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DESIGN AND IMPLEMENTATION OF MULTI AGENT SYSTEM IN IDAPS MICRO GRID FOR OPTIMAL LOAD SCHEDULING NETWORK

Manoj Kumar Bhardwaj[1], Shimi S.L[2], S.Chatterji[3]

[1]Department of Electrical Engineering, IET, Mangalayatan University, Aligarh, (India)
[2,3]Department of Electrical Engineering, NITTTR, Chandigarh, (India)

ABSTRACT

This paper is describing about design and implementation of multi agent system in intelligent distributed autonomous power system (IDAPS) for a smart grid called micro grid for optimal load scheduling network. The different control architecture contains agents like Load agent, Control agent, and DER agent which are responsible for quick action for micro grid control. The multi agent controller is used as an open source agent building toolkit Java Agent Development framework (JADE). MATLab environment is used for Simulation. Interfacing is done with the help of MACSimJX to Simulink model with multi agent system during normal, fault and over load conditions. Simulation is carried out and Simulation results show that the proposed Multi-agent based controller effectively coordinated with different loads in micro grid to fulfill the requirement of continuous power supply to critical loads during all the worst conditions like fault, normal, and overload situations.

Keywords: Intelligent Distributed Autonomous Power System (IDAPS), Distributed Energy Resources (DER), Java Agent Development (JADE), Multi Agent Control For Simulink Program (Macsimj), Multi Agent System (MAS) And Micro Grid.

I. INTRODUCTION

Nowadays, intelligent control multi agent system (MAS)[1] may be considered as an effective controller, and may be used as online monitoring and smooth operation in various system conditions. The criterion of multi agent systems in power applications have been discussed by McArthur [2 and 3]. The design and implementation of multi agent systems in the micro grid using JADE is being demonstrated [4]. An architecture of multi agent systems using TCP/IP is proposed [5,6,7,8,9]. By using JADE and MACSimJX for the Micro grid for the design and implementation of multi agent system is reported [10,11,12,13,14,15]. An intelligent agent based distributed autonomous system is described [16,17]. The middle-ware communication of MACSimJX is demonstrated [18]. In this paper an agent based controller which includes characteristics of different loads and can be isolated the uncritical loads from the main grid to maintain the continuity of power supply during critical loads and fault conditions. The paper is categorized into seven sections. Section-1 gives the idea of concept and literature review. In section-2, JADE architecture of multi agent system is defined shortly.

In section-3 detailed the variable methods of agents of the given multi agent controller. Section-4 showing the Simulink model of micro grid. Section-5 represents communication between agent based controller and Simulink model. In section-6, is the result of simulation model of multi agent controller for given Simulink model is being seen during fault and normal conditions. Finally, section-7 showing conclusion of the paper.

II. FORMATION OF JADE ARCHITECTURE WITH AGENT BASED CONTROLLER

An agent may be defined by its characteristics like autonomous, reactive, pro-active, with social ability has been shown by Wooldridge [12]. For an implementation of multi agent controller, number of open-source agent platforms available in the literature. Java Agent Development Environment (JADE) is most suitable platform for implementing multi agent controller, which conforms to FIPA (Foundation for Intelligent Physical Agents) standard. JADE platform consists mainly three components which automatically activated at the agent platform. The general terminologies used in agent usage following

- Agent Management System (AMS): Agent management system maintains a directory of agent identifiers (AID) along with agent state. It is essential that each agent must be registered with an AMS to get a valid AID.
- Directory Facilitator (DF): Directory facilitator is the agent providing the default yellow page service in the platform, shown in Fig.1.
- Agent Communication Channel (ACC): Agent communication channel is software component which controls an exchange of messages within and between the platforms.

The design of multi agent system is done in a hierarchical manner because such architecture aligns mostly with structure of the distribution network.

