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Distributed Management for Micro Grids by Using Multi Agent System

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Abstract:
In market operations, distributed generators (DGs) and price-sensitive loads participate in a micro grid energy market implemented. Each DG and each price-sensitive load is represented by the respective agents who 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 micro grid, hourly power reference signals and load control signals are passed to DG and load models developed in MATLAB/Simulink. 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 micro grids.

I. INTRODUCTION:
A Micro Grid could be defined as a low voltage distribution network with distributed energy sources (micro turbines, fuel cells, PV, diesel, etc.) altogether with storage devices (flywheel, batteries, etc.) and loads. These systems could be operated, either interconnected to the main grid or either isolated from it, by means of a local management system with a communication infrastructure allowing control actions to be taken following any given strategy and objective.

In the recent years, inverter technology has matured in both functionality and efficiency while prices have decreased. Most of the micro source and micro storage equipment is connected through power electronic devices providing, to some extent, features such as active power output management, reactive power control, load balancing, voltage support and fast dynamic response without a significant harmonic distortion. 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. When the grid power reserve diminishes quickly, the grid operator needs emergent load reduction for stable operation. This procedure is called as demand response. One of the popular demand response programs is emergency demand response (EDR) that offers incentives to the customers who instantly reduce their load. In this paper, the control objective of the MAS based microgrid control is to find the optimal condition for EDR. 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.

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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.

AN INTELLIGENT MICROGRID:

As shown in Fig. 1, the building blocks of IDAPS include physical and cyber layers. The former is composed of loosely connected DER devices and loads which can communicate with one another via the latter, i.e. web-based communication overlay architecture employing multi-agent technology and web services. The IDAPS operation is divided into two modes: (1) normal operating conditions and (2) emergency conditions when upstream grids fail. During normal operating conditions, the IDAPS structure is complementary to the main electricity grid. Households or businesses can purchase electricity from the grid as usual. Yet, their membership in the IDAPS microgrid allows electricity customers to purchase electricity from their neighbors.

The end-use customers will thus have the choice of buying a part of their electricity from the DER units available locally if the offers are price competitive, or have other attractive features like green power. Once upstream outage conditions are detected, an IDAPS microgrid will island itself from the grid and start to operate autonomously. IDAPS agents will communicate with one another, as well as reconfigure and coordinate IDAPS components in such a way to secure critical loads during outages. Critical loads within an IDAPS microgrid will first be served by their internal sources, and any shortfall can be made up through open market purchases among different IDAPS microgrids Since the IDAPS microgrid deals with the power systems of the future, important assumptions are listed below.

•It is required that sufficient DER capability be placed in each IDAPS micro-grid to secure critical loads located in each cell during outages.

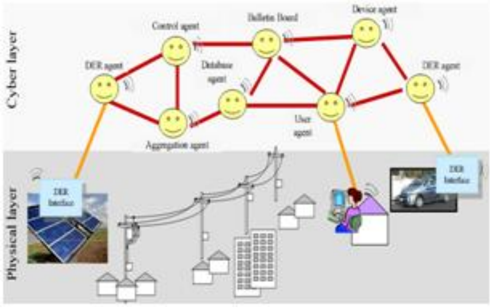

Fig 1: Physical and cyber layers in an IDAPS microgrid

•It is assumed that some of the current technical, regulatory and economic barriers to DG interconnection can be bypassed.

•It is assumed that DER units and electronic devices, including circuit breakers, have communication interfaces and are addressable by IP addresses.

•It is assumed that at least one type of communication medium must be available to facilitate communicationsamong local generators, loads and electronic devices.

Management functions:

The agent based Micro Grid Management System provides the following functionality:

• SCADA like system; it is able to acquire data from the sources inside the micro grid and send commands.
•Selling bids managing system; the generators can produce selling bids and send them to a central market manager (based on the Spanish electricity market).

•Power schedule tracking system; the generators' local controller agents retrieve power scheduling information and send the set points to the generators.
•Secondary regulation system; it is in charge of analyzing planned generation targets and real

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measurements and performing suitable corrections over generation schedules.

•Load shifting system; the load shifting process consists in delaying the time period when a load is effectively connected in accordance with some optimization criteria.

•Load curtailment system; it decreases the power consumption of the loads.

MULTI-AGENT SYSTEM:

Figure 2also shows the concept of MAS-based micro-grid control system. Each intelligent agent takes charge of decision-making for a DER or a smart load. Intelligent agents have reactive, proactive, and social abilities so that they can react to the environmental changes, follow the final goal, and interact between other agents in a cooperative or competitive manner. The agent should have fundamental modules such as data collection, communication, decision- making, action implementation, and knowledge management. Coordination of multiple intelligent agents is an important issue. In the developed control system, the Microgrid Central Coordinator (MGCC) coordinates multiple intelligent agents. When a special control request arrives from the main grid such as emergency demand responses, the MGCC informs agents of the control objectives for the whole microgrid.

