

Implementation of FLC in Power Control for Hybrid AC/DC Micro grid

B. SRAVANKUMAR¹, A. PURNA CHANDRA RAO²

¹*PG Scholar, Department of Electrical & Electronics Engineering,
P.V.P. Siddhartha Institute of Technology Vijayawada-520007, A.P, India*

²*Department of Electrical & Electronics Engineering,
P.V.P. Siddhartha Institute of Technology Vijayawada-520007, A.P, India*

Abstract: -In this paper hybrid AC/DC micro grid comprises of DC and AC sub grids interconnected by power electronic interfaces. But existing micro grids are purely AC or DC grids. The major purpose is to manage the power flow among all sources distributed throughout the different types of sub grids. The hybrid grid reduces the process of multiple DC-AC-DC or AC-DC-DC conversions in an individual grid where the number of converter stations for converting AC to DC or DC to AC power are reduced. These power generating stations interconnected to form a micro grid system needed number of multiple reverse conversations (AC-DC or DC-AC) for consumer applications this results increase circuit complexity, cost and system have less reliability. The proposed grid can operate in both standalone and grid connected mode. Fuzzy controller is used for smooth power transfer.

Keywords: -Hybrid micro grid, Proportional integral controller, Standalone, Grid connected mode.

I. INTRODUCTION

The increasing number of renewable energy sources and distributed generation (DG) requires new technique for the operation and management of the electricity grid to enhance proper power sharing. In the present power scenarios, when distributed generations are mentioned for small scale generations to meet the various customer demand. The coordination of these small scale generations may consist of photovoltaic, batteries, wind and fuel cells which are formed as Micro-grid [1]. Interest on micro grid is rapidly increasing as it is based on the renewable energy sources, which connects to utility grid and various types of loads. In the grid tied mode, it is connected with utility whereas in case of autonomous mode it is totally disconnected. In case of autonomous mode it becomes totally independent and fulfills the demands of customers from the renewable energy sources [2],[3]. Grid connected, Islanding mode, Transition mode. Therefore a suitable control strategy is required to coordinate the operation of DC sources AC sources and IC, which need a fast communication link reliability concern, which uses a decentralized control among which droop control method can be used for which proper power sharing between AC and DC micro grid.

During islanding operation the IC act as a role of supplier to one micro grid at the same time act as load to other micro grid and shares the power demand between existing sources. Another challenge is that 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 dc sources [4]. Therefore a specified droop control method is needed to coordinate the power flows and to cover acceptable power sharing. A two stage modified droop method is used for the bidirectional power control of the IC during different operation modes of the hybrid AC/DC micro grid. By measuring the AC micro grid frequency and the DC micro grid voltage and using proposed droop characteristic [5, 6]. The power management strategy provides the power reference for the IC control to share the power demand between the existing power sources in both ac and dc micro grid.

Through this control strategy, the two micro grids can be treated as a unified micro grid in which the demanded load power can be shared between the existing energy sources in this hybrid micro grid. Therefore, the installed power reserve can support the two micro grids commonly and it allows reduced amount of reserve power for each micro grid [7, 8]. Since the majority of renewable energy sources, generate DC power or need a DC link for grid connection and as a result of increasing modern dc loads, DC micro grids have recently emerged for their benefits in terms of efficiency, cost and system that can eliminate the DC-AC or AC-DC power conversion stages and their accompanied energy losses [9,10]. However, since the majority of the power grids are presently ac type, AC micro-grids are still dominant and purely DC micro-grids are not expected to emerge exclusively in power grids. Therefore, DC micro-grids are prone to be developed in AC types even

though in subordinate. Consequently, linking AC micro-grids with DC micro-grids and employing the profits of the both micro-grids, has become interesting in recent studies [11]. This paper is arranged as follows: in Section II, explain the system structure and operation modes of hybrid AC/DC micro grid. In Section III, Droop control strategy for individual AC micro grids and DC micro grids is explained. In section IV, proposed IC control during islanding are discussed. In section V, fuzzy logic controller is explained. In section VI, Power Control and Management in a Hybrid AC/DC Micro grid is analyzed, and the corresponding results are also presented with fuzzy logic controller. Finally, conclusion is given in Section VII.

II. SYSTEM STRUCTURE AND OPERATION MODES

A simple hybrid AC/DC micro grid is shown in Fig. 1. It consists of an ac micro grid with conventional DG sources, a DC micro grid with two DC type sources and an IC links the two micro grids together. Each of these micro grids also includes their individual loads. Besides, during normal grid operation the hybrid micro grid is connected to the main utility grid through the AC micro grid. Basically, the micro grids are thought to operate in grid-connected or islanding modes in the grid-connected operation mode of the hybrid micro grid, the AC micro grid dynamics are governed directly by the main utility grid and the IC primarily regulates the DC micro grid voltage and controls the power balance, as well. In this operating condition the DC sources can generate a constant power or can operate in maximum power point for the renewable energy sources. In the islanding mode of operation, and during light loading of the DC part, the demanded power is shared among the DC sources using the $(P-V_{dc})$ droop characteristics. When over-loading happens in the DC micro grid, the interlinking converter will also participate in load sharing using the proposed AC-DC droop control. In the following, the performance of the hybrid AC/DC micro grid is described in either of these two modes.

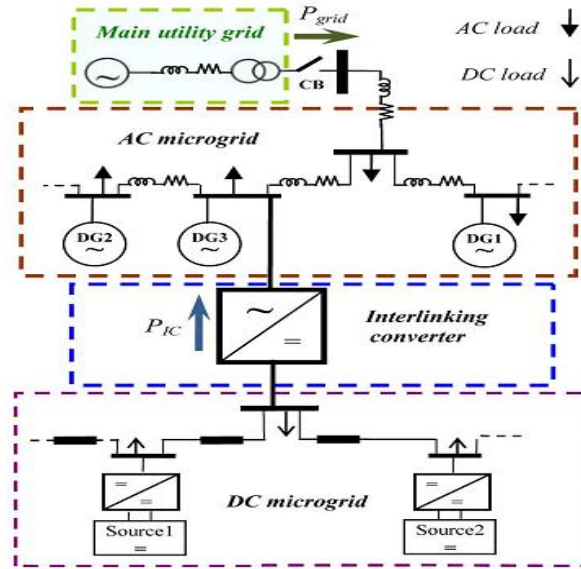


Fig.1. A typical hybrid AC/DC micro grid.

A. Grid-Connected Mode

While the hybrid AC/DC micro grid is connected to the main utility grid, dg sources in the AC micro grid are expected to either generate a specified real/reactive power, or act as terminal voltage regulator with a specified amount of active power and variable reactive power [5]. On the other hand, the utility grid operates as slack bus to support the difference in the active/reactive power demand and to sustain the micro grid frequency. Similarly, in DC micro grid, DG sources would be controlled to generate a specified active power. However, the utility grid is still responsible for voltage support and power balance through the IC. According to Fig. 1 and neglecting the power losses, this mode can be described,

$$\text{DC micro grid : } P_{IC}^* = \sum P_{dc,i}^{load} + P_{dc}^{loss} - \sum P_{dc,i} \quad (1)$$

$$\text{AC micro grid: } P_{grid}^* = \sum P_{ac,i}^{load} + P_{ac}^{loss} + P_{ic}^* - \sum P_{ac,,i} \quad (2)$$

In this mode the renewable energy sources in the micro grid can operate in maximum power point, energy storages can charge and non-renewable sources can be managed, e.g., for peak shaving purposes, loss reduction or economical goals. In the ac micro grid, DGs could also generate a specified reactive power, regulate terminal voltage or may be used for power quality aims [21]. These power management studies have been studied in DC micro grids [7], [8] and it is not intended to be followed in this paper.

B. Islanding Mode

When the hybrid grid operates in the islanding mode, an interlinking converter acts as a converter and inverter mode to supply the power from AC micro grid to DC micro grid and DC micro grid to AC micro grid for balanced the power in both grids. In this mode Utility grid is not supplying power, Static switch is open, Feeder A, B, C is being supplied by Micro sources, Feeder D (not sensitive) is dead. In the islanding mode, the total load demand should be shared and managed autonomously by the existing DGs in the both micro grids, which involves rapid and flexible active/reactive power control strategies to minimize the micro grid dynamics. Different operating states may occur during islanding operation of the hybrid micro grid. For the sake of appropriate performance of the hybrid AC/DC micro grid under different grid conditions, four main operating states are considered in the islanding mode, as follows:

