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Frequency Controller Design for Distributed Generation by Load Shedding: Multi-Agent Systems Approach

M. R. Vaezi, R. Ghasemi, A. Akramizadeh

Abstract**—**Frequency stability of microgrids under islanded operation attracts particular attention recently. A new cooperative frequency control strategy based on centralized multi-agent system (CMAS) is proposed in this study. Based on this strategy, agents sent data and furthermore each component has its own to center operating decisions (MGCC).After deciding on the information, they are returned. Frequency control strategies include primary and secondary frequency control and disposal of multi-stage load in which this study will also provide a method and algorithm for load shedding. This could also be a big problem for the performance of micro-grid in times of disaster. The simulation results show the promising performance of the proposed structure of the controller based on multi agent systems.

Keywords**—**Frequency Control, Islanded Micro-grid, Load shedding, Multi-agent System.

I. Introduction

THE electric grid is evolving toward what has been defined as the “smart grid paradigm” [1]. The development of communication infrastructures provides power electronics interfaces with the ability to control complex power systems in efficient and scalable ways and in real time. Multi-agent systems (MAS) are based on distributing information and computing algorithms for complex networks, and are an excellent technological solution for this application. This paper focuses on applications of MAS in power systems and describes how they can be used with other artificial intelligence techniques in order to make the grid smarter and more flexible. In addition to presenting the basics of multi-agent theory, this chapter covers some design procedures and provides several examples, as well as perspectives for future developments of MAS in power systems control. One of the most important parameters is to control the microgrid frequency. The change represents a change in the rate of production and consumption and therefore a very important factor in the operation and control of the microgrid. The operation of a network, information on the frequency of which shall be recorded the moment and this means that a large volume of information in a record time limit should be examined. It should be noted that the change in frequency of more than nominal value in addition to causing damage to the facility's power grid, the means of electricity subscribers will also have detrimental effects Also, if the frequency of the micro-grid and allowed optimal control and even collapse the network will not cause instability. Micro-grid frequency response correction, especially in the event of an error, is one of the deceived factors in the stability and performance of the system.

Mohammad RezaVaezi, Reza Ghasemi and Ali Akramizadeh joined the Department of Control Engineering, Damavand Branch, Islamic Azad University, Damavand, Iran (e-mail: Rezawaezi@gmail.com, Rezaghasemi@ Damavandiau.ac.ir, Akramizadeh@gmail.com).

The implementation of a control network based on multi-agent systems where the user is able to decide intelligently converts a lot of research in this area. A multi-agent system is a combination of different factors cooperates to achieve the overall goal of a system. Agents must include a list of protocols that are well defined and represent different ways of communicating with nature (human or other agents) belonging to the system. Multi-agents systems (MAS), which have been applied in computer science studies for years, have characteristics that make them suitable for acting as a basis for building modern distributed control systems. In addition, artificial intelligence techniques can be embedded in some agents with smart features, particularly in automating tasks traditionally performed by human operators [1].

Frequency control of an autonomous microgrid is achieved by coordinating the energy storage (ES), such as superconducting magnetic energy storage (SMES) and battery energy storage (BES), available distributed generators (DGs), such as wind turbines (WTs), photovoltaic (PVs), and micro turbines (MTs), and controllable loads. An autonomous microgrid is an isolated power system with a small equivalent inertia, which makes its frequency control more difficult than conventional power systems. Because of the operation mode, transfer and intermittent characteristics of some distributed generators, frequency deviation caused by active power deficiency or shortage often occurs in an islanded microgrid [2], [3]. As a result, the frequency of the microgrid will fluctuate and may change rapidly due to the low inertia present and even experience a blackout unless there is adequate available spinning reserve to balance it [2], [3]. ESs can absorb or inject instantaneous power to provide support for primary frequency control [4]. Subsequently, it was recognized that the power distribution of DGs can also play an important role in maintaining the frequency stability and regulating the micro-grid to a new balanced state [5], [6].

