DC-Voltage Regulation for Solar-Variable Speed Hybrid System

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ABSTRACT

Recently interest on DC systems has been grown up extensively for more efficient connection with renewable energy. During the operation, there happens DC_link voltage variations. This paper focuses on the DC voltage stabilization applied in stand-alone DC microgrid to improve the system stability by keeping the voltage within limits. Batteries and a variable speed diesel generator cover the shortage of power after all available renewable energy is consumed. Load shedding or power generation reduction should automatically takes place if the maximum tolerable voltage variation is exceeded. PSIM based simulation results are presented to evaluate the performance of the proposed control measures.

I. INTRODUCTION

Renewable energy integration in today's power production system has been considered as a feasible solution in microgrid technology [1]. As the central controlled microgrid needs a real time feedback based on communication from the entire system to the central controller, it needs a high speed data exchange. But it is not preferable in stand-alone DC microgrid (DCMG) because it may result to the reduction of system reliability due to possible communication errors and delay time. Contrarily, the voltage droop control can be utilized so that all units may be controlled autonomously using real time data detected locally [2,3].

DCMG control system has to make sure that some changes can occur in the system, for example one source, ESS or some loads may be removed from or added to the system anytime depending on present circumstances. It should also be capable to assure the optimum power flow balance, and finally to enable ESS to compensate the possible voltage fluctuation and to support the system to reduce or rise the power surplus or deficit accordingly [4]

In principle, the diesel generator must be designed to meet the average load. The use of variable speed diesel generator (VSDG) in a stand-alone DCMG results to the improvement of energy efficiency and fuel consumption reduction compared to the constant speed diesel generator (CSDG) and this increases the reliability of whole system [5].

This paper proposes the optimal method to regulate DC voltage by coordinating DCMG components using well designed controllers that perform well with constant power load and that enhance the performance of the system technically and economically. Figure 1 shows the configuration of DCMG to consider in this paper.

II. PROPOSED OPERATION AND CONTROL STRATEGIES

1. System operation

Figure 2 shows the proposed operation range of DCMG system. It can be divided into three operation ranges.

Operation range A:

In this operation range, the system operates properly at the well regulated voltage that equals the DC-reference bus voltage V_{bus}^{*} and the total available power meets the load in a coordinated manner as described by flowcharts shown in Fig. 3 and Fig. 4.

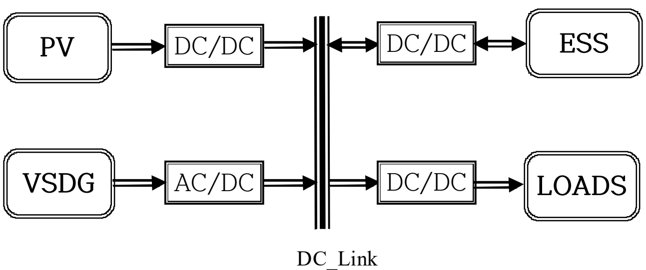


Fig. 1. Hybrid DC microgrid system structure

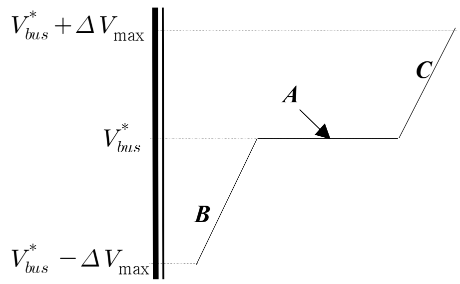


Fig. 2. Proposed operation ranges of system

Operation range B:

The system is said to be operating in range B when the total output power from PV, VSDG, and ESS is lower than the load demand under the condition that $-\Delta V_{max} \le \Delta V < 0$.

Operation range C:

In this range, the voltage condition is $0 < \Delta V \le \Delta V_{max}$. The voltage variation is due to the power flow unbalance caused by the lower load demand or the higher power production.

2. Control system

2.1 Droop control for DC microgrid

Consider 2 parallel sources sharing a common load. Any voltage difference between sources must result in current circulation between DC sources. This control regulates the output reference voltage by means of reducing linearly the output rated voltage as the output current increases with virtual output impedance of sources.