Islanding state I: This operation state corresponds to the islanding operation of hybrid AC/DC micro grid during which power generation in AC micro grid and DC micro grid suffices their individual loads (light load condition). The generation units in each micro grid will regulate its power to meet the load. In this state, the IC halts transferring power and can just supply reactive power for the AC micro grid. This state is expressed by,

$$P_{ic}^* = P_{grid}^* = 0 \quad (3)$$

$$\text{DC micro-grid: } \sum_i P_{dc,i}^{load} \leq \sum_i P_{dc,i} \quad (4)$$

$$\text{AC micro-grid: } \sum_i P_{ac,i}^{load} \leq \sum_i P_{ac,i} \quad (5)$$

Islanding state II: This state represents the case where the generated power in AC micro grid is deficient for the AC load demand but there is surplus power in the DC micro grid. Therefore, the required power should be supplied by the dc sources through the IC. In this state we have,

$$\text{DC micro-grid: } \sum_i P_{dc,i}^{load} < \sum_i P_{dc,i} \quad (6)$$

$$\text{AC micro-grid: } \sum_i P_{ac,i}^{load} > \sum_i P_{ac,i} \quad (7)$$

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

Islanding state III: This state is similar to state II, except that the power deficit occurs in the DC micro grid and the AC micro grid is in light load condition. Therefore, the AC micro grid supplies the required power for DC micro grid. In this case,

$$\text{DC micro-grid : } \sum_i P_{dc,i}^{load} > \sum_i P_{dc,i} \quad (9)$$

$$\text{AC micro-grid : } \sum_i P_{ac,i}^{load} < \sum_i P_{ac,i} \quad (10)$$

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

Islanding state IV: This operation state relates to the case during which the load demand in both AC micro grid and DC micro grid are greater than the maximum available sources capacity (overload condition). In this state, the IC halts transferring power and a proper load shedding strategy must be run to stabilize the grids. This state is described by,

$$P_{ic}^* = P_{grid}^* = 0 \quad (12)$$

$$\text{DC micro-grid: } \sum_i P_{dc,i}^{load} \geq \sum_i P_{dc,i} \quad (13)$$

$$\text{AC micro-grid: } \sum_i P_{ac,i}^{load} \geq \sum_i P_{ac,i} \quad (14)$$

III. DROOP CONTROL STRATEGY FOR INDIVIDUAL MICRO GRIDS

(i) Control of DGS in the AC Micro grid

Power management based on droop control is currently well recognized in ac micro grids. Real power generation of a DG is specified based on frequency-droop (w-P) characteristic [4]. Since there is no dominant source to enforce the base frequency in the islanded micro grid, the frequency of the micro grid varies by means of demanded power variations. The main idea of this control is to increase the active power generation of DGs

when the system frequency decreases. Similarly, for reactive power management voltage-droop (V-Q) is exploited. Reactive power generation of a DG is determined based on deviations in the bus voltage. Therefore, the DG source acts in response to the measured local voltage deviations caused by either the system or the local load's-P and V-Q characteristics could be described mathematically by,

$$P^{ref} = -\frac{1}{K_{ac}}(w^0 - w) + P^0 \quad (15)$$

$$Q^{ref} = -\frac{1}{K_{qmax}}(V^0 - V) + Q^0 \quad (16)$$

By this power control method, during the grid-connected mode where the frequency of the system is fixed, real power generation of the DG is controlled by P_0 .

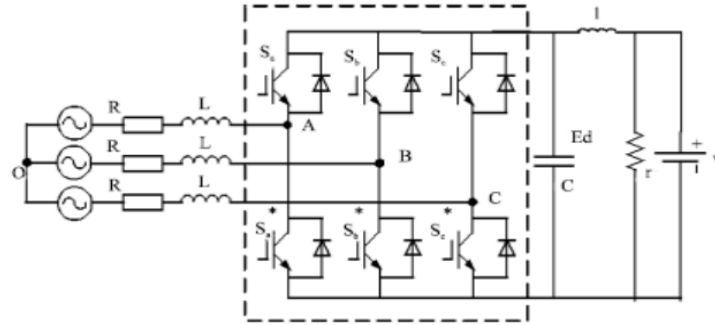


Fig.2. Configuration of the IC interfacing AC and DC micro grids.

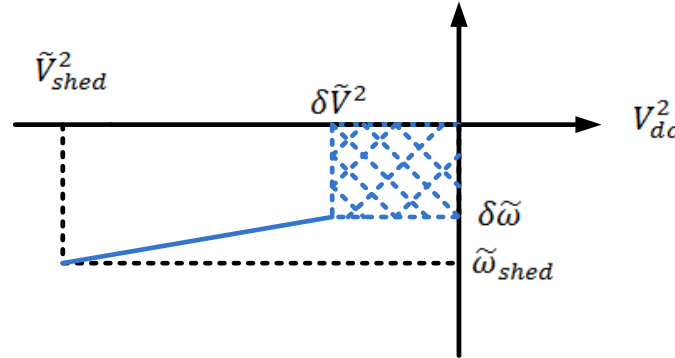


Fig. 3. Proposed AC-DC droop characteristic.

(ii) Control of DGs in DC Micro grid

Alternatively, for the DC micro grid the dc voltage-droop ($V_{dc} -P$) control method is used for power sharing between DG sources in the micro grid. Typical ($V_{dc} -P$) droop characteristics can be expressed by

$$P^{ref} = -\frac{1}{k_{dc}}(V_{dc}^0 - V_{dc}) + P_{dc}^0 \quad (17)$$

IV. PROPOSED IC CONTROL FOR ISLANDING OPERATION

In addition to the power sharing strategies adopted for the standalone DC or AC micro grids, it is required to develop a proper control strategy for the IC to share the demanded power between these two micro grids. However, the power management for the IC control is different from the proposed strategies currently used for the energy sources in the standalone AC or DC micro grids. In contrast to the AC or DC microgrids, the IC is expected to manage a bidirectional flow of power between the AC and DC micro grids. In addition the IC should cooperate in power sharing between the energy sources in both micro grids with dissimilar droop characteristics. This is due to the fact that at any instant the IC takes the role of supplier to one micro grid and at the same time acts as a load for the other micro grid. These challenging issues can be handled by exploiting a proper control strategy for the IC to transfer the required power between the micro grids. In order to eliminate fast communication links, a modified droop based control strategy is proposed to attain desirable performance.

As discussed in the previous sections, during the islanding operation of the hybrid AC/DC micro grid different operating states might arise and the IC should recognize these states and manage the whole hybrid micro grid. The following decentralized control strategy is adopted for this purpose. The power management 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 micro grid are

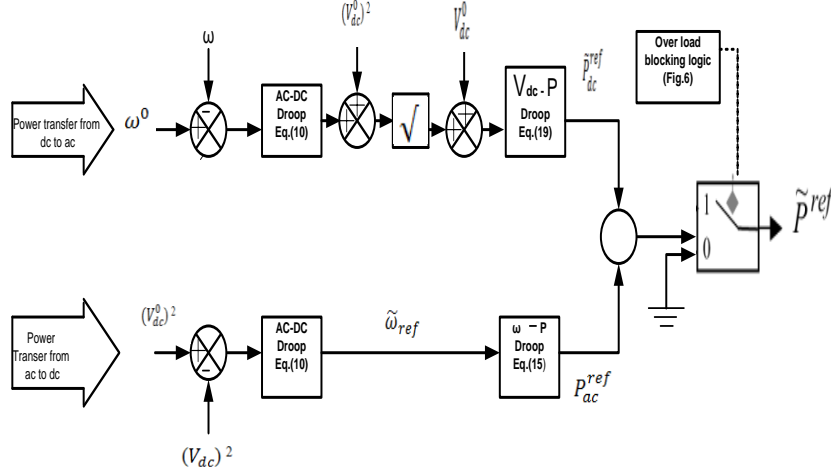


Fig.4. Proposed real power controller for the IC.

Utilized as input to the power management system. Considering the electrical energy stored in the DC capacitor is,

$$W_{dc} = C_{dc} V_{dc}^2 \quad (18)$$

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

$$\frac{d}{dt} W_{dc} = \frac{1}{2} c_{dc} \frac{d}{dt} (V_{dc}^2) = P_{dc} - P_{ac} = \Delta P \quad (19)$$

On the other side, considering the w-P characteristic in the AC micro grid, The “AC-DC droop” characteristic is shown in Fig.3. $\delta\omega$ and δ_V are the dead zone bands for the allowable variation of angular frequency and DC voltage, respectively. Dead zone is utilized in the proposed “AC-DC droop” in order to prevent any power transfer during light load operation of individual micro grids. During such operation condition the generating units in each micro grid will regulate the generated power to supply the corresponding micro grid load using the relevant $V_{dc}-P$ or $w-P$ droop characteristics. v_{shed}^2 and w_{shed} are respectively the minimum DC voltage and AC micro grid frequency drop in dc and ac micro grids that the system is supposed to undergo load shedding. Furthermore, since the IC is not the mere frequency or DC voltage controller in the hybrid AC/DC micro grid, it is necessary to participate in power sharing between AC and DC sources. To implement this scheme, the output of the AC/DC droop is fed to the $V_{dc}-P$ or $w-P$ and droops of the IC. It is necessary to mention that since positive sign for power transfer in the IC is considered to be from DC to AC, the power for $V_{dc}-P$ droop should be regarded with negative sign. Finally, according to V_{dc}^{ref} and w^{ref} the amount of power to be transferred via the IC is determined by the two reference power calculated through these two loops. A schematic block diagram of the proposed power management strategy for the IC is depicted in Fig.4. The impact of the proposed droop control for the IC on the power sharing of sources in each micro grid is illustrated within two load increase scenarios in each microgrid,

1) In the first scenario it is assumed that the DC micro grid is near overloading and there is excess power in the AC micro grid. Upon increasing the load in the dc micro grid, the DC voltage will accordingly decrease. If the voltage drop is beyond δ_V , referring to the proposed AC-DC droop (Fig. 3) this voltage deviation produces a new reference angular frequency w_{ref} . This w_{ref} will then determines the reference power for the IC power controller using the conventional $w-P$ droop. This is the amount of power to be transferred from AC to DC micro grid. Therefore, the IC treats as a source for the dc micro grid and partly restores the voltage of the dc

micro grid. On the other hand, the IC takes the roll of a load for the AC micro grid and increases the power generation of the aAC sources.