A two-layered hierarchical frequency control scheme with microgrid central control (MGCC) was proposed to achieve cooperative frequency recovery by coordinating the ESs and DGs [7], [8]. Similar to two-layered hierarchical frequency control, the corresponding centralized multi-agent system (CMAS) also requires a powerful MGCC [9], [10], which is expensive and can easily suffer failures when handling huge amounts of data. An incremental cost consensus algorithm under different communication network topologies in a smart grid was studied and the convergence of the proposed algorithm was analyzed in [11]. An MAS-based scheme for a microgrid was presented in [12] to secure critical loads for a PV based microgrid, and a centralized MAS-based frequency control method was proposed and investigated in [9] to enhance the frequency stability of an islanded microgrid. In [13] focused on micro-grid and propose a new multi-agent-based load shedding scheme and multi-agent architecture to realize the resilient power grid. Therefore, in this study, we present an algorithm for load shedding in which each agent in addition to voltage and frequency load will be a priority for load shedding. Also this algorithm to assessing which must be removed before the fuzzy method is applied. We used fuzzy; its fast response is selected, faster system starting when you want to remove loads and the resulting loss of voltage and frequency in system is greatly reduced. Load shedding method proposed in this study is ensured that loads essential in the island microgrid. An example is shown in Fig. 1.

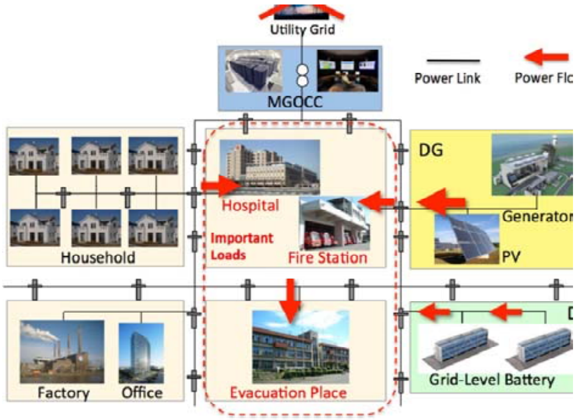


Fig. 1 Overview of the Priority of Load shedding

II. Related Work and Problem

An agent (or an intelligent agent) can perceive its environment and makes a decision against changes of the environment, and can act to resolve them autonomously according to its design purpose using its reactivity, proactiveness, and social ability [14]. Since the characteristics of multiagent system are well suited for the operation of microgrid, it is well established that agent-based operation is efficient for microgrid operations well as for Smart Grid operation [15]. There are researches which focus on microgrid operation by applying multiagent system [15]-[17]. In the existing research [15]-[17], the agents in the proposed system collect information of each component and send the information to decision making agent. The decision is sent back to the component agents. For example, one of the existing researches [17] proposed a system that adjusts the amount of thermal power generation, taking into account the amount of load demands. Also, since micro grid has distributed generator and usually some of them are using renewable energy, this research considers the transition of power generated by Wind turbine generates. This research [17] is trying to adjust the load demands, which are the given value in their simulation. Although managing demand from loads is challenging because there are several aspects to deal with. In the field of agent-based micro grid operation, there is also a research which focuses on the division of power in islanded micro grid [18], which is closely related to the focus of this paper. This research investigates a load-shedding scheme using the Talmud rule in islanded micro grid operation based on a multi agent system. The Talmud rule originating from the Talmud literature has been used in bankruptcy problems of finance, economics, and communications [19]. They propose to use Talmud bankruptcy rule to divide power in micro grid. In the existing model of micro grid operation, since demand side and supply side operate independently, it is highly challenging to ensure the power for particular loads which are socially important in a disaster situation. It is a crucial problem for micro grid operation during a disaster situation, because it is highly challenging to ensure the power for the important loads. The socially important loads are, for example, hospitals, evacuation places and other places which are crucial to sustain people’s life in the disaster situation. Another aspect of problems among the existing research is about the architecture of multi agent system [15]-[17]. In this existing research, there are agents which represent MGOCC, Load, DG, and DS. When MGOCC agent tries to gather information in the micro grid, all the agents representing Load, DG and DS send messages to MGOCC agent at the same time. This paper focuses on the autonomous islanded microgrid. Operations in a disaster situation, these points mentioned below are considered to be the issues in the exiting researches.

1) Ensuring the power for important loads is difficult in islanded microgrid using the existing operational Scheme.
2) Concentrated computational cost in MGOCC Agent.

