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AC-DC Hybrid Microgrid with Harmonic Elimination

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ABSTRACT: Hybrid ac/dc microgrids have been planned for the better interconnection of different distributed generation systems (DG) to the power grid, and exploiting the prominent features of both ac and dc microgrids. Connecting these microgrids requires an interlinking ac/dc converter (IC) with a proper power management and control strategy. During the islanding operation of the hybrid ac/dc microgrid, the IC is intended to take the role of supplier to one microgrid and at the same time acts as a load to the other microgrid and the power management system should be able to share the power demand between the existing ac and dc sources in both microgrids. The paper proposes a decentralized power sharing method in order to eliminate the need for any communication between DGs or microgrids.The interlinking converter uses PI controller in dq reference frame which along with the coordinated control logic, controls the power flow. But when a non linear load was connected to the system it was found that the current waveform was having high harmonic content. Also in certain load conditions when the power in the hybrid grid becomes too low it is not feasible to connect the non linear load. Hence an active filter has also been designed and incorporated in the system so as to make the system more reliable. Hysteresis control in dq reference frame is used for this. The performance of the proposed power control strategy is validated for different operating conditions with and without the active shunt filter is validatedin the PSCAD/EMTDC software environment.

KEYWORDS: AC-DC Hybrid Microgrid; Distributed Generation; decentralized power sharing; Interlinking Converter; PI controller.

I. INTRODUCTION

Due to increasing deployment of DGs in power systems, managing the power of different DGs and the grid has raised a major concern. In this field, microgrids have become a widely accepted concept for the superior connection of DGs in power networks. Corresponding to the conventional power systems, ac microgrids have been established foremost and a variety of surveys have been reported particularly on the subject of power sharing of parallel-connected sources. 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 microgrids 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. However, since the majority of the power grids are presently ac type, ac microgrids are still dominant and purely dc microgrids are not expected to emerge exclusively in power grids. Therefore, dc microgrids are prone to be developed in ac types even though in subordinate. Consequently, linking ac microgrids with dc microgrids and employing the profits of the both microgrids, has become interesting in recent studies. The idea is to merge the ac and dc microgrids through a bidirectional ac/dc converter and establishing a hybrid ac/dc microgrid in which ac or dc type energy sources and loads can flexibly integrate into the microgrids and power can smoothly flow between the two microgrids. The main idea is to use the locally generated energy and reducing the power draw from the grid. A coordinate control scheme is developed in order to manage the whole system in different operating conditions.

A microgrid is a controllable component of the smart grid defined as a part of distribution network capable of supplying its own local load even in the case of disconnection from the upstream network. Microgrids incorporate large amount of renewable and non-renewable distributed generation (DG) that are connected to the system either directly or by power electronics (PE) interface. The need for microgrids is so significant for many reasons but the most important issue is to the need to move to renewable sources of energy with very less carbon emission. Technical concerns over dynamics of microgrids especially in autonomous (island) mode necessitate revision of current paradigms in control of energy systems. [1] [2]

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During disturbances, the generation and corresponding loads can separate from the distribution system to isolate the microgrid's load from the disturbance (providing UPS services) without harming the transmission grid's integrity. This ability to island generation and loads together has a potential to provide a higher local reliability than that provided by the power system as a whole. In this model it is also critical to be able to use the waste heat by placing the sources near the heat load. The microgrid concept eliminates the need for a transmission system. Whatever power is generated shall be consumed locally. In the microgrids the generation would be in small scale and it is desirable essentially to have renewable energy sources, so as to reduce the carbon emissions and also reduce the dependence on non-renewable energy sources. [3,4]

Already, a smart grid based on an ac grid is proposed. However, no study or research is presented or published on a smart grid based on a dc grid. The paper [5] presents an ac/dc hybrid smart power system. The proposed system has advantages of both dc and ac grids. By applying power consumption control with the droop characteristic, the dc bus voltage is maintained within the acceptable range. The paper [5] presents a dc smart grid to achieve the suppression of dc bus voltage fluctuation by using controllable loads and stabilizing control of the connected ac grid. The power fluctuation due to renewable plant and loads is suppressed by the current control of controllable loads based on droop characteristics. By using the proposed system, the wind power and photovoltaic generators are able to operate at maximum power point with the reduction in cost by reducing storage equipment and by incorporating system frequency and dc bus voltage controls.