After receiving the individual proposal of the agents, the MGCC dispatches the control command to the agents. The overall decision making procedure follows the Contract Net Protocol (CNP).The CNP provides a formal procedure in the coordination procedure in MAS-based management systems. The contract between the MGCC and the agents can be reached by the process of decision-making and interaction based on two way communication. Figure 3illustrates the concept of the CNP based decision making procedure. The overall procedure starts when the main grid requests for certain actions such as demand response.

In the CNP procedure, decision making processes can be found both in the MGCC and the agent side. Agents make a decision such as how much it will participate in the present task requested by the MGCC. To approach an optimal solution, the agents evaluate the detailed conditions of the task and check local information such as generation cost, state-of-charge of a battery, energy market price, and so on. Agents can use artificial intelligent algorithms such as knowledge based expert system, fuzzy systems, or neural networks to attain maximum benefits from the task. The MGCC decides the overall operation scheme for a microgrid after receiving the bids from the agents. If the bids from the agents are not enough to meet the request from the grid, the MGCC can modify the task conditions to lead additional participation from the agents.

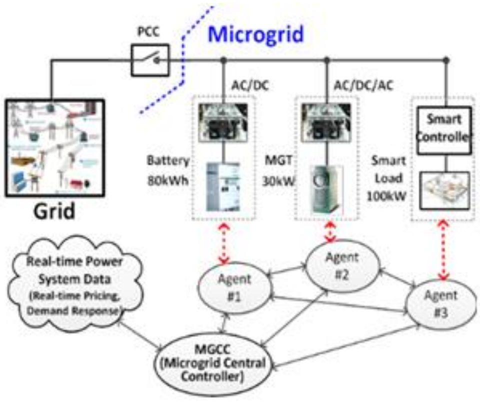

Figure 2: Configuration of microgrid with MAS-based control system

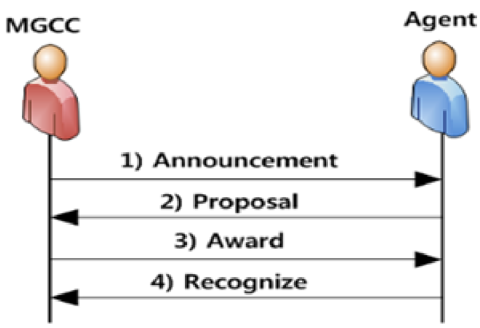

Figure 3: Concept of Contract Net Protocol between MGCC and agents

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PROPOSED ENRGY CONTROL MAS:

The server has a wireless connection with the client as shown in Fig. 4. This is done using socket programming, which forms a part of the application program. This communication enablesa 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. 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.

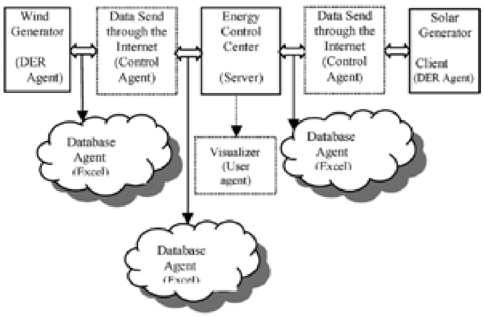

Figure 4: Block diagram of Energy Control center

The block diagram of the multi-agent system simulation model is given in Fig. 5. 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.

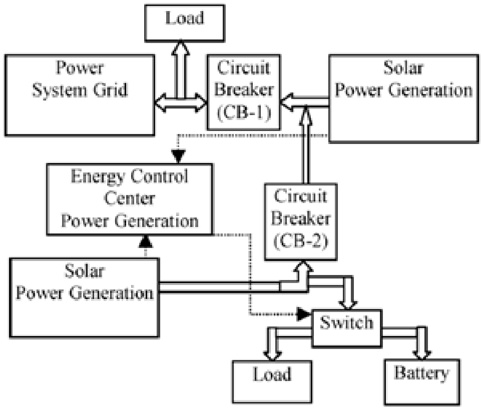

Figure 5: Block diagram of power system interconnected with wind and solar power generation scheme.

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 gridis 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 Fig. 5,depending upon the availability of DERs.

SIMULATION RESULTS:

In this work, simulation model of wind power generator is created in computer-1 as shown in Fig. 5. 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 indifferent 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.

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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 Fig. 5 shows the multi-agent system used in this work. The flexibility of the proposed method is that the ECC can be modeled in computer-1or 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 Fig. 5. The simulation model of the block diagram given in Fig.6 is developed in MATLAB/SIMULINK to study the model.

