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# RTDS를 이용한 신재생에너지 기반 마이크로그리드 시뮬레이션 해석

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# Simulation analysis of a renewable energy based microgrid using RTDS

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**Abstract** - Due to enhanced demands on quality, security and reliability of the electric power energy system, a microgrid has become a subject of special interest. In this paper, output characteristics of energy storage system (ESS) with an electric double layer capacitor (EDLC) and battery energy storage system (BESS) of a renewable energy based microgrid were analyzed under grid-connected and islanded operation modes. The microgrid which consists of photovoltaic and wind power turbine generators, diesel generator, ESS with an EDLC, BESS and loads was modeled using real time digital simulator. The results present the effective control patterns of the microgrid system.

## 1. Introduction

Nowadays, as the demand of the quality, security and reliability of the electrical energy and power supply has become increasingly higher, the traditional bulk grid can no longer meet the demand because of its own flaws. A microgrid is viewed as an alternative plan for this problem [1].

A microgrid can be defined as an integrated energy system consisting of distributed generators such as photovoltaic (PV) and wind power generators with power electronic converters, energy storage devices (i.e batteries, super-capacitor and flywheels) and customer loads, which can operate either in grid-connected or islanded operation mode [2]. A microgrid can improve security and flexibility, and therefore it will be the direction of future development. As an essential part of a microgrid, energy storage system plays an important role [3] for smoothing output power oscillation of renewable energy and so on.

Simulation analysis of a renewable energy based microgrid using real time digital simulator (RTDS) is investigated in this paper. The modeled microgrid consists of PV and wind power generation systems, battery energy storage system (BESS), energy storage system (ESS) with an electric double layer capacitor (EDLC), diesel generator and loads.

The simulation results show the characteristics of BESS and ESS with an EDLC during either grid connected or islanded operation mode. The study results can effectively be utilized to develop management system for a microgrid.

## 2. Microgrid modeling using RTDS

Table 1 shows the capacity of each systems in the microgrid which consists of wind power generator, PV power generator, diesel engine generator, ESS with an EDLC, BESS and loads. The simulations in this paper were implemented for both grid-connected operation mode and islanded operation mode.

**<Table 1> Capacity of each systems**

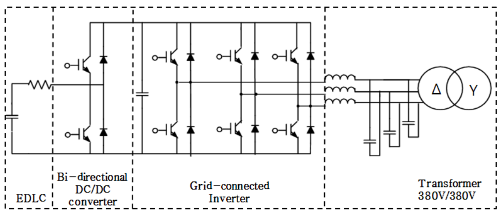
| System | PV array | Wind turbine | Diesel Engine | EDLC | BESS |
|---|---|---|---|---|---|
| Capacity | 20 kW | 30 kW | 50 kW | 150 kW | 70 kW |

### 2.1 ESS with an EDLC modeling

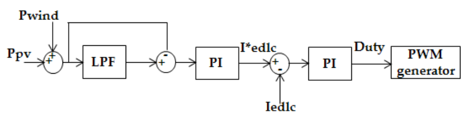
Fig. 1 shows the configuration of the ESS with an EDLC. EDLC bank parameters are given in Table 2. EDLC is charged and discharged by bi-directional DC/DC converter and DC-link capacitor is connected to the grid through inverter. If PV and wind power generation systems produce electric power more than the demanded then EDLC charges power from renewable energy source (charge mode). If PV and wind power generation systems produce electric power less than the demanded then EDLC supplies power for grid (discharge mode). Output power oscillation of renewable energy is smoothen by repeating charge or discharge mode of EDLC. The control block diagram of ESS is shown in Fig. 2. Fig. 3 represents the control block diagram of grid-connected inverter. DC-link voltage is maintained and DC power is converted to AC power by grid-connected inverter.

**<Table 2> EDLC bank parameters**

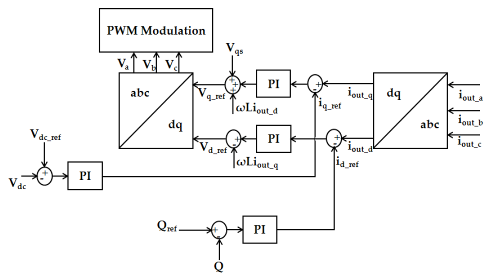
| | |
|---|---|
| Rated voltage | 369 V |
| Stored energy | 4.5 MJ |
| Capacitance | 66 F |




**<Fig. 1> Configuration of ESS with an EDLC**



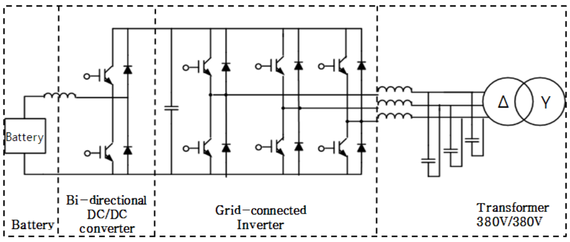

**<Fig. 2> Control block diagram DC/DC converter for ESS with an EDLC**



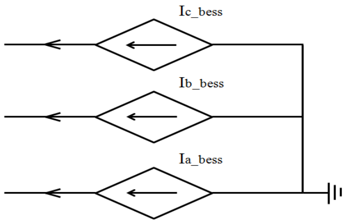

**<Fig. 3> Control block diagram of grid-connected inverter**

### 2.2 BESS modeling

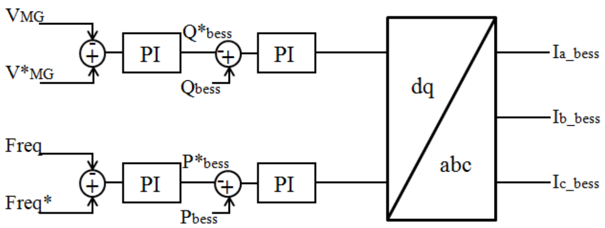
BESS outputs power as much the ordered value from energy management system(EMS) but EMS was not considered in this paper. Fig. 4 shows the configuration of the BESS. Basic structure of BESS is the same as the power converter for EDLC. In this paper, a simplified BESS model that is made of DC current source was used instead of real BESS model. Fig. 5 shows the configuration of simplified BESS. BESS controls not only frequency of the microgrid as 60 Hz but also voltage of the microgrid as 380V. Control block diagram of BESS is presented in Fig. 6. Frequency of the microgrid is controled by a d-axis current control, the voltage of the microgrid is controled by q-axis current control. Through dq reverse transformation, each of 3 DC current sources produces current to maintain frequency and voltage of the microgrid properly.




<Fig. 4> Configuration of BESS




<Fig. 5> Configuration of simplified BESS

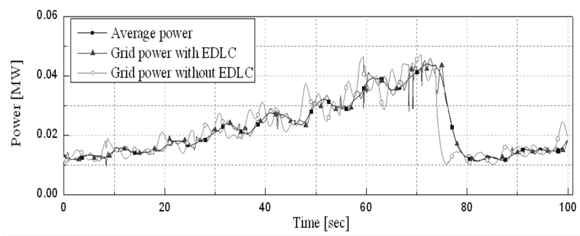



<Fig. 6> Control block diagram of BESS

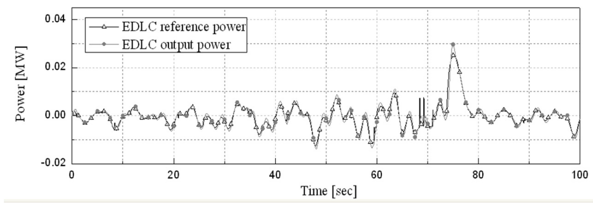
## 3. Simulation results

### 3.1 Grid-connected operation mode

As shown in Fig. 7, output power oscillation of renewable energy sources is stabilized by EDLC. Fig. 8 shows EDLC reference output power value for smoothing oscillation and actual EDLC output power.



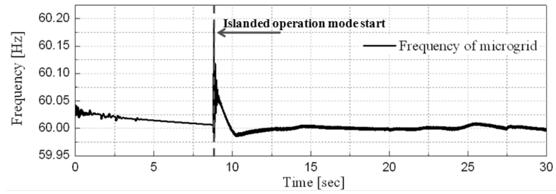

<Fig. 7> Smoothen power of grid by EDLC



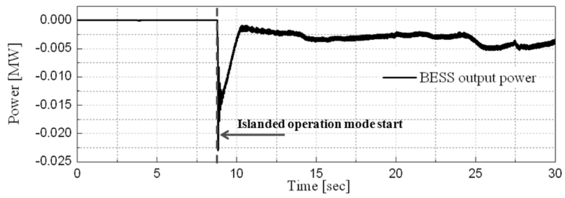

<Fig. 8> Reference power and actual output power of EDLC

### 3.2 Islanded operation mode

Fig. 9 represents that microgrid is detached from grid at 7 sec, and in that very same instant, a frequency of microgrid rises but immediately it is maintained about 60 Hz by BESS. The output power of BESS is fluctuated for control the frequency of microgrid as shown in Fig 10.




<Fig. 9>Frequency of microgrid in islanded operation mode




<Fig. 10> Output power of BESS

## 4. Conclusions

This paper presents the analysis results of a renewable energy based microgrid. Microgrid which has PV and wind power generation systems, diesel generator, ESS with EDLC, BESS and loads was modeled using RTDS. The study investigates a control method of ESS with an EDLC and BESS for microgrid. ESS with an EDLC effectively made renewable energy source output power smooth because of the high response speed of EDLC. Also, BESS controled frequency of microgrid effectively.


### Acknowledgements

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### [Reference s]


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