The paper [6] proposes a hybrid ac/dc micro grid to reduce the processes of multiple dc–ac–dc or ac–dc–ac conversions in an individual ac or dc grid. The hybrid grid consists of both ac and dc networks connected together by multi-bidirectional converters. The proposed hybrid grid can operate in a grid-tied or autonomous mode. 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. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature, and load are also considered in system control and operation. The simulation results show that the system can maintain stable operation under the proposed coordination control schemes when the grid is switched from one operating condition to another. Although the hybrid grid can reduce the processes of dc/ac and ac/dc conversions in an individual ac or dc grid, there are many practical problems for implementing the hybrid grid based on the current ac dominated infrastructure. The total system efficiency depends on the reduction of conversion losses and the increase for an extra dc link. It is also difficult for companies to redesign their home and office products without the embedded ac/dc rectifiers although it is theoretically possible. Therefore, the hybrid grids may be implemented when some small customers want to install their own PV systems on the roofs and are willing to use LED lighting systems and EV charging systems. The hybrid grid may also be feasible for some small isolated industrial plants with both PV system and wind turbine generator as the major power supply.

The coexistence of ac and dc subgrids in a hybrid microgrid is likely given that modern distributed sources can either be ac or dc. Linking these subgrids is a power converter, whose topology should preferably be not too unconventional. This is to avoid unnecessary compromises to reliability, simplicity, and industry relevance of the converter. The desired operating features of the hybrid microgrid can then be added through this interlinking converter. To demonstrate, an appropriate control scheme is developed for controlling the interlinking converter. The objective is to keep the hybrid microgrid in autonomous operation with active power proportionally shared among its distributed sources. Power sharing should depend only on the source ratings and not their placements within the hybrid microgrid. The proposed scheme can also be extended to include energy storage within the interlinking converter. An interlinking control scheme has been presented for regulating power flows in a hybrid ac–dc microgrid,whereby the control parameters for the interlinking converter is voltage at the DC side and frequency at the AC side. The results show that proportional active power sharing can be enforced based on ratings and not placements of sources within the hybrid microgrid. [7]

Harmonics are caused by non-linear loads, that is loads that draw a nonsinusoidal current from a sinusoidal voltage source. Some examples of harmonic producing loads are electric arc furnaces, static VAR compensators, inverters, DC converters, switch-mode power supplies, and AC or DC motor drives. In the case of a motor drive, the AC current at the input to the rectifier looks more like a square wave than a sinewave. High levels of harmonic distortion can cause such effects as increased transformer, capacitor, motor or generator heating, misoperation of electronic equipment (which relies on voltage zero crossing detection or is sensitive to wave shape), incorrect readings on meters, misoperation of protective relays, interference with telephone circuits, etc. The likelihood of such ill effects occurring is greatly increased if a resonant condition occurs. Resonance occurs when a harmonic frequency produced by a non-linear load closely coincides with a power system natural frequency. There are 2 forms of resonance which can occur: parallel resonance and series resonance. Parallel resonance occurs when the natural frequency of the parallel

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combination of capacitor banks and the system inductance falls at or near a harmonic frequency. This can cause substantial amplification of the harmonic current that flows between the capacitors and the system inductance and lead to capacitor fuse blowing or failure or transformer overheating. Series resonance is a result of a series combination of inductance and capacitance and presents a low impedance path for harmonic currents at the natural frequency. The effect of a series resonance can be a high voltage distortion level between the inductance and capacitance.[8][9][10]

There are many methods for modeling a Voltage source inverter. The various methods include pulse width modulation switching using PI controllers for current control, dead beat control strategy, hysteresis control, fuzzy logic control etc. The PI control technique implemented in the dq reference frame was found to have very high speed response to changes. The hysteresis control method of control was found to have excellent characteristics when implemented for the control of Active shunt filters.[10][11][12]

II. SYSTEM DESCRIPTION

i) The Control Strategy

A simple hybrid ac/dc microgrid is proposed. It consists of an ac microgrid with conventional DG sources, a dc microgrid with two dc type sources and an IC links the two microgrids together. Each of these microgrids also includes their individual loads. Besides, during normal grid operation the hybrid microgrid is connected to the main utility grid through the ac microgrid. Basically, the microgrids are thought to operate in grid-connected or islanding modes [1]. In the grid-connected operation mode of the hybrid microgrid, the ac microgrid dynamics are governed directly by the main utility grid and the IC primarily regulates the dc microgrid 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 droop characteristics. When over-loading happens in the dc microgrid, 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 microgrid is described in either of these two modes.