2) The other scenario happens when the AC micro grid is near overloading. When the ac load increases again, causes the frequency to decrease below δ_w . Referring to the proposed AC-DC droop a new reference voltage V_{dc}^{ref} is presented. Finally, by using the V_{dc} -P droop the required power to be transferred to the dc micro grid is determined. Therefore, according to these two scenarios whenever the load increases in one of the micro grids, the “AC-DC droop” characteristic relates the AC and DC micro grids using the dc link performance and the equivalent frequency droop characteristic of the AC micro grid which is determined by,

$$\Delta P = k_w \Delta_w, k_w = \left(\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n} \right) + D \quad (20)$$

Where R_1, \dots, R_n are droop coefficient of ac sources and D is the load-damping constant of the ac micro grid. Using this droop characteristic it is possible to relate the different droops of AC and DC micro grid and consequently share the power in the whole micro grid. By this power management strategy the response of IC in different islanding states is as follows:

Islanding state I: Throughout this state, $\Delta_w < \delta_w$ and $\Delta V_{dc}^2 < \delta V^2$ therefore the output of “AC-DC droop” is

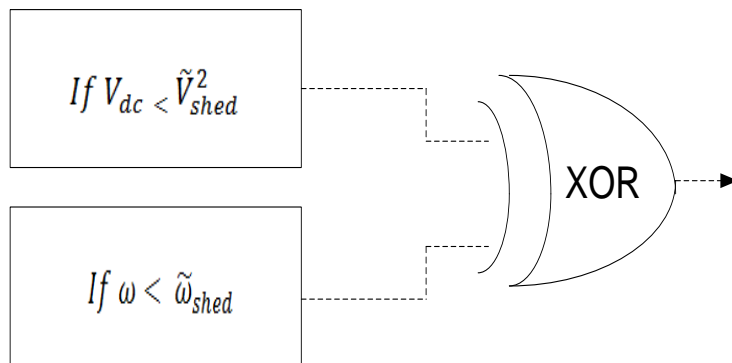


Fig.5. Overload blocking logic for real power controller of the IC.

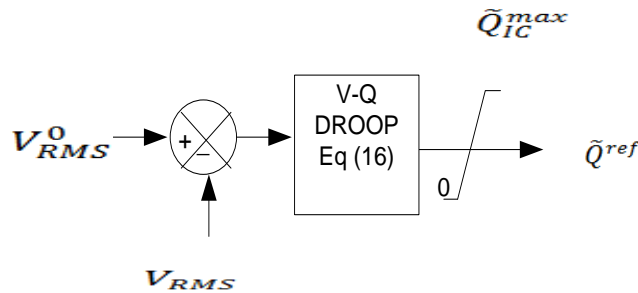


Fig. 6. Reactive power controller for the IC.

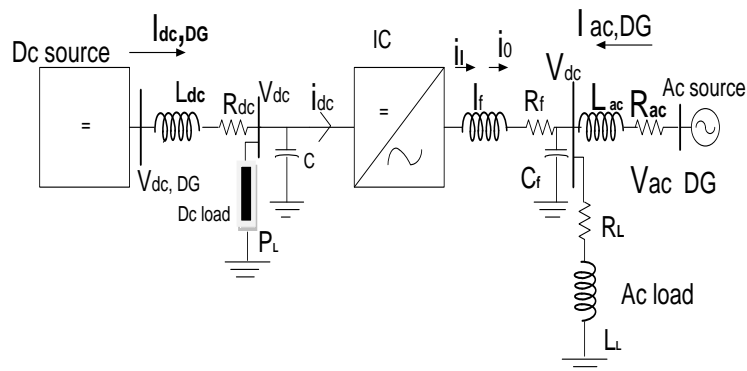


Fig. 7. Simplified equivalent model of the hybrid micro-grid.

$V_{dc}^{ref} = V_{dc}^0$ for DC micro grid and $w^{ref} = w_0$ for AC microgrid. Consequently, $P^{ref} = 0$ and IC transfers no power.

Islanding state II: In this state $\Delta V_{dc}^2 < \delta V^2$ but $\Delta w > \delta w$ therefore, $P^{ref} = -P_{dc}^{ref}$ and IC supplies power to the AC micro grid.

Islanding state III: In this state $\Delta w < \delta w$ but $\Delta V_{dc}^2 > \delta V^2$ therefore, $P^{ref} = P_{dc}^{ref}$ and IC supplies power to the Dc micro grid.

Islanding state IV: During this state, $w < w_{shed}$ and $V_{dc}^2 < V_{shed}^2$. In order to block the IC for any power transfer, an overload blocking logic is added at the output the proposed droop control in which by using an “EXCLUSIVE OR (XOR)” logic, whenever both micro grids enter overloading the IC is blocked and no power will transfer. The reactive power control of the IC is more straightforward since there is no reactive power in DC microgrid and the IC is designated to play as a voltage support in droop-control mode to share the reactive power with other DGs in ac microgrid. The reactive power sharing is based on the conventional droop the local RMS voltage is measured and using the V– Q droop, the reactive power reference is determined. Since the active power transfer is the prime task of the IC, a dynamic reactive power limit is added to the control block to consider the capacity limit of the IC. The hybrid micro-grid shown in Fig. 1 is simplified from the perspective of IC, as shown in Fig. 7. Finally, a current control scheme is utilized in IC control for tracking the reference active/reactive power calculated by the power management system.

V. FUZZY LOGIC CONTROL

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to power system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of compensator. The basic scheme of a fuzzy logic controller is shown in Fig .7. and consists of four principal components such as: a fuzzy fiction interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzy fiction interface which yields non fuzzy control action from an inferred fuzzy control action.

Rule Base: the elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control, which requires coarse in-put/output variables; in the steady state, small errors need fine control, which requires fine input/output variables. Based on this the elements of the rule table are obtained as shown in Table, with ‘ V_{dc} ’ and ‘ V_{dc-ref} ’ as inputs.

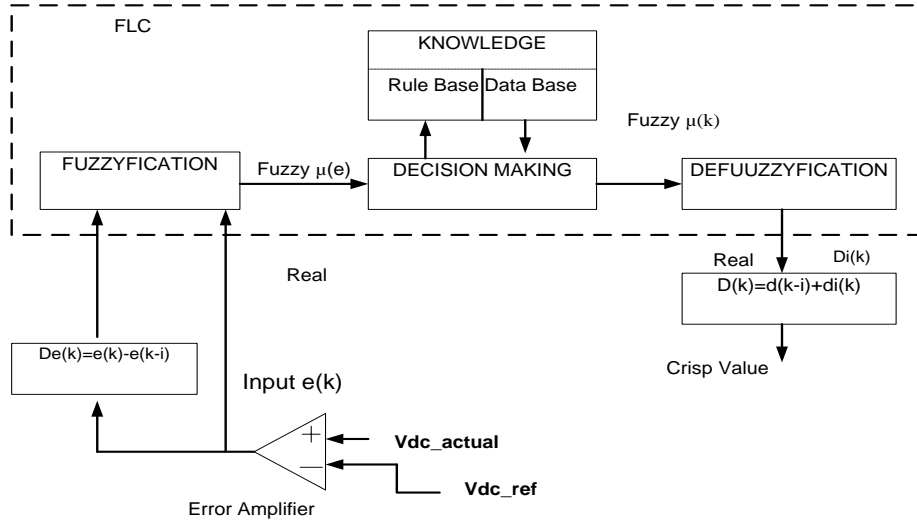


Fig.8. Block diagram of the Fuzzy Logic Controller (FLC) for Proposed Converter.

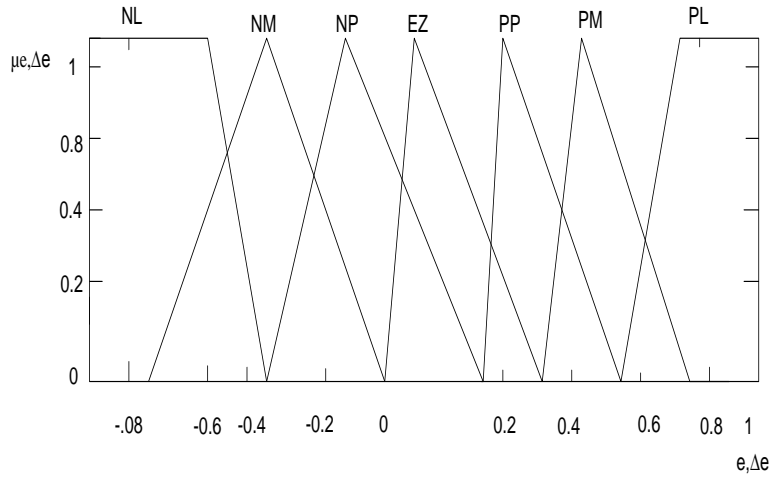


Fig.9. Membership functions for Input, Change in input, Output.

TABLE 1FUZZY RULES

$e \rightarrow$	NL	NM	NS	EZ	PS	PM	PL
$\Delta e \downarrow$							
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NL	NM	NS	EZ
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

VI. RESULTS

In order to demonstrate the proposed methods, simulation test have been carried out in this paper based on a typical hybrid AC/DC micro grid shown in Fig1. Using MATLAB/simulation. The system consists of an ac micro grid with conventional DG sources, a DC micro grid with two DC type sources and an IC links the two

micro grids together and connected to the main utility grid. In this paper, grid connected mode was simulated by MATLAB and shows the DC bus voltage (V), AC RMS Voltage (V), frequency (HZ), total harmonic distortion (THD), when AC/DC loads are connected to the main utility grid, islanding mode when AC and DC load is varying, when both loads are in light load and over load condition and FLC in hybrid AC/DC micro grid.

