Grid-Connected Peak Load Compensation System Based on Lithium Polymer Battery Energy Storage System

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ABSTRACT

we proposed a grid connected peak load compensation system with high discharge current characteristics based on lithium polymer battery for development of the next generation power-station. The lithium polymer battery has faster discharge current characteristics than conventional battery, so that can compensate high active power demanded by load in a short time using the low capacity battery bank. Therefore, it is possible to control power leveling of grid by measuring storage energy of battery and active power which is needed from load. The validity of proposed system was verified through the simulation and experiment.

1. Introduction

Battery Energy Storage System (BESS) enables to improve loading factors, to delay investment on spinning reserve, voltage and frequency control, generation and transmission line, and to improve the reliability of supplies. However, the previous Battery Energy Storage System is an energy saving system, based on lead-acid batteries. This system requires 1:1 ratio of the system capacity to the loaded energy capacity. It contains limitations on energy density and the volume. It also has the potential secondary environmental pollution due to battery wastes.

This paper proposes grid-connected peak-load compensation system, using lithium-polymer battery, in order to overcome problems of the secondary batteries. Lithium-polymer battery enables discharge with high current rate, and it can supply power by a small battery capacity to instant peak-load because of high discharge characteristic[1-4]. Through simulation, the characteristics of the overall system performance are confirmed, and the performances are verified by the experimental results using 10kW prototype.

2. Configuration of system

Fig. 1 shows a block diagram of peak-load compensation system. The proposed system is composed of a battery bank, a bi-direction DC/DC converter, and a bi-directional DC/AC inverter. The bi-directional DC/DC converter is able to transfer power between the battery bank and the bi-directional DC/AC inverter in both directions, either in battery charging mode or in battery discharging mode. The three-phase bi-directional DC/AC inverter is synchronized and connected to the grid. The inverter controls DC-link voltage desired level of 650[V].

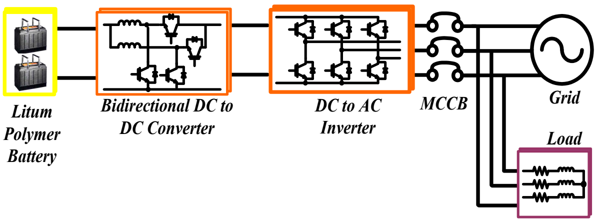

Fig. 1 Peak load compensation system block diagram

2.1 Lithum-Polymer Battery

Lithium-polymer battery has three times more of average voltage of 3.7[V] (4.2[V] in full) in a basic cell than Ni-Cd battery and Ni-MH battery. There is no memory effect, which reduces the capacity when the battery is not fully charged. Moreover, there is relatively small parasitic resistance, because the pole and membrane are integrated. Thus, it can be used as a battery bank with a high voltage.

Therefore, lithium-polymer battery can discharge the high-energy density with high efficiency within a short period of time, which is very compatible for supplying the peak-load with a small capacity battery.

Table 1 Specification data of Li-Polymer battery

Battery Bank		
Nominal Voltage		300[V]
Configuration		80[cell]
Cell Specification		
Typical Capacity		31.0 [Ah]
Nominal Voltage		3.7 [V]
Charging Condition	Max Current	62.0[A]
	Voltage	4.2[V]±0.03[V]
Discharging Condition	Continuous Current	155.0 [A]
	Peak Current	310.0 [A]
	Cut-off Volage	2.7[V]
Cycle Life [@ 80% DOD]		>800 Cycles
Operating Temp	Charge	0~40℃
	Discharge	-20~60℃

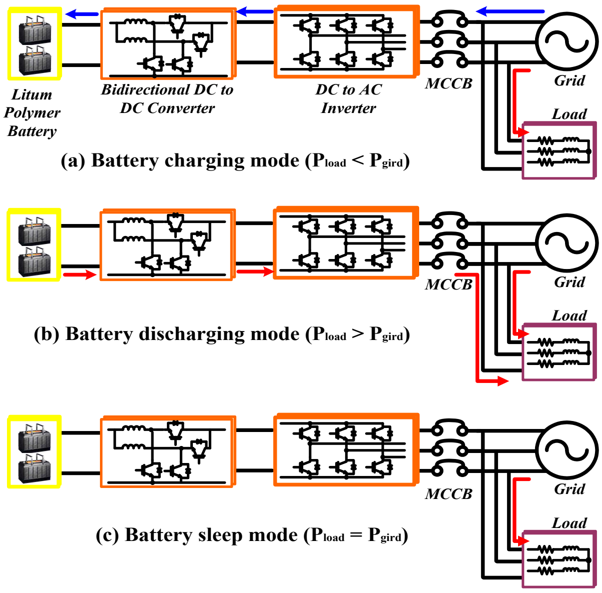

Fig. 2 Operation mode according to battery charging and discharging

2.2 Operation mode

The operation modes according to battery charge and discharge are controlled by load power. The maximum power receiving from the grid in this paper is 10[kW].