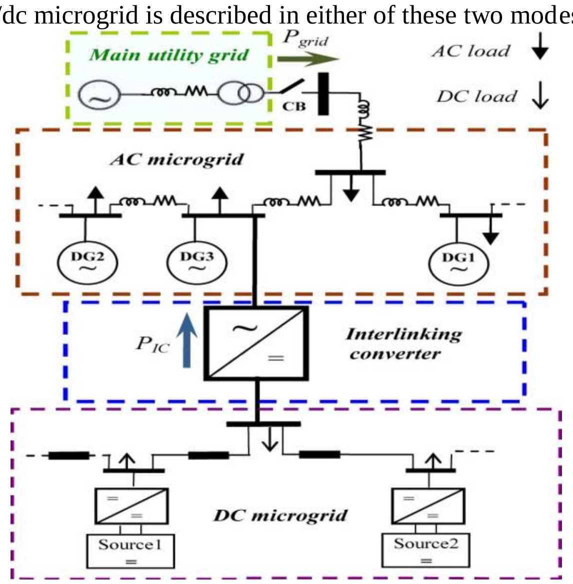

Fig 1 :Proposed System

To accomplish the coordinated control E_a, the DC grid voltage and the W_m, angular frequency of the machine (frequency of the grid) is continuously monitored. Whenever there is reduction in frequency or voltage reference power is calculated according to the droop characteristic. The block diagram for the coordinated control is provided below.

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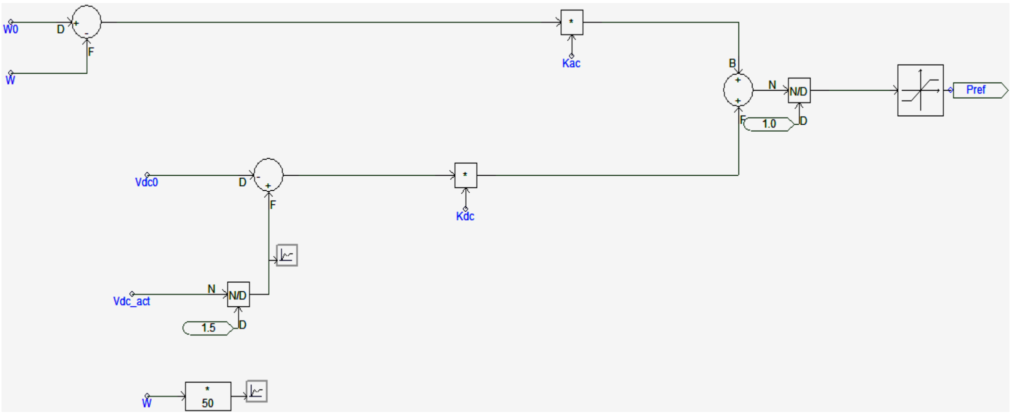