Case1: When AC/DC micro grid is connected to the main utility grid

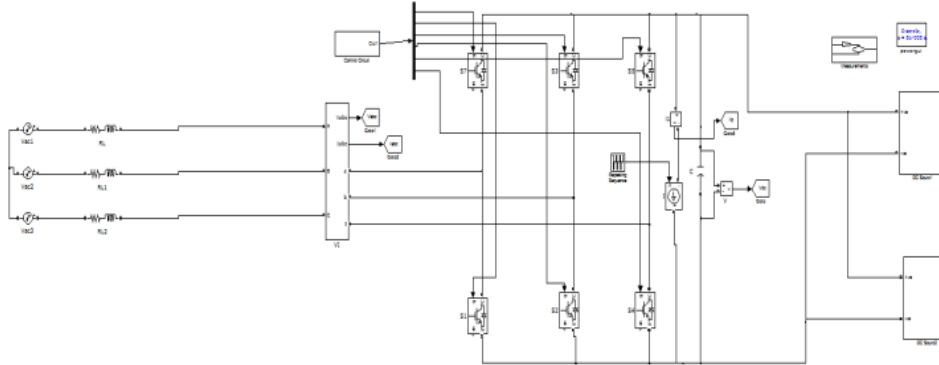


Fig.10. Simulink diagram of hybrid AC/DC micro grid when connected to main utility grid.

Fig.10. Shows the simulink diagram of hybrid AC/DC micro grid when connected to main utility grid. In this DC load demand is high (400 KW), but two DC sources are not meeting the required load demand at time $t = 1$ sec DC load is suddenly drop to 200 KW as shown in fig.11.(a). and DC voltage has some disturbance is shown in fig.11.(b). To over come these problems Interlinking converter (IC) moves to inverting mode and transfer sufficient power from AC side to DC side. At time $t = 2$ sec load is increased and approximately matches the generated DC power is shown in fig.11.(a).

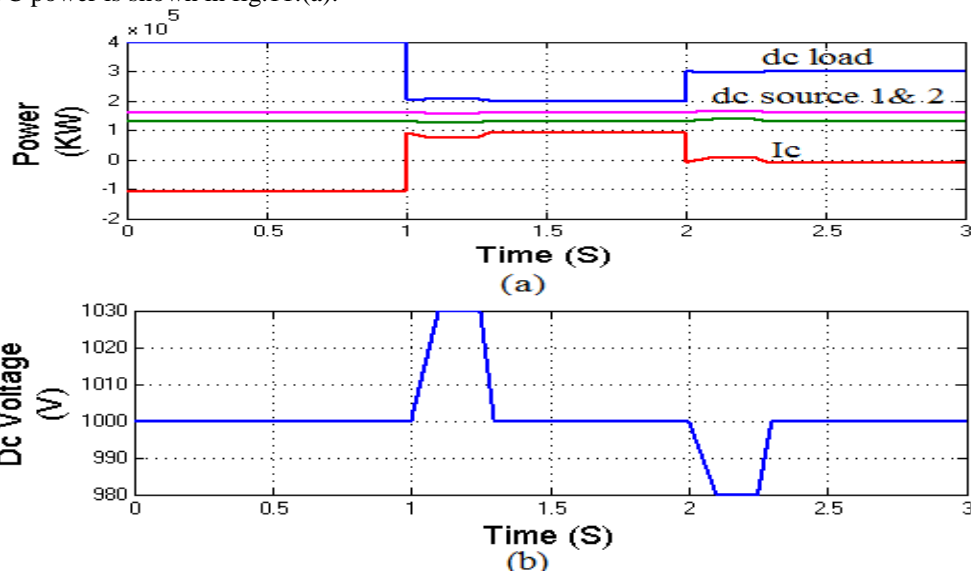


Fig.11. Simulation waveform of (a) Active power atDCside and interlinking converter (b) DC Voltage (V).

Case2: Islanding mode when AC load is varying

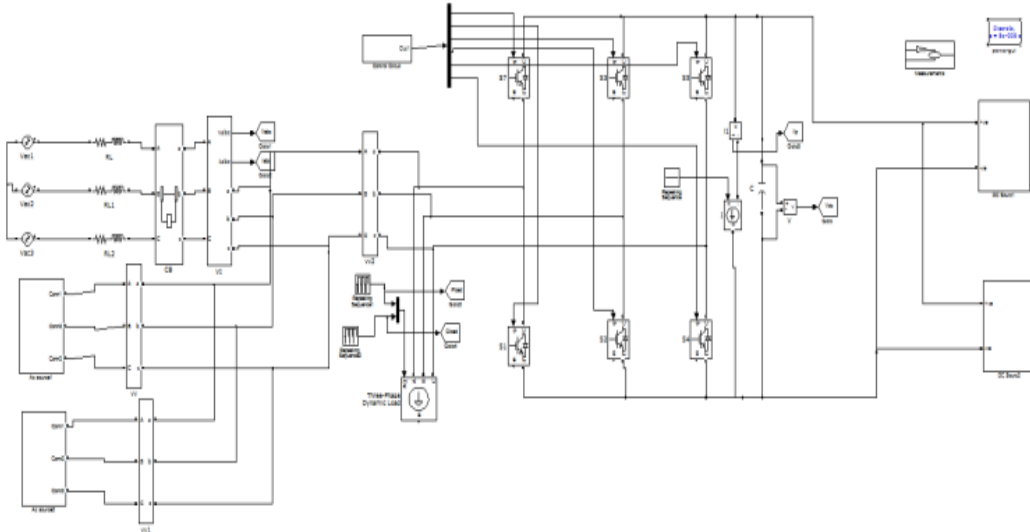
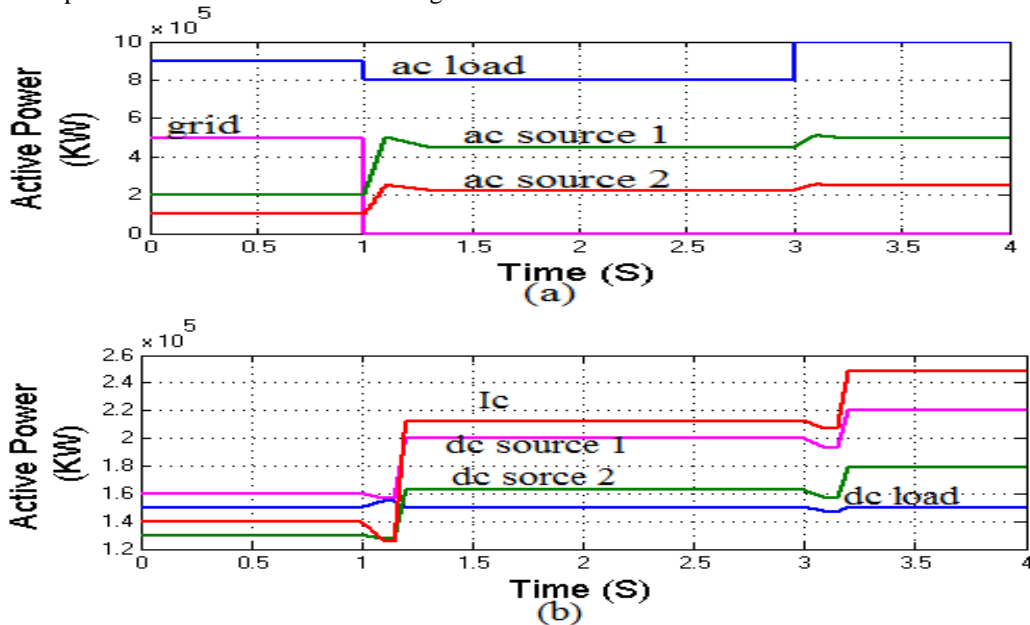


Fig.12. Simulink diagram of islanding mode with AC variable load.

Fig.12. shows the simulinkdiagram of islanding mode with AC variable load. In this hybrid AC/DC micro grid is operated in transition from grid connecting mode to islanding mode. At time $t = 1$ sec micro grid is disconnected from the main utility grid and having AC load demand of active power of 900 KW and reactive power of 300 KVAR, is high, but two AC sources are not meeting the required load demand. In this condition AC load is drop to 800 KW and 250 KVAR as shown in fig.13.(a). and (c) which causes frequency drop as shown in fig.13.(e). In order to balance the power, The Interlinking converter (IC) shares the surplus power from DC side to AC side as shown in fig.13.(b). At time $t = 3$ sec ac load is increased further and this causes the IC to transfer more power from DC side to AC micro grid.



