generation dispatch load forecasting, load management, Reactive power/voltage control and security assessment.

Rule-based fuzzy sets are used in power system and improbability is associated with the each rule in the rule-base. Example, the circuit breaker trips in the distribution due to the over current in the circuit. The two uncertainties to be modeled are “often” and “high,” which are most easily represented as a fuzzy measure and fuzzy set, respectively. The mathematical modeling is developed to address the numerical values associated with the improbability.

Fuzzy controller is a traditional control design for the development of fuzzy set. The controller follows a set of laws to take the decision that are

IF Temp is high and positive

AND Temp change is large and negative

THEN control output is small and negative

This membership functions depend on the valid range of input and output values. Within power systems, fuzzy logic controllers have been proposed primarily for stabilization control.

Fuzzy decision-making and optimization consider optimal power flow. Objectives could be cost minimization, minimal control adjustments and minimal emission of pollutants or maximization of adequate security margins. Physical constraints must include generator and load bus voltage levels, line flow limits and reserve margins. Fuzzy mathematics provides a mathematical framework for these considerations.

4. Applications of MAS in power system engineering

4.1 Case Study

4.1.1 Introduction

In this section, case study is carried out using multi-agent system for tariff management in power system. This method uses various types of multi-agent systems

for control center, data collection and intelligent operation. Solar with battery storage and wind power plants are simulated using MATLAB Simulink, solar and wind simulation are done in systems 1 and 2 this is connected in the grid. The fuzzy logic controller was developed in system 3, communication between the systems is done using TCP/IP protocol [21].

The simulation of the smart grid demand side management using MATLAB/Simulink was done. In this, work was carried out in three different simulation environments. Simulation of solar power generation using photovoltaic is done in system 1 with battery storage as shown in **Figure 3**. In these, batteries are connected to the solar power module through the intelligent circuit breaker and it is controlled by the fuzzy controller. In this work, solar radiation is taken as a constant value. For load analysis, critical and non-critical loads are connected in the grid. This solar output is connected to the power grid through circuit barker 1. Measuring of grid parameters like line voltage, line current, load voltage, load current and frequency are measured in every stage using the measuring devices. The measured values are converted and sent to the fuzzy logic controller.

4.2 Controller design and functioning

Fuzzy logic intelligent controllers (FLC) are used in this work because of the compactness of the controller design. There is a possibility to add more number of inputs and outputs variables in FLC. The output of the FLC gives better result based on the else-if statement. More number of statements formed using else-if condition for enhanced result. Fuzzy inference learning system model that converters input to the resultant output are used in this case study. Fuzzy system has two types namely Mamdani and Sugeno or Takagi-Sugeno. This two methods are common for their fuzzing operation and the only different is output that it generates in Sugeno model generates linear or constant output, whereas the Mamdami generates variable output [22–25].

Solar power plant was designed using PV solar modules with 36 number of solar cells connected in series and power output of 230 W. Series and parallel combination are made for the maximum power output of 20 kW. This system is also enhanced with the batteries to store the excess power from the solar plant. Connection of solar power plant is done using internet protocol (IP)-enabled circuit breaker. **Figure 3** shows the solar power plant for the simulation model.

In MATLAB Simulink, self-excited wind power plant for 5 MW with capacitor bank was designed in order to provide steady power quality. Output of the wind power plant is connected to the main grid using the IP-enhanced circuit breakers as shown in **Figure 4**. Wind voltage, current, power and power factor are monitored using various sensors. The outputs from the sensors are converted into predefined values and send to the FLC. FLC receives the values from solar power plant and main grid for the intelligent tariff management system functionality. The output from the FLC are defuzzing, it is in the range of 1–10. Input to the IP-enabled circuits breakers are taken from the defuzzing output. The circuit breaker states will change accordingly with respect to the type of fuzzy rules employed.

The design of 20 kW solar power plant and 5 MW wind power plant using MATLAB simulation are shown in **Figures 3** and **4**. For better understanding, simulation models are developed in three different environments. Solar power plant was designed in system 1 and wind power plant was designed in system 2. Fuzzy logic system was created in the system 3. Measured parameters from sensors are converted and stored in the excel file for future references. The breakers get activated through step pulse from FLC which is controlled by energy control center command (ECC). The control parameters are converted into excel values through fuzzy commands