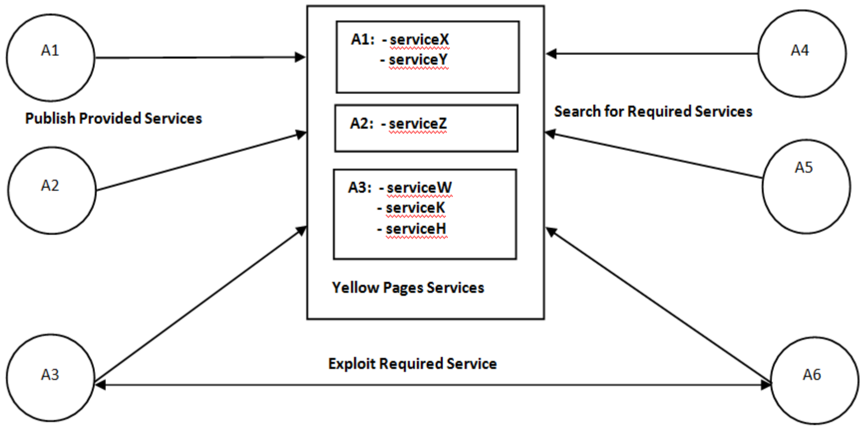

Fig.1 Yellow Page Services by Directory Facilitator

III. DIFFERENT FUNCTIONS OF AGENTS FOR AGENT BASED CONTROLLER

Following are the functional responsibilities of agents for the proposed agent based controller:

1. Control agent: The system load current and detection of power during emergency conditions and performs actions to open the main circuit breaker are to be monitored by the control agent. Also organise all the agents in system to provide information that the system is subjected to fault or not, shown in flow chart of Fig.2.
2. DER agent: It works as storing relevant DER information, with monitoring and controlling DER power

levels. It responds according to the messages of control agent and quickly sends proposal messages according to the received message sends connect/disconnect control to the breaker.

3. Load agent: Its having information of users/loads, as per power consumption and load number unit. Also has the preference of critical and non-critical load condition. When any load shedding message is received then it will isolate that particular load.

Multi agent system contains control agent, DER agent, and load agent are developed in JADE atmosphere. Behavior of control agent is given in the flow chart shown in Fig.3.

IV. DETAIL OF SIMULINK MODEL OF IDAPS MICRO GRID

IDAPS micro grid is related with the future of power systems and consists of physical and cyber layer as shown in Fig.4, following are the important points to be considered and act accordingly. It is to be considered that enough DER capability be placed in each IDAPS micro grid to protect critical loads situated in each cell during outages. It is to be considered that few technical, regulatory and economic barriers to DG interconnection may be ignored. It is to be considered that DER units and other electronic devices, like circuit breakers, must have communication interfaces and are addressable by IP addresses. It is to be considered that minimum one type of communication medium must be available to facilitate communications among local generators, loads and electronic devices. The communication means may be a wired local area network (LAN) or a wireless network system.