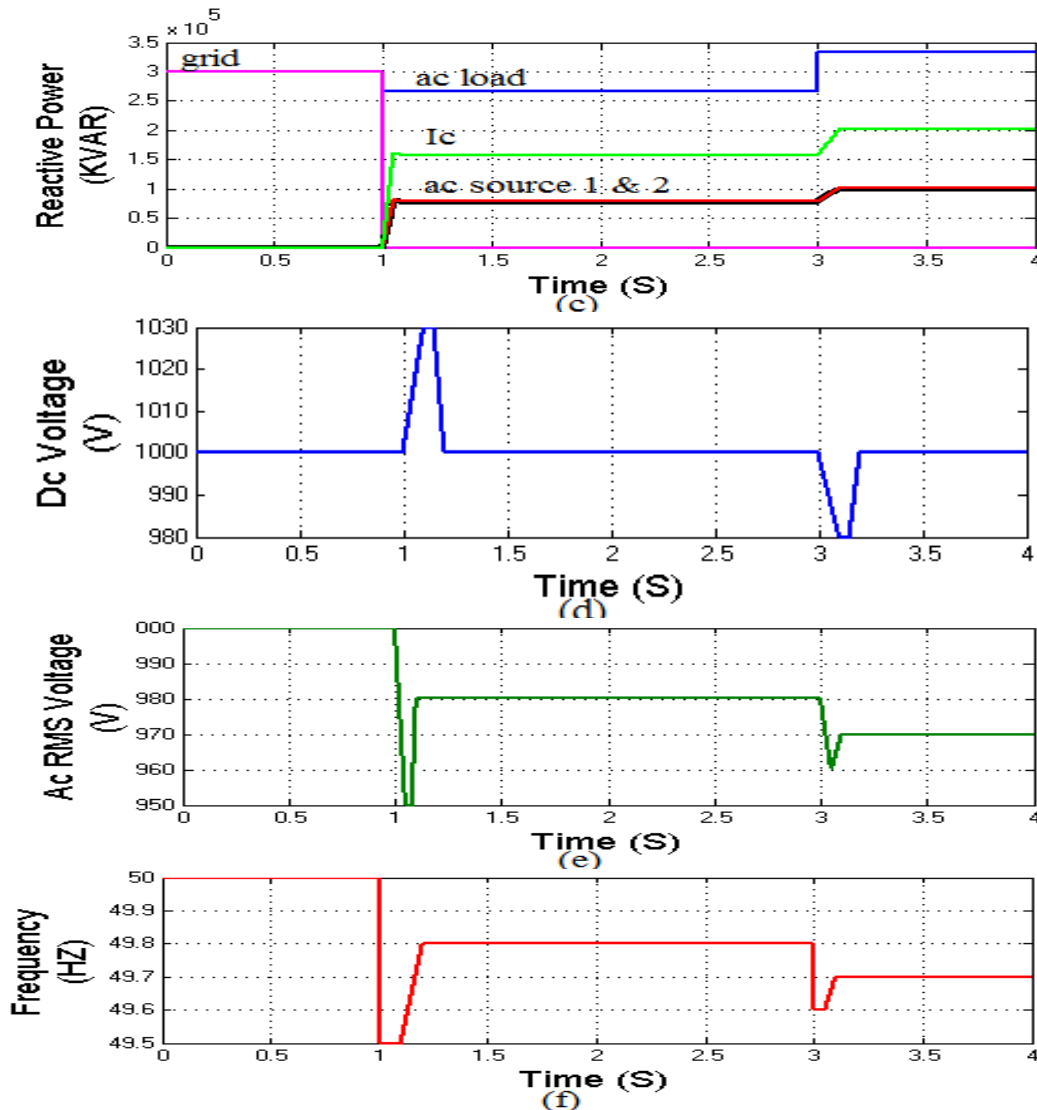


Fig.13. Simulation waveform of (a) Active power at AC side (b) IC, Active power at DC side (c) Reactive power at AC side, IC (d)DC Voltage (V) (e) AC RMSVoltage (V) (f) Frequency (Hz).

Case 3: Islanding mode when DC load is varying

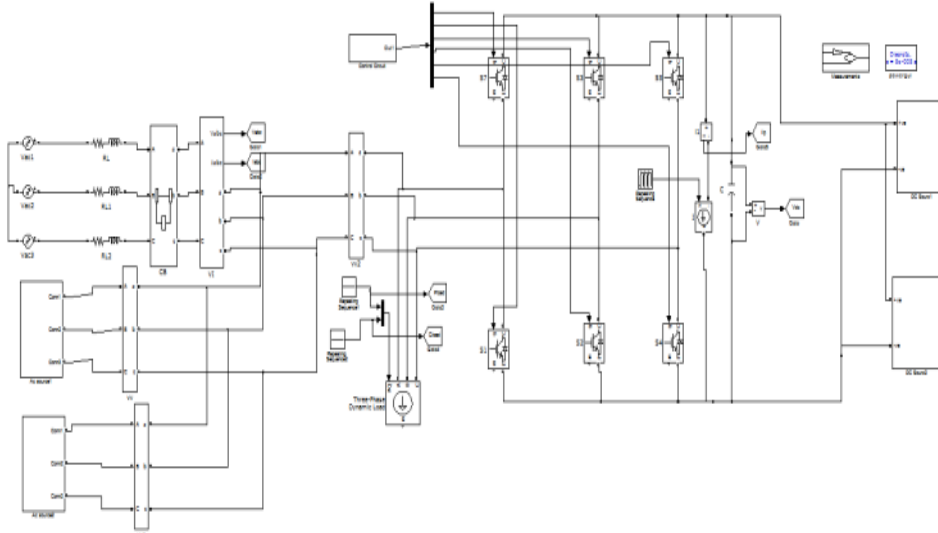
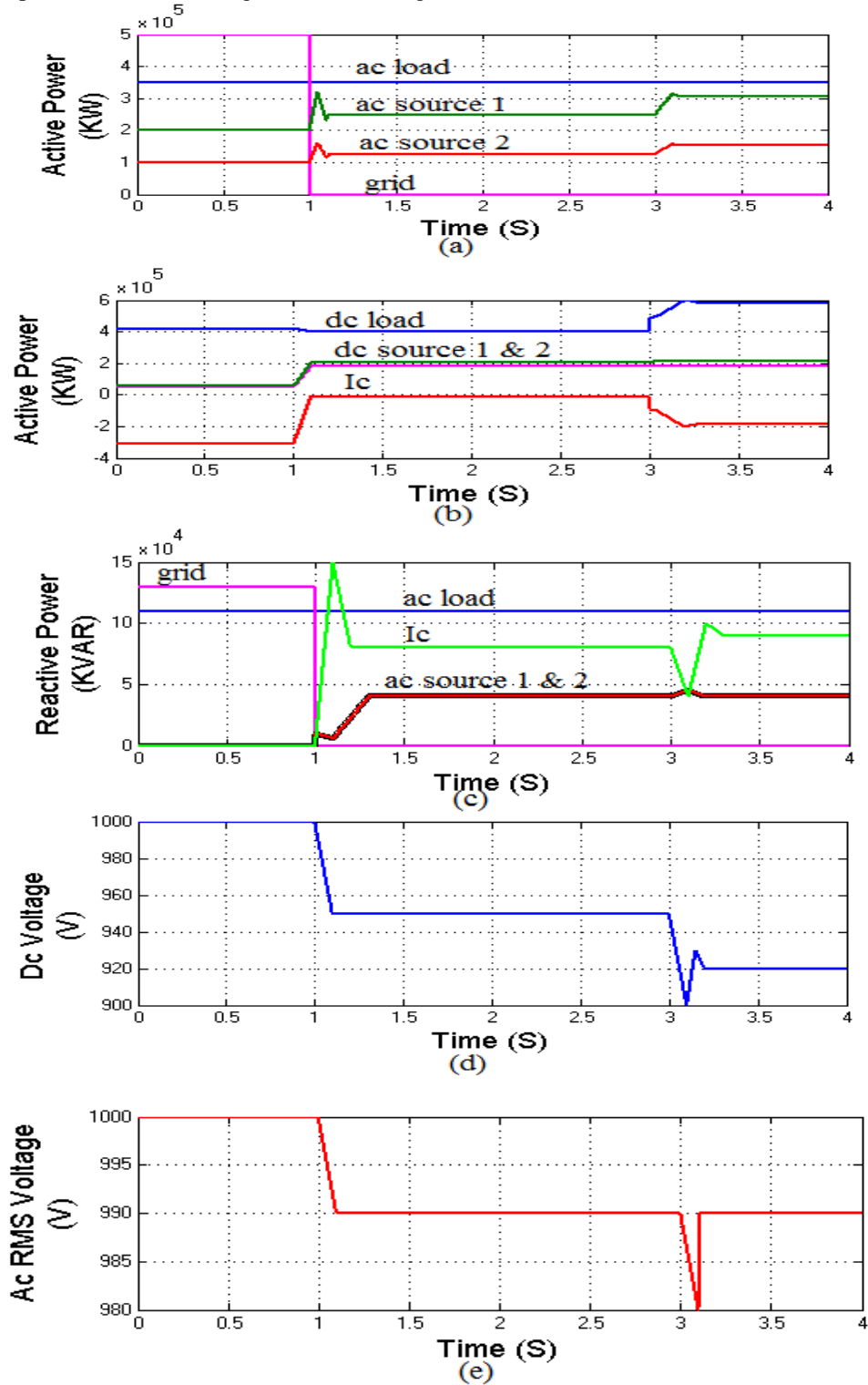


Fig.14. Simulink diagram of islanding mode with DC variable load.

Fig.14. Shows the simulink block diagram of islanding mode with DC variable load. Similar to case 2, in this case before islanding occurs, DC load is operating at 420 KW. At time $t = 1$ sec grid is disconnected from main utility grid, so islanding mode is occurred and DC load power is greater than the rated power of the DC sources shown in fig.15.(b). which causes voltage drop in dc voltage as shown in fig.15. (d). In order to balance the power, the IC controller shares the power in the AC micro grid with the DC sources to the DC micro grid side. At time $t = 3.5$ sec DC load is increased to 600 KW as shown in fig.15. (b). and this causes the IC to transfer more power from AC micro grid to DC micro grid.



