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Modeling of Intelligent Energy Control Center for Distributed Generators Using Multi-Agent System

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Abstract

In market operations, distributed generators (DGs) and price-sensitive loads participate in a microgrid energy market implemented in JADE. Each DG and each price-sensitive load is represented by the respective agents which perform various functions such as scheduling, coordination and market clearing subject to system, DG and load constraints. Each agent is assigned to one of the several agent objectives which maximizes either DG or load surpluses or both. In simulated operation of a microgrid, hourly power reference signals and load control signals from JADE are passed to DG and load models developed in MATLAB/Simulink using MACSimJX. Simulated operation of DGs and loads are studied by performing simulations under different agent objectives. Results from simulation studies demonstrate the effectiveness of implementing multi-agent system (MAS) in the distributed management of microgrids.

Index Terms—***Deregulated energy market, distributed generation, JADE, MACSimJX, microgrid, multi-agent system.***

INTRODUCTION

An economical and efficient electric power system is a vital component of a nation's economy. The demand for electrical energy is ever increasing. Today over 21% of the total electrical energy generated in India is lost in transmission (4%–6%) and distribution (15%–18%). It is possible to bring down the distribution losses with the help of newer technologies in the electrical power sector, which will enable better monitoring and control. Distribution losses can be reduced, if the DER is connected near the load end. The smooth operation of a power system requires a control architecture that consists of hardware and software protocols for exchanging system status and control signals. This is accomplished by supervisory control and data acquisition (SCADA) systems. A smart grid is an intelligent grid that integrates advanced sensing technologies, controls and communicates with current electricity grid at transmission and distribution levels. Later, multi-agent system is utilized as an application development tool that enables system integrators to create sophisticated supervisory and control applications for a variety of technological domains, mainly in the power industry. Multi-agent system offers various advantages over the SCADA system by the implementation of an intelligent grid. Modeling the power distribution management process focusing on outage management has been elaborated by Hammer in. Planning for distributed generation and securing SCADA system is described by Roger in. Intelligent Distributed

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Autonomous Power System is given in. Interaction between distributed generation and the distribution network operation aspect is explained in. Proposal of a local DC distribution network with distributed energy resources is given in. Esmaili and Das elaborated a novel power conversion system for distributed energy resources. SCADA system provides communication architecture capable of controlling and maintaining power system hardware using certain signaling protocols. The energy control center (ECC) has traditionally been the decision center for the power generation and transmission of interconnected system. It consists of Energy Management System (EMS) software. The Energy control center functions for power system are mentioned in by Ankaliki. Most utility companies purchase their EMS from one or more EMS vendors. These EMS vendors are companies that specialize in design, development, installation and maintenance of EMS within ECCs. The main objective of this work is to develop and implement an intelligent ECC using multi-agent system that would enable real-time management of DER with smart grid.

DESCRIPTION OF ENERGY CONTROL CENTER AND MULTI-AGENT SYSTEM

This work is an attempt made to implement a system similar to an industrial SCADA system. A multi-agent system which stands a few steps ahead of a SCADA system is used to manage the grid. The component of multi-agent system and their functionality are given. The block diagram is shown in block diagram of ECC. The server has a wireless connection with the client as shown in block diagram of ECC. This is done using socket programming, which forms a part of the application program. This communication enables a DER agent (from the client side) to manage the power that is to be distributed to the necessary loads. DER agent, solar and wind power generator are connected to ECC through the Internet. This data is stored in database agent in ECC. The control action is taken by FLC present in ECC, based on the data from DER. This is done by control agent. In this work, the Internet is used for communication.

The multi-agent system operations are shown in operation of multi agent. User agent, control agent and DER agent communicate with the database agent. This database is sent to the server through a Remote Terminal Unit (RTU) like a conventional SCADA system. RTUs are special purpose computers which contain analog to digital converters (ADC) and digital to analog converters (DAC). These converters' digital inputs are used to get the status and outputs are used to control. They can be connected to any hardware device to acquire the analog data from any other device. The visualizer receives copies of all messages exchanged within the multi-agent system and is responsible for displaying these messages to the user with user agents. The various applications used in the system are shown in applications used.

