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Multi-Agent based Microgrid Coordinated Control

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Abstract

There are obvious advantages in collaborative work for the system based on the multi-agent technology. According to a concrete microgrid in this paper, multi-agent control system is designed based on the microgrid control goals. The structure of multi-agent microgrid control system and the specific functions of each agent are proposed, expounding the microgrid coordinated control strategies at the grid-connected and islanded state respectively. The model of microgrid based on the multi-agent is established in the MATLAB/SIMULINK. The simulation model has simulated the microgrid's characteristics of running operation performance both under the grid-connected and islanded situation. Simulation results show that multi-agent microgrid control system can fully satisfy the requirement of power balance control and inhibit frequency fluctuation under the two situation.

*Keywords:*power system, microgrid, multi-agent, coordinated control

1. Introduction

It is the distributed feature and flexible control strategy of microgrid which make the traditionally centralized way of dispatch very difficult to achieve[1]. However, multi-agent becomes an effective way to solve the coordinated control of microgrid for its autonomy, sociality, reactivity and Initiative. Researchers domestic and foreign have put forward the microgrid frameworks based on the multi-agent system successively, and a lot of research has been done about multi-agent system [2-3].

The main goal of reference [4] is to develop a distributed MAS for generation scheduling and monitoring of energy resources for optimized microgrid operation. Reference [5] has done a pioneering work, PSCAD / EMTDC which is used in the electromagnetic transient simulation, PSLF(Power System for Load-Flow) that is used for the electromechanical transient simulation and NS2 for network simulation have all been organically combined by the EPOCHS(Electric Power and Communication

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Synchronizing Simulator) platform developed in[5]. AgentHQ (Agent Headquarter) serving as the proxy of agents, that is, agents achieve mutual messaging and communicating with the simulation components through AgentHQ. And it links the RTIs(Runtime Infrastructure) of basic components and to be responsible for the process of synchronous simulation and message sharing between components. References [6] has proposed the microgrid control framework based on the multi-agent system (MAS). It takes advantage of central control agent to realize rapid control and achieve economic optimization at the same time in the grid-connected state; while under the islanded condition, the central control agent regulates the power of each distributed resource and guarantees the steady and safe transition when necessary.

Because of the randomness and volatility of output power of wind and solar energy, especially for the small scale renewable hybrid power system, it is easily to lead to considerable fluctuation of frequency. It is very difficult to meet the requirement of power quality if the rapid frequency fluctuation is only controlled by gas turbine. Therefore, the main purpose of this paper is to design a microgrid coordinated control system based on the multi-agent system. It is through the multi-agent coordinated control to implement power balance in the microgrid, on the one hand, to minimize the power supplied by the distribution network as much as possible under the grid-connected situation; on the other hand, to meet the load demand and restrain frequency fluctuation in the islanded state.

2. Microgrid overview and control objectives

2.1. Microgrid overview

The hybrid power generation system designed in this article includes a gas turbine, a wind turbine, photovoltaic cell and fuel cell. The gas turbine, wind and solar energy are the main energy for the system, while the fuel cell works as the backup power whose fuel comes from the hydrogen produced by the electrolyzer and it plays a role of regulating energy and balancing the power supplied and consumed. The microgrid can not only work in the grid-connected state but also in the islanded state. Figure.1 is the schematic of the microgrid system. All the load supplied by the micro-sources includes two parts: one part is the primary load which has a relatively high requirement of reliability, and because of the stability of the gas turbine, it's presumed that the gas turbine supplies most of the primary load. The other part is the electrolyzer load, its electrolytic power can be changed along with the need of the system at any time. Changing the power consumed by the electrolyzer can be achieved by varying the pipe pressure and the control speed reaches the level of ms. Because of the randomness of wind and solar energy, the power generated by the two sources is mainly used for the electrolyzer to produce hydrogen.

