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DESIGNING AN ENERGY STORAGE SYSTEM FUZZY PI CONTROLLER IN MICROGRID FOR ISLANDED OPERATION

Heung-seok Lee, Bon-gil Koo, June-ho Park
Dept. of Electrical and Computer Engineering
Pusan National University Busan, Republic of Korea
zznada@naver.com, Cancer2000@hanmail.net, parkjh@pusan.ac.kr

***Abstract*— The microgrid is operated in the grid- connected mode and the islanded mode according to the upstream grid. Commonly, microgrid operates the grid- connected mode. But, when a fault occurs in the upstream grid, it should disconnect and shift into islanded operation mode. It is important to maintain the voltage and frequency constant values in islanded mode. To achieve these management goals appropriately, In this paper, the coordinated control strategy between Diesel generator and BESS(Battery Energy Storage System) is needed. And a fuzzy PI controller is proposed to improve the frequency and voltage control performance of the BESS. The performance of suggested Fuzzy PI Controller and coordinated control were simulated by PSCAD/EMTDC.**

***Index Terms*— Coordinated Control, BESS, Fuzzy Logic Controller.**

I. INTRODUCTION

All Microgrid is made up of Distributed generators, Distributed Sources, renewable energy sources, Load, etc. The Microgrid operates in grid-connect mode, but, when a fault occurs in the upstream grid, it should disconnect and shift into islanded operation mode. In grid-connect mode, the frequency and voltage of the microgrid is maintained by the main grid. In an islanded operation, however, which has relatively few microsources, the local frequency control of the microgrid is not straightforward. During a disturbance, the frequency of the microgrid may change rapidly due to the low inertia present in the microgrid.

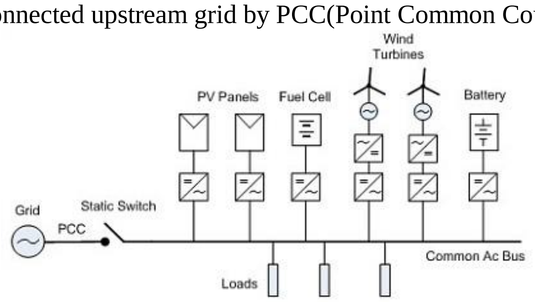
Therefore, local frequency control is one of the main issues in islanded operation. To achieve the management goals in two different operation modes, the cooperative control strategy is needed[1].

This paper presents coordinated control between Diesel generators and BESS using Fuzzy PI Controller. Fuzzy PI Controller is used at BESS charge and discharge process in microgrid for islanded operation.

II. MICROGIRD

A. Configuration of the Microgrid

Microgrid consists of low Voltage distribution system with Distributed generators, renewable energy sources, ESS, load and etc.. Fig. 1 is typical configuration of microgrid. Microgrid has connected upstream grid by PCC(Point Common Coupling).



a. Sample of a table footnote. *(table footnote)*

Fig. 1. **Typical configuration of Microgrid**

B. Hirearchical control of microgrid

Microgrid has a hierarchical control structure. It has two layer: MGCC(Microgrid Central Controller) and LC(Local Controller). The MGCC is a centralized controller that deal with management function and provides power output set point to LC. LC is transmission power output set point to microsources and BESS[1].

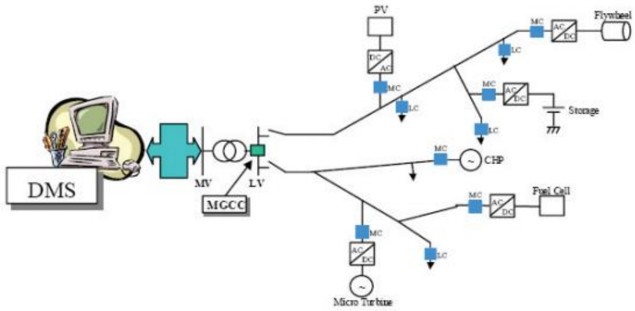


Fig. 2. **Hierarchical control structure of Microgrid**

III. COORDINATED CONTROL FOR ISLANDED MICROGRID

The main concept for islanded operation involves the cooperative control of the ESS and other controllable microsources. During islanding, the power balance between supply and demand does not match at the moment. As a result, the frequency and the voltage of the microgrid will fluctuate. The controller of inverter in the ESS responds in milliseconds. Otherwise, the diesel generator, gas engine, and fuel cell have a relatively slow response time. Obviously, the ESS should play an important role in maintaining the frequency and the voltage of the microgrid during islanded operation. In islanded operation, by proper power-balancing action of the ESS, the frequency and the voltage of the microgrid can be regulated at the normal values. However, the control capability of the ESS for balancing between generation and consumption may be limited by its available system capacity. Therefore, the power output of the ESS should be brought back to zero as soon as possible by the secondary control in MMS in order to secure the maximum spinning reserve.