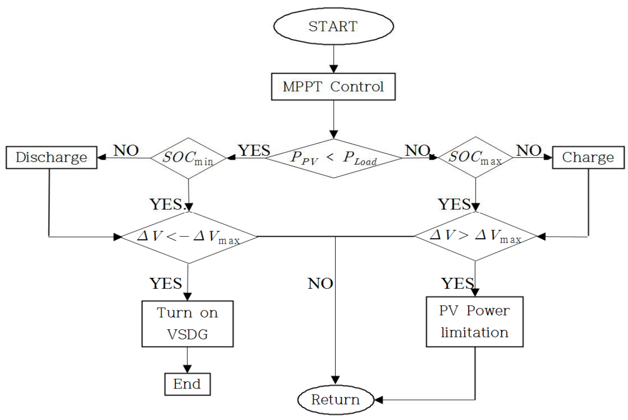


Fig. 3. Proposed operation when VSDG is OFF

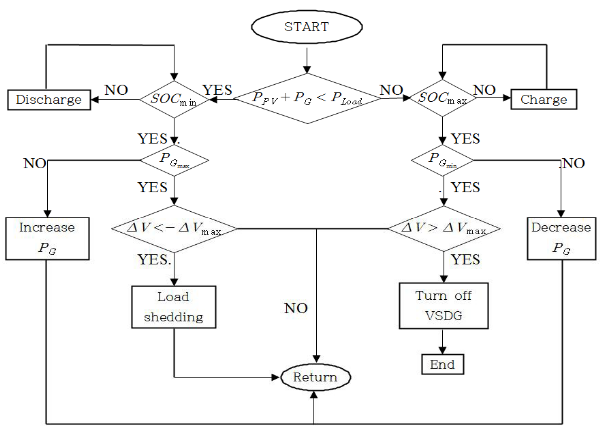


Fig. 4 Proposed operation when VSDG is ON

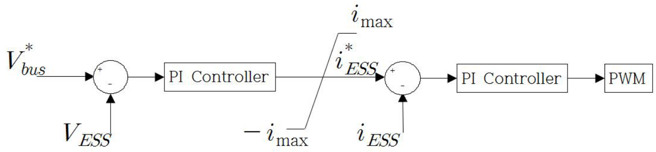


Fig. 5. ESS control block diagram

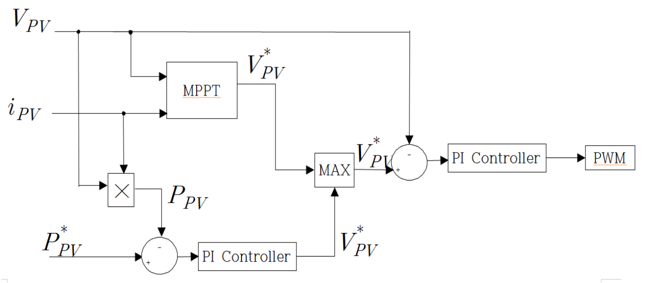


Fig. 6. PV control block diagram

$$V_{droop_1}^* = V_{ref} - r_{v_1} i_1 \qquad (1)$$

$$V_{droop_2}^* = V_{ref} - r_{v_2} i_2 \qquad (2)$$

The regulated V_{droop}^* is used by the controller so that the stable operation can be ensured.

2.2 Storage control

In storage control system as shown in Fig. 5, the ESS output voltage V_{ESS} is compared to the reference bus voltage V_{bus}^* and the error is sent to the PI controller to find the storage system reference current i_{ESS}^*. The current limiter is added to assure the ESS protection by limiting i_{ESS}^* in $[-i_{max}, i_{max}]$ range. Then the difference between i_{ESS}^* and the storage current i_{ESS} is sent to the next PI controller to generate the PWM signal.