Fig 2:Coordinated Control strategy

The equations involved are

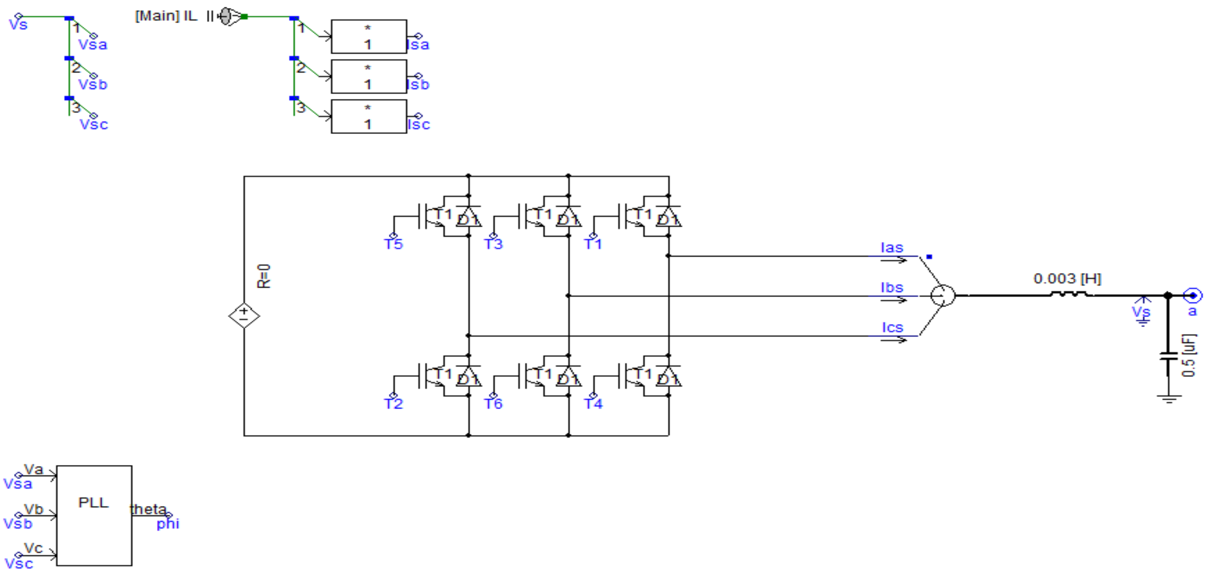
$$P_{ac}^{ref} = \frac{1}{K_{ac}} (f_0 - f)$$

$$P_{dc}^{ref} = \frac{1}{K_{dc}} (V_{dc}^{0} - V_{dc})$$

These are respectively the DC droop equation and the AC droop equation. This equations are used to calculate the reference power.

(ii)Active Shunt Filter Design

A non linear load is connected to the system and to study its effects.The non linear load was found drawing high harmonic currents and hence an active shunt filter has been designed which could be incorporated in the system. The current absorbed by the load is measured and it is transformed into dq reference frame.The need for transformation into dq reference frame is to have better control.Then the direct current component is passed through a third order butterworth filter.The output of the butterworth filter(containing only the fundamental component) is subtracted from the direct current drawn by the load.This results in extraction of harmonics.Now the harmonic content extracted is passed through dq-abc convertion block.This current is taken as the reference for the hysteresis controller.



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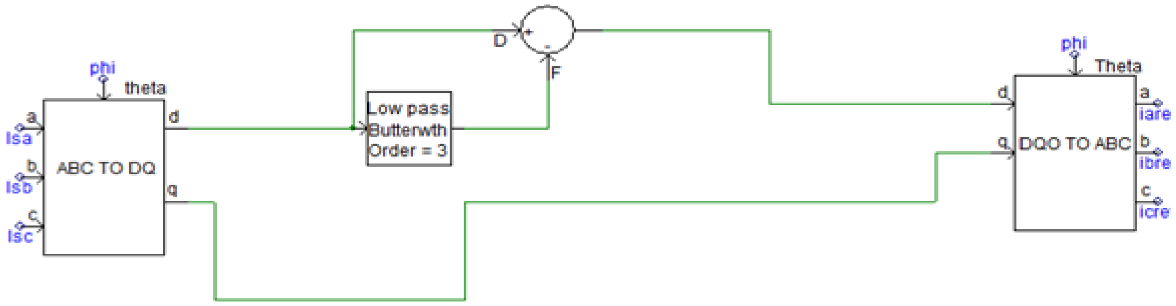

Fig3:Low Pass Hysteresis Filter.

III. SIMULATION RESULT

Simulation model of the DSTATCOM inverter is given above. A renewable energy source of wind type having a 20kW is fed directly to the three phase grid. In between this wind energy and grid the designed inverter is placed. SHE method is used here as modulation technique. Control for that is also shown in the simulink model. Switching angles are calculated offline using newton raphson method. This value of switching angles are used for the generation firing pulses for inverter switches.