A. Solution

We propose solutions for the problems mentioned in the previous section. These solutions are summarized as follows: Using the agent-based hierarchical for microgrid and disposed of according to priority loads times.

B. Procedure

When power is not available for all loads, first MGCC be required to ensure the main loads. The sentence does not mean that be not provide other loads, it loads the main power supply to the loads will be left will no longer does. In this study, each of which has been given priority loads, that some of the loads have the same priority. The algorithm used is shown in Fig. 2, all loads their requests and changes immediately sent to the MGCC. Also Distributed generation is doing the same thing.

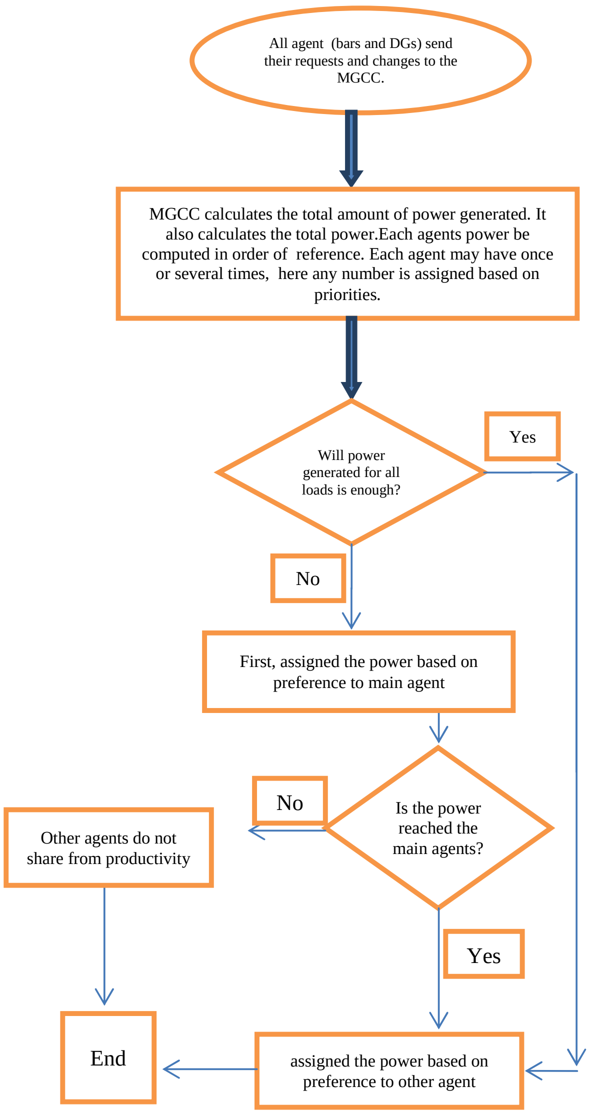


Fig. 2 The algorithm of load shedding

III. Model and Structure of Microgrid

In islanded microgrid, two control levels of MAS are distinguished as presented:

First Level: Microgrid central frequency controller (MGCC) agent. The MGCC is the main responsible for the frequency control of the microgrid. It simply coordinates the local controllers, which assumes the main responsibility for frequency stabilization. MGCC monitors frequency, collects the information of generations and loads, sends commands to local agents, and communicates with upper distribution network controller when microgrid works in grid-connected mode.

Second Level: Local controller (LC) agent. LC includes distributed generation agent (GA), energy storage agent (SA), and load agent (LA).MGCC control the GA, SA and LA to improve the frequency stability of micro grid. In the second level agents can only control their local parameters, but anyway ordered to change their performance from MGCC.

IV. Experiment and Evaluation

In order to evaluate the proposed load shedding scheme and hierarchical architecture, we have designed and developed a miniature microgrid for demonstration experiment. The main purpose of performing demonstration experiment is to evaluate the effectiveness of our load shedding scheme in physical difficulties, such as the gap between sensed value of power consumption and actual power consumption, overload of power by loads, etc. The system is used for load shedding, including the following:

- Producers agent (including wind turbine is 3)
- Load agent (which is three loads: the load divided into 3 major and 3 normal.)
- Central agent: a moment of sampling the voltage and frequency.