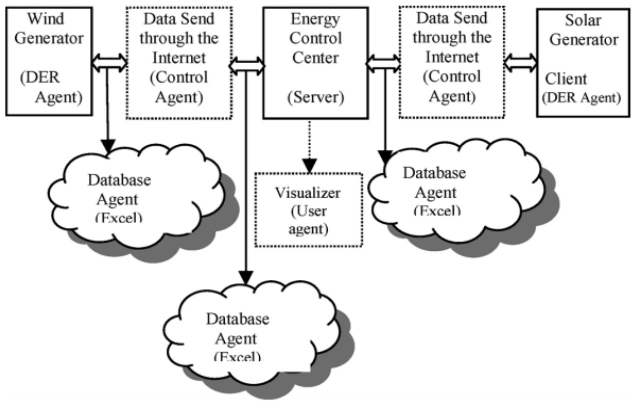

Fig 2.1 Block diagram of ECC

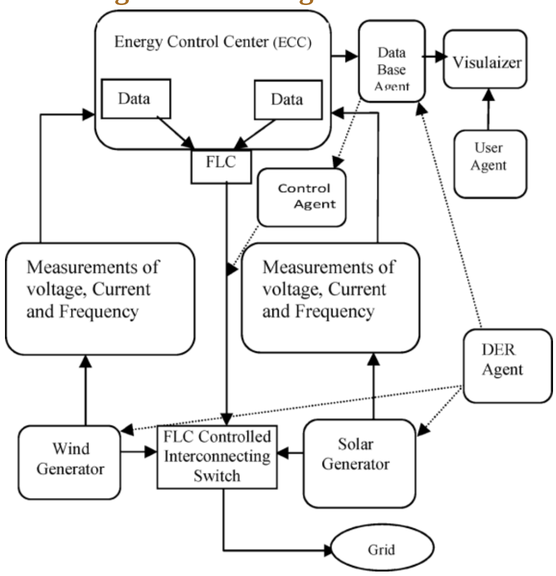

Fig 2.2 Operation of multi- agent

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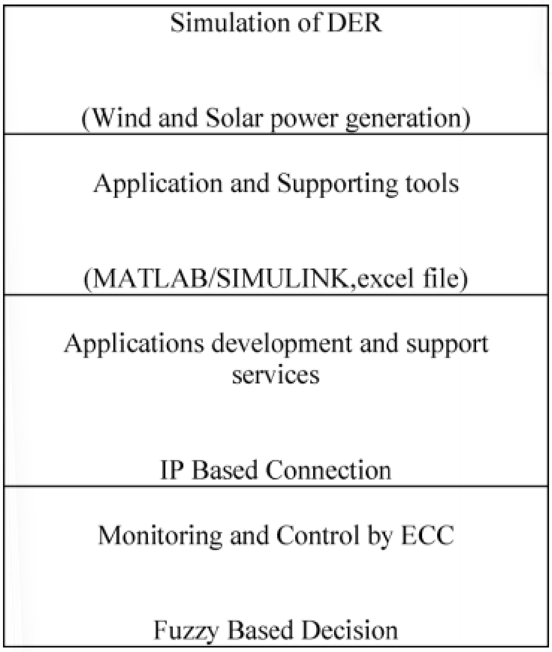

Fig 2.3 Applications used

BLOCK DIAGRAM OF THE SIMULATION MODEL

The block diagram of the multi-agent system simulation model is given in diagram of power system interconnected wind and solar power generation scheme. Wind power generation consists of a wind mill, induction generator connected to the grid through circuit breaker and the load. Solar power generation consists of solar panel, inverter, transformer connected to the load and circuit breaker. The interconnection of wind power, solar power and grid forms the power system smart grid with DER. The voltage measured in wind power generator and solar power generator is sent to ECC through the Internet. The FLC present in ECC activates the circuit breaker according to the voltage requirement. The addition/removal of solar panels to the grid is controlled by FLC. If solar panel is removed from the grid, it will be connected to charge the battery. Since FLC is used for the control, it can be extended to control circuit breaker (CB-1) and circuit breaker (CB-2), as given in Block diagram of power system interconnected wind and solar power generation scheme depending upon the availability of DERs.

