Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 6, Issue 09, September -2019

Management of Autonomous Power in Interconnected AC-DC Micro grids and Distributed Energy Resources

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Abstract — *Microgrid have been widely used for the better interconnection of DGs. I n comparison to the conventional power system ac microgrid have been proposed for increasing the use of inexhaustible energy sources provoke dc power which require a dc link for the grid connection and as a outcome of increasing modern dc loads. Dc microgrid have following benefits like adaptability cost and no of conversion stages. The ac microgrid are efficient in power system but it is not replaced by the dc microgrid, so we are connecting ac and dc microgrid by interlinking converter (IC) for good power management and decentralized control, which will include the main features of both ac and dc microgrid. According to the operation of the hybrid ac/dc microgrid, the IC take the role of supplier to one microgrid and at the same time acts as a load to the other microgrid so that the power management system should be able to divide the power requirement between the old ac and dc sources in both the microgrids. This paper includes the power flow control and management issues amongst multiple sources distributed all over in both ac and dc microgrids. The paper provides a decentralized power sharing method because of the need for communication between DGs or microgrids. The expected power control strategy is validated for different operating circumstances using MATLAB software environment.*

Keywords- *Decentralized control strategy, hybrid ac/dc micro grid, interlinking ac/dc converter, power management.*

I. INTRODUCTION

Due to day by day development of DGs in power system and then managing the power from DGs by using the grid is the major concern. So micro grid concept is used for the better interconnection of DGs in to the grid. In accordance to conventional power system AC micro grid has been proposed. Now a days we are using renewable energy sources which mostly generate the DC power which need a DC link for the grid connection. So the DC micro grid is used for increasing the use of modern DC loads because they provide the benefits in terms of efficiency, cost and system that can eliminate the dc-ac , ac-dc power conversion stages and their power losses. Now a days we are totally dependent on power grid which are ac type and which is dominant, but the DC grid does not replace the AC grid totally. So we are connecting AC and DC micro grid, which are linked by interlinking converter (IC). This is called as bidirectional ac/dc converter which is a hybrid ac/dc micro grid. Like other micro grid the hybrid ac/dc micro grid can also operate in any of the three modes like Grid connected, Islanding mode, Transition mode. Therefore a proper control strategy is required to handle the operation of dc sources, ac sources and IC which need a fast communication link and reliability concern, and also uses a decentralized control in which droop control method can be used for proper power sharing between ac and dc micro grid. During islanding operation, the IC act as a supplier for one micro grid at the same time act as load to other micro grid and also shares the power demand between existing sources. Since the generated power in each micro grid is limited the power management system should be able to share the power demand between the existing ac and as well as dc sources. So for that a droop control method is required to coordinate the power flows and to cover the acceptable power sharing. A two-stage modified droop method is used for the bidirectional power control of the IC using different operation modes of the hybrid ac/dc micro grid. The power management system uses the power reference for the IC control to share the power demand between the existing power sources in both ac and dc micro grid. Using this control strategy the both the micro grids can be used as a single micro grid in which the demanded load power is shared between the existing energy sources. Therefore, the installed power reserve can support the two micro grids and it also allows less usage of reserve power for each micro grid. The main contribution of this project during islanding operation is that the IC plays a major role to manage the demanded power between ac and dc micro grids.

II. SYSTEM STRUCTURE AND OPERATION MODES

A hybrid ac/dc microgrid consists of an ac microgrid with conventional DG sources, dc microgrid with two dc type sources and an IC connects the two microgrids together. Each microgrids consist of their individual loads. During normal grid operation the hybrid microgrid is connected to the main utility grid through the ac microgrid. Usually, the microgrids are operated in grid connected modes or islanding modes. In the grid connected operation mode for the hybrid microgrid, the ac microgrid dynamics are connected directly by the main utility grid and the IC regulates the dc microgrid voltage and controls the power balance. In this operating mode the dc sources generate a constant power, or it can operate in maximum power point for the renewable energy sources. In the islanding mode of operation, and during the light loading of the dc part, the demanded power is shared among the dc sources using the droop mode characteristics. When overloading occurs in the dc microgrid, the interlinking converter will also be used in load sharing using the proposed ac-dc droop control. The performance of the hybrid ac/dc microgrid is described in either of these two modes.