Each of loads takes active and reactive power. These loads are isolated by isolation from the power grid. Normal loads are green and major loads are red. There is also ranked among the loads with the same priority. What a load on those higher priorities. Load agent is made from 6 loads. Normal loads are green and major loads are red. Centralized control Agent contains 3 parts of sampled and a load shedding decision part. The MGCC allows load shedding. Loads that will be wiped out in the next section separated from other loads. This part of a fuzzy control algorithm is used for load shedding.

V. Simulation

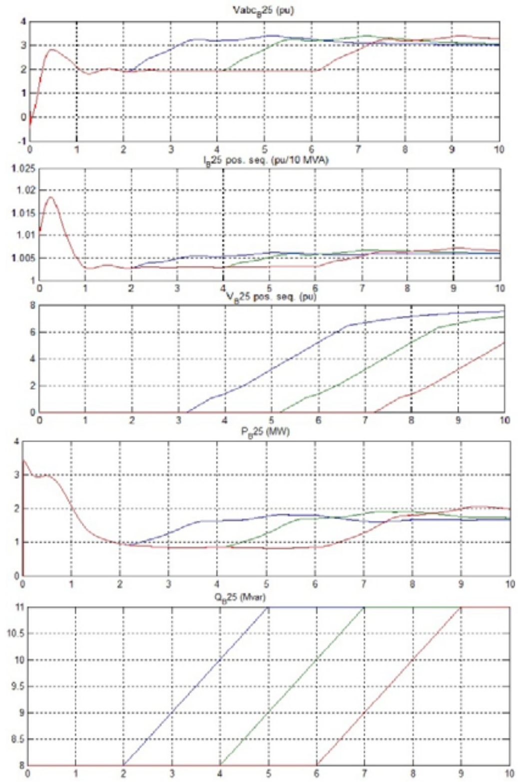
This paper is analyzed a system, using the simulation software Matlab 2013. Results are shown for different scenarios for each load.

A. Normal Operation of the Grid Idle Load

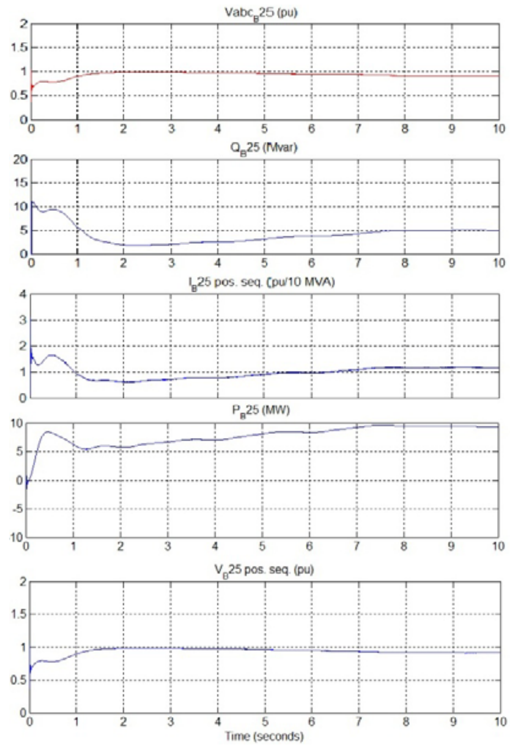
Fig. 3 is waveform generation and load. Because of the system no-load production voltage also higher 2Pu, but the B25 bus voltage remains on 1Pu and not have much changes and transient state has very few. The Power consumption has reached near 10Pu and reactive power 5Pu looks.

B. Placing System in Full Load

In this mode, all loads are applied to the system with the proviso that removal load shedding part, the results are shown the Fig. 4.