In this work, simulation model of wind power generator is created in computer-1 as shown in representation of multi agent system. It is considered as client. The voltage, current, frequency and power of DER can be measured. This is known as DER agent. It is converted in to excel sheet using MATLAB commands which is called database agent. This can be sent through the Internet to computer-2, which is a server. In this computer, solar power generation SIMULINK model is created and ECC is also developed in different file.

ECC can be developed in either computer-1 or 2. The database agents of wind power and solar power are converted into MATALB command and loaded in To File in SIMULINK, which is given as an input to ECC. Based on the voltage magnitude received in FLC, the decision will be taken whether solar power should be used for charging battery or connected to grid/load. The FLC decision is again converted into MATALB command and loaded in To File in SIMULINK, which is used in solar power generation model in computer-2. The representation of multi agent system shows the multi-agent system used in this work. The flexibility of the proposed method is that the ECC can be modeled in computer-1 or 2. After running the simulation, results are sent through the Internet.

The circuit breaker (CB-1) is connecting wind power generation to grid. The circuit breaker (CB-2) is connecting solar power generation to grid. To utilize the maximum power from solar panel, switch is used to connect the solar power to local load or charging the battery as shown in Block diagram of power system interconnected wind and solar power generation scheme.

The interconnection of wind power, solar power and grid forms the power system smart grid with DER. The voltage measured in wind power generator and solar power generator is sent to ECC through the Internet. The FLC present in ECC activates the circuit breaker according to the voltage requirement. The addition/removal of solar panels to the grid is

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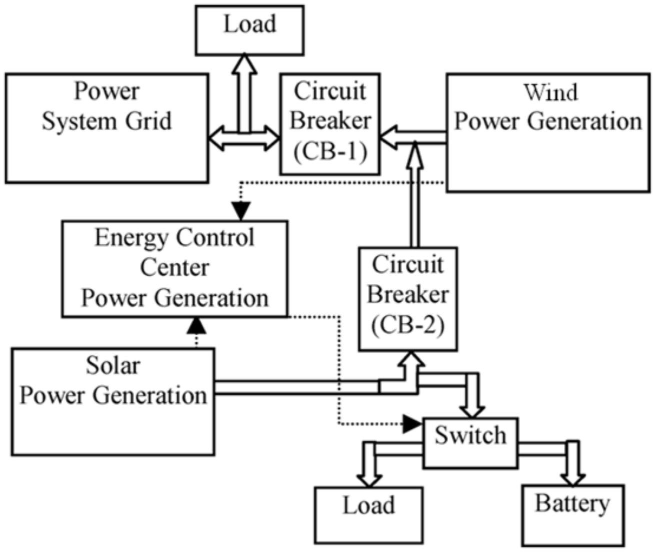

Fig 4.1 Block diagram of power system interconnected wind and solar power generation scheme