Fig. 3 shows the coordinated control strategy in this paper[1].

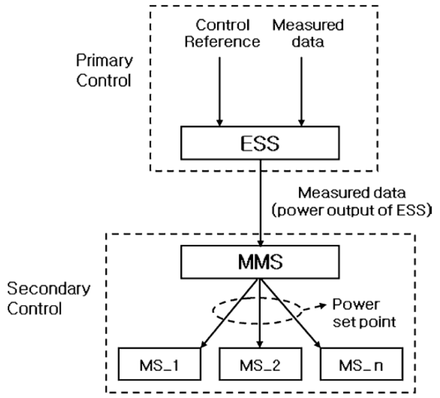


Fig. 3. **Coordinated control strategy in islanded microgrid**

IV. CONTROL STRATEGY OF ACTIVE & REACTIVE POWER OF BESS

A. Fuzzy PI Controller

1) Fuzzy Logic Controller

A Fuzzy Logic Controller can be regarded as a nonlinear static function that maps controller inputs onto controller outputs. A Controller is used to control some system, or plant. The system has a desired response that must be maintained under whatever inputs are received. The inputs to the system can, however, change the state of the system, which cause a change in response. The task of the controller in then to take corrective action by providing a set of inputs that ensures the desired response. As shown in Fig. 6, a fuzzy logic controller consists of four main components, which are integral to operation of the controller [3-4].

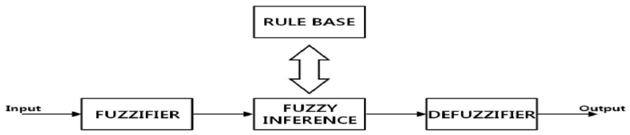


Fig. 4. **General configuration of fuzzy logic controller**

2) Fuzzy PI Controller in BESS

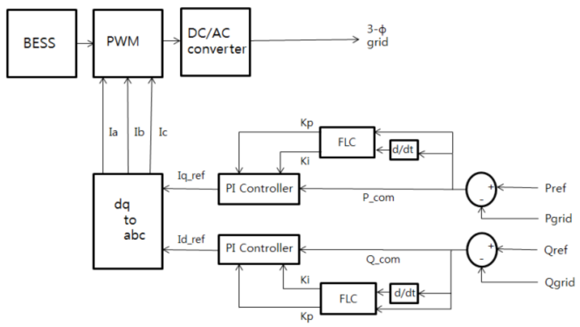


Fig. 5. **General configuration of fuzzy PI controller of the BESS**

Value of compensation of BESS is $P_{\_com}$ and differential of $P_{\_com}$ is $dP_{\_com}$ is input value of the Fuzzy Logic Controller. Using Fuzzy Logic Controller, find the PI Controller's gain Kp, Ki. Kp, Ki is real-time update to PI Controller. In other words, PI Controller's gains are variable not fixed. So, more and faster response and control than fixed PI gains[2].

3) Desinging Fuzzy PI Controller

First, making the Fuzzy controller, We construct the fuzzy rule. The fuzzy rule is defined as a conditional statement in the form

$$If\ X\ is\ A$$
$$\text{Then Y is B}$$

Where X and Y are inguistic variables; A and B are linguistic values determined by fuzzy sets on the universe of discourse X and Y, respectively.

Second, We need to construct the membership function of Fuzzy controller at BESS for charge and discharge. As a result of a Fuzzy controller, We get the gain of PI controller. For making the membership function, Using the try & error method. The process is as follows;

TABLE I. FUZZY RULE

Ec \ E	NB	NM	NS	ZE	PS	PM	PB
NB	VL	L	ML	M	S	S	VS
NM	L	ML	M	S	VS	S	S
NS	ML	M	M	S	S	S	S
ZE	M	M	S	VS	S	M	M
PS	S	S	S	S	M	M	ML
PM	S	S	VS	S	M	ML	L
PB	VS	VS	VS	ML	ML	ML	VL

For example, A view of active power. E is a difference of reference value of active power and grid value of active power. Ec is differential of E.