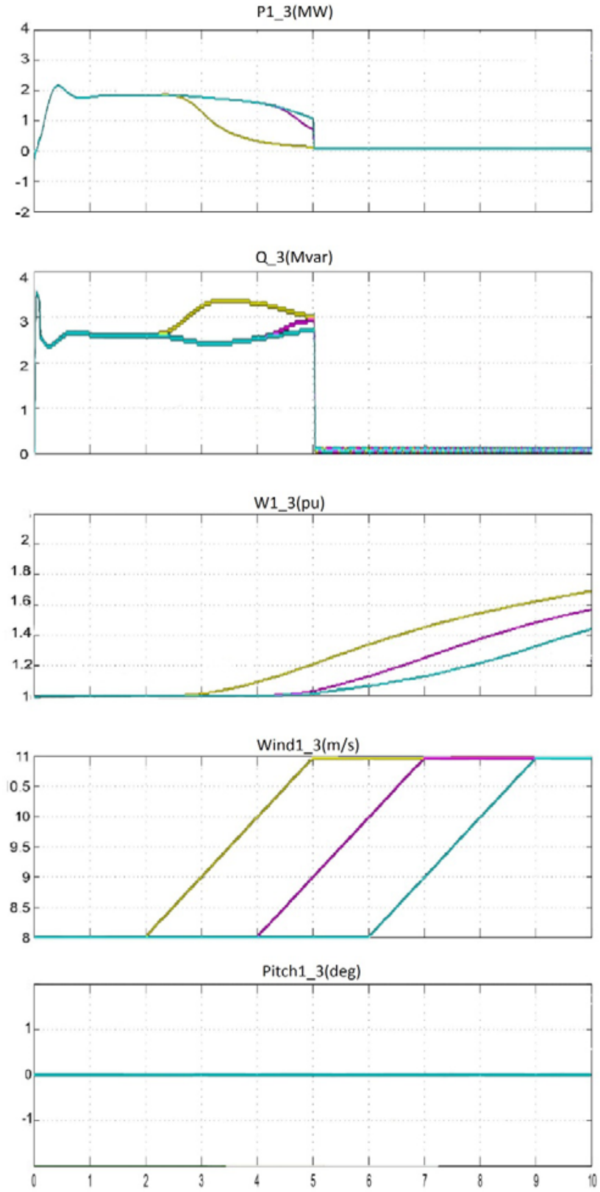


(a) Part production curves

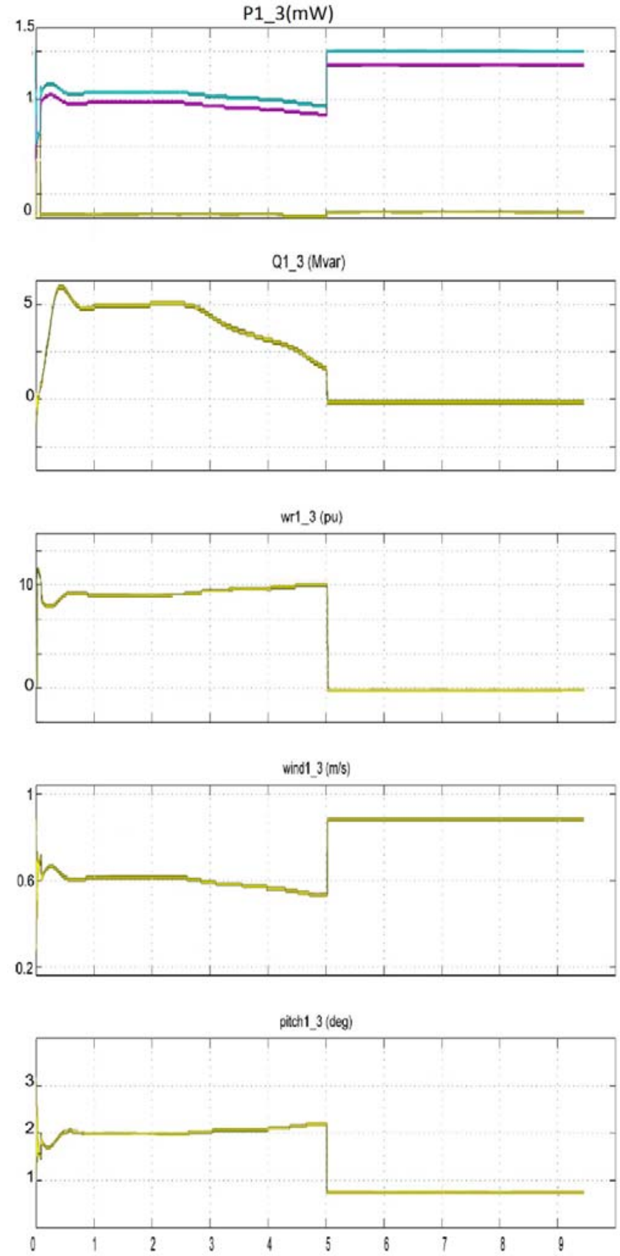


(b) Part load curves

Fig. 3 Curves of no load and normal operation of the grid: (a) Curves for part production (b) curves for part load