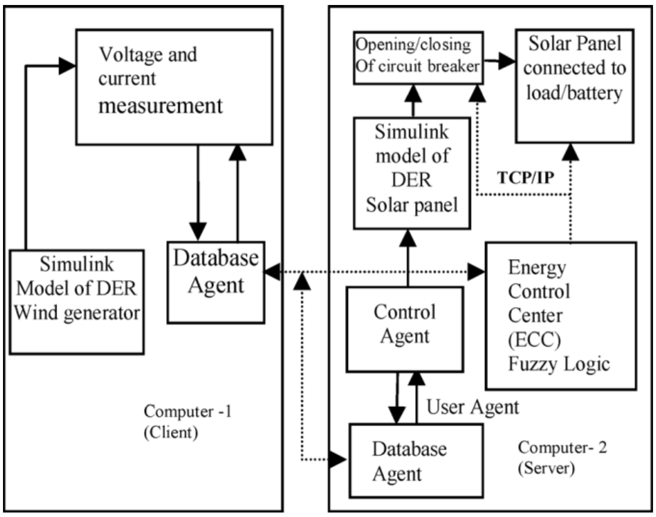

Fig 4.2 Representation of multi-agent system

Energy Control Center:

Energy Control Center (ECC)) is designed and built for system operation. In order to have an efficient power system operation and control, various control centers have to be operated in the hierarchical level.

There are 4 types of control centers.
i) Local Control Centre
ii) Area Load Dispatch Centre
iii) State Load Dispatch Centre
iv) Regional Control Centre

Today's Supervisory control systems normally consist of a computer system and a number of remote terminal units (RTUs), located in the power stations and substations. Communications between the RTUs and the computer usually take place via radio links or via power line carrier equipment. The computer serves the personnel in the control center by presenting information about the current status of the power system and by passing on manually initiated control actions. Automatic control is used for different sub functions, e.g. sequential control and control of the network frequency. Video display units and keyboards are normally used for the man machine communications. In addition, map boards; printer and analog recorders are installed as required. Major supervisory control systems generally consist of several energy control centers, which co-operate in a hierarchical configuration.

The basic functions in a supervisory control system consist of:

- Acquisition from the power system of tele metered data, indications and other variables on these variables. E.g. Calculations of the variables e.g. calculation of the apparent power
- P2+Q2.Where P & Q are tele metered values
- Supervision of acquired and calculated variables with respect to changes and violation of limit values
- Storage of current variables for sequent use. E.g. in trend curve daily reports
- Presentation of acquired calculation, stored variables on video display units and other media. These variables may be presented in the form of one line diagram or curves.
- Transmission of commands to RTUs.

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The scope of the functions in an EMS system must always be adapted to the power system and operative organization of the customer. A broad spectrum of computing functions is therefore available. Since most of the building blocks consist of software, it is simple to adapt and upgrade the system as required. In addition to network model calculations, EMS comprises standardized solutions for the following functions

- Production Control (Automatic Generation Control-AGC)
- Economic Dispatch Calculation (EDC)
- Contingency Analysis
- Operators Load Flow (OFL)
- Load Forecasting.

In simple terms, the goal of system control centre design is the implementation of security control. Security control requires the proper integration of both automatic and manual control functions, i.e. a total systems approach with the human operator being an integral part of the control system design. Security control requires that all conditions of operation be recognized and that control decisions by the man-computer system must be made not only when the power system is operating normally, but also when it is operating under abnormal conditions.

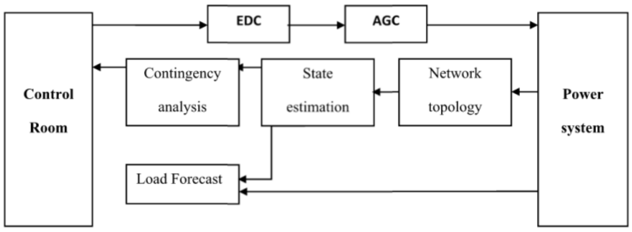


Fig 4.3 Overview of EMS

The power system may be assumed as being operated under two sets of constraints: load constraints and operating constraints. The load constraints impose the requirement that the load demand must be met by the system. The operating constraints impose maximum or minimum operating limits on system variables and are associated with both steady state and stability limitations. Mathematically, the load constraints can be expressed in the form of the familiar load flow equations. The operating constraints can be expressed in the form of inequalities such as an equipment loadings, bus voltage, phase angle differences, generator real and reactive powers etc. The conditions of operation can than be categorized into three operating states.