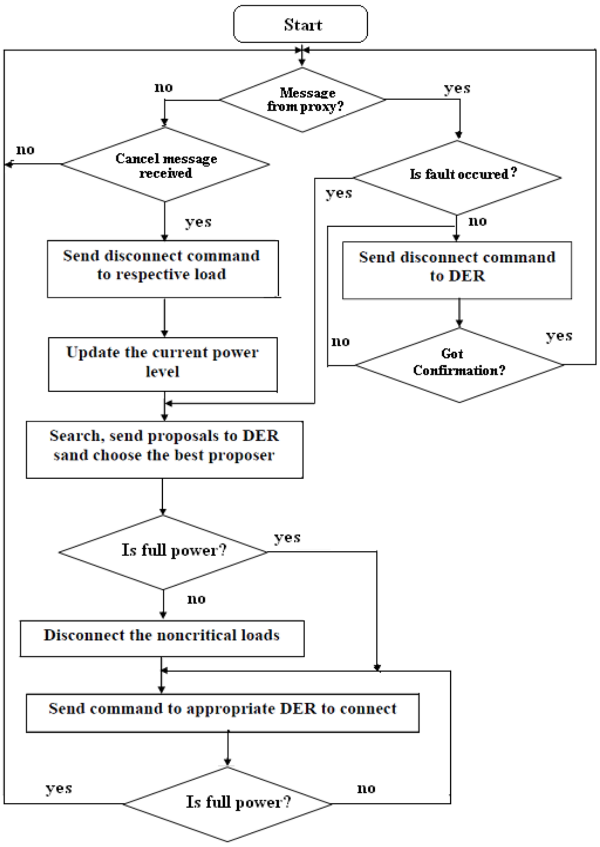

Fig.2 Flow Chart of Control Agent

For implementing the proposed multi agent system, a simulation test bed is created in MATLab/Simulink as a simplified distribution circuit consisting of two distributed generators of 50 kW each, grid interface (inverter, pulse width modulation i.e., PWM controller, low-pass filter and isolation transformer), loads (including 100 kW critical loads and 50 kW non-critical loads) and load circuit breakers, a distribution transformer (12.47 kV / 440 V), the main circuit breaker and the utility grid at 12.47 kV shown in Fig.6. The multi agent system receives and sends messages from/to the circuit and performs control and management activities. Circuit showing dc to ac conversion unit of a 440 V, 50 kW micro turbines connected to a 440 V power grid. The Turbine-Generator-Rectifier group is modeled as a simple dc current source injecting the requested dc power into the dc bus. The SPWM modulator uses a carrier frequency of 15 kHz. The control system uses two regulators: an inner current loop controlling the current at bus B2 and an outer dc voltage regulator controls the dc bus voltage.