2.2. Control objectives

Because the fluctuation of frequency Δf is mainly related to the active power, then the frequency stability of the network should be focused on whether the supply and demand of active power of the microgrid is balanced or not. Microgrid system should meet the following conditions:

$$\Delta P = P^G - P^L \to 0 \tag{1}$$

$$P^G = P_{WT} + P_{PV} + P_{FC} + P_{MT} = P_{WT} + P_{PV} + P_{FC}^{ini} + P_{MT}^{ini} + (\Delta P_{FC} + \Delta P_{MT}) \tag{2}$$

$$P^L = P_{Load} + P_{ES} = P_{Load} + P_{ES}^{ini} + \Delta P_{ES}^{ini} \tag{3}$$

Constraints:

$$P_{FC}^{\min} \le P_{FC} \le P_{FC}^{\max},\ P_{MT}^{\min} \le P_{MT} \le P_{MT}^{\max},\ P_{ES}^{\min} \le P_{ES} \le P_{ES}^{\max}$$

where P^G is the sum of active power of all the micro-sources in the microgrid, P^L is the sum of load active power consumption in the microgrid, ΔP is the difference between P^G and P^L, P_{WT} is the active power of wind turbine, P_{PV} is the active power of photovoltaic cell, P_{FC} is the active power of fuel cell, P_{MT} is the active power of micro-turbine generator, P_{FC}^{ini} is the initial active power of fuel cell, P_{MT}^{ini} is the initial active power of micro-turbine generator, ΔP_{FC} is the variation of active power of fuel cell, ΔP_{MT} is the variation of active power of micro-turbine generator, P_{Load} is the active power consumption of the primary load, P_{ES} is the active power consumption of the electrolyzer, P_{ES}^{ini} is the initial active power consumption of the electrolyzer, ΔP_{ES}^{ini} is the variation of active power of electrolyzer, $P_{FC}^{\min}$ and $P_{FC}^{\max}$ are the minimum and maximum active power of the fuel cell respectively, $P_{MT}^{\min}$ and $P_{MT}^{\max}$ are the minimum and maximum active power of the micro-turbine generator respectively, $P_{ES}^{\min}$ and $P_{ES}^{\max}$ are the minimum and maximum active power of the electrolyzer.

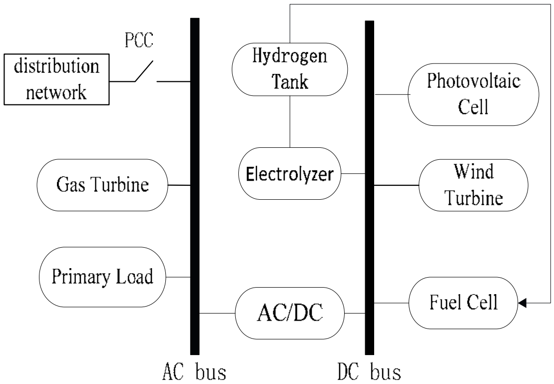

Fig. 1. The system configuration Figure

3. Multi-agent based microgrid coordinated control system

3.1. The structure of multi-agent microgrid

The control structure is shown in Figure.2. Every agent is capable of data processing and communicating with each other through the Database Agent to carry out coordinated dispatch. Load Agent includes the Electrolyzer Agent and the Primary Load Agent.

Every micro-source agent is responsible for the corresponding operation, management, reporting operating status and data, and receiving the dispatch and management of MGC Agent. In order to avoid improper instructions sent by MGC Agent or the instructions failed to send which are caused by communication failures or sudden condition changes, each micro-source agent should judge if the instructions sent by MGC correct or not based on its status right now. When self-judgment does not match with the given instructions, the agent must ask MGC Agent for control instructions repeatedly.

3.2. Multi-agent based power coordinated control strategy

The gas turbine supplies most primary load in the grid-connected state and it also supports frequency in the islanded network state. In order to take full advantage of wind and solar energy, MPPT mode is adopted both by the wind turbine and photovoltaic cell, The fluctuation of power and frequency is responded and inhibited by the gas turbine and the electrolyzer.

Agent power coordinated strategy is shown in Figure. 3, Specific steps are as follows:

1)Initialization, initial operating parameters are distributed to each agent by the MGC Agent, MPPT mode is adopted by the wind turbine and photovoltaic cell as stated above (1 in Figure.3).

2)Every agent will report running parameters (output power, switch status, etc.) to the MGC Agent(2 in Figure.3), MGC Agent calculates the amount of microgrid power shortfall ΔP the before moment, and sends ΔP to the Gas Turbine Agent and the Electrolyzer Agent.(4 in Figure.3).

3)PCC Agent doesn't only report operating parameters to the MGC Agent, but also distributes the power exchange P_{tie} between the microgrid and the distribution network to the Gas Turbine Agent and the Electrolyzer Agent (3 in Figure.3).

4)Gas Turbine Agent and the Electrolyzer Agent adjust the output power and the power consumed respectively according to ΔP and P_{tie}, then back to the step 2.

