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A Cognizant Approach to Microgrid Load Management via Multi-Agent

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***Abstract*— The microgrid systems that are capable of integrating generation, load, and storage assets into an autonomous power system will be a characteristic of the power systems of the future. The purpose of this study is to present the design and development of a multiagent system for the control of a microgrid. Afterwards, a strategy that is based on fuzzy logic is given in order to accomplish priority-based load management of a microgrid infrastructure.**

***Index Terms*— Artificial intelligence, micro grid, multi agent system, smart grid**

I. INTRODUCTION

With the continued increase in the energy consumption, the electrical power systems all over the world are becoming more and more complex. The modern power systems are very large in size and complex in nature. The constant increase in the demand and depletion of the conventional energy sources, the power balance is becoming difficult and this is forcing the systems to be operated near stability limits. The security reasons require the important data and quick decisions for the sophisticated controls. In addition, support to the main grid through locally available distributed generation, especially the wind and solar energy, is to be harnessed. The challenges in the large complex interconnected grid operation and the integration of the renewable sources require intelligent or SMART grid systems. A smart grid is an evolved electricity grid system using processor- based remote control and automation for the operation and control of the grid. Such smart grid can address some of the problems of conventional electrical grids.

The growth of distributed generation imposes new technologies in the power systems operation. In addition to this, the deregulation of markets and environmental concerns puts great stress in power system networks and their control systems. This stress can be eased by building new infrastructures. A good form of controlling the set of small distribution generation and loads is the Microgrid concept. The microgrid is a subsystem of the Smart Grid, and is composed of distributed generation systems (DGs), distributed storage devices (DSs), and the usual loads [1]. Fig.1 shows the overview of the microgrid.

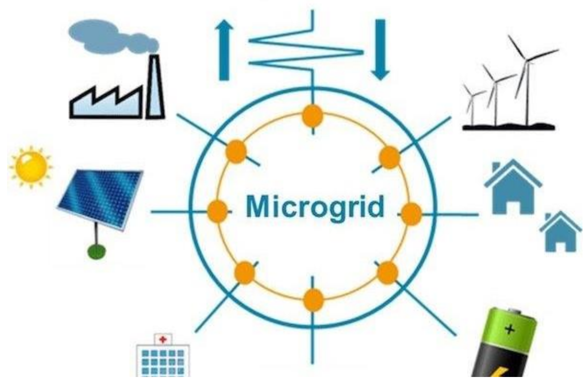

Fig. 1: Overview of the microgrid.

The microgrid can be operated either in grid connected mode or in islanded mode. In the grid-connected mode, a power balance can be maintained by power exchange with the power grid. In contrast, the power balance is to be established using the locally available generation and storage in islanded operation, as there is no power exchange with power grid. In case of deficit supply, load shedding and supply from DS units is used for the balance. Load shedding is a critical problem because it makes consumers uncomfortable [2].

The control decision process that manages microgrid assets is devised from the distributed agents that consists a Multi- Agent Systems (MAS). In multi-agent systems, a complex problem is divided into a number of less complex problems which are handled by many agents, while in a single agent case, which is a centralized system, it is handled by a single agent. In particular, MAS can be regarded as an intelligent distributed system. These maps suitably to smart grids due to the distributed and heterogeneous nature of the problem. An intelligent agent can understand its environment, can make adaptive decision against changes of the environment, and can resolve them autonomously.

The application of MAS in microgrid is investigated in [2]. The agents in this system acquire information of every component and send it to decision making agent. The decision arrived is sent back to the component agents. In agent-based microgrid operation field, research work which focuses on the division of power in islanded microgrid is gaining importance. The present work is related to this field.

The present paper presents the autonomousoperation of DC microgrid, in the island mode. It proposes: (i) a priority-based loadshedding based on fuzzy logic, (ii) agent- based hierarchical operation of microgrid and (iii) time based priority change of loads for islanded DC microgrid.