- Normal (or Preventive) State
- Emergency State
- Restorative State

A system is in the normal state when the load and operating constraints are satisfied. It is reasonable to assume that in the normal state the power system is in a quasi-steady-state condition. For any given time, the intersection of the load constraints and the operating constraints defines the space of all feasible normal operating states. The power system may be operated any where in this space.

A system is in the emergency state when the operating constraints are not completely satisfied. Two types of emergency may be noted. One is when only steady state operating constraints are being violated, e.g. an equipment-loading limit is exceeded or the voltage at a bus is below a given level. The other is when a stability operating constraint is violated and as a result of which the system cannot maintain stability. The first type of emergency may be called “Steady State emergency” and the second type, “dynamic emergency”. A system is in the restorative state when the load constraints are not completely satisfied. This means a condition of either a partial or a total system shutdown. In case of a partial shutdown the reduced system may be in an emergency state. This is the start of a cascading situation and, if uncorrected, would lead to a further deterioration of the system. A normal operating point can be classified as being either secure or insecure with reference top an arbitrary set of disturbances or next contingencies. A normal system is said to be secure, i.e. at a secure operating point, if it can undergo any contingency in the next-contingency set without getting in to an emergency condition. On the other hand if there is at least one contingency in the next-contingency set which would bring about an emergency, the normal system would be called insecure.

Result analysis:

The wind velocity is assumed constant (12 m/s). After the simulation, the results are stored in workspace which is converted into excel sheet using MATLAB command window in the file names "solar" and "wind". When the wind power generation the induction generator generates the voltage after few seconds. The induction generator is under self excited mode. It requires few cycles to induce the voltage because, the induction generator is not connected with the grid. The output of FLC is used to control the solar panel. Before simulation, the excel files are converted into database agent in MATLAB command window and loaded to the workspace. Based on the magnitude of voltage received in the inputs, the decision is taken by the FLC. The output of FLC is constant value (1, 2, 3, 4, and 5) and this is used to drive the multi port switch. Based on the output of FLC, the number of panels are added or removed in the model. To demonstrate this, circuit breaker (CB-1) is closed after 0.1 s. This can be observed in wind voltage waveform. Solar power generator is connected to the grid through the circuit breaker (CB-2) after 0.3 s.

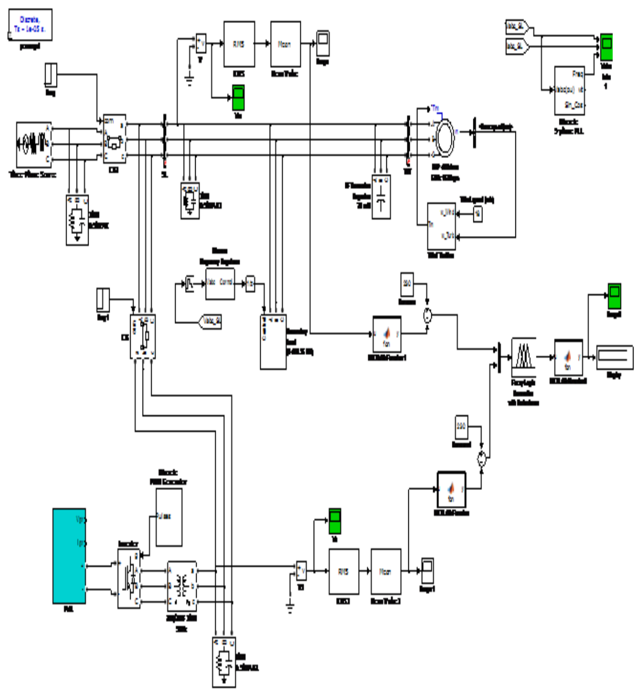


Fig 7.1 Simulation diagram of power system interconnected with wind and solar power generation scheme