(a) Curves for part production

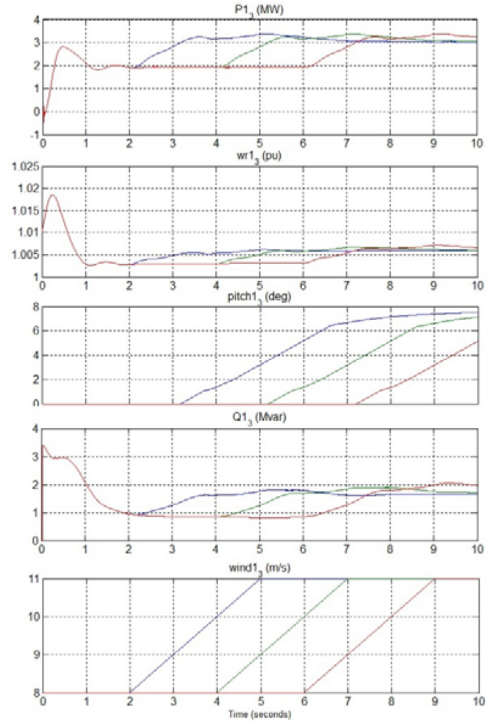


B) Curves for part load

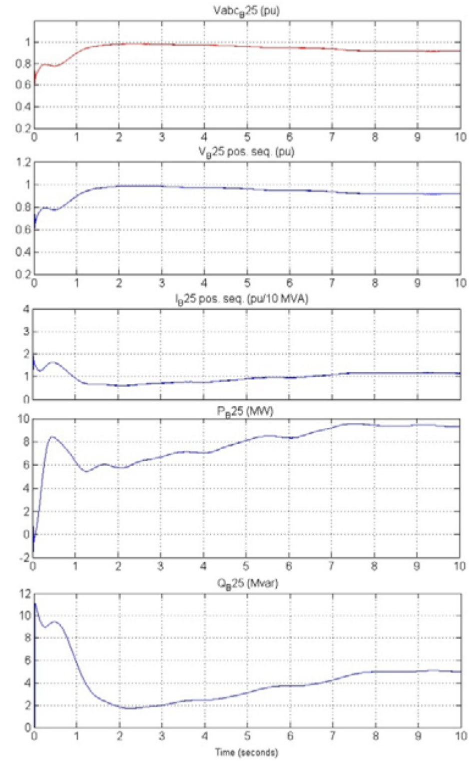
Fig. 4 Grid function curves at full load without load shedding part: (a) curves for part production (b) curves for part load

C. Enable the Load Shedding

At this stage we enter part load shedding. Load shedding algorithm starts working and two times that normal load is considered out of orbit. The mentioned results are shown in the Fig. 4. The MGCC ordered to isolator units, and load it is removed from the circuit. On this algorithm first starting to separate the loads normal, and then towards major loads and separated their network priority.