The Mode 1 is a battery charge mode and if the load power is less than 10[kW], then the system charges the batteries. The Mode 2 is a battery discharge mode and if the load power is greater than 10[kW], the system discharges the battery to compensate the peak load. The Mode 3 is a sleep mode and if the load power is between 9[kW]~10[kW] then the system do not operate.

The equation (1) represents the power relationship while battery charge mode and the equation (2) represents the power relationship while battery discharge mode. The power receiving from the grid is fixed to 10[kW].

$$\text{Battery charge mode} \quad P_{grid} = P_{load} + P_{battery} \qquad (1)$$

$$\text{battery discharge mode} \quad P_{load} = P_{grid} + P_{battery} \qquad (2)$$

If the initial grid power is 10kW, it detects the voltage and the flow of electricity of load and calculates the load power and then calculated load power will be compared with the first power system to decide the mode of battery charging or discharging and the amount of discharging and charging of the batteries.

The load power(P_{load}) can be present as equation(3).

$$P_{load} = \sqrt{3} \times 380 \times \frac{1}{\sqrt{2}} \times I_{load\,\max} \quad (3)$$

The battery charge conditions is shown in equation (4) and the initial charge current reference of the battery can be present as equation (5).

$$Battery\ Charging\ Mode: P_{load} \le 9kW, P_{grid} = 10kW \quad (4)$$

$$I_{batt\_charge\_ref} = \frac{P_{grid} - P_{load}}{V_{batt\_charge}} \quad (5)$$

On the other hand, the battery discharge condition is represented in equation (6) and the discharge current reference of the battery can be present by equation (7).

$$Battery\ Discharging\ Mode: P_{load} \ge P_{grid}, P_{grid} = 10kW \quad (6)$$

$$I_{batt\_discharge\_ref} = \frac{P_{load} - P_{grid}}{V_{batt\_discharge}} \quad (7)$$

The fig. 3 indicates the load power, Grid power and battery power according to the operating mode.

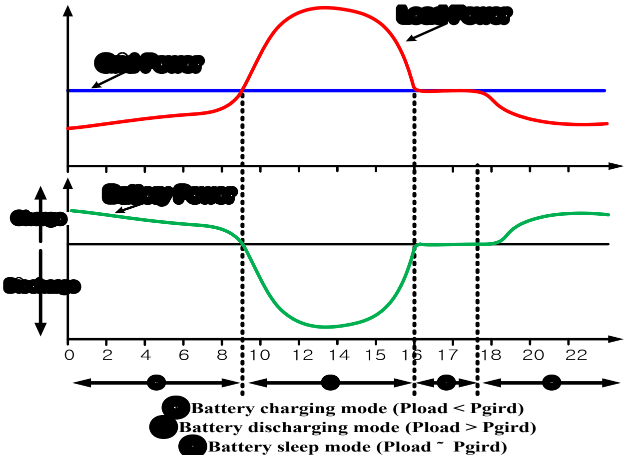

Fig. 3 A pattern of load power, gird power and battery power

3. Simulation and experimental result

The simulation was performed by using PSIM software. Fig. 4 presents the three kinds of mode according to the load variations and shows the main waveforms when charging the battery. The load power is 7kW during 0.2s˜0.4s and surplus power of the grid, which is 3kW, charges the battery.

During 0.4s~0.6s, the load capacity is 10kW and the proposed system is not working during this time. The load power becomes 20kW from 0.6s and the battery compensates 10kW demanded by load. Therefore, the grid power for load variation is also fixed to 10[kW].

Fig. 4 presents ① load power, ②grid power and ③ power for charging/discharging the battery. ④ is the gate signal of bi-directional converter when charging a battery and ⑤ is a gate signal of bi-directional converter when discharging a battery. The bidirectional dc/dc converter is not operate at the battery sleep mode since the load power is finally supplied all by grid.