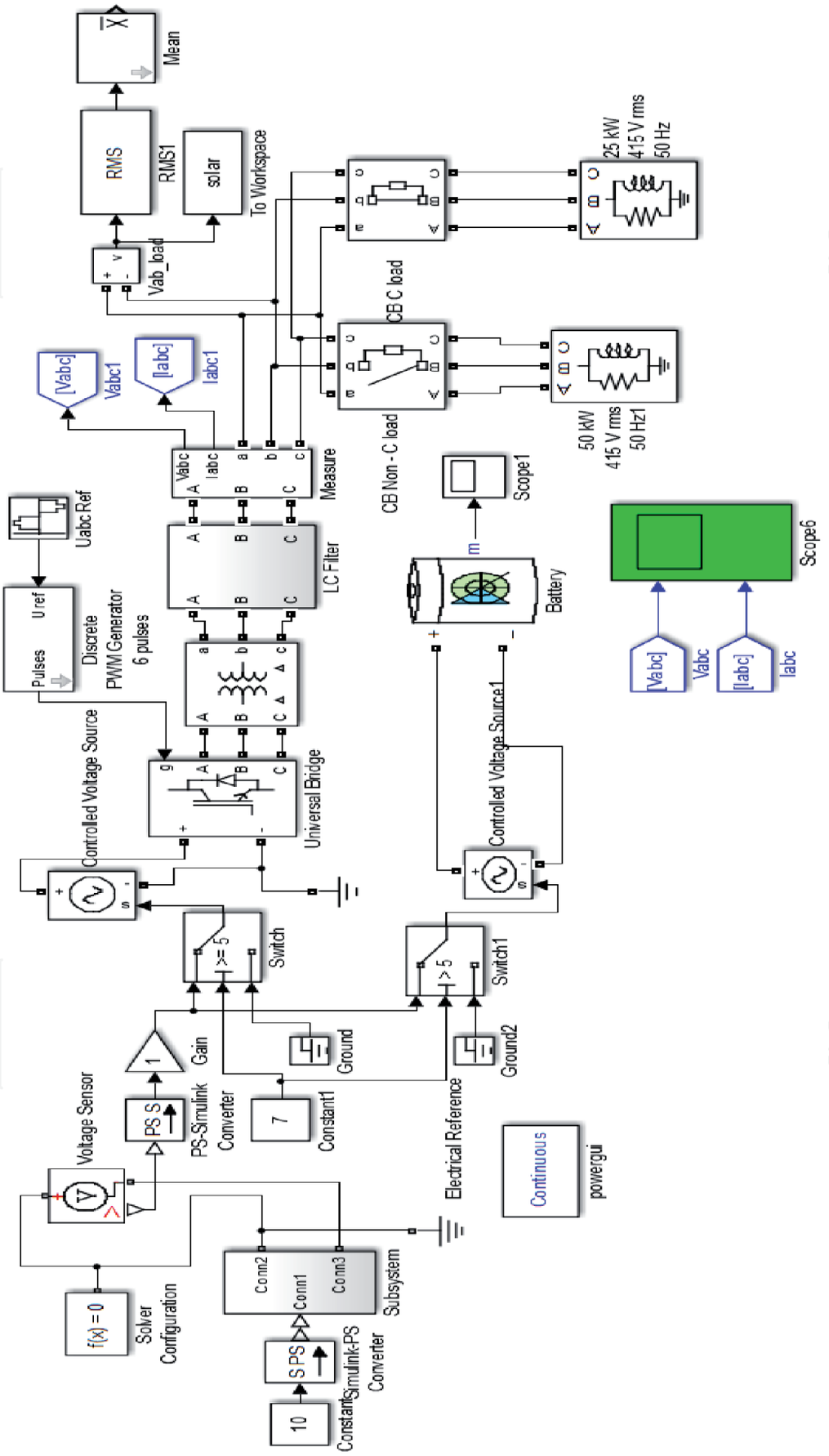

Figure 3.
Simulation of the solar power plant.

