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ENERGY MANAGEMENT OF A HYBRID MICRO-GRID WITH POWER ELECTRONIC CONVERTERS

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ABSTRACT

The widespread interconnection of distributed generators (DGs) has created possibility of microgrid, both in AC and DC forms. Combining both AC and DC systems, hybrid microgrid has been proposed by many researchers. While a B2B connection between two AC systems could bestow are liable, isolated and efficient coupling, an extra DC bus connection can facilitate use of the DC micro sources. In this paper, a hybrid microgrid structure with DC bus connection atB2B converter is proposed. The main contribution of this paper lies in enabling this new hybrid structure for grid connected microgrid through B2B converters. Control voltage between the microgrid and utility provides a new model system for hybrid microgrid. Different control modes are developed to demonstrate the efficacy of the proposed microgrid structure and associated controls.

KEY WORDS
Hybrid Microgrid, converters back to back Distributed Generation Energy Management

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INTRODUCTION

The necessity of an AC or DC microgrid is governed by available micro sources and connected loads. A hybrid structure can ensure a sustainable configuration blending both the forms. In this paper, a hybrid microgrid structure or a grid connected microgrid with DC connection at back to back (B2B) converters is proposed [1]–[12]. In [3], an assessment and mitigation strategies for system level dynamic interaction (to achieve tight regulation of load requirement) with control power converters is investigated in a hybrid microgrid. An effective control method to reshape the DC side admittance is proposed to improve the system stability. In [4], a real-time circulating current reduction method, for parallel harmonic-elimination pulse width modulation (HEPWM) inverters used to employ power transfer between AC and DC buses in hybrid microgrid, is proposed. The proposed method can provide an extra15% modulation index range which is a great benefit for power converter applications in this area. The stability issues in a hybrid microgrid are very well addressed in [5], [6]. The proposed control schemes improve the voltage stability in the DC bus and the efficacy of the controller is verified considering the uncertainty of the generators and loads existed in microgrid. In [7], different effective and simple control strategies for hybrid AC-DC microgrid (both grid-connected and islanded operations) are described. The proposed control can keep the power balance and ensures stable AC/DC bus. A decoupled control framework is developed for the hybrid microgrid and the performances are evaluated. The power electronics interfaces and controls for a microgrid with both DC and AC links are investigated in[8].

The presence of AC and DC sources requires detail investigation of the control aspects in such systems. The coordination control algorithms are proposed in [1] to balance the power flow between the AC and the DC grids and to maintain both the DC andthe AC voltages. Another efficient AC/DC microgrid structure is presented in [2]; where the hybrid grid is consist of AC and DC network connected through multi bidirectional converters. The coordination control algorithms are proposed for smooth power transfer between AC and DC links and for stable system operation under various generation and load conditions. A general framework to aggregate a wide range of distributed energy resources at several levels with DC,AC, and synchronous links is proposed with variety of power electronics interfaces and control schemes. The energy management system in an AC and DC bus liked microgrid, is described in [9] for different operating modes. The need of frequency and voltage control is identified along with the DC bus voltage. A centralized power control scheme for a hybrid microgrid is proposed in [10]. The proposed scheme control the power flow of the multiple AC-DC bidirectional converters connected in parallel that connect AC and DC buses. The power management system plays a crucial role in any microgrid and can ensure improved steady state performance [11] [12]. An Energy Management System for the optimal operation of smart grids and microgrids is proposed in [13]. An adaptive algorithm based on advanced control techniques is used to allow energy saving, customers participation in the market etc. A two level architecture for distributed energy resource management for multiple microgrids using multi agent systems (MAS) is proposed in [14]. A central power-management system (PMS) with a decentralized, robust control strategy for autonomous mode of operation of a microgrid is proposed in [15]. AGPS system is used to synchronize the oscillators of the Voltage Source Converter (VSC) DGs.

System Structure

The basic system structure is shown in [Fig. 1].

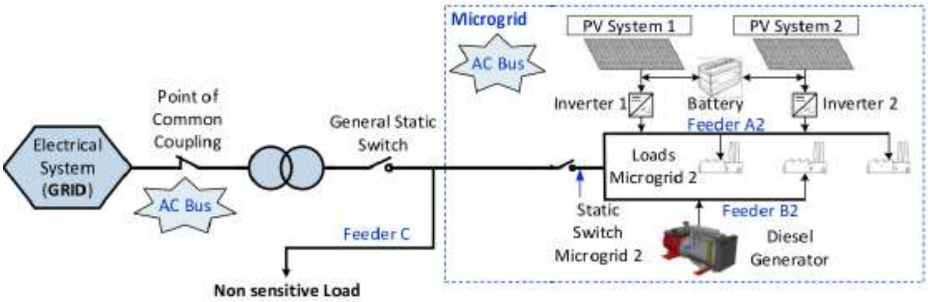

Fig. 1: System structure with AC DC microgrids.

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Control of DC microgrid

The control scheme of the DC microgrid is shown"[Fig. 1]". The utility interfacing VSC (VSC-1) controls the DC voltage while the DC micro sources may operate in fixed power control or droop control mode. The current reference of the DC micro sources operating inconstant P control can be derived as

$$I_{FCref} = \left(K_{PP} + \frac{K_{iPP}}{s}\right)(P_{dref} - P_{dmeas}) \quad (1)$$

For droop control operation, the current reference iscalculated as

$$I_{FCref} = \left(K_{pd} + \frac{K_{id}}{s}\right) \times (V_{drated} - V_{dmeas} - K_{DRP}(P_{dref} - P_{dmeas})) \quad (2)$$

In this paper fuel cells and PVs are considered as the DCmicro sources.
Control of AC microgrid

It is assumed that only VSC interfaced micro sources are present in the AC microgrid. However, the proposed method can also accommodate inertial DGs. It must be noted that the DGs in AC microgrid are VSC interfaced and they are represented by ideal DC sources. In the AC Microgrid the power set points and measured powers are used to calculate the limited power reference. The power errors are fed to the power controller to derive the current references. The voltage reference is then calculated based on the measured current, measured voltage and current reference values. The frequency and voltage regulation are achieved with measured output powers.
The current references are calculated as

$$I_{dref} = \left(K_{pac} + \frac{K_{ipac}}{s}\right) \times (P_{dref} - P_{meas}) \quad (3)$$

$$I_{qref} = \left(K_{qac} + \frac{K_{iqac}}{s}\right) \times (Q_{ref} - Q_{meas}) \quad (4)$$

The voltage references are calculated as

$$V_{dref} = \left(K_{vdac} + \frac{K_{ivdac}}{s}\right) \times (I_{dref} - I_{dmeas}) + V_{dmeas} + I_{dmeas}R_{tr} + I_{qmeas}X_{tr} \quad (5)$$

$$V_{qref} = \left(K_{vqac} + \frac{K_{ivqac}}{s}\right) \times (I_{qref} - I_{qmeas}) + V_{qmeas} + I_{qmeas}R_{tr} + I_{dmeas}X_{tr} \quad (6)$$

The frequency and voltage regulation is implemented as

$$V_{ref} = sqrt \times (V_{dref}^2 + V_{qref}^2) - K_{drpv}(Q_{rated} - Q_{meas}) \quad (7)$$

$$\delta_{ref} = sqrt \times \left(\frac{V_{qref}}{V_{dref}}\right) - K_{drpp}(P_{rated} - P_{meas})\ (8)$$

Control of back to back converters

There are two VSCs in the B2B connection as shown in [Fig. 1]. Two three phase H bridge converters are connected through the common DC link. It must be noted that the filter design of each VSC depends on the system requirements and converter control. The used IGBTs inback to back converter are controllable switches.

VSC-1 controls the voltage in the DC bus to a predefined magnitude (3.5 kV) and control of VSC-1 output voltage angle is achieved as

$$\delta_{ref} = \left(K_{vdc} + \frac{K_{vidc}}{s}\right) - (V_{dcref} - V_{dcmeas-av})\ (9)$$

VSC-2 can be controlled to supply:

- a fixed power from AC microgrid to the DC bus;
- a fixed power to AC microgrid from the DC bus;
- extra power requirement of the AC microgrid in droop control mode.

For supplying fixed power in either direction, the PCC of the AC microgrid is used as the point of reference. The output voltage magnitude and angle references of VSC-2are calculated as

$$V_T = \frac{V_P^2 + Q_{Tref}X_G}{V_P \cos(\delta_r - \delta_p)}\ (10)$$

$$\delta_T = \tan^{-1}\left(\frac{P_{Tref}X_G}{V_P^2 + Q_{Tref}X_G}\right) + \delta_P\ (11)$$

where PTref and QTref are the power references and the PCC voltage is denoted by $V_P < \delta_P$

In droop control mode, the reference voltage is calculated as

$$\delta_r = \delta_{T\,max} - m_T \times (P_T - P_{T\,max})$$

$$V_T = V_{T\,max} - n_T \times (Q_T - Q_{T\,max})(12)$$

where VTmax and δ Tmax are the voltage magnitude and angle, respectively, when it is supplying the maximum load. The droop coefficients ensure acceptable voltage and frequency regulations while supplying the powers.

Simulation

The simulation results are presented in this section. Over view of simulation system shown in "Figure 2".

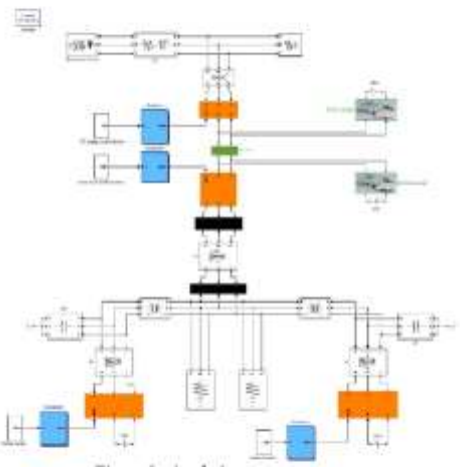

Fig. 2: Simulation system structure.

In this paper, three operating scenarios are considered.

1) Case 1: In this case a fixed power is supplied from the utility to the AC microgrid (or vice versa) and voltage control is achieved for the DC microgrid. As the power from the AC grid is controlled in this case, it is more suitable for a contractual scenario with the AC microgrid.

2) Case 2: In this case, extra power requirement in the AC microgrid is supplied by the utility while the micro sources in the AC microgrid operate on fixed power output. The DC microgrid micro sources may operate with fixed power or droop control.
3) Case 3: The last case considers the possible system contingencies and islanded operation of the microgrid.
The variants of case are as follows.
(a) Fault at the back to back DC bus. With the fault at the DC bus, B2B is blocked and the breakers isolate the systems. Loss of utility connection may need change in control mode and load shedding in the microgrids.
(b) Fault at the utility side. Fault at the utility side initiates connected breakers and VSC-1 is blocked. Power exchange between the microgrids is still possible with VSC-2 control mode changed to voltage control.
(c) Fault in the AC or DC microgrid.

RESULT AND DISCUSSION

In this section, a few of the simulation results (for the cases described in Previous Section) are presented. The system and controller parameters are given in [Table 1–3].

In this case, a load change (1.05 MW to 0.5025 MW at0.1 s and then back to 1.05 MW at 0.35 s) in AC microgrid is simulated while the power flow through theB2B is kept constant. It is desired that the change in power requirement in AC microgrid is compensated by the DGs in AC microgrid. The system response is shown in "[Fig. 3]". It can be seen that the DC bus voltage remain undisturbed. The DGs in the AC microgrid share the remaining power requirement. In a different scenario, a fixed percentage of the load power requirement in the AC microgrid is supplied through theB2B. The system response is shown in [Fig. 4]. The DC bus voltage show a stable system operation.

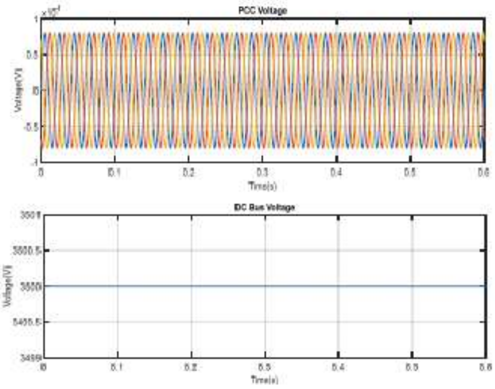

Fig. 3: Case 1: Change in AC microgrid load. PCC poin Voltage ; and DC bus voltage.

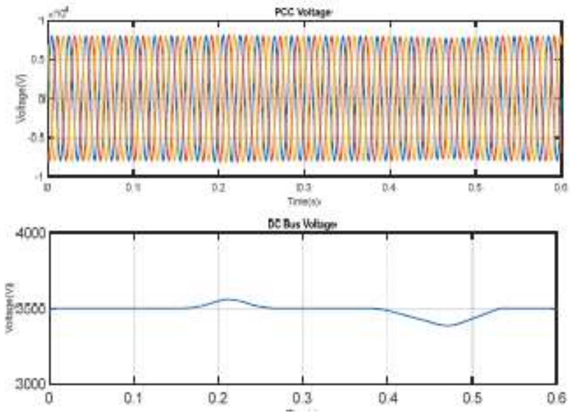

Fig. 4: Case 1: Change in AC microgrid load and power flow from B2B. . PCC poin voltage; and DC bus voltage.

CONCLUSIONS

In this paper, a hybrid microgrid structure for grid connected microgrid through B2B is proposed. The proposed control scheme can provide an isolated and reliable system connection. Various control modes of the micro sources in the microgrids are investigated to validate system sustainability in different power flow and system contingencies. A stable system ensures the efficacy of the proposed scheme and control methods.

CONFLICT OF INTEREST
There is no conflict of interest.

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FINANCIAL DISCLOSURE
None

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