Analog Controller for Battery to Stabilize DC-bus Voltage of DC-AC Microgrid

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***Abstract*—Stabilization of the DC bus voltage is an important task in DC-AC microgrid system with renewable energy source such as solar system. A battery energy storage system (BESS) has become a general solution to stabilize the DC-bus voltage in DC-AC microgrid. This paper develops the analog BESS controller which requires neither computation nor dc-bus voltage measurement, so that the system can be implemented simply and easily. Even though others methods can stabilize and control the DC-bus voltage, it has complicated structure in control and low adaptive capability. The proposed topology is simple but is able to compensate the solar source variation and stabilize the DC-bus voltage under any loads and distributed generation (DG) conditions. In addition, the design of analog controller is presented to obtain a robust system. In order to verify the effectiveness of the proposed control strategy, simulation is carried out by using PSIM software.**

***Keywords*— DC-bus stabilization, microgrid, battery control, analog controller**

I. INTRODUCTION

Distributed generations (DGs) in microgrid system are getting attractive in modern power system. A hybrid DC-AC microgrid has both DG unit and battery energy storage system (BESS), so that it is able to meet any load demand condition. One of the biggest problems in the DC-AC microgrid is to maintain the power balance between the powers supplied and load demand [1]. The mismatch between the supplied power and consuming power causes the DC-bus voltage variation, and it can lead to shutdown whole system if the system is not controlled correctly. In general, the DC-bus voltage can be regulated by either the grid-connected inverter or the BESS [2]. In this paper, we apply the BESS to avoid the DC bus voltage variation.

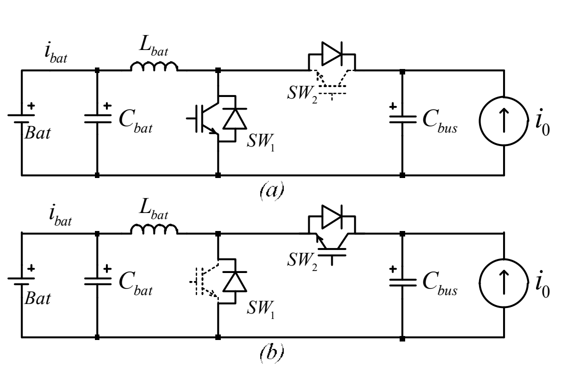

Fig. 1: BESS operation principle. (a) Discharge mode. (b) Charge mode

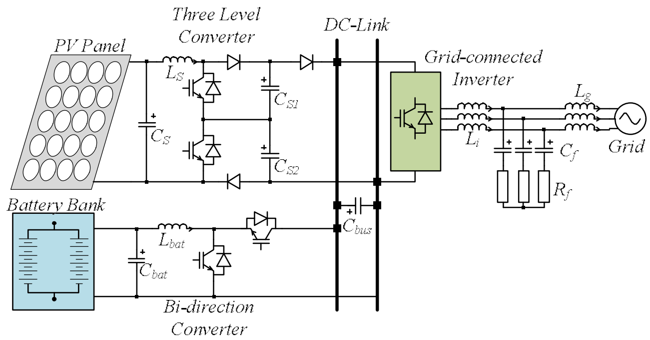

Fig. 2. Configuration of the DC-AC Microgrid

In order to control and stabilize the DC-bus voltage, Nonlinear-Disturbance-Observer-Based DC-Bus Voltage Control (NDO) [3] and DC Voltage Variation Based Autonomous Control (DC-VVBAC) [4] are introduced. However, they have complicated structure and low adaptive capability. To overcome these problems, this paper propose a topology with analog controller for BESS to stabilize the DC-bus voltage with simple structure, high capability and stability against high variation of solar source which is one of the popular DGs sources in microgrid.

II. SYSTEM CONFIGURATION AND DC BUS VOLTAGE CONTROL STRATEGY

Fig. 2 shows a typical DC-AC microgrid, which includes the solar source, the BESS, and the grid. In this system, the solar source is controlled with maximum power point tracking (MPPT), and its converter is three-level boost converter. The battery storage system is covered by bi-directional converter. The three phase inverter supplies AC power the grid and loads.

In the proposed system, the BESS is controlled by analog controller to stabilize DC-bus voltage. The DC-bus voltage depends on the power flow including the solar source and the loads. From the balanced power system, the basic relationship is obtained as follows:

$$C_{bus}\frac{dV_{bus}}{dt} = i_{bat} + i_{pv} - i_{inv} \quad (1)$$

where, C_{bus} represents the value of the DC bus capacitor; V_{bus}, i_{bat}, i_{pv} and i_{inv} denote the DC-bus voltage, output DC currents of BESS, solar source converter, and inverter, respectively.