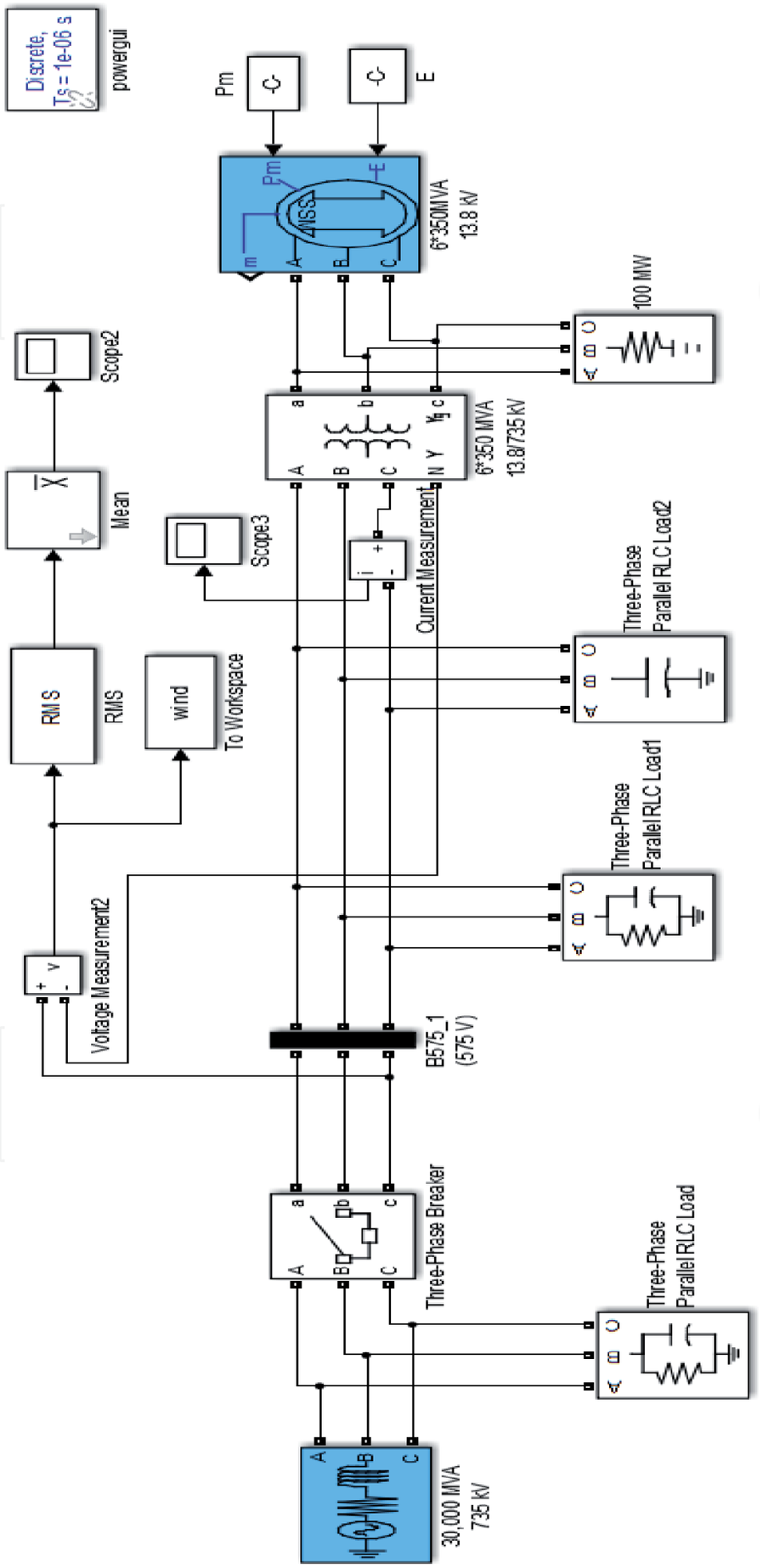

Figure 4.
Simulation of the wind power generator.

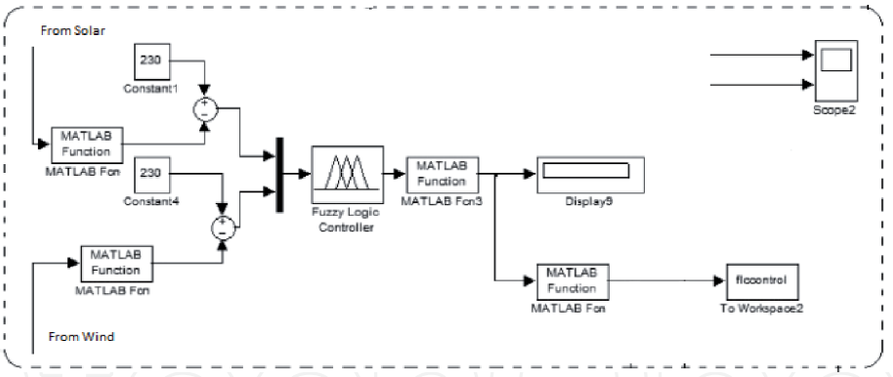

Figure 5.
Fuzzy logic controllers in operation in system 3.

and these excel files are transferred into a database agent using MATLAB command and loaded to the workspace before it simulates. Based on the voltage value received from the input, FLC decides upon the course of action. The ECC takes the responsibility of monitoring and controlling the magnitude of the wind and solar voltage production in a regular time frame. TCP/IP network data transmission are used to transfer the data for solar and wind power plants (**Figure 5**).

5. Conclusion

The standard communication techniques and TCP/IP communication are used to develop the multi-agent system. The purpose of a multi-agent system is to implement effective demand-side management in the smart grid/microgrid. The system implements the algorithm for demand responses based on time of day tariff and real-time tariff management using the MATLAB command and Simulink model. Simulation of solar and wind models are developed in two different Simulink environments.

Design and implementation of a multi-agent using fuzzy logic tool kit were described; it includes import and exports the data from the grid, solar and wind modules using MATLAB command. The multi-agent system development requires parameter specification, design process, data flow and environment that will generates the multi-agent codes. This constrains are consider to develop the code in the fuzzy logic controller. In the data agent, control agent, database agent and renewable agents are developed for the efficient function of the system. In solar power generation, the excess power in the systems is stored using batteries. These agents are collecting the present status of the system to achieve the over goal of the system. MATLAB command is used to convert the data from various agents into an excel sheet and it is again given to the controller. For a better understanding of the two simulation environments are developed for solar and wind, the control agents are developed in the separate system. The communication between the systems established using TCP/IP protocol for reliable and secure were discussed. At last, the system was tested; a consumer gets benefited for implement the real-time tariff method compared with a time of day tariff and show in table and graphical representation. In this study is more useful for the researchers to analysis functions of the multi-agent system in a smart grid. Furthermore, it develops the new system architecture for smart grid demand-side management.

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