# Evaluation of Power Flow Control Strategy and DC−link Voltage Regulation for DC Microgrid

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## ABSTRACT

In this paper, an effective power flow control strategy (PFCS) based on the centralized control approach and a DC−link (DCV) restoration algorithm for DC microgrid (DCMG) are presented. By investigating the statuses of system power units, eleven operating modes are given to ensure the system power balance under various conditions. To avoid the system power imbalance caused by the delay of grid fault detection, a reliable DCV restoration algorithm is proposed. In the proposed scheme, when an abnormal variation of the DCV is detected, the battery instantly starts a local emergency control mode to restore the DCV to the nominal value regardless of the control mode from the central controller. The simulations and experiments are carried out to prove the effectiveness of the PFCS and the proposed DCV restoration algorithm.

## 1. Introduction

Recently, renewable energy sources (RESs)−based DC microgrid (DCMG) becomes a future trend in electric power system due to the advantages such as easy integration of resources, flexible installation location, and reliable operation. Since DCMG is a complex power system consisting of many operating modes, an effective power flow control strategy (PFCS) is essential to guarantee a stable operation of DCMG. So far, many researches based on the centralized control approach have been presented to achieve the system power balance in DCMG [1]. However, in most studies, the delay of grid fault detection and its effect on the DCV regulation and system stability have not been considered yet.

This paper presents an effective PFCS based on the centralized control method and a reliable DCV restoration algorithm for DCMG. The DCMG configuration used in this study consists of a wind power generation system (WPGS), a battery−based ESS, DC loads, and a utility grid (UG) connection system. By considering the relationship of supply−demand power as well as the statuses of system units, eleven operating modes (OMs) of DCMG are presented to ensure the stability of DC−link voltage (DCV) and power balance in DCMG under various conditions. In order to deal with the system power imbalance caused by the delay of grid fault detection, the DCV restoration algorithm is proposed. In the proposed scheme, a local emergency control mode (LECM) is introduced to restore the DCV quickly to the nominal value regardless of the control signals from the central controller (CC). Simulation and experimental result are provided to prove the effectiveness of the PFCS and proposed DCV restoration algorithm.

## 2. PFCS and Proposed DCV Regulation Scheme

Fig. 1 shows the PFCS of DCMG considered in this paper. Based on the relationship of wind power and load demand as well as the statuses of the UG and battery, eleven OMs of DCMG are determined. The control mode with star '*' indicates that it is in charge of the DCV regulation and system power balance. Symbols in Fig. 1 are defined in Table 1.

Table 1. Symbol definition for Figure 1.

| Symbol | Definition | Symbol | Definition |
|---|---|---|---|
| W | WPGS | B | Battery |
| G | UG | L | Load |
| IDLE | Idle mode | $P_L$ | Load power |
| DIS | Disconnect | SH | Load shedding |
| MPPT | Maximum power point tracking | NC/RE | No change/Load reconnection |
| VCM | Voltage control mode | DCVM−C | DCV control by charging mode |
| DCVM−R | DCV control by rectifier mode | DCVM−D | DCV control by discharging mode |
| DCVM−I | DCV control by inverter mode | BCCM | Battery current control mode |

Fig. 2 shows the proposed DCV restoration algorithm by the battery. In this figure, the execution mode (EM) denotes the operating mode from the CC while EM* denotes the final operating mode which will be applied for converter of battery. As soon as the DCV becomes lower than the first predefined minimum level of $V_{DC}^{min1}$, the LECM is triggered to restore the DCV. The restoration procedure consists of two stages. During the first stage, flag *F1* is set to 1 and EM* is assigned to BCCM, in which the battery is discharged with the maximum discharging current to restore the DCV to the nominal value as soon as possible. As the DCV approaches the second predefined minimum level of $V_{DC}^{min2}$ ( $V_{DC}^{min2} > V_{DC}^{min1}$ ), the second stage of the LECM is started. During this stage, *F2* is set to 1 and EM* is assigned to DCVM−D, in which the battery regulates the DCV to restore it completely to the nominal value. As a result, the DCV is regulated with DCVM−D by battery converter during period of detection delay. When the change of EM is detected, the local controller resets flags *F1* and *F2* to 0 to return back to the normal control mode from the LECM.