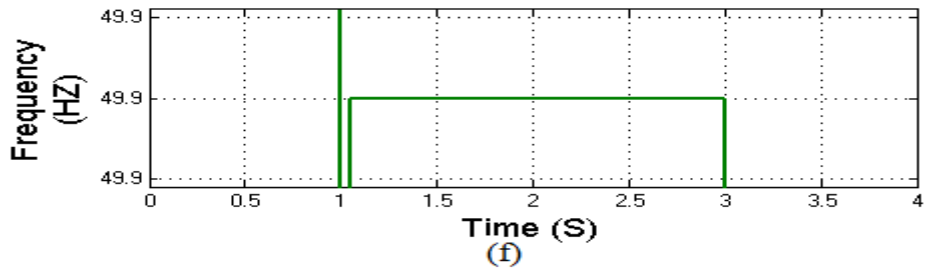


Fig.15. Simulation wave form of (a) Grid, Active power on AC side (b) Active power on DC side, IC (c) Grid, Reactive power on AC side, IC (d) DC Voltage (V) (e) AC RMS Voltage (V) (f) Frequency(Hz).

Case 4: When both loads are in light load condition

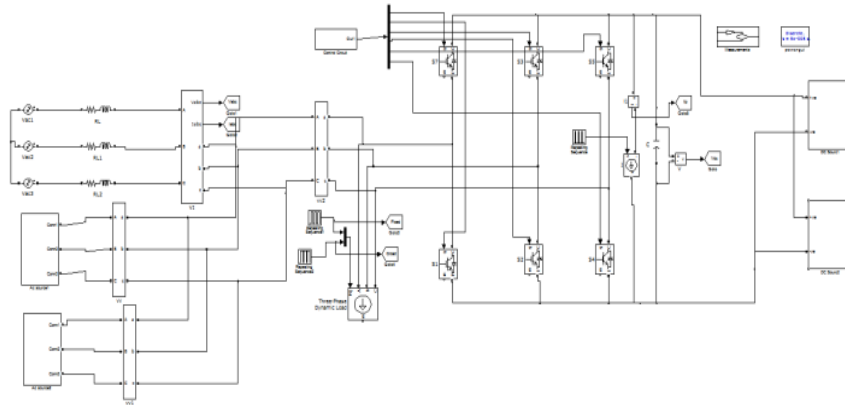
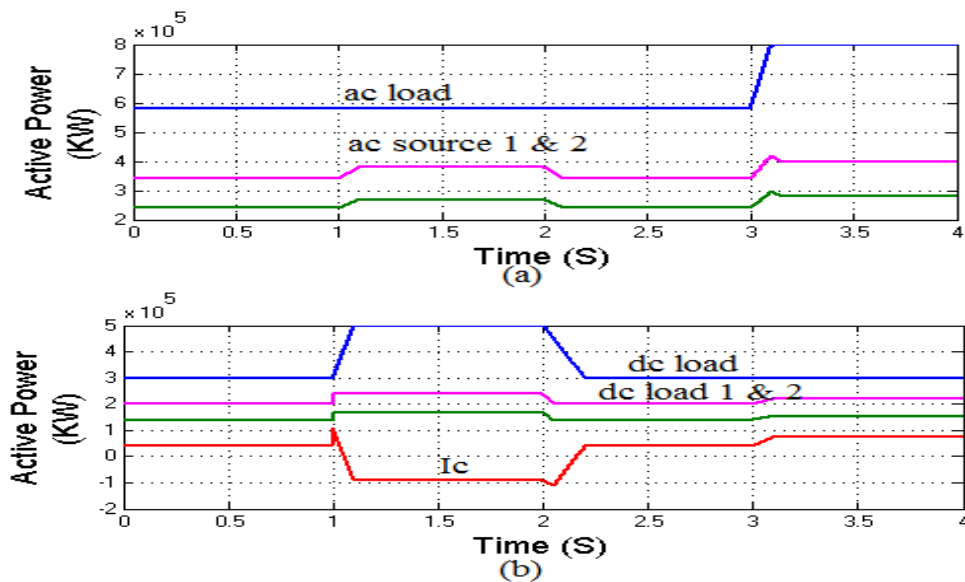


Fig.16. Simulink diagram when both AC load and DC loads are in light load condition.

Fig.16. Shows the Simulink diagram when both AC load and DC loads are in light load condition. In this case two micro grids are initially operated in load condition that means that the load power in both AC and DC micro grids are less than total rating of individual sources. So, the IC transfers no power. At time $t = 1$ sec load is increased in DC micro grid in which the power demand is greater than the DC generation shown in fig.17. (b). which causes voltage drop in DC link voltage as shown in fig.17. (d). at time $t = 2$ sec DC load is decreases and DC micro grid is enters the initial condition is shown in shown fig.17. (b). at time $t = 3$ sec ac load is increased and IC detects the frequency drop as shown in fig.17. (a) and (e).



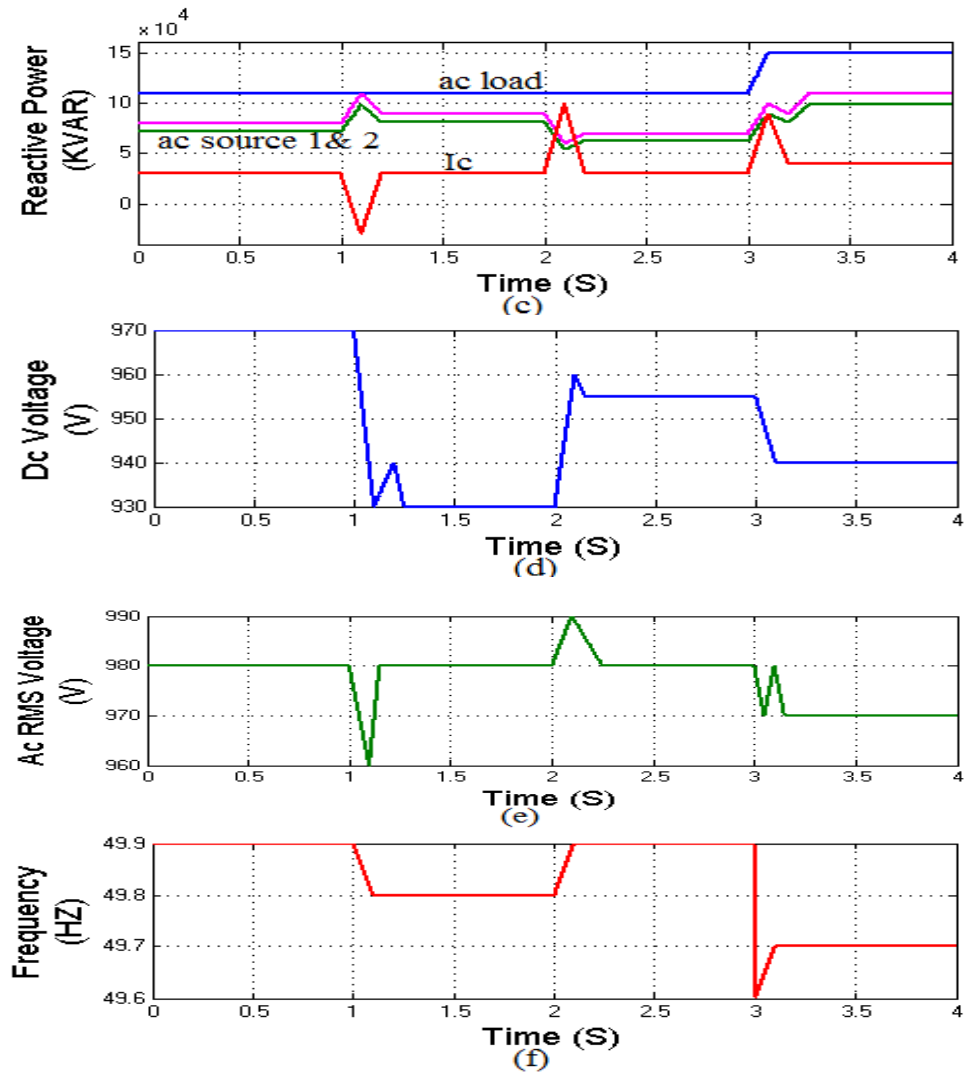


Fig.17. Simulation waveform of (a) Active power at AC side (b) Active power at DC side and IC (c) Reactive power at AC side, IC (d) DC Voltage (V) (e) AC RMS Voltage (V) (f) Frequency (HZ).