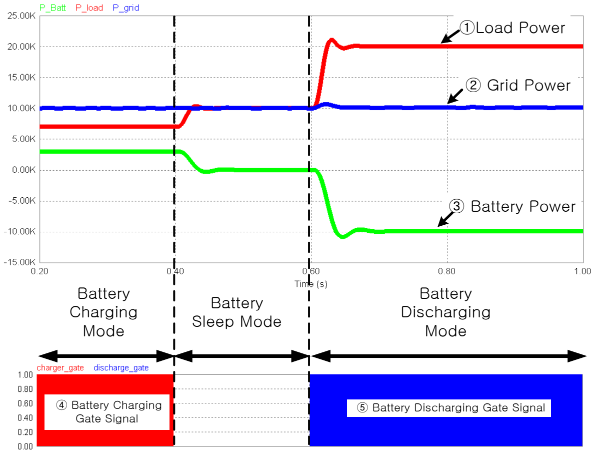

Fig. 4 Waveforms of 3 mode operation

Table 2 The parameters of the proposed system

System Capacity(P)	10[kW]	
Grid Power(P_g)	10[kW]	
Grid Voltage	Three-Phase 380[V], 60[Hz]	
Battery Nominal Voltage	Charging Mode 340[V]	
	Discharging Mode 300[V]	
DC-link Voltage	650[V]	
	Space Vector PWM	
Switching Frequency(f_s)	DC/DC Converter	15kHz
	Three-Phase Inverter	10kHz

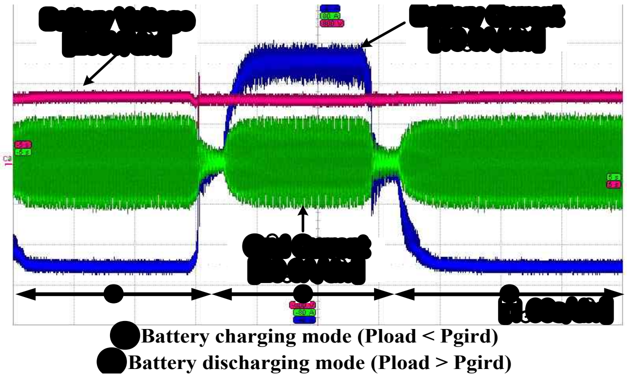

Fig. 5 Waveforms of battery charging-discharging mode operation

Fig. 5 is experimental waveforms which shows the dynamic characteristics of battery charge/discharge. In the first section, the battery current is negative since it charges the battery. And it discharges the battery to compensate the peak load on the second section.

4 Conclusion

This paper suggests a grid connected peak load compensation system based on lithium-polymer battery.

Through a simulation and experiment, it is confirmed that the proposed system controls the battery charging or discharging based on the required load power, and the grid power was kept constant power.

In the future, an additional study will be done to improve the response which appears on the behavior transition while charging or discharging.

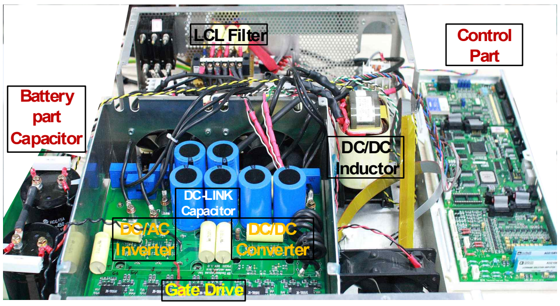

Fig. 6 Grid-connected peak-load compensation system

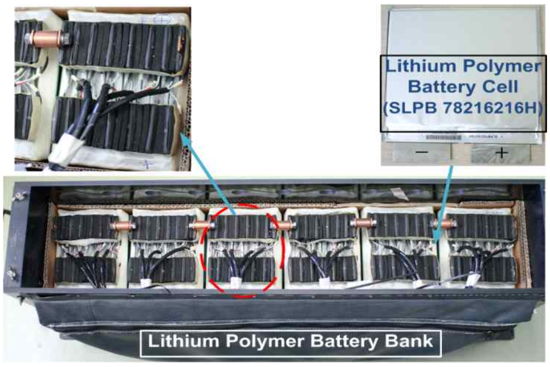

Fig. 7 Lithium-polymer battery bank

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