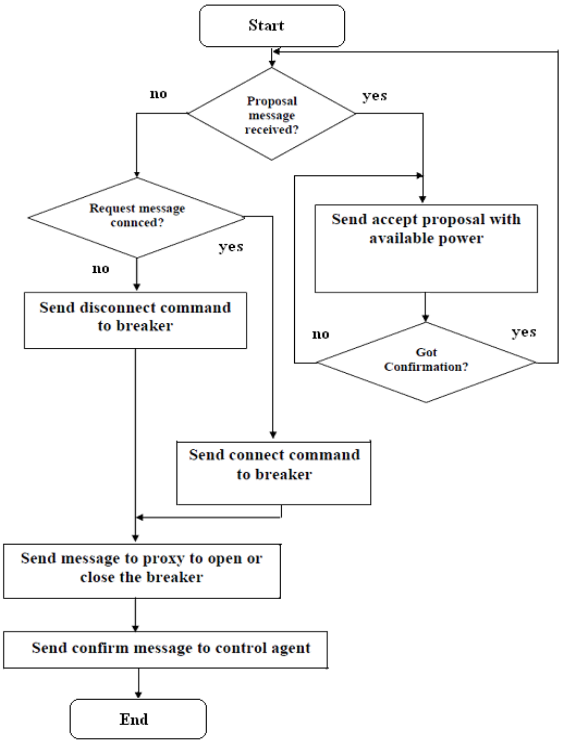

Fig.3 Flow Chart of DER Agent

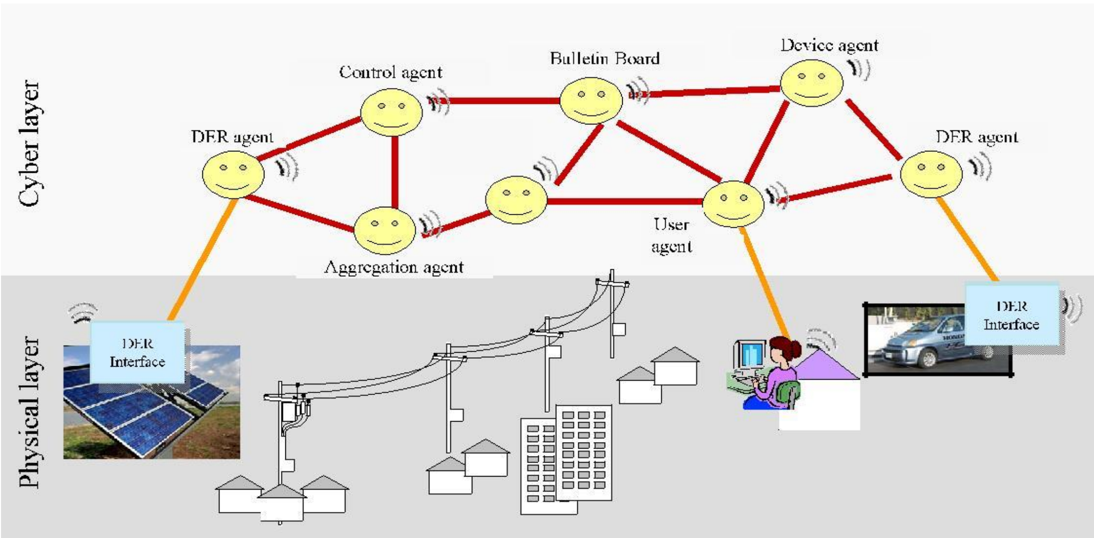

Fig.4 Physical and Cyber Layers in an IDAPS Micro Grid

V. DESIGN OF COMMUNICATION NETWORK BETWEEN AGENT BASED CONTROLLER AND SIMULINK MODEL

An implementation of the communication network between agent based controller and simulation model is given in Fig.5. Due to this communication network multi agent system receives or sends data to or from the micro grid model in Simulink form. Muti agent system collects information to understand the status of the agents for taking necessary control actions and applied to the concerned electric model. This multi agent control for Simulink program is being developed as a medium for implementation of agent design which is developed in object oriented programming with C++ or Java. It is being seen that MACSim is client-server architecture and embedded into Simulink with S-function, after that a server code is attached with the separate program as indicated in Fig.6. The communication network between the client and server is performed via defined software.

A JADE model is implemented to receive data from Simulink via MACSim and send the same to relevant agents for processing the data. Suppose agents have completed the data work, it must be returned to Simulink via same channels. Agents are designed in a way to perform peculiar goal. Agent task force must be defined as per programming already fed in JADE. MACSim and JADE both are run simultaneously and interfaced with MATLab/Simulink.

