Power management system for hybrid AC/DC microgrid based on high frequency isolated interlink converter

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Abstract. The hybrid AC/DC microgrid systems have been popular and being developed as the next generation power systems because of the comprehensive combination of both AC and DC microgrid systems. Power management scheme is one of the most critical operation aspects for hybrid microgrids because the system is operating with various generation sources and loads such as renewable energy sources, energy storage systems and AC and DC loads. Therefore, in this research, control strategies and power management scheme is considered for all possible operation modes of standalone and grid-connected conditions. In the existing microgrid system in Electrical Power Engineering department in Yangon Technological University, rooftop PV plant and battery are cooperating to supply the electricity. The inverter in this system allows the unidirectional power flow from DC to AC and there is no specific power management system for grid-connected and standalone operation mode. To provide bidirectional power flow in the existing system, the configuration of converter and control strategies for power management system are developed in this research. To provide the bidirectional power flow between AC bus and DC bus, the bidirectional interlink power converter with high frequency isolation is applied. The control system including the power balancing between generation and demand, DC link voltage control and AC link voltage and frequency control is considered. By applying droop control method in the developed system, power flow balancing between AC bus and DC bus is maintained. And also, using high frequency isolation transformer in interlink converter provides fast response of the system performance and maintaining continuous power supply within each AC system and DC system during disturbance condition in one subsystem. The performance of the proposed power management system is demonstrated by using MATLAB/Simulink.

Keywords: Hybrid microgrid, High frequency isolation, Interlink converter, Power Management System

1. Introduction

Integrating distributed generations (DG) to the utility grid is gaining popularity day by day for concerning about environmental issue, improving of power quality and reliability issue. DGs based renewable energy sources such as solar and wind energy is increasing because of accessing from natural potential resources. Increasing of interest on harvesting energy from renewable resources formed the system called microgrid which is organized with renewable energy (PVs, wind etc.) as power supply source, power electronics converters as power conditioning system and energy storage devices such as
batteries for back up energy system to maintain continuous power supply to the loads. The microgrids can operate either in standalone or grid-connected modes. The hybrid AC/DC microgrids which have advantages of both AC and DC power systems, and are considerable to be the most possible future distribution and transmission systems, are being interested rapidly because of the consisting of dc power sources in microgrids such as Photovoltaics, fuel cell, energy storages and modern dc loads, and considering the existing century-long ac power systems [1].

Power management system and control strategies are the critical aspects of hybrid microgrid system operation because those systems face more challenges when operating in standalone mode. During this mode, the voltage and frequency variation can occur by load variation. And also, active and reactive power flow should be maintained in balance between AC and DC bus for the stability consideration [2], [3], [4]. In power management system, output powers, voltages and frequency are controlled depending on generation and demand power. However, the power management system of hybrid microgrids is more complex compared to AC or DC microgrids. Therefore, the hybrid microgrids could not operate in stable and reliable conditions without a proper power management system [5].

In this paper, the power management system based on high frequency isolated interlink converter is considered for improving the existing microgrid system in Electrical Power Engineering Department in Yangon Technological University. The performance of the proposed management system is demonstrated by simulation results. The implementation of hardware for high frequency isolated bidirectional interlink converter and charge controller for battery system, and experimental work will be done as the extended plan of this paper.

2. Proposed System Configuration
In the existing microgrid system in EP department, YTU, PV plant with the capacity of 6kW and battery bank (20 x 12V, 200Ah batteries in series) are cooperating to supply the electricity for the seminar room and the head office. The inverter allows the unidirectional power flow from DC to AC and there is no specific power management system for grid-connected and standalone operation mode as shown in Figure 1. The inverter in the existing system does not support bidirectional power flow and it allows power flow from DC bus to AC bus. Therefore, in this research, the configuration of converter is developed which is used to link the DC and AC buses to provide bidirectional power flow between DC and AC buses and the control system and power management strategies are considered for both grid-connected and standalone operation mode as shown in Figure 2 where PV, energy storage (ES) and DC load are connected to DC bus. In this system, the capacity-oriented energy storage type which could not
fast response to system, battery, is used because long-term energy balancing is necessary to buffer out
low frequency power oscillation and compensate the power requirement in hybrid AC/DC microgrid system. Interlink converter which is composed of high frequency isolation transformer, two controlled switches at each side of transformer, dc link capacitor and three-phase DC-AC converter, is connected between AC and DC bus to provide the bidirectional power flow depending on the power requirement in the system.

In the developed converter configuration for both grid-connected and standalone operation modes, the control system such as the power balancing between generation and demand, dc link voltage control and ac link voltage and frequency control have to be considered as well as charging and discharging of the energy storage (battery bank) system.

3. Power Management and Control Strategies

The power management system determines the output power of generating sources and controls the voltage and frequency of the system to be maintained stable. In the proposed hybrid AC/DC microgrid system, dc link voltage and power flow balancing between generations and loads are controlled for both standalone and grid-connected modes. AC link voltage and frequency control are also necessary in standalone mode. The above objectives of control scheme are considered for all possible operation modes of hybrid system. The overview of power management and control system of the proposed system is shown in Figure 3. The reference value of active power flow necessary from interlink converter for both directional flow is determined from droop control of dc voltage and ac frequency and the reactive power flow is determined by ac voltage droop control as shown in equation (1) and (2) where \( P_{IC}^*, Q_{IC}^*, f^*, V_{ac}^* \) and \( V_{dc}^* \) are the reference value of active and reactive power determined by interlink converter control, frequency and voltage of AC bus and voltage of DC bus, and \( m_{V}, m_{ac} \) are droop coefficients.

![Figure 3 Control System of the proposed hybrid AC/DC microgrid system.](image)
respectively. For PV plant, MPPT (Maximum Power Point Tracking) control system is used for DC-DC boost converter.

\[
\begin{align*}
\left( \frac{f^* - f}{f^*} \right) & \left( \frac{V_{dc}^* - V_{dc}}{V_{dc}^*} \right) m_{f,v} = P_{IC}^* \\
\left( V_{dc}^* - V_{ac} \right) m_{ac} &= Q_{IC}^*
\end{align*}
\]  

(1)  

(2)

4. Simulation and Results

In this section, the results from simulation of the proposed system for all possible operation modes in both standalone and grid-connected modes are described. For standalone mode, the power flow is DC to AC with PV generation source which supplies to both AC and DC loads and the battery storage is connected to provide the necessary power according to the system requirement as shown in Figure 4 (a).

![Fig. 4 Simulation of standalone condition](image1)

(a) single-line diagram.  
(b) Waveforms of load power, SOC(%) of battery, AC side frequency and DC bus voltage.

![Fig. 5 Simulation of grid-connected condition](image2)

(a) single-line diagram  
(b) Waveforms of load power, SOC (%) of battery, AC side frequency and DC bus.
When the total load ($P_{load}$) is less than generation unit ($P_{PV}$), the battery is charged and it discharges the required power to the system when total load is greater than PV power as shown in Fig. 4 (b). In this condition, the AC side frequency can be maintained stable as well as DC bus voltage as shown in Fig. 4 (b).

In grid-connected operation mode shown in Figure 5 (a), the power flow is from AC to DC by interlink converter. According to the weather condition, the output power from PV plant is decreasing which is not sufficient to supply all the load. The necessary power to supply for both AC and DC load is obtained from the grid. In this grid-connected condition, the system is simulated with PV output change and load increasing. When both load increasing and PV output decreasing happen instantaneously, the output of DC bus voltage becomes lower than its rated value as shown in Fig. 5(b).

When the system operation is changed from grid-connected mode to stand-alone mode, the system response is shown in Figure 6.

![Diagram](image)

Figure 6 Simulation of system operation from grid-connected to stand-alone mode.
(a) Single-line diagram.
(b) Waveforms of frequency, DC bus voltage and battery SOC (%).

5. Conclusions
In this paper, system configuration of the existing microgrid system is developed as hybrid AC/DC microgrid and power management and control scheme are also considered for the developed system configuration for both standalone and grid-connected operation modes. According to the simulation results, it shows that the proposed power management and control is effective for the developed hybrid...
AC/DC microgrid for bidirectional power flow. The AC frequency can be maintained stable in standalone mode and DC voltage can be maintained constant in both standalone and grid-connected mode by applying the proposed control method. As a next step of this research, experimental work with the developed interlink bidirectional converter and power management system will be carried out in Electrical Power Engineering department, Yangon Technological University.

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