## 3. Simulation and Experimental Results

To validate the effectiveness of the PFCS and the proposed DCV restoration algorithm, the simulations and experiments

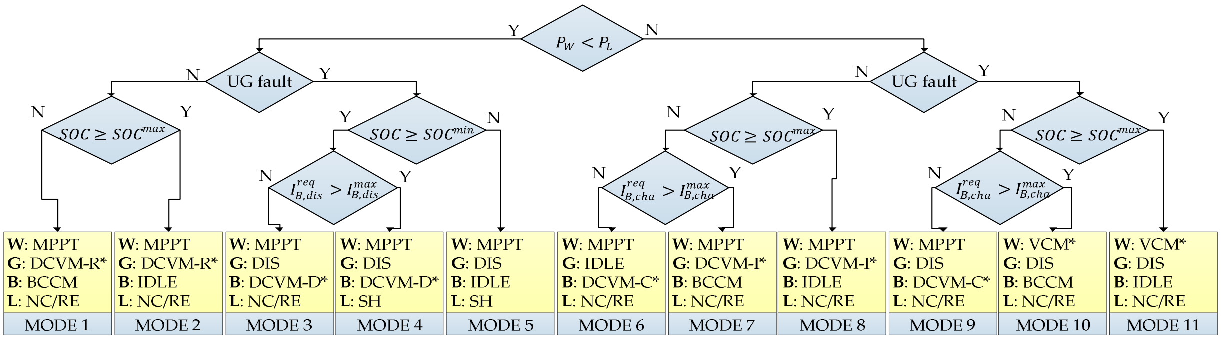

Fig. 1. PFCS of DCMG.

have been carried out. Fig. 3 shows the simulation results for the PFCS. As can be seen in Fig. 3, the DCV is maintained to the nominal value of 400 V irrespective of the variations of load and wind power. Fig. 4 shows the configuration of the experimental system including three power converters to connect the UG, battery, and WPGS in DCMG. Fig. 5 presents the experimental results for the proposed DCV restoration algorithm by the battery. As can be seen in this figure, by using the proposed scheme, the DCV is well regulated at nominal value of 400 V even in case of delay in grid fault detection.

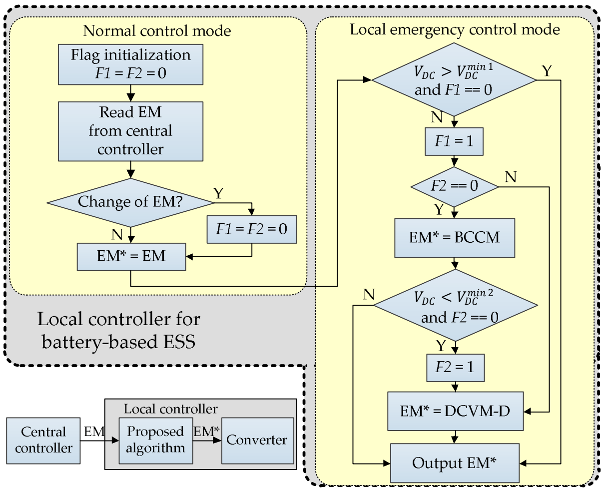

Fig. 2. Proposed DCV restoration algorithm by battery.

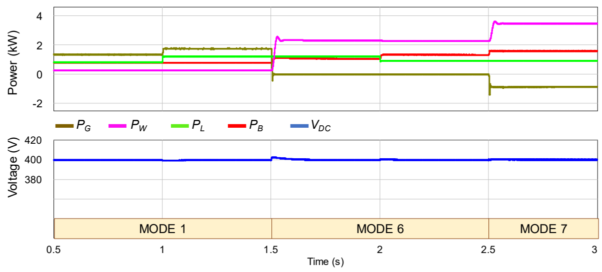

Fig. 3. Simulation results for the PFCS.

## 4. Conclusion

This paper has presented an effective PFCS and proposed the DCV restoration algorithm for DCMG. By considering the relationship of supply−demand power, the statuses of system units, the power balance of DCMG can be achieved in both the grid−connected and islanded operations. To prevent the system power imbalance caused by the delay of grid fault detection, the DCV restoration algorithm is introduced. The simulation and experimental results confirm the effectiveness of the PFCS and the proposed DCV restoration scheme.

Fig. 4. Experimental system.

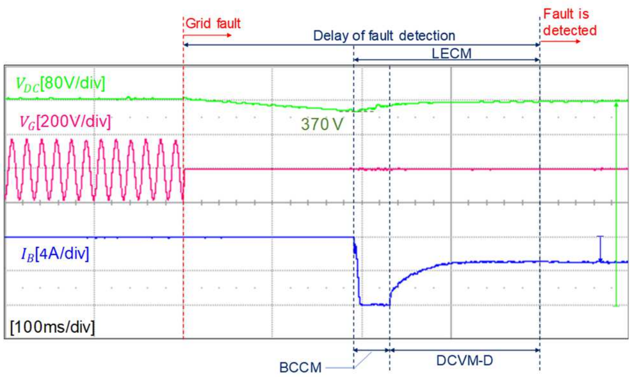

Fig. 5. Experimental result for the proposed DCV restoration.

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF−2016R1D1A1B03930975).

## References

[1] P. Sanjeev, N. P. Padhy, and P. Agarwal. "Peak Energy Management Using Renewable Integrated DC Microgrid," IEEE Trans. Smart Grid, vol. 9, no. 5, pp. 4906−4917, Sep. 2018.