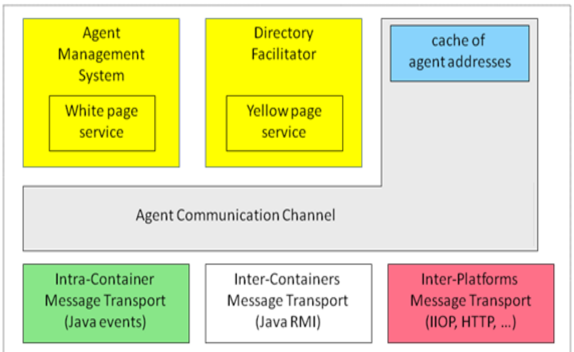

Fig.5 Internal Architecture of JADE

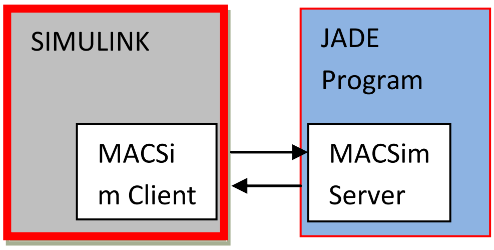

Fig.6 Structure of MACSim

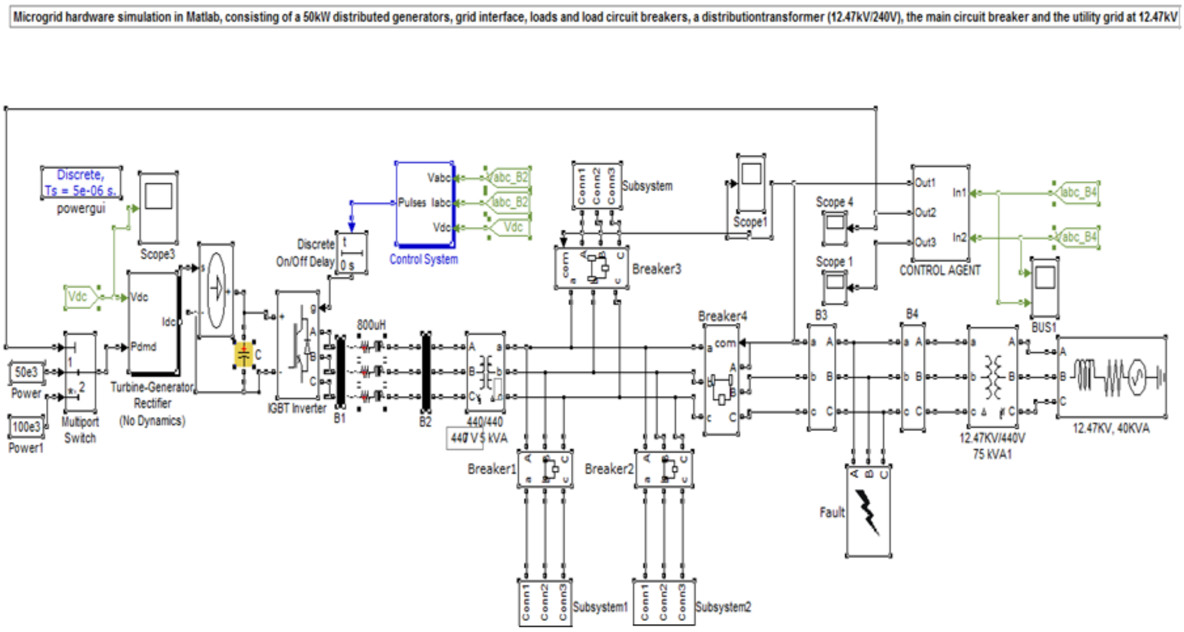

Fig.7 MATLAB/SIMULINK Model of IDAPS Micro Grid

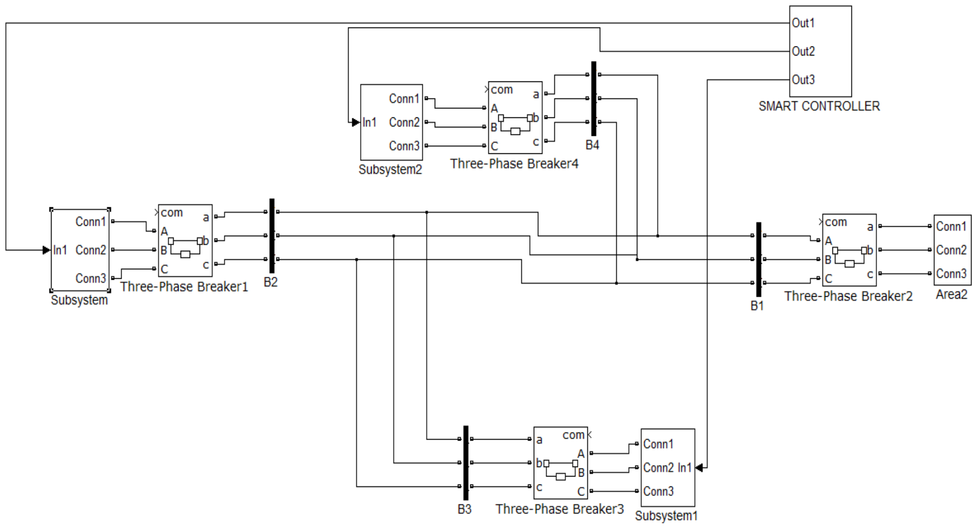

Fig.8 Simulation Model of Optimal Load Scheduling Network

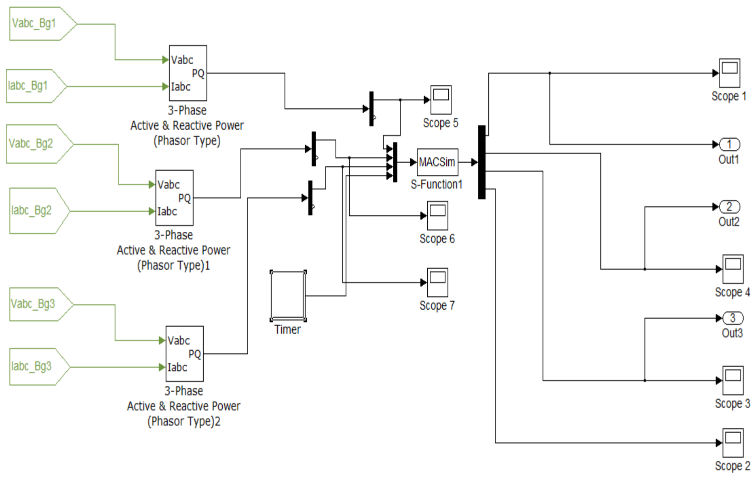

Fig.9 Smart Controller for Optimal Load Scheduling Network

VI. RESULTS AND DISCUSSIONS

An electric simulation model is integrated with an implemented MAS prototype. It has seen that the MAS has isolated micro grid during fault conditions and to provide loads with immediate preference of available DER sources. Supposed that the load power becomes higher than the DER power and GRID power both then non-critical load should be disconnected. For checking the performance and operation of the MAS, a sample system of optimal load scheduling network is simulated and evaluated shown in Fig.8. Also, the smart controller for optimal load scheduling network is shown in Fig.9.