II. METHODOLOGY

The proposed new technique for load management consists of fuzzy logic load management controller (FLLMC) with load controller unit (LCU). The FLLMC identifies the type of load disturbance as event-based or response-based. It then estimates the power imbalance. Accordingly FLLMC decides the amount and type of load based priority. The corresponding signal is sent to LCU which shed the required load. This scheme is implemented on distribution DC network consisting of two units of DGs (PV and wind turbine). Figure 2 shows the block diagram of fuzzy approach to load shedding of islanded dc microgrid operation based on MAS.

The loads are classified based on non- interruptible and interruptible loads as high priority and low priority loads and additionally medium priority load that may be semi interruptible load. First of all, the Lowest priority load will be shed. The medium priority loads are next considered for shedding. If required, high priority loads will be shed as a last step. FLLMC decides the control value and transmit it to LCU using communication link. Remote terminal units for real-time data and Remote Circuit Breaker (RCB) are employed at each of the load feeder. The system state variables are monitored by FLLMC and breakers status are read by LCU. FLLMC recognizes two types in load disturbance. The event-based case occurs when any of DG units is tripped in the islanded mode. This may happen when present capacity of DG unit is insufficient to supply total load. Response-based case occurs due to sudden increment of load in the system.

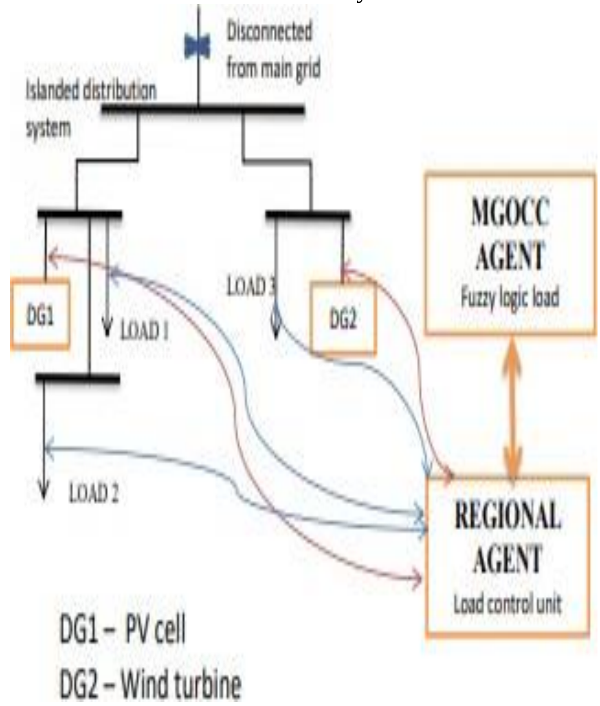

Fig. 2: Block diagram of a fuzzy approach to load shedding of islanded DC microgrid operation based on multi-agent system.

III. FUZZY ALGORITHM TO CONTROL THE DC MICROGRID

FLLMC consists of all the basic modules of a fuzzy system as shown in Fig.3.

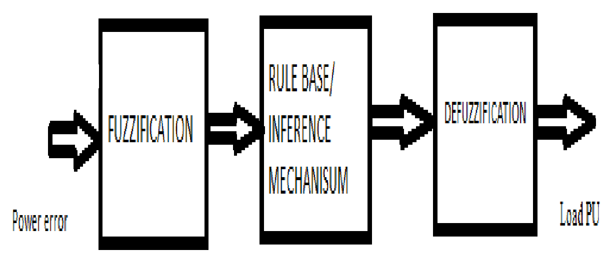

Fig. 3: Block diagram of proposed FLLSC.

Real input values are transformed into fuzzy set values in the fuzzification process. Triangular membership functions are used shown in Figure 4 and 5 shows input power error and output load PU membership functions.

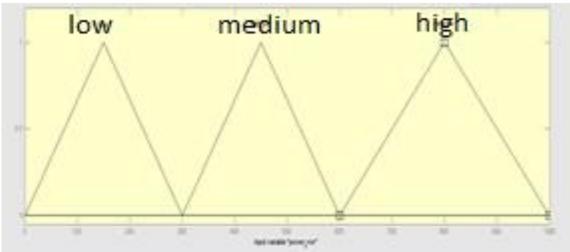

Fig. 4: Membership function for power error.