A. Grid-Connected Mode When the hybrid ac/dc microgrid is connected to the main utility grid the DG sources in the ac microgrid generate a specified real power or reactive power or used as terminal voltage regulator with a specified amount of active power and variable reactive power. And the utility grid operates as slack bus to support the difference in the active power or reactive power demand and to sustain the microgrid frequency. Similarly, in dc microgrid, DG sources are controlled to generate a specified active power. However, the role of utility grid is for voltage support and power balance through the IC. According to Fig. 1 and by neglecting the power losses, this mode can be described,

$$\text{Dc microgrid: } P_{IC}^{*} = \sum_i P_{dc,i}^{load} + P_{dc}^{ploss} - \sum_i P_{dc,i} \quad (1)$$

$$\text{Ac microgrid: } P_{grid}^{*} = \sum_i P_{ac,i}^{load} + P_{ac}^{ploss} - P_{IC}^{*} - \sum_i P_{ac,i} \quad (2)$$

In this mode the renewable energy sources in the microgrid can operate with maximum power point so that the energy storages can charge, and the nonrenewable sources can be managed, e.g., used for peak shaving purposes, loss reduction or for economic goals. In the ac microgrid, DGs also generate a specified reactive power, regulate terminal voltage and used for power quality aims.

The more challenging condition is the islanding operation of the hybrid ac/dc microgrid. In the islanding mode, the total load demand is shared and managed by the existing DGs in the both the microgrids, which includes rapid and flexible active or reactive power control strategies to minimize the microgrid dynamics. A proper load shedding strategy is required in case of loss in local generated power to maintain the system stability. This paper uses decentralized control strategies based on droop control to manage the power sharing among ac sources as well as dc sources and in between the ac and dc microgrid. Different operating states occur during islanding operation of the hybrid microgrid. Four main operating states are there in the islanding mode:

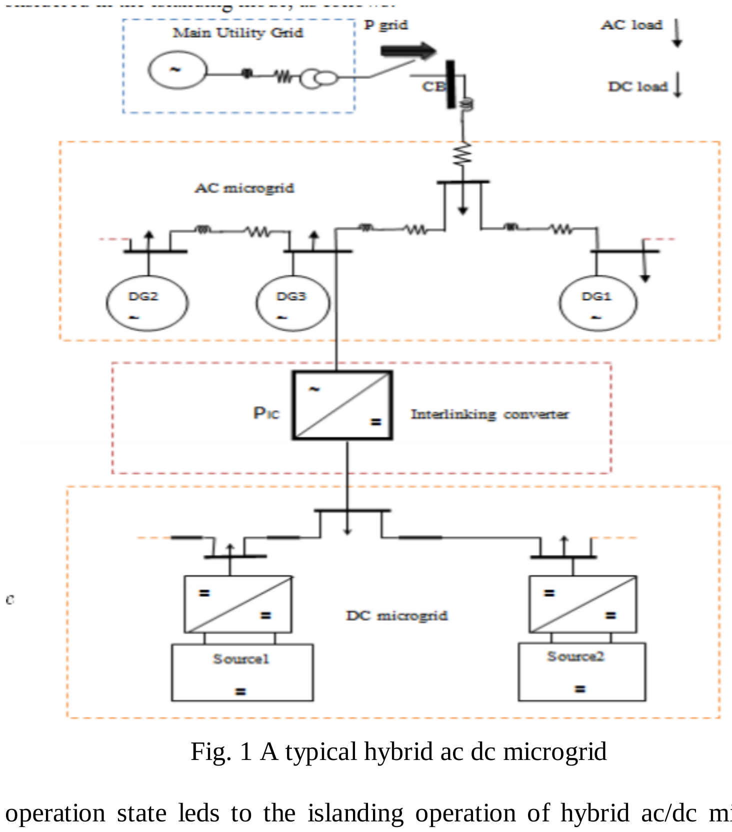

Fig. 1 A typical hybrid ac dc microgrid

Islanding state I: This operation state leds to the islanding operation of hybrid ac/dc microgrid during which power generation in ac microgrid and dc microgrid. The generation units in each microgrid will regulate the power to meet the load. In this state, the IC holds the transferring of power and can just supply reactive power to the ac microgrid. This state is expressed by

$$P_{IC}^{*} = 0, \; P_{grid}^{*} = 0 \quad (3)$$

$$\sum_i P_{dc,i}^{load} \leq \sum_i P_{dc,i} \quad (4)$$

$$\sum_i P_{ac,i}^{load} \leq \sum_i P_{ac,i} \quad (5)$$

Islanding state II: In this state the generated power in ac microgrid is deficient for the ac load demand but there is additional amount of power in the dc microgrid. So, the required power is supplied by the dc sources through the IC. In this state we have Islanding state

$$\sum_i P_{dc,i}^{load} < \sum_i P_{dc,i} \quad (6)$$

$$\sum_i P_{ac,i}^{load} > \sum_i P_{ac,i} \quad (7)$$

$$P_{grid}^{*} = 0, P_{IC}^{*} = \sum_i P_{ac,i} - \sum_i P_{ac,i}^{load} - P_{ac}^{loss} \quad (8)$$

III: This state is similar to state II, except that the power deficit occurs in the dc microgrid and the ac microgrid is in light load condition. Therefore, the ac microgrid supplies the required power for dc microgrid. In this case,

$$\sum_i P_{dc,i}^{load} > \sum_i P_{dc,i} \quad (9)$$

$$\sum_i P_{ac,i}^{load} < \sum_i P_{ac,i} \quad (10)$$

$$P_{grid}^{*} = 0, P_{IC}^{*} = \sum_i P_{dc,i} - \sum_i P_{dc,i}^{load} - P_{dc}^{loss} \quad (11)$$

Islanding state IV: In this operation state the load demand in both ac microgrid and dc microgrid are greater than the maximum available sources capacity i.e the overload condition. In this state, the IC stops the transferring of power and a proper load shedding strategy is run to stabilize the grids. This state is described as,

$$\sum_i P_{dc,i}^{load} \geq \sum_i P_{dc,i} \quad (12)$$

$$\sum_i P_{ac,i}^{load} \geq \sum_i P_{ac,i} \quad (13)$$

$$P_{IC}^{*} = 0, \; P_{grid}^{*} = 0 \quad (14)$$

III. PROPOSED IC CONTROL FOR ISLANDING OPERATION

Along with the power sharing strategies used for the standalone dc or ac microgrids, it is also required to develop a proper control strategy for the IC to share the demanded power between two microgrids. The power management for the IC control is different from the proposed strategies methods which is currently used as the energy sources in the standalone ac or dc micro grids. The IC manages the bidirectional flow of power between the ac and dc microgrids. The IC helps in power sharing between the energy sources in both microgrids with dissimilar droop characteristics. IC takes the role of supplier to one microgrid and at the same time acts as a load for the other microgrid. These situations can be handled by exploiting a proper control strategy for the IC so that it can transfer the required power between the microgrids. So to eliminate the fast communication links, a modified droop-based control strategy is proposed to obtain the desirable performance. During the islanding operation of the hybrid ac/dc microgrid different operating states might come and the IC should be able to recognize these states and manage the whole hybrid microgrid. The power management system should determine the amount of active power that the IC must transfer from one micro grid to the other. In order to provide the power reference command, the dc bus voltage of the IC and the frequency of the ac microgrid are used as an input to the power management system. According to Fig. 2, the electrical energy stored in the dc capacitor **is,**

$$W_{dc} = \frac{1}{2} C_{dc} V_{dc}^2 \quad (15)$$

Ignoring the switching losses in the converter $P_{dc} \approx P_{ac}$ the dynamics in the dc capacitor energy is the difference of the power transfer between ac and dc micro grids. Therefore,

$$\frac{d}{dt} W_{dc} = \frac{1}{2} C_{dc} \frac{d}{dt}(V_{dc}^2) = P_{dc} - P_{ac} = \Delta P \quad (16)$$