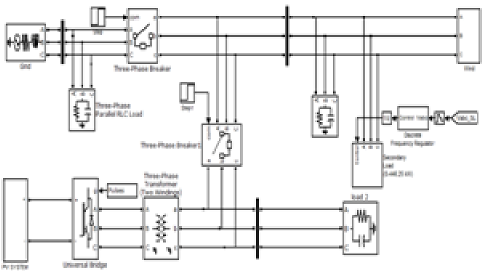
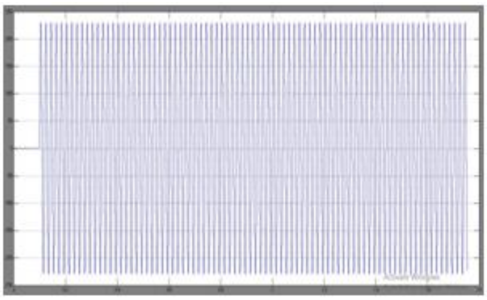


Figure6: Simulation diagram of solar power fed in to the battery or load



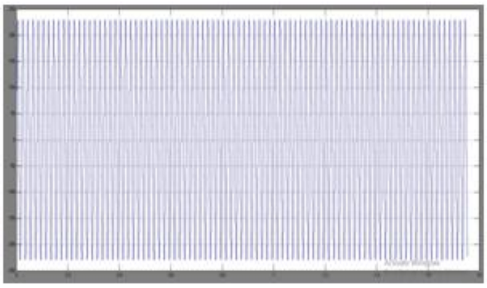


Figure 7: Voltage waveform of wind and solar power – circuit breaker (CB-1) closed after 0.1 s and circuit breaker (CB-2) closed after 0.3 s to interconnect solar power to wind.

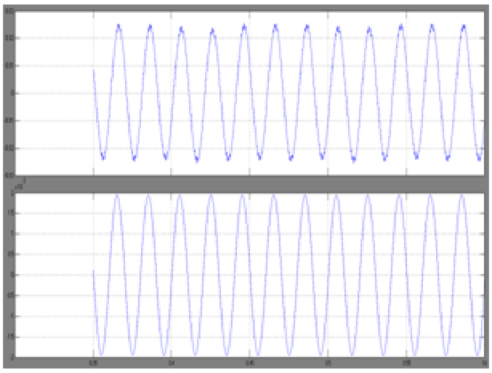
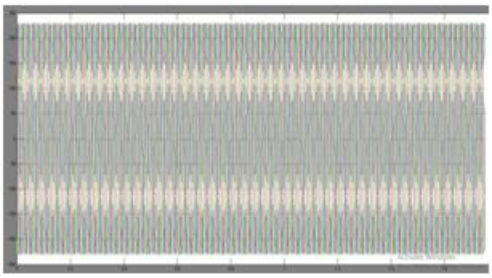
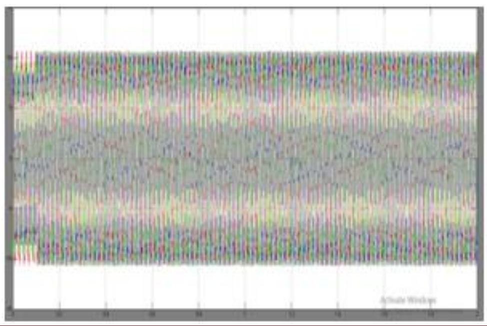


Fig 8: Voltage waveform of wind and solar power circuit breaker-1 closed after 0.1 s and circuit breaker -2 closed after 0.3 s to interconnect solar power to wind observed up to 0.6 s.





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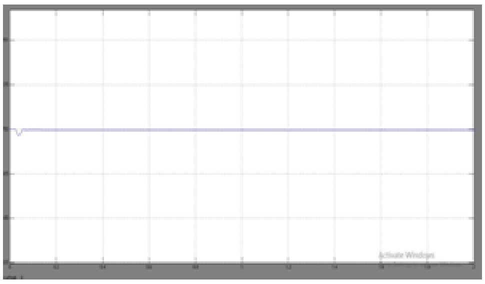

Fig 9: Plant voltage, current and frequency of proposed system

CONCLUSION:

Microgrids are expected to be an integral part of the electricity grid of the future offering improved resiliency, integration of DERs, bi-directional vehicle charging, advanced storage and demand management. The multi agent system were designed and implemented. To verify the feasibility of the proposed multivalent system, simulation analysis was carried out. The results of simulation showed that the proposed agent-based microgrid was appropriately operated as described. The multiagent can easily be applied to microgrids based on different market rules because the software-based multiagent system can be modified easily.

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