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DISTRIBUTED POWER METHOD FOR OPERATING THE MICRO-GRID

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ABSTRACT

Among researches in the use renewable energy resources, the study is actively in progress about micro-grid system applied DC distribution. Wind and photovoltaic (PV) sources which used at micro-grid as distributed power have flexible generation. When comparing with flexible generation curve and demand load curve, the produced power of micro-grid has deficient or excess case. So, Only pure generation of solar and wind turbine is hard to achieve stable power supply. Because of these reason, operating methods need for stable power supply. This paper analyzes the daily pattern of power and presents the operating methods of micro-grid consist of PV module and wind turbine. Also, the operating method checked through simulation.

I. INTRODUCTION

As the interest in environmental problems increased, the study has been proceeding about energy source without pollutants. The micro-grid is designed to be a stand-operation using renewable energy. So, the micro-grid includes PV module and wind turbine to generate power. Fig. 1 shows the general micro-grid including distributed power. This micro-grid is possible to generate self-power and supply stable power by Energy Storage System (ESS). In case of PV modules, solar power which is one of power sources of micro-grid is affected by insolation. The generated solar power increases in the day and is zero in the night. On other hand, wind power is affected by wind speed. The wind power is possible to generate all the time. The varying wind speed affected to generated wind power [1]-[2]. Regardless of production of power, the average load power changes depending on demand. Thus, total energy can be insufficient or excessed than required power.

To solve this problem, this paper will explain the micro-grid system in section 2. Then, Section 3 analyzes the supply power and demand power of the micro-grid. The operating algorithm will be introduced in section 4. Simulation result of control will be given in section 5. The experimental results are shown in section 6. The conclusion will be given in section 7.

II. STRUCTURE OF MICRO-GRID SYSTEM

Fig. 2 shows detail circuit of micro-grid including PV module, wind turbine, battery and grid. Wind turbine‘s output is AC power because of the use of synchronous generator.

The direction of power generated wind turbine is unidirectional from AC to DC bus. Wind turbine is connected to DC bus through AC/DC PWM converter. PV module converts isolation to low DC voltage using semiconductor. The direction of power generated PV module is unidirectional from DC to DC bus. The boost converter is used between DC bus and PV module to match voltage level of DC bus with PV output. According to the control state of micro-grid, battery is charging or discharging.

The bi-directional converter is used between DC bus and battery for charging and discharging. In preparation for an excess current, the bi-directional converter needs transformer. The transformer prevents secondary accident because of insulation. Thus, isolated full-bridge DC/DC converter is used between DC bus and battery.

The power from the distributed powers and grid is transferred through bi-directional DC-DC converter. Because the distributed power in this system generates uncontrollable one-way power, common DC-link voltage control is required to control power of grid and load. Also, the common DC-link voltage should be controlled constant. DC-link voltage control is performed through bi-directional DC-DC converter between grid and common DC-link. The bi-directional