On the other hand, considering the $\omega - P$ characteristic in the ac micro grid,

$$\Delta\omega = \omega^0 - \omega = K_\omega \Delta P \quad (17)$$

According to (16) and (17), using the forward Euler approximation formula with sampling period [22] and assuming the microgrid frequency as constant, a new droop characteristic for the IC called ―ac-dc droop‖ is defined as,

$$(\omega^0 - \omega) = k\omega \{(V_{dc}^0)^2 - (Vdc)^2\}, \quad k\omega = K\omega.(\frac{1}{2}\frac{C_{dc}}{T_s})$$

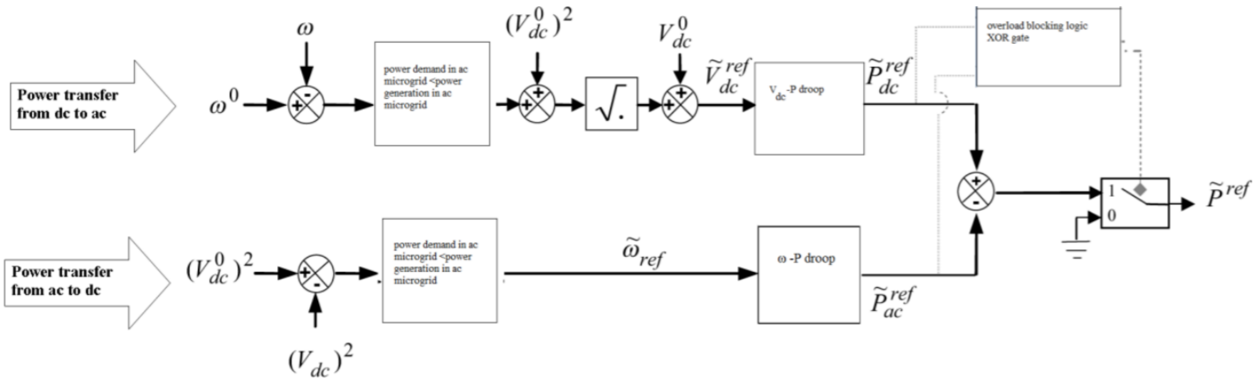

Fig. 2 Proposed real power controller for the IC.

IV. APPLICATION

1. It manages the power deficit in the DC microgrid efficiently and autonomously.

2. They are also used to avoid unnecessary operational losses.

3. The hybrid grid can be used to provide a reliable, high quality and more efficient power to consumer.

4. The hybrid grid is feasible for small isolated industrial plants in which both PV systems and wind turbine generator are used as the major power supply.

V. CONCLUSION

The designing of hybrid microgrid for power system is done in MATLAB or SIMULINK environment. This paper includes the grid tied mode of operation of hybrid grid. The models are developed for all the converters to maintain stable system under various loads and resource conditions. MPPT algorithm is used to utilize the maximum power from DC sources and to coordinate the power exchange between DC and AC grid. The hybrid grid can minimize the processes of DC/AC and AC/DC conversions in an individual AC or DC grid. There are many problems for the implementation of the hybrid grid using the current AC dominated infrastructure. The efficiency of the total system depends on the reduction of conversion of losses and the increase for an extra DC link. The hybrid grid can also be used to provide a reliable, high quality and more efficient power to consumer. The hybrid grid may be feasible for small isolated industrial plants using both PV systems and wind turbine generator as the major power supply.

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