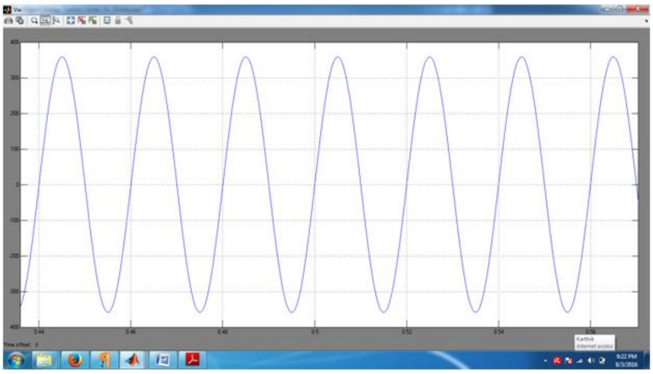
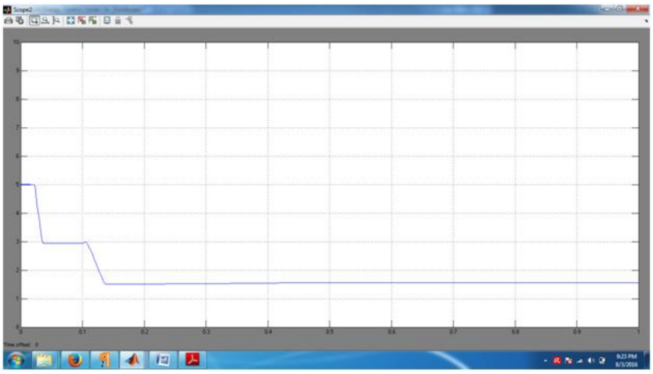
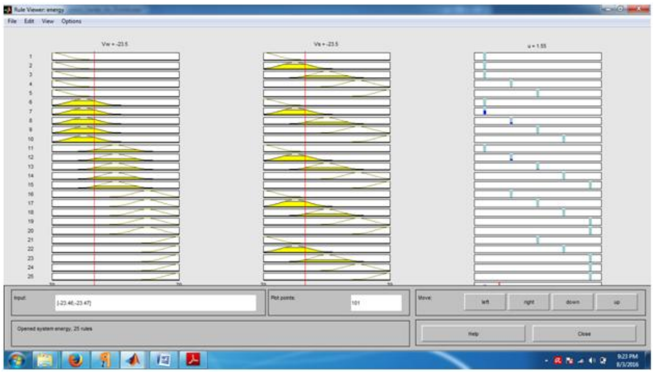


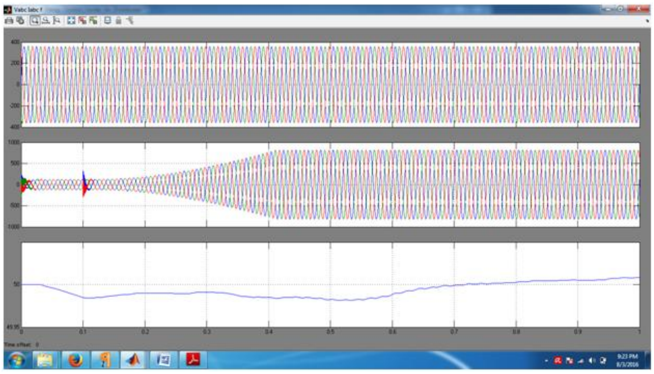
Fig 7.2 Sine wave of wind generation system



7.3 Scope output of wind energy system



7.4 Rule viewer of output energy



7.5 Output waves of energy control system

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CONCLUSION

The simulation model of ECC, controlling the solar power generation and wind power generation interconnected with grid using multi-agent system is described in this paper. The voltage of wind and solar power are stored in a excel sheet as a database agent. Intelligent controller FLC controls the switch provided in the solar panel to add/remove depending upon the voltage requirements. This excel sheet acting as a monitoring tool to access the simulation results, provides the visualization of the grid. The results prove that the multi-agent component controls the Distributed Energy Resources.

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