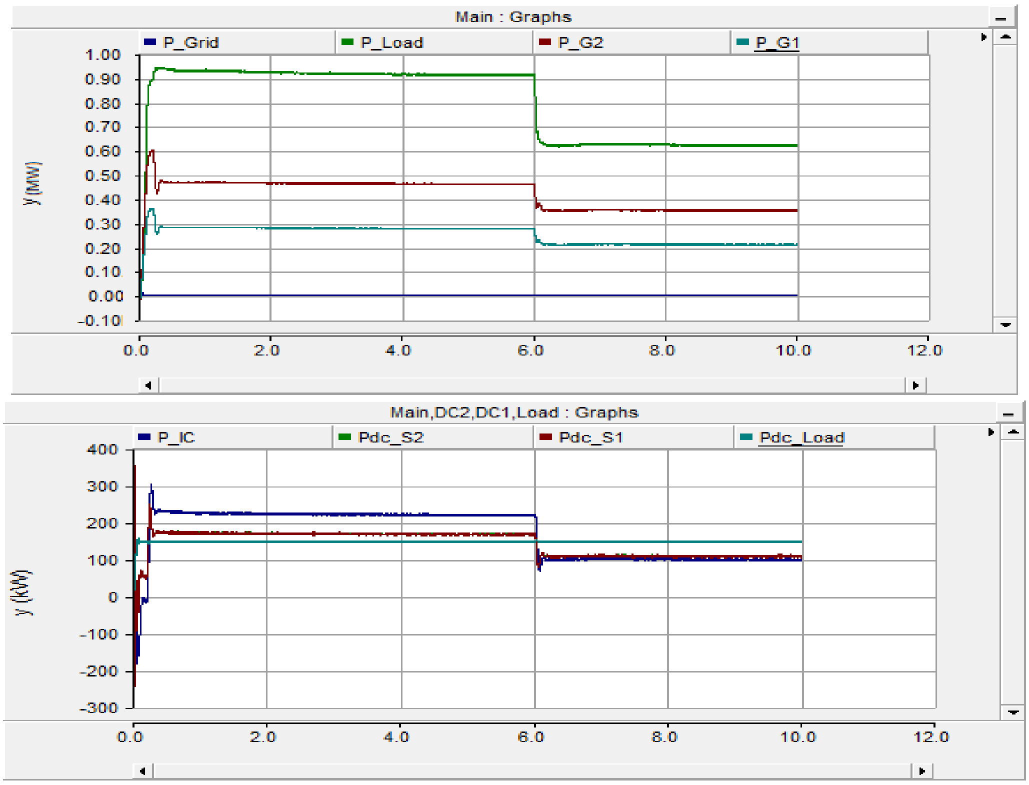

Fig 4:Grid disconnected mode graphs

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Observations

Table 1 Till 6 seconds.

Source/Load	Power (kW)
Grid power	0
DC Load Power	150
AC Load	930
Interlinking Load Power	200
DC source 1 Power	180
DC Source 2 Power	180
AC source 1 Power	470
AC source 2 Power	280

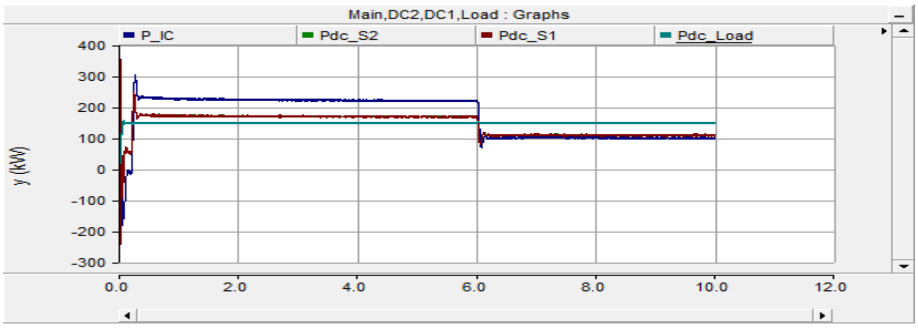
After 6 seconds timed circuit breaker is switched on.The AC microgrid load is decreased and corresponding changes in the power flows are plotted after simulation.