The ΔP in the step 2) is:

$$\Delta P = P_{WP} + P_{PV} + P_{FC} + P_{MT} + P_{tie} - P_{Load} - P_{ES} \tag{4}$$

PI control is adopted as the gas turbine and electrolyzer control method in the step 4). There is no step 3 in the state of islanded network.

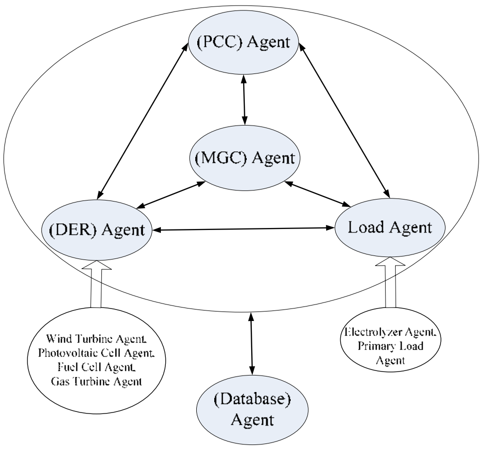

Fig. 2. Multi-Agent based distributed

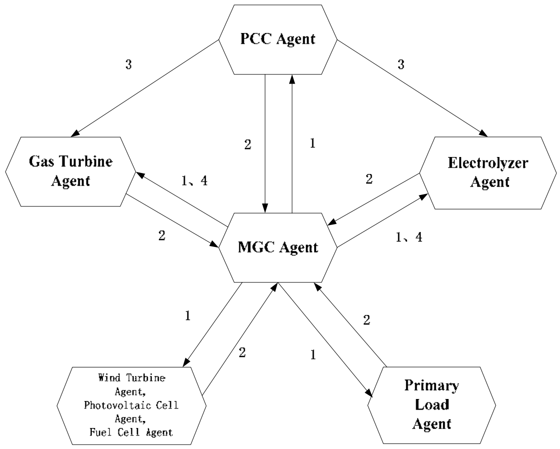

Fig. 3. Multi-Agent power coordinated strategy control framework for microgrid

4. Multi-agent based microgrid coordinated control simulation

4.1. Grid-connected simulation resultsy

Figure.4 and Figure.5 are respectively the result without multi-agent control and the result of multi-agent control. The comparison of the two cases' power exchange from the distribution network can be seen in Figure 6, if there's no coordinated communication among the PCC Agent, the Gas Turbine Agent and the Electrolyzer Agent, In the grid-connected state, when the load changes, there is no obvious output power variation of gas turbine and electrolyzer, power shortfall is mainly made up for by the distribution network, thus the fluctuation of power exchange is relatively large; while if there is coordinated communication among the PCC Agent, the Gas Turbine Agent and the Electrolyzer Agent, when the load changes, the gas turbine and electrolyzer will adjust the output power to achieve the balance between supply and demand and minimize the power supplied by the distribution network as much as possible, nearly remaining at zero from Figure. 6. In the Figure.7 and

Figure.8, because of the frequency support from distribution network, the fluctuation of frequency is very small, less than 8×10^{-4}Hz.