2.3 PV control

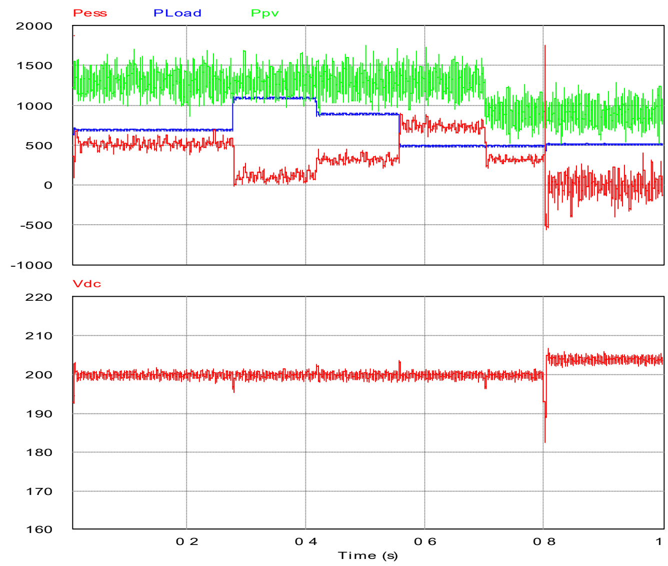
The solar generator is controlled to meet the maximum power point tracking (MPPT). The PV voltage V_{PV} and PV current i_{PV} are checked by MPPT to obtain the reference PV voltage V_{PV}^* and this later is compared to V_{PV}. The error undergoes PI control to find an appropriate duty ratio for PWM so that V_{PV} may be well regulated.

III. SIMULATION RESULTS

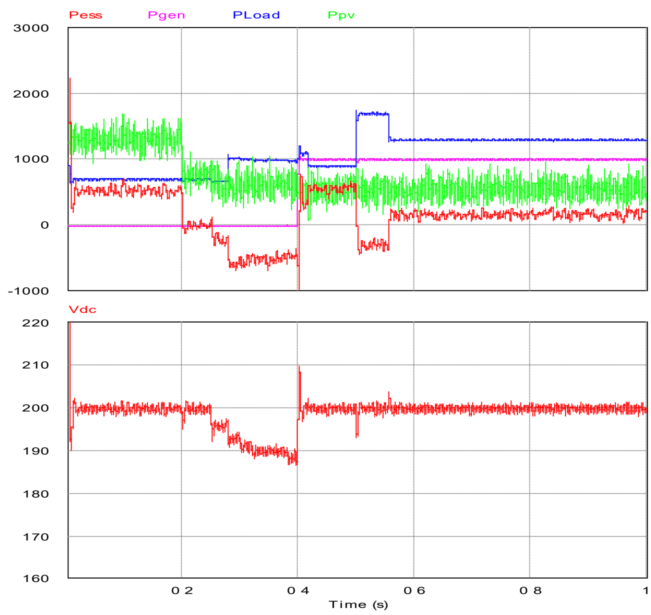
PSiM simulator is used as a tool to test a proposed standalone DCMG. The simulated photovoltaic power is averaged to be 1200W and the rated power of VSDG is 1500W. The storage system capacity is 750W and the load power varies from 500W to 1000W. The DC voltage link for this study is 200V and the maximum tolerable voltage variation equals 5% of the DC voltage link which is 10V.

In Fig. 7(a), the behavior of the system is represented. From 0s to 0.8s, the system is balanced for different load changes. The DC voltage link stays to be regulated to the reference DC voltage that equals to 200V and is operating in range A as previously defined. As the battery is in charging mode, the battery can reach the maximum state of charge (SOC) at 0.8s. Then the charging power becomes zero and the DC voltage goes up to 204V and the system operates in range C.

In Fig. 7(b), the PV power is weakened from 0.2s, then the ESS stops to be charged. From 0.25s, the ESS starts the discharging mode to help PV to cover the load demand as the PV power is being lowered. From 0.28s, ESS and PV output powers are no longer able to satisfy the load demand as the load increases and the ESS power reaches its maximum capacity, then the system operates in range B. At 0.4s the voltage tends to go out of boundaries but the VSDG starts automatically to cover the power shortage and regulates the DC voltage to follow the reference DC voltage.



(a)



(b)

Fig. 7. Simulation results for power flow and voltage

IV. CONCLUSION

This paper presents an idea of regulating the DC voltage in standalone DCMG. It proposes the ways to manage the solar source, ESS and VSDG source by means of voltage ranges. The droop control method can be one of the safest means to achieve the best performance of the system. The proposed operation system is verified by PSiM simulation results study that show a good performance of the system.

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