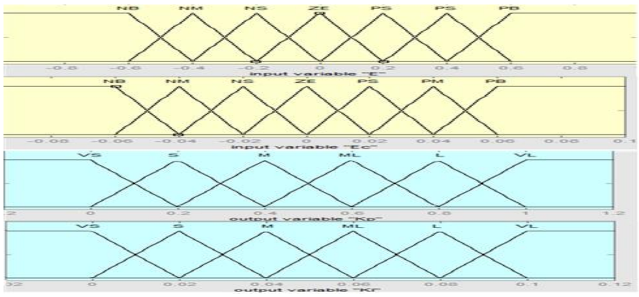


Fig. 6. **The membership function for the input E and Ec, output Ki and Kp**

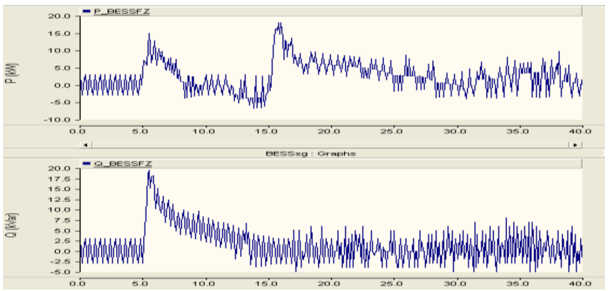


Fig. 7. **Output power of BESS**

In fig 6, 7 are the process of obtaining the optimal membership function at BESS. Using the membership function of fig 6, then the output of BESS is fig 7. This output is not suitable. So, we apply another membership function.

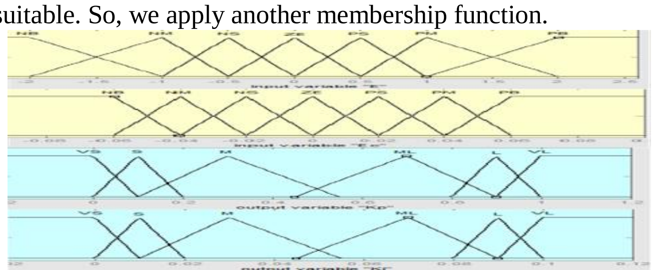


Fig. 8. **The membership function for the input E and Ec, output Ki and Kp**

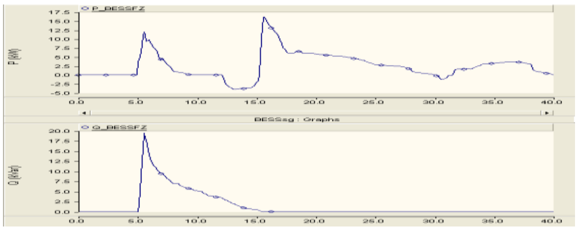


Fig. 9. **Output power of BESS**

In fig 8,9 are the process of obtaining the optimal membership function at BESS. Using the membership function of fig 8, then the output of BESS is fig 9. This output is suitable. So, we apply fig. 8 of membership function.

4) Wind generator

In fig 10 is the graph of wind speed and wind generation power output. The wind speed was applied randomly. The wind generator power output is depend on wind speed. When the wind speed is faster to increase active power generation. Like Fig 10. But, reactive power is decrease. Because the wind generator are composed with squirrel cage induction generator. The squirrel cage induction generator's characteristic is absoring reactive power in order to the active power output. So, reactive power is decrease when active power is increase.

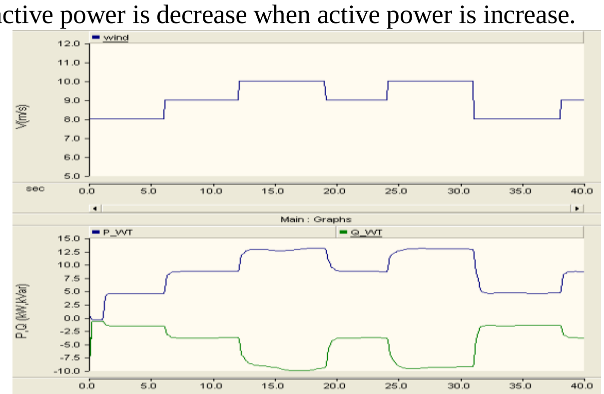


Fig. 10. **Wind Speed and Wind generation output**

V. SIMULTAION

Fig. 11 shows the configuration of the microgrid test model. The Microgrid system consists of Diesel generators, BESS, STS, Load and Wind generators. The details of test system are given in Table II.

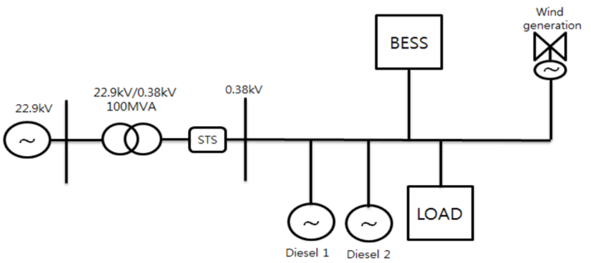


Fig. 11. **Microgrid test model**

TABLE II. COMPONENT OF MICROGRID

ITEM	**Description and Parameters**
Test System Configuration	Diesel generators Wind generator BESS Load
Generation Capacity	Diesel generator : 50kW, 40kW Wind generator: 20kW BESS : 20kW
Load	90kW+j25kVar

A. Simulation result

A simulation platform under the PSCAD/EMTDC environment was developed to evaluate the dynamic behavior of the microgrid. The initial value of Microgrid Load is 60kW+j25kVar, Diesel 1 is 30kW+j8kVar, Diesel 2 is 20kW+j4kVar and BESS is 0kW because microgrid is grid-connected mode. The two consecutive events were applied. A disconnect from the utility grid occurred at t=5s and the active load increased from 60kW to 90kW at t=15s.