From the battery side, the current injected from the solar source and the current absorbed by the inverter can be regarded as a combined current source as shown in Fig. 1, where C_{bat} and L_{bat} are the input capacitor and inductor of the bi-directional converter in the BESS. And, i_0 represents the total current injected to the DC bus, which can be described as

$$i_0 = i_{pv} - i_{inv} \quad . \tag{2}$$

The operation mode of BESS depends on the state of charge (SOC) of battery, the power levels of solar source, and the load. In case of BESS in standby mode, the DC-bus voltage can be controlled by the inverter or the solar source converter.

A. Discharge Mode Analysis and Controller Design

In discharge mode, the battery converter regulates the DC-bus voltage at the nominal voltage by injecting the current into the DC bus. The analog controller for battery converter in discharge mode is shown in Fig. 4.

In Fig. 4, the type 3 amplifier is selected with high gain margin and phase margin to keep the DC-bus voltage stable. The parameters of the controller are calculated to satisfy around 16 decibel gain margin and 50 degrees phase margin.

B. Charge Mode Analysis and Controller Design

In this mode, the current i_0 in (2) must be positive. In order to keep the DC-bus voltage constant, the battery must absorb amount of current i_0. The type 3 amplifier is modified to control battery converter in this mode as shown in Fig. 5. The parameters of the controller are defined to satisfy the fast response with 2kHz open loop cross frequency.

III. Simulation Results

Simulation results are shown in Fig. 3 in case that the solar source power is changed rapidly from 7kW to 4kW and the load is increased from 10A-peak to 15A-peak current. In this condition, the DC-bus voltage is decreased from 700V to 670V, and the BESS changes the mode from charge to discharge so as to maintain the DC bus voltage at 700V constant voltage after 50ms.

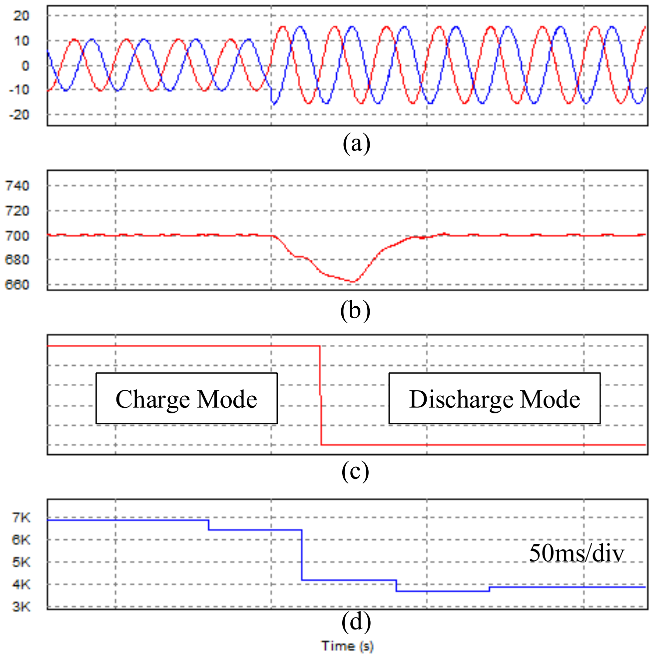

Fig. 3: (a) AC Load current (b) DC bus voltage (c) Battery mode - Low is discharge, high is charge mode (d) Solar power

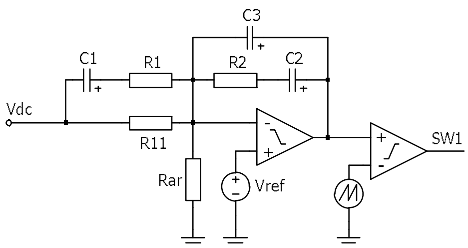

Fig. 4: Type 3 amplifier for discharging controller

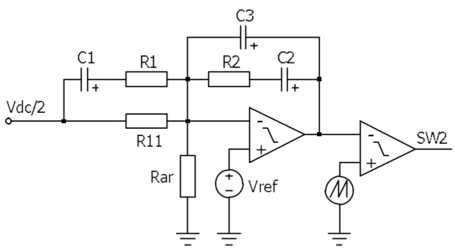

Fig. 5: Modified type 3 amplifier for charging controller

IV. Conclusions

A simple analog controller for BESS was proposed in this paper. With the proposed topology, the system can be stabilized against the load variation and the solar power source perturbation without any computation time. The simulation results shows the effectiveness of the proposed topology, and it can be applied easily to control BESS.

Acknowledgment

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