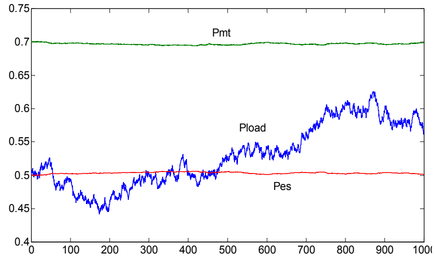

Figure 4. Simulation result not by multi-agent control

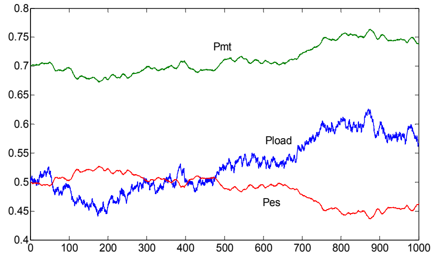

Figure 5. Simulation result of multi-agent control

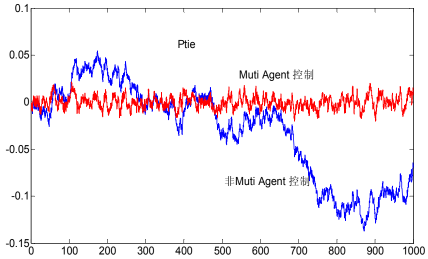

Figure 6. The comparison of power exchange with distribution network

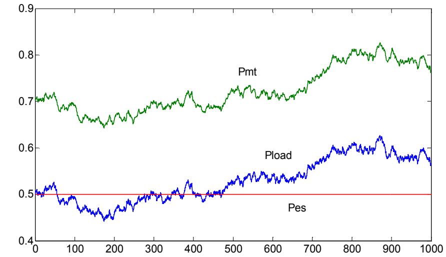

Figure 7. Simulation result not by multi-agent control

4.2. Islanded network simulation results

In Figure. 7, there is no Electrolyzer Agent, only gas turbine responds to the variation of load. Figure. 8 is the result of multi-agent coordinated control of Gas Turbine Agent and Electrolyzer Agent to maintain the balance of power within the microgrid. The fluctuation of frequency in the two cases above is in Figure. 9. The maximum fluctuation of frequency reaches 0.25Hz without the help of Electrolyzer Agent while with the multi-agent coordinated control, the maximum fluctuation of frequency is only 0.05Hz.

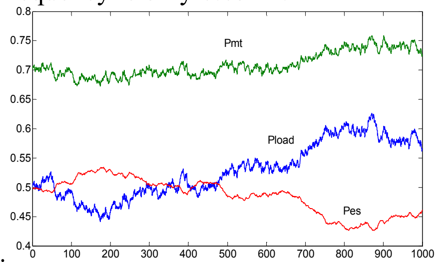

Figure 8. Simulation result by multi-agent control

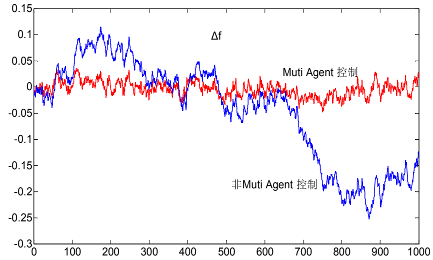

Figure 9.The comparison of frequency fluctuation

5. Conclusion

The model of microgrid based on the multi-agent control structure and control strategies mentioned above is established through which the microgrid's characteristics of running operation performance both at the grid-connected and islanded state are studied. Then come to the following conclusions:1)Under the grid-connected situation, the power exchanged between the microgrid and the distribution network can be minimized by multi-agent control, the power shortfall caused by the load variation is made up for by the microgrid, while it's only the distribution network to fill the power gap completely with the traditional control method.2) Under the islanded situation, it can maintain the balance of active power and restrain frequency.

References

[1] Van der Geer J, Hanraads JAJ, Lupton RA. The art of writing a scientific article. *J Sci Commun* 2000;**163**:51–9.

[2] Strunk Jr W, White EB. *The elements of style*. 3rd ed. New York: Macmillan; 1979.

[3] Mettam GR, Adams LB. How to prepare an electronic version of your article. In: Jones BS, Smith RZ, editors. *Introduction to the electronic age*, New York: E-Publishing Inc; 1999, p. 281–304

[1] Hatziargyriou, N., Asano, H., Iravani, R., Marnay, C.. *Microgrids*. IEEE Power and Energy, vol. 5, pp.78 - 94,July 2007.

[2] Oyarzabal, J., Jimeno, J., Ruela, J., Engler, A. and Hardt, C.. *Agent based micro grid management system.* IEEE International Conference on Future Power Systems, pp.1-6 , Nov. 2005 .

[3] Rahman, S., Pipattanasomporn, M.and Teklu, Y.. *Intelligent Distributed Autonomous Power System (IDAPS)*. IEEE Power Engineering Society General Meeting, pp.1-8, June 2007.

[4] Logenthiran, T., Srinivasan, D., Khambadkone, A.M.and Aung, H.N., *Multi-agent System (MAS) for Short-Term Generation Scheduling of a Microgrid*. 2010 IEEE International Conference on Sustainable Energy Technologies (ICSET) ,pp.1-6 , Dec. 2010.

[5] Hopkinson, K.M., Birman, K.P., Giovanini, R., Coury, D.V. and Wang, X. et al.. *EPOCHS: integrated commercial off-the-shelf software for agent-based electric power and communication simulation*. Proceedings of the 2003 Winter Simulation Conference, pp.1158- 1166 , Dec. 2003.

[6] WU Zhi and GU Wei. *Active power and frequency control of islanded microgrid based on multi-agent technology* Electric Power Automation Equipment, vol. 29, pp.57-61 , Nov.2009 .