6.1 Result of Occurrence of Three-Phase Fault

When a three-phase fault occurs near the main grid, grid is isolated by an immediate action of multi agent system and hence secured all critical loads. Here, per unit line-line base voltage is 440 V and per unit base power is 100 kW. In the duration of 0.02 seconds control agents senses the changes and provide the information between the agents and immediately a main breaker is opened at 0.02 second due to a control action. The fault occurs at 0.06 seconds and remedial of the fault is at 0.08 second.

6.2 During the Grid-Connected Mode

The frequency as well as the voltage of micro grid must be controlled in such a way that they must follow the frequency and voltage of the grid, which are 50 Hz and 1 per unit respectively. The total demand of micro grid is 100 kW for critical loads and 50 kW for non-critical loads. During this mode, DER source supplies 50 kW internally and main grid supplies 100 kW. It has been shown in Fig.13, the current and voltage output is 1 per unit each of DER till 0.06 second. The total power required by the critical and non-critical loads is shown in Fig.14.

6.3 During the Transition

At 0.02 second, control agent detects the fault, and informs to load agent and DER agent. Control agent provides control signal to main circuit breaker to isolate the main grid, and coordinates with load and DER agents to take proper action immediately, shown in Fig.10, Now, it is considered that DER generates power with its full capacity. DER agent connects second DER of 50 kW to bear the critical loads shown in Fig.11. Herewith load agent checks the sufficient power availability from DER agent. It has also seen that if it is not fulfilling the requirements then, it rejects the noncritical loads (less priority) shown in Fig.12.

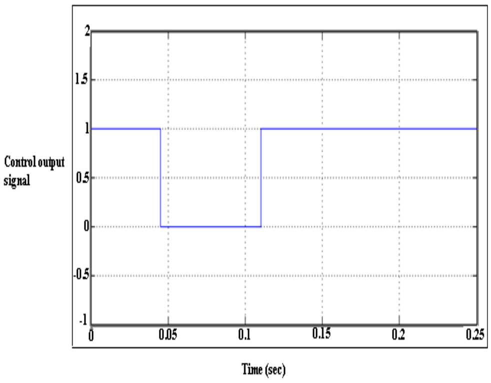

Fig.10 Control Agent Signal

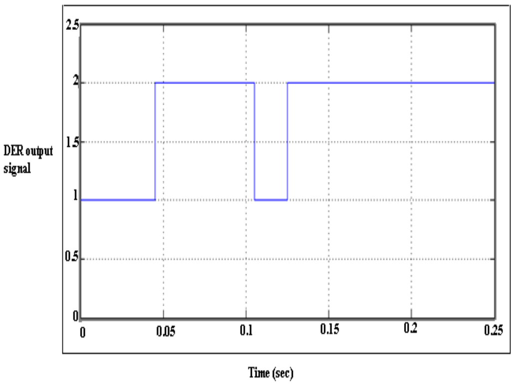

Fig.11 DER Agent Signal

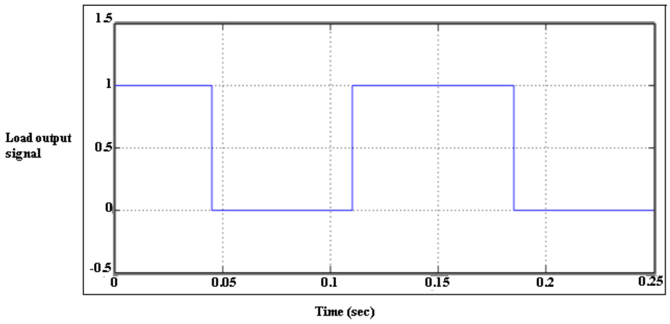

Fig.12 Load Agent Signal

6.4 In the Island Mode

When the fault is occurred at 0.06 second, the main grid is disconnected at 0.06 second and the critical loads are supplied from DER source. During island mode, micro grid is operated, which consists of critical loads, frequency is controlled at 50Hz and voltage is at 1 per unit. The total system load is of 150 kW while the distributed generator produces internal 100 kW to supply these critical loads. Hence, the remaining non-critical loads are being removed by load agent to maintain stable operation of the network system.

6.5 Restoring to Grid Connected Mode

The fault is cleared at 0.08 second, as per power network time constant, the fault current becomes at normal value just after 0.204 second. Though the voltage when reaches to permissible value, it has detected by control agent and to inform to DER agent and load agent immediately. Control agent provides control signal to close the main circuit breaker. DER agent coordinates with the control agent and disconnects with DER and hence also to disconnected with the second DER and reduces its capacity to normal power capacity of 50 kW as mentioned in Fig.13.