(a) Curves for part production



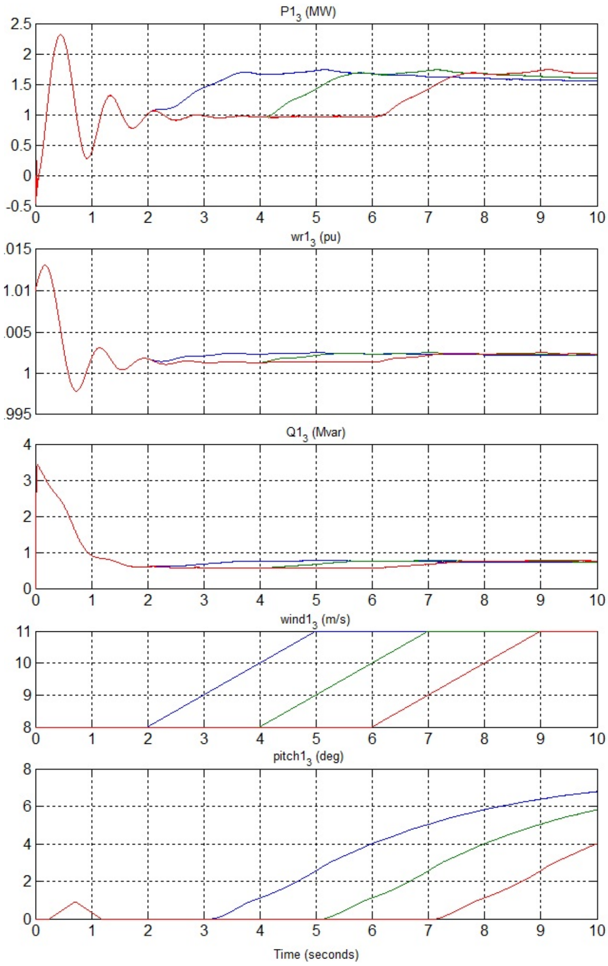
(b) Curves for part load

Fig. 5 The desired system curves, after applying the load shedding algorithm and out of two loads of grid part: (a) curves for part production (b) curves for part load

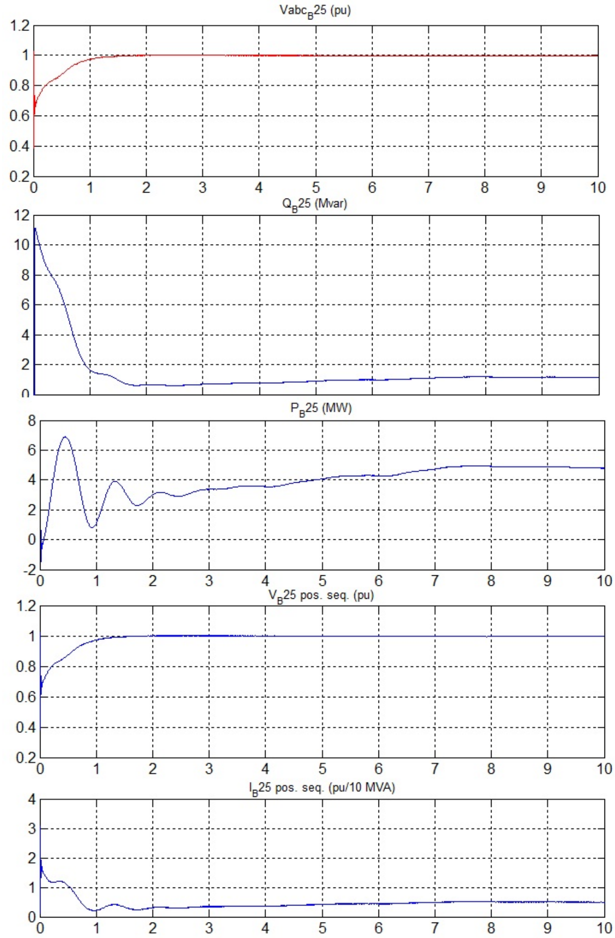
Following adding the part control (load shedding algorithm) to desired system, two loads out of circuit, and finally system will reaches its optimal performance.

D.Reduce by Half the Production Power and Load Shedding Algorithm

On system desired for all normal loads are switched off and the system goes back to normal shows in Fig. 6.



(a) Curves for part production



(b) Curves for part load

Fig. 6 The reduced power production: (a) curves for part production (b) curves for part load

VI. Conclusion

In this paper, application of MAS for the frequency control of islanded Microgrid by Load shedding method is presented. As seen on the simulation, Load shedding algorithm is able correctly loads desired to remove from outside circuit and also differentiate for removed the normal loads and important loads. Thus, in the normal load, there is priorities that this prioritize the border is very important, and it is also considered for the study. Simulation results show that the frequency of islanded microgrid is controlled by the proposed multi-agent system properly. Output of each distributed generation and energy device is dominated by intelligent agents successfully.

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