Case 5: When bothside loads are in over load condition

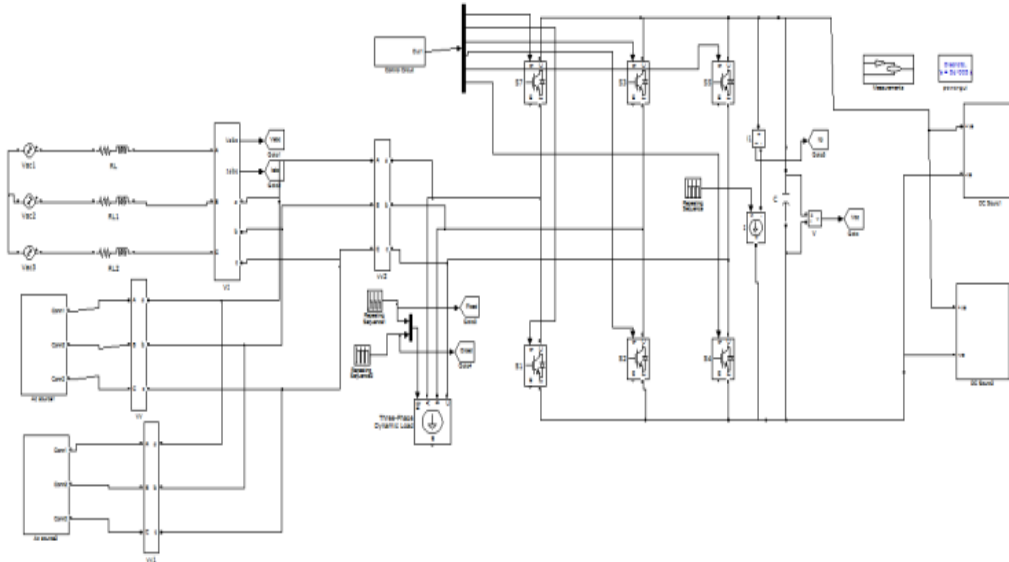
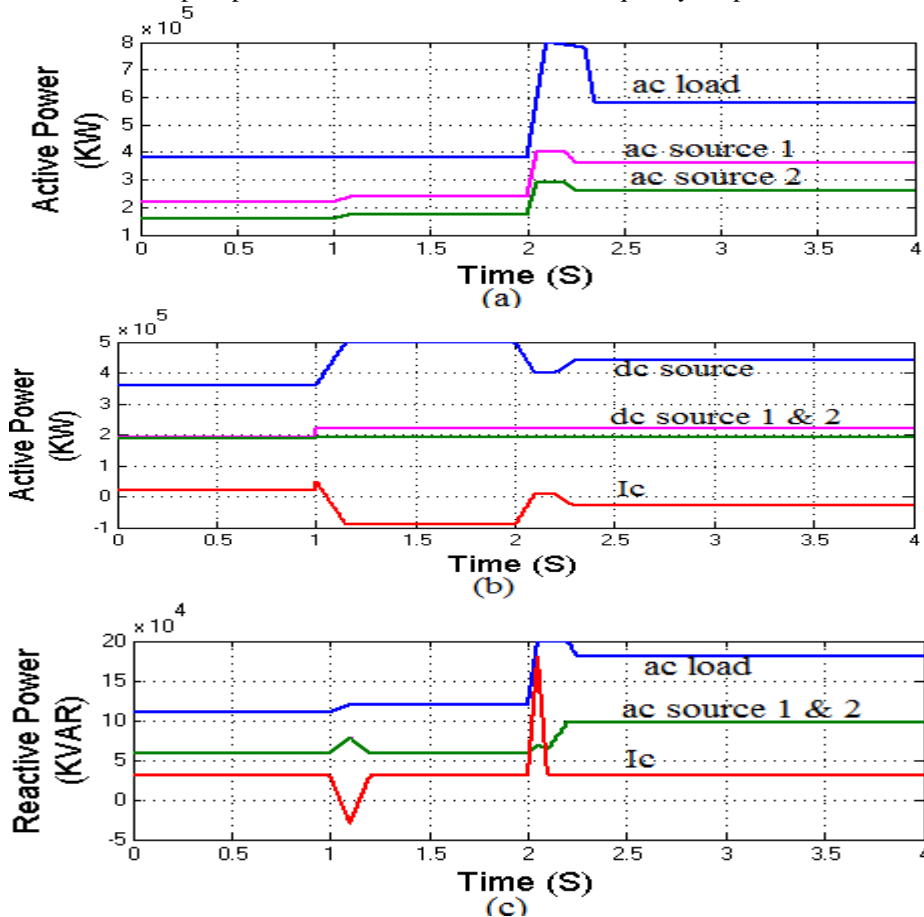


Fig.18.Simulink diagram of both AC load and DC loads are in over load condition.

Fig.18. Shows the simulink diagram of both AC load and DC loads are in over load condition. In this both micro grids are primarily operating in light load condition. At $t = 1$ sec DC load is increased to 500 KW that is over loading power in increased in DC micro grid is shown in fig.19.(b). Which cause voltage disturbances as shown in fig.19.(d). In which the IC transfer the required power to AC side. At time $t = 2$ sec the AC load is also increased to 800 KW at active power and 280 KVAR at reactive power, that means the AC micro grid is in over load condition is shown in figs.19.(a) and (c). Which causes frequency drop is shown in fig.19.(e). So, IC transfers surplus power to DCside and detects the frequency drop.



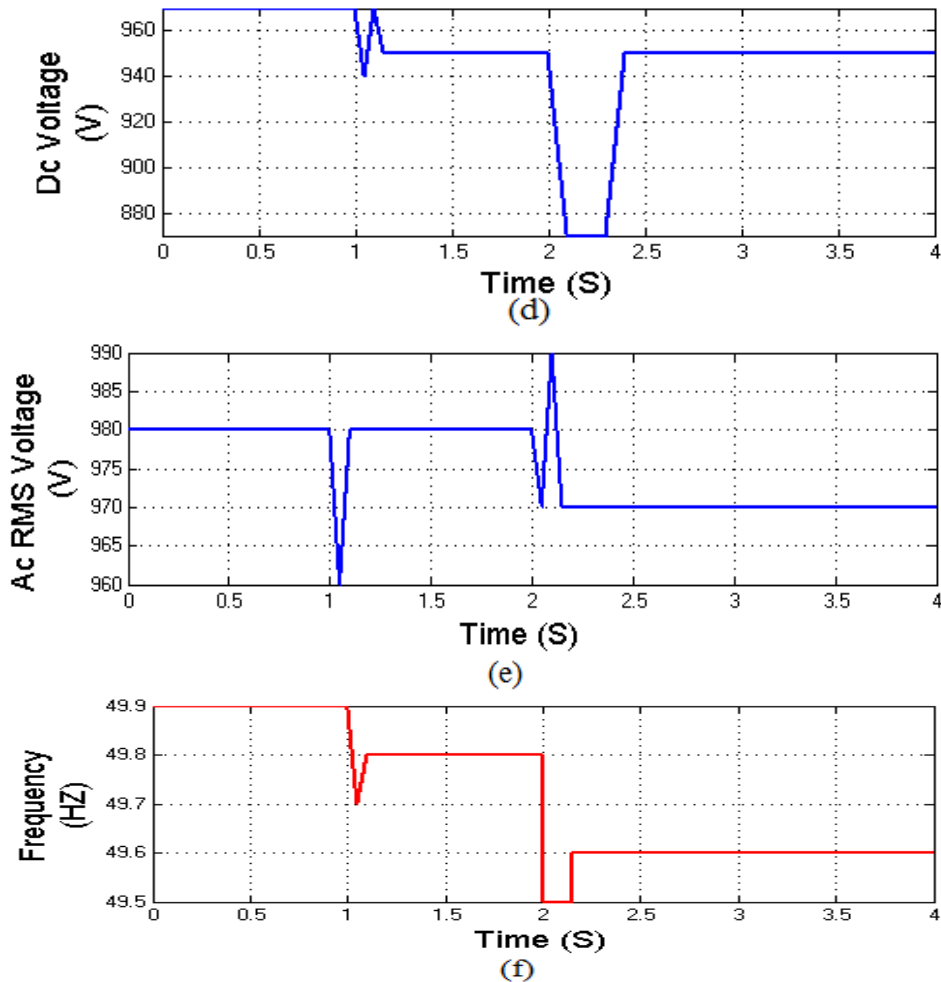


Fig.19. Simulation waveforms of (a) Active power at AC side (b) Active power at DC load, IC (c) Reactive power at AC side, IC (d)DC Voltage (V) (e) AC RMS Voltage (V) (f) Frequency (HZ).

Case 6: FLC in hybrid AC/DC micro grid

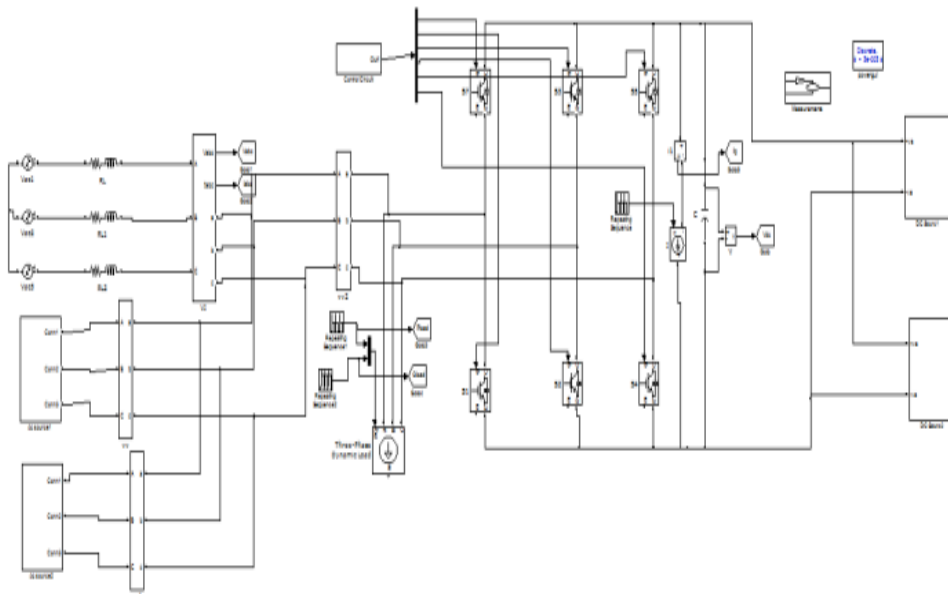


Fig.20. Simulink diagram of FLC in hybrid AC/DC micro grid.