6.6 During Overload

At 0.10 second load rises by 50 kW, which shows that the total system load is of 200 kW. So, load agent informs to DER agent and DER agent randomly connects with second DER of 50 kW to access an extra load. Now, 100 kW power is supplied from DER source and 100 kW power is supplied from grid to fulfill the requirement of 200 kW load. Similarly, at 0.16 second, again the load increases by 50 kW. Finally, total load reaches to 250 kW. Load agent checks the power availability condition from DER which has full power and hence, load agent removes non-critical loads as shown in Fig.14.

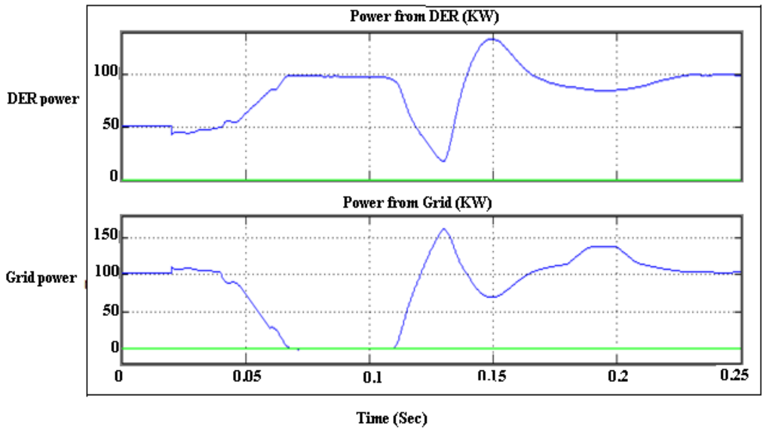

Fig.13 Power Flow Diagram

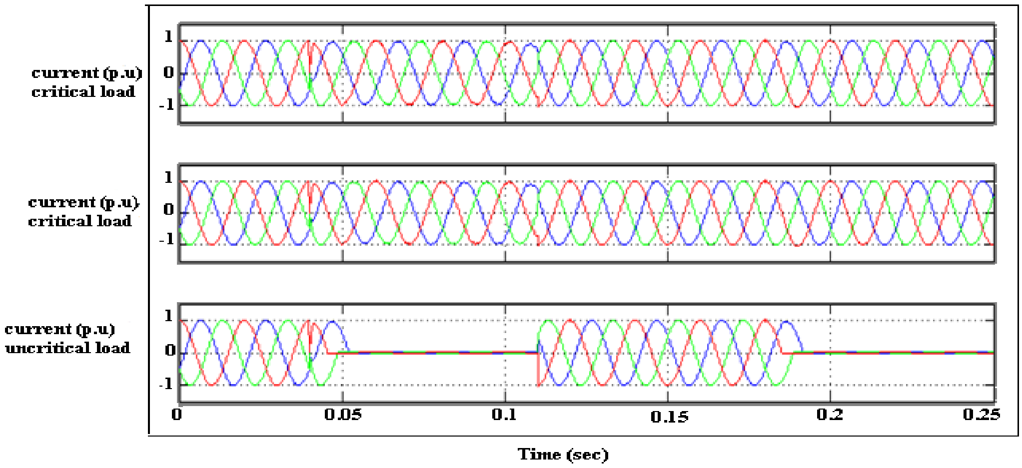

Fig.14 Current Waveforms through Critical and Non Critical Loads

Control agent communicates with DER and load agents via informative messages; this can be observed from Fig.14. By these information and precise control algorithm it sends messages to the agents. At lastly, control signals from JADE environment are channeled to Simulink via MACSimJX.

VII. CONCLUSIONS

This paper presents the design and implementation of multi agent system in IDAPS micro grid for optimal load scheduling network. An experimental result demonstrates the capability of multi agent controller to island the micro grid, once an upstream outage is detected and continue supplying to critical loads during fault and optimal load conditions. An experimental model has been simulated in MATLab and the agents are connected to Simulink via MACSimJX. An implementation of multi agent controller by using JADE is also defined. The results have also being showing continuity of power supply to the critical loads while power is failure from the grid side.

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