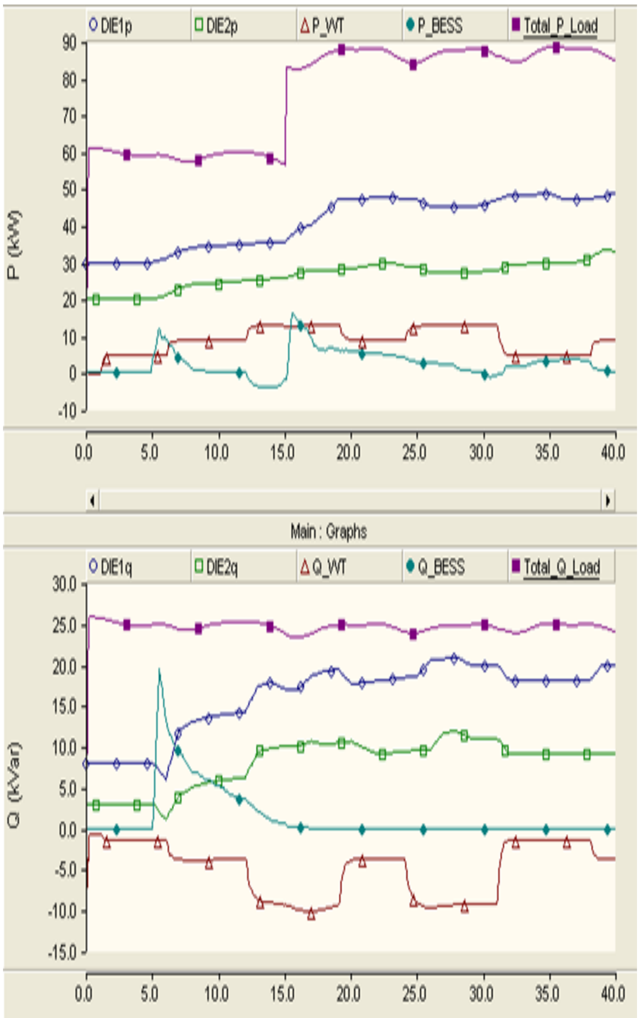


Fig. 12. **Result of Simulation**

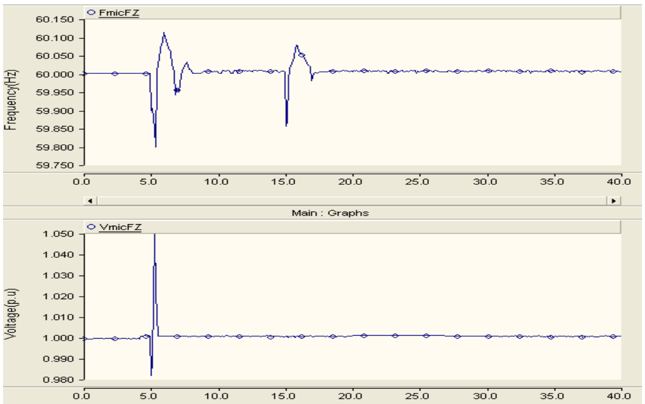


Fig. 13. **Frequency and Voltage graph**

In fig. 12 After islanding, the power output of BESS changes from zero to certain value to control the frequency and the voltage in microgrid. At the time, Diesel generators power output also changes for meeting power supply and demand in microgrid. In the event of a active load increased from 60kW to 90kW at t=15s. The power output of BESS changes immediately. In succession the power output of BESS changes to zero for preparing to inject or absorb power in microgrid. In Fig 9. Also, coordinated control was correctly operation. For this reason, In Fig. 13 microgrid voltage and frequency are stability.

VI. CONCLUSION

In this paper, proposed a Fuzzy PI Controller for active, reactive power control at BESS in islanded microgrid operation. Microgrid is non-linear system and difficult for mathematical modeling. So, PI Controller that using fuzzy logic is easier than general PI Controller to model analysis. Because fuzzy logic has strength to non-linear model analysis and need not mathematical modeling and robustness.

The coordinated control between BESS and Diesel generators, during islanding, results that the BESS can handle the frequency and the voltage. But, BESS have a capacity for energy storage. Therefore, power output of ESS should be brought back to zero as soon as possible. At the time output of diesel generators are increased to meet power demand and supply.

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