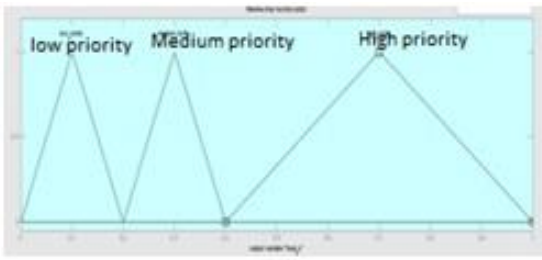

Fig. 5: Membership function for load PU.

In the FLLMC, fuzzy-rule-base is used in IF-THEN rule form to map the input and output control. The rules used are:

1. IF power error is low THEN shed is the Low priority load.
2. IF power error is medium THEN shed is the Low priority load.
3. IF power error is medium THEN shed is the Medium priority load.
4. IF power error is high shed is the Low priority load.
5. IF power error is high THEN shed is the Medium priority load.
6. IF power error is high THEN shed is the High priority load.

Inference engine decides control signals from the rule-base. Defuzzification converts the fuzzy-linguistic variables into corresponding real-values [4]

IV. MULTI AGENT SYSTEM FOR MICROGRID MANAGEMENT

MAS architecture maps the complex problems of microgrids[5] more aptly. For communications among agents, messages are sent using the agent communicationlanguage (ACL). A message format and a template format used in the proposed MAS, respectively, are shown below.

(<performative>: from <agent name>: to <agent name>: content <OAV type data>)

(template name: ID identifier OAV type data list)

Where OAV type data are composed of an object, an attribute of the object, and the value of the attribute.

Many options such as Internet, power line communication (PLC), fiber optic lines, leased lines, and wireless communications can be used as communication links. Fig.6 shows the basic structure of such a MAS for islanded microgrid operation.

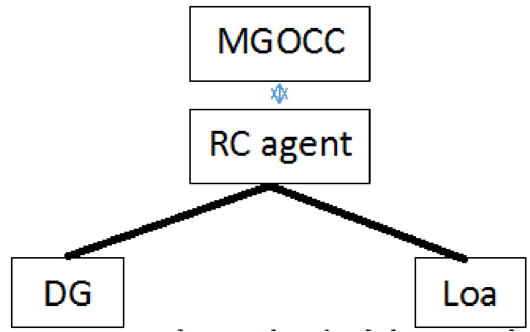

Fig. 6: Basic Structure of a MAS for Islanded Microgrid Operation.

The message flow strategy among the agents for cooperative distributed problem solving is shown in Fig.7. Firstly, Agent MGOCC request necessary information from RC Agents. RC Agent gets the demand power from Load Agent, and generated capacity from DG Agent.

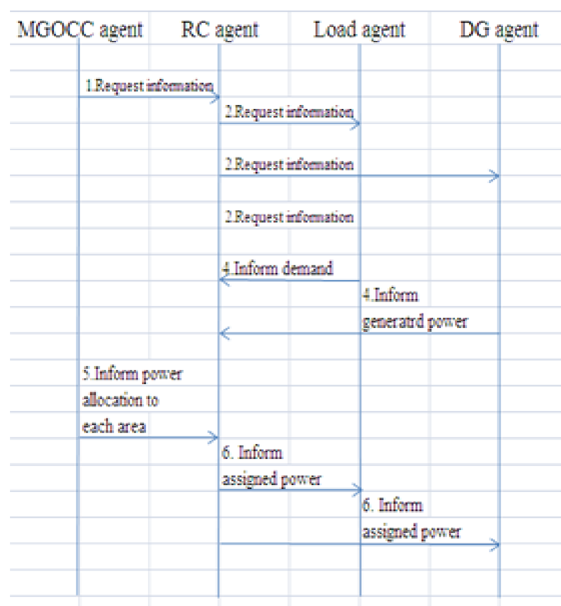

Fig.7: Message Flow among Agents

RC Agents then aggregate information and send it to MGOCC Agent which will arrive at the control decision based these inputs. The decision is communicated to RC Agents. RC Agents then send power allocation information to Load Agents [6].

V. EXPERIMENTAL SETUP

Figure 8 shows the overall system setup for experimental testing. The agents are the heart of the grid control system to maintain the microgrid in stable conditions. The operational flow charts of DC microgrid in islanded condition are shown in Fig.9.

Experiments are carried out for Multi- agent system for Priority Based Load Shedding in Micro Grid and studied the different performance characteristics of the system. At each stage of operation we observed the priority and time based shedding of the load.

The microcontroller that act as Fuzzy Logic Load Shedding Controller (FLLSC) otherwise known as main controller monitor and determine the system state at every instant. The microcontrollers for load shedding module were responsible for shedding the load according to the priority and timing. The total operation is carried out in different stages of islanded mode operation of the microgrid.

Fig. 8: System Setup for Experimental Testing.

VI. RESULTS AND DISCUSSIONS

The system operation has been carried out in three stages:

Stage 1: The main loads (switches-SWs)of all the prior regions are in ON position. when the sub loads of region1 (higher priority load) SW1, SW2 and SW3 are increased in steps, we observed the shedding of region 3 (least priority) loads followed by region 2 (medium priority) loads.

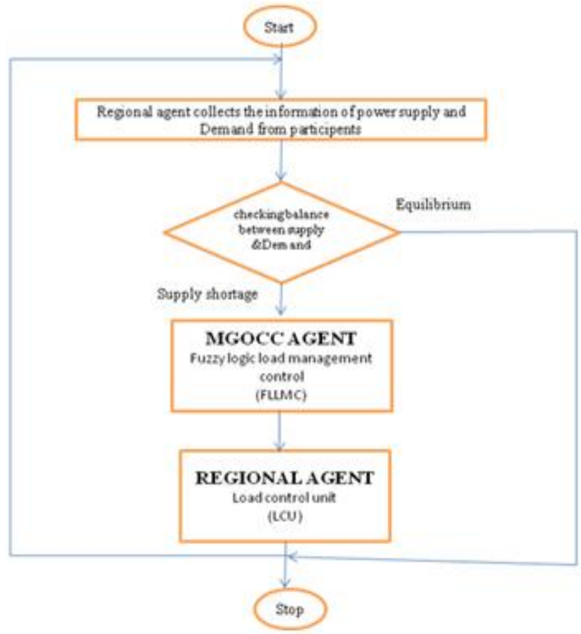

Fig. 9: Flow Chart of Load Shedding System.

Stage 2: The main load (SW) of all the regions is in ON position. By keeping the sub loads of highest and least prior load constant we increased the medium priority load, and observed the shedding of least priority load.

Stage 3: Some loads in medium prior and least prior regions are in ON position. By overloading highest priority loads, weobserved the shedding of all the loads of medium and least priority loads.

From the above results it is observed that the region 1 always remained as the highest priority. It can draw the required power without any interruption or it can said that it can get uninterruptable power supply. This feature can help in providing power for important loads in critical situations. Thus, the proposed scheme can achieve proper management of availablepower.

VII. CONCLUSION

In order to assure the power for the important loads, we proposed a new load shedding scheme using multi-agent architecture. This includes the efficient management of available power according to the time and priority of loads based on fuzzy approach. In addition, we also have developed a miniature micro grid using Microcontrollers, in order to demonstrate the effect of our proposed technique. The results of the experiments are suggestive of the effectiveness of the proposed scheme.

In addition to the proposed load shedding scheme we could include generation control systems and hence can control the generation according to the load requirement, a distribution storage system which is capable of storing the surplus generation in the system and dischargeswhen a power shortage occurs. Implementing the smart meters will helps in giving indication regarding the management of power according to availability. Increasing the number of agents will improve the operating efficiency and it will also help in providingpriority with in the prior loads. And also we can increase the performance and get accurate result by adding the more fuzzy rules.

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