Fig.20. Shows the simulink diagram of FLC in hybrid AC/DC micro grid. The above cases have controlled by using PI controller and power electronic conversion has occurred through the interlinking converter (IC) from AC micro grid to DC micro grid. Due to this conversion, in this case, total harmonic distortion (THD) occurred in grid current up to 4.10% is shown in fig. (21). so, these harmonics are reduced to 0.04%, by using the fuzzy logic controller (FLC) is shown in fig. (22). and table 2 shows the comparison of THD in micro grid current with PI controller and FL controller.

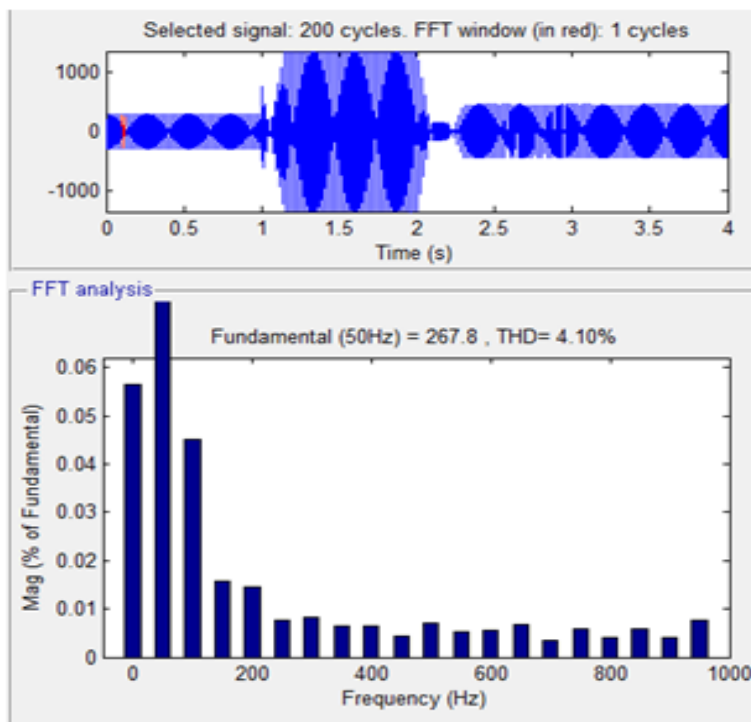


Fig.21. THD in grid current with PI controller.

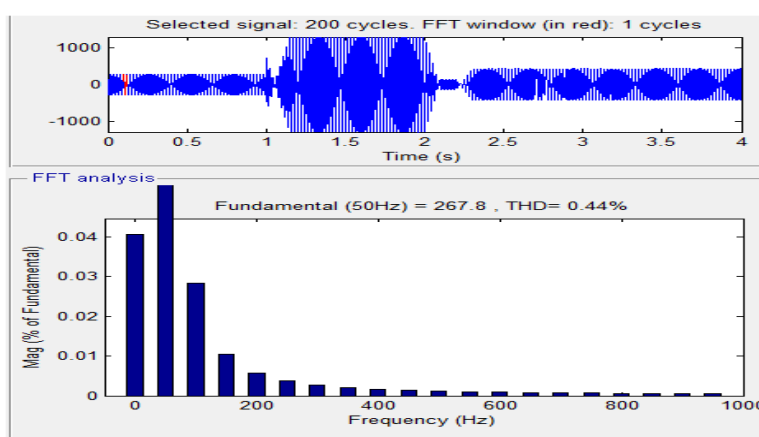


Fig.22. THD in grid current with fuzzy logic controller.

TABLE 2 THD in grid current

	PI CONTROLLER	FUZZY LOGIC CONTROLLER
THD	4.10%	0.04%

VII. CONCLUSION

In this paper hybrid AC/DC micro grid comprises of AC micro grid and DC micro grid interconnected by power electronic interfaces. The major purpose is to manage and control the power flow between the AC micro grid and DC micro grid through the AC source and DC source using the interlinking converter (IC). This conversion has been occurring between AC to DC or DC to AC using interlinking converter (IC) due to this

conversion total harmonic distortion (THD) has occurred in grid current up to 4.10%. In the presence of fuzzy logic controller (FLC) these harmonics are reduced to 0.04%.

REFERENCES

- [1]. N. Eghtedarpour and E. Farjah, Distributed charge/discharge control of energy storages in a renewable energy-based DC micro grid, *IET Renew. Power Gen.*, vol. 8, no. 1, pp. 45–57, Jan. 2014.
- [2]. A. Karabiber, C. Keles, A. Kaygusuz, and B. B. Alagoz, “An approach for the integration of renewable distributed generation in hybrid DC/AC micro grids,” *J. Renewable Energy*, vol. 52, pp. 251–259, Apr. 2013.
- [3]. P. C. Loh, D. Li, Y. K. Chai, and F. Blaabjerg, “Hybrid AC-DC micro grids with energy storages and progressive energy flow tuning,” *IEEE Trans. Power Electron.*, vol. 28, no. 4, pp. 1533–1543, Apr. 2013.
- [4]. P. C. Loh, D. Li, Y. K. Chai, and F. Blaabjerg, “Autonomous control of interlinking converter with energy storage in hybrid AC-DC micro grid,” *IEEE Trans. Ind. Appl.*, vol. 49, no. 3, pp. 1374–1382, May/Jun. 2013.
- [5]. P. C. Loh, D. Li, Y. K. Chai, and F. Blaabjerg, “Autonomous operation of hybrid micro grid with AC and DC subgrids,” *IEEE Trans. Power Electron.*, vol. 28, no. 5, pp. 2214–2223, May 2013.
- [6]. N. Eghtedarpour and E. Farjah, “Control strategy for distributed integration of photovoltaic and energy storage systems in dc micro grids,” *J. Renewable Energy*, vol. 45, pp. 96–110, Sep. 2012.
- [7]. L. Xu and D. Chen, “Control and operation of a DC micro grid with variable generation and energy storage,” *IEEE Trans. Power Del.*, vol. 26, no. 4, pp. 2513–2522, Oct. 2011.
- [8]. X. Liu, P. Wang, and P. C. Loh, “A hybrid AC/DC micro grid and its coordination control,” *IEEE Trans. Smart Grid*, vol. 2, no. 2, pp. 278–286, 2011.
- [9]. M. N. Ambia, A. Al-Durra, and S. M. Muyeen, “Centralized power control strategy for AC-DC hybrid micro grid system using multi-converter scheme,” in *Proc. IECON 2011—37th Annu. Conf. IEEE Ind. Electron. Soc.*, Nov. 2011, pp. 843–848.
- [10]. J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. Vicuna, and M. Castilla, “Hierarchical control of droop controlled AC and DC micro grids a general approach toward standardization,” *IEEE Trans. Ind. Electron.*, vol. 58, no. 1, pp. 158–166, Jan. 2011.
- [11]. D. Bo, Y. Li, Z. Zheng, and L. Xu, “Control strategies of micro grid with hybrid DC and AC buses,” in *Proc. 14th Eur. Conf. Power Electron. Appl. (EPE 2011)*, pp. 1–8.
- [12]. I.-Y. Chung, W. Liu, D. A. Cartes, E. G. Collins, Jr, and S. Moon, “Control methods of inverter interfaced distributed generators in a micro grid system,” *IEEE Trans. Ind. Appl.*, vol. 46, no. 3, pp. 1078–1088, May/Jun. 2010.
- [13]. K. Kurohane, T. Senjyu, A. Yona, N. Urasaki, and T. Funabashi, “A hybrid smart AC/DC power system,” *IEEE Trans. Smart Grid*, vol. 1, no. 2, pp. 199–204, Sep. 2010.
- [14]. C. Jin, P. C. Loh, P. Wang, Y. Mill, and F. Blaabjerg, “Autonomous operation of hybrid AC-DC micro grids,” in *Proc. IEEE ICSET, Kandy, Sri Lanka, Dec. 6–9, 2010*.
- [15]. H. Nikkhajoei and R. H. Lasseter, Distributed generation interface to the certs micro grid, *IEEE Trans. Power Del.*, vol. 24, no. 3, pp. 1598–1608, Jul. 2009.
- [16]. F. Katiraei, M. R. Iravani, A. L. Dimes, and N. D. Hatziargyriou, “Micro grids management: control and operation aspects of micro grids,” *IEEE Power Energy Mag.*, vol. 6, no. 3, pp. 54–65, May/Jun. 2008.
- [17]. C. K. Sao and P. W. Lehn, “Control and power management of converter fed micro grids,” *IEEE Trans. Power System*, vol. 23, no. 3, pp. 1088–1098, Aug. 2008.
- [18]. F. Katiraei and M. R. Iravani, “Power management strategies for a micro grid with multiple distributed generation units,” *IEEE Trans. Power Syst.*, vol. 21, no. 4, pp. 1821–1831, Nov. 2006.
- [19]. R. H. Lasseter and P. Paigi, “Micro grid: A conceptual solution,” in *Proc. IEEE-PESC’04, 2004*, pp. 4285–4290.
- [20]. M. E. Baran and N. R. Mahajan, “DC distribution for industrial systems opportunities and challenges,” *IEEE Trans. Ind. Appl.*, vol. 39, no. 6, pp. 1596–1601, Nov./Dec. 2003.