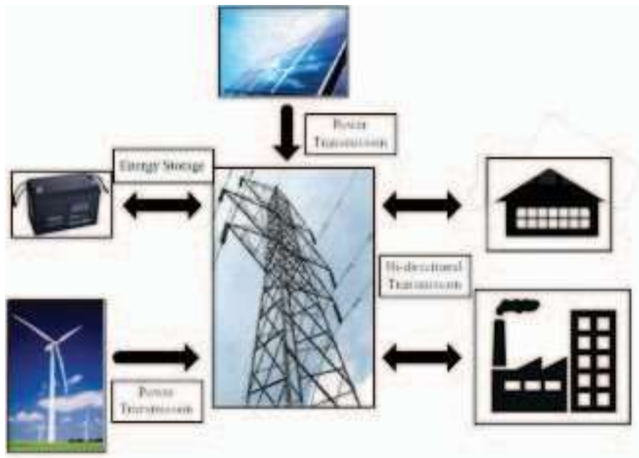
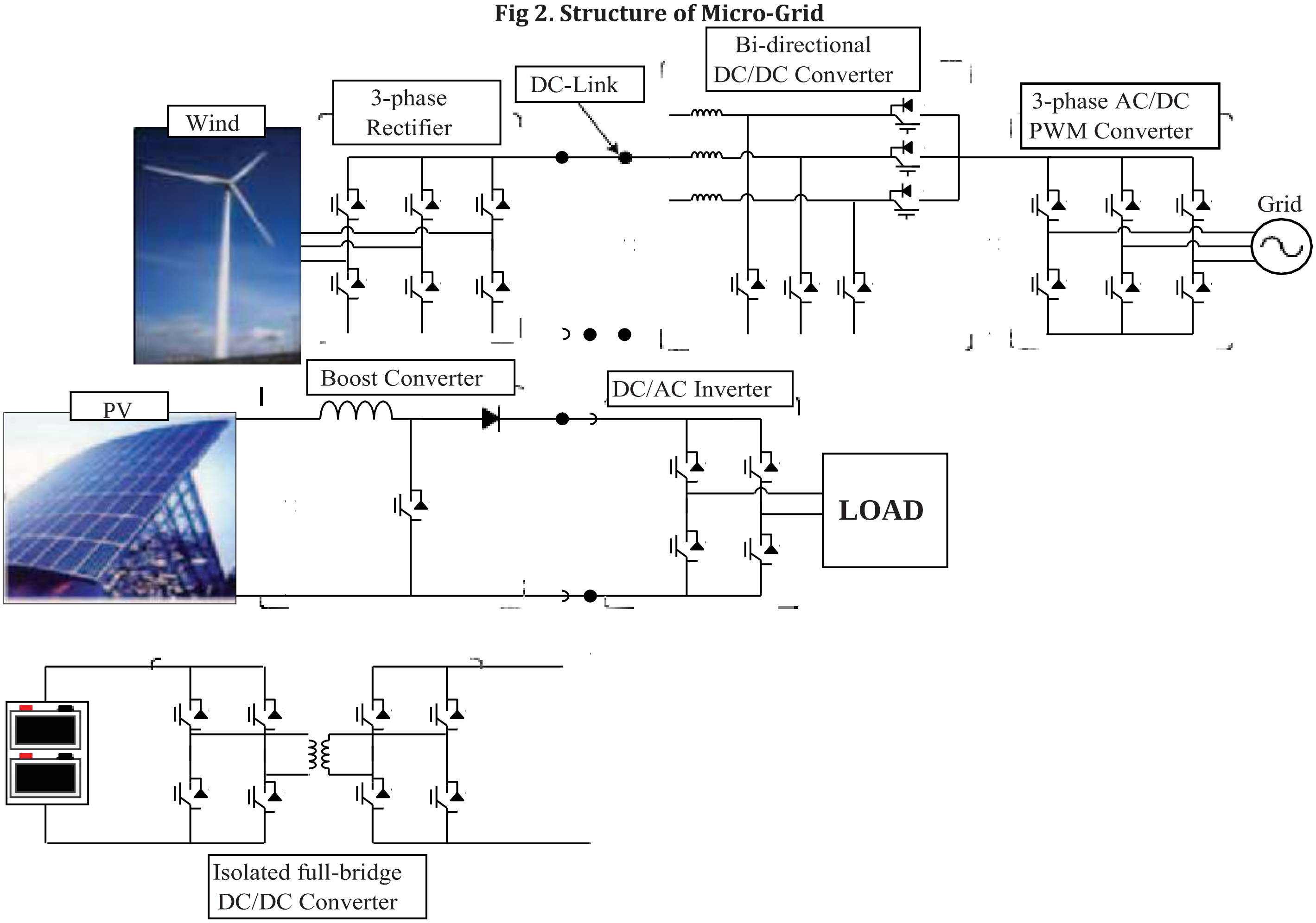


Fig 1. Configuration of Micro-Grid System

Fig 2. Structure of Micro-Grid



DC-DC converter is configured interleaved for stable DC-link control. In terms of constant common DC-link voltage control, DC-link voltage is increased when the power generated from PV and wind turbine is higher than load power. In order to constant DC-link voltage control, the residual power is transferred to grid. In the contrary, when the load power is higher than generated power, grid power handles load power for constant voltage control.

III. ANALYSIS OF SUPPLY AND DEMAND POWER OF MICRO-GRID

When generating power in a clean energy, it is influenced by the weather conditions or the place of generation facilities.

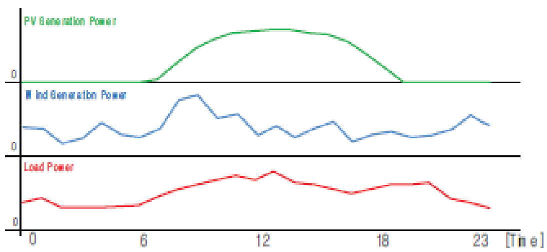


Fig. 3. The power curve in micro-grid

Therefore, PV and wind power is connected to the micro-grid shows a different power curve produced according to the weather, as shown Fig. 2. PV is affected only at the time the sun floating. Thus, PV can be produced electric power only on the morning and afternoon floating in the sun. Through the sunlight, the amount of power actually generated is calculated from (1).

$$P_p = V_p \times I_p \qquad (1)$$

Becausewind power is dependent only on the wind speed, regardless of the time, this generation is always fluidly changed. Using a sensor as with PV the electric power generated by wind power generation is calculated as (2).

Since the power consumed by the micro grid is proportional to the electric power demand, peak hour power demand has shown the highest. Figure 3 shows briefly the power relationship according to the time. Load power that is used for comparison is calculated as (3).

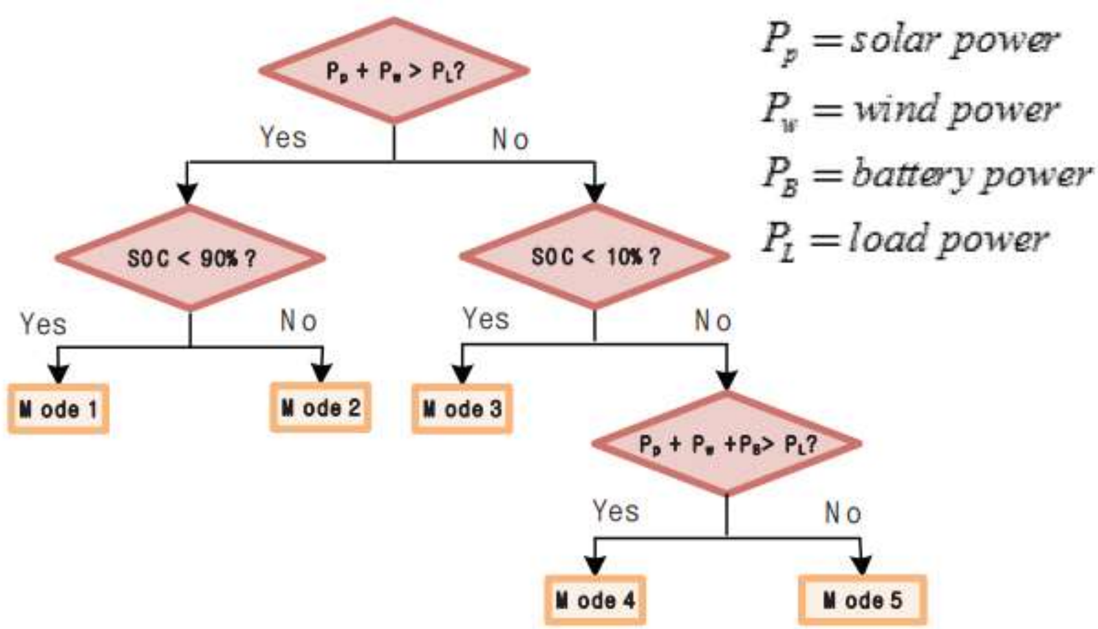


Fig.4. proposed algorithm

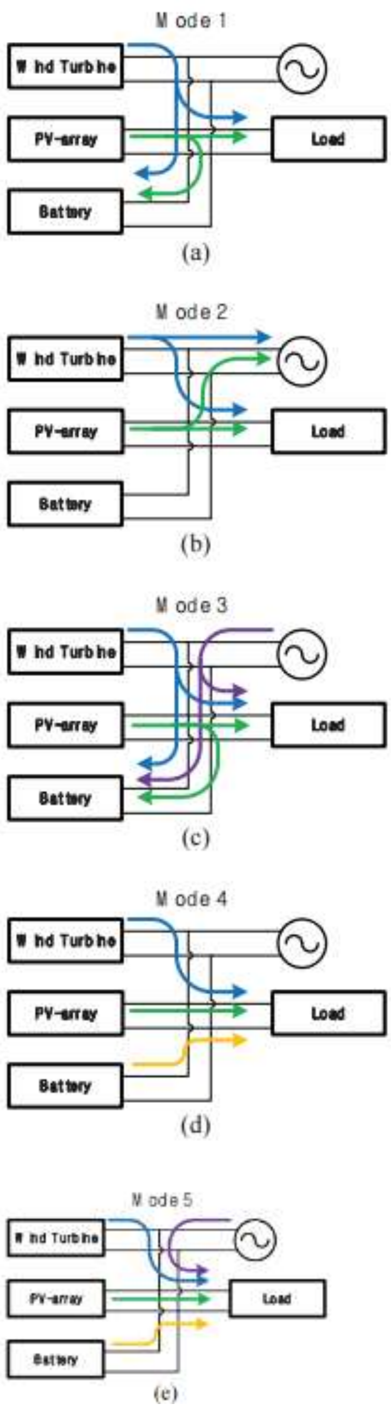


Fig. 5. Power flow of (a) mode 1, (b)2, (c) mode 3, (d) mode 4, (e) mode 5.

$$P_L = V_L \times I_L \quad (3)$$

Currently power of the Batteries installed as a backup or responsible for the load purpose is equal to (4). Since the charge capacity of the battery is limited, the power of the battery should consider the SOC as follows:

$$P_B = V_B \times I_B \quad (4)$$

Fig. 4 shows algorithm considering flexible generation and load. The proposed algorithm consists of 5 modes. Once, the proposed algorithm preferentially checks power generated by solar and wind. Because both the energy source is in flux, the solar power and wind power are considered at same time. If the power generated by renewable energy sources is higher than the required power, the surplus power transmits to battery or grid.

$$P_W + P_p \text{ Ç } P_L + P_B \quad (5)$$

The power relationships of mode 2 is the same as (6). Mode 2 is supplied to the load and the grid because the battery is fully charged. At this time, by the reverse transmission of power into the grid, the financial profit occur.

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$$P_W + P_p \text{ Ç } P_L + P_{grid} \quad (6)$$

Mode 3 is determined by the current SOC. In mode 3, the grid, PV and wind power is supplied to the load and charges the battery at the same time. Power relationship at this time is the same as (7).

$$P_W + P_p + P_{grid} \text{ Ç } P_L + P_B \quad (7)$$

The other modes decide the use of grid. If the load power is higher than the total power except grid in micro-grid, the operating mode is mode 4. Mode 4 supplies a power produced by wind, PV and battery to the load without using the grid. Power relationship at this time is the same as (8).

$$P_W + P_p + P_{grid} \text{ Ç } P_L \quad (8)$$

In mode 5, because the generated power and the battery power cannot meet the power demand, the grid is used together. Power relationship at this time is the same as (9).

$$P_W + P_p + P_B + P_{grid} \text{ Ç } P_L \quad (9)$$

IV. THE APPLICATION OF ALGORITHM

Fig. 6 shows the application of the proposed algorithm. To compare with each of power, first block uses a sensor on each output. The value of sensor transmits to the algorithm block. The algorithm block separates modes from 1 to 5. Each of modes determines references of ESS and Grid. The references are applied the converters which located between the DC bus and the device. The grid reference and the ESS reference are divided into positive and negative. If grid reference is positive, the flow of the electric power flows from grid to DC bus. If the opposition, the direction of power flow is reverse. In case of ESS, if the ESS reference is positive, the battery is charging. In contrast, the battery is discharging. Finally, the output is sensed again as current value.

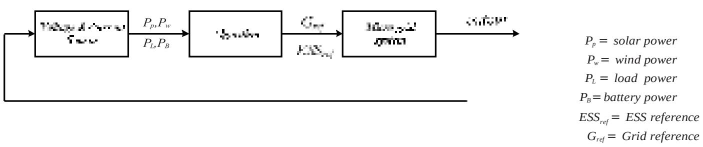


Fig. 6. The control diagram of micro-grid

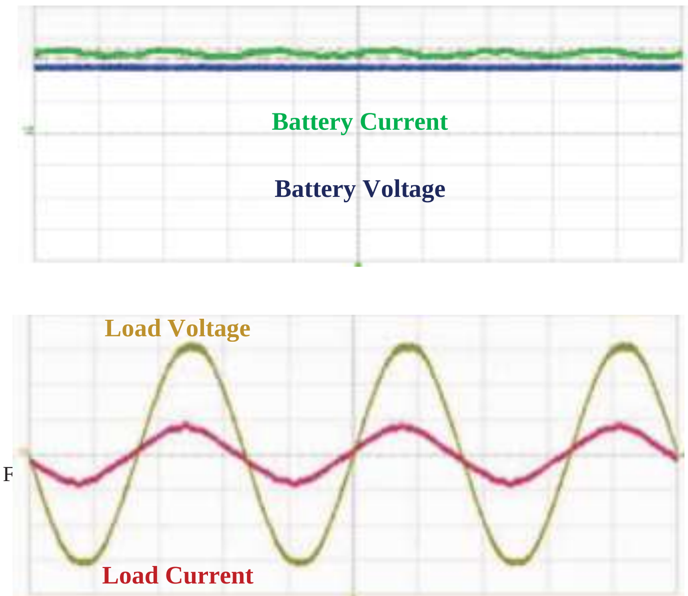
V. SIMULATION & EXPERIMENT RESULTS

Fig.7 shows the battery discharging current corresponding to the PV power generation and wind generation. Capacity of system is consisted of PV 3kW, wind turbine 5kW and battery 3kW. Wind power and PV affected by the environmental factors are non-linear. The battery should handle with the load power when generation is lower than load power. It can be confirmed that the discharge current of the battery is reduced during the time to increase solar power and wind power. Also, It can be seen that increasing discharge current to the battery during the time to decrease solar power and wind power.

Fig. 7. Waveforms of PV, wind, battery, and dc-link waveform.

The experiment is composed by using TMS28335.PV module's capacity is 3kW. Wind power's Induction Motor (IM) is 5kW. Battery's capacity is composed of lead-acid batteries 3kW. The experiment was progressed by adjusting the load according to pattern for checking control by the algorithm. Fig. 8 shows that battery supplies power to the load by discharging. The waveform of Fig. 8 is measured in the mode 4 and mode 5. Fig. 9 is wind power's waveform when IM generated power. IM is rotated by load motor. Also 3-phase voltages are generated normally.

Fig. 8. Voltage and current waveform from battery to load



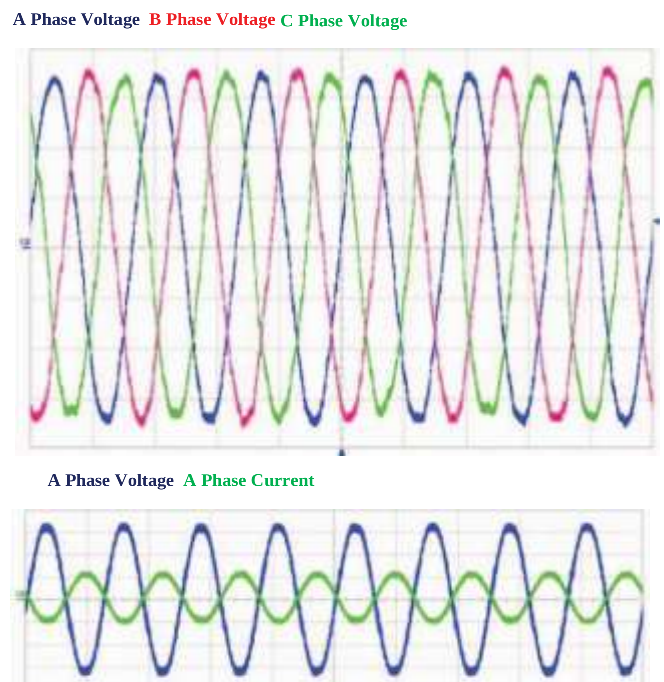


Fig. 9. Voltage and current waveform from wind turbine to de-link.

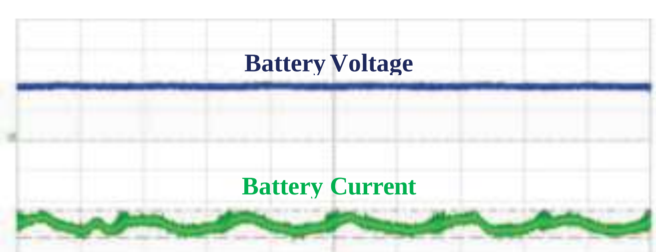
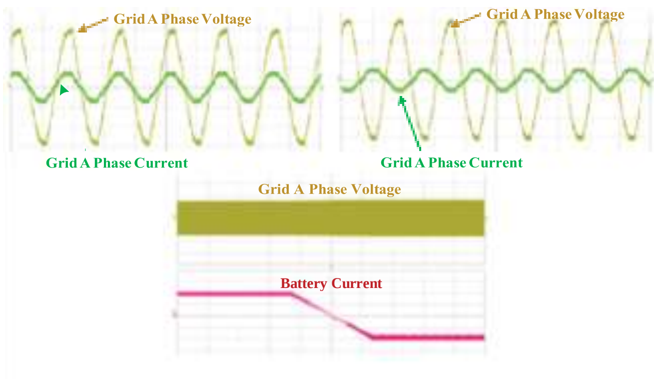


Fig. 10. Voltage and current waveform from PV to dc-link

Fig. 11 Voltage and current waveform from dc-link to grid.



The Waveform of Fig. 9 is measured at all modes. Fig. 10 is a solar power waveform supplied to the dc-link. Fig. 10 shows that a constant voltage level formed and a current flows. This waveform will be measured during the day. Fig. 11 shows supplying power from grid to dc-link. Also, Fig. 11 shows reverse transmission from dc-link to grid. Fig. 11 is measured in mode 2, 3, and 5.

VI CONCLUSION

This paper analyzes the daily power patterns of PV and the wind turbine in micro-grid. Also, this paper proposes the operating algorithm for stable and efficient power supply in micro-grid. The effect of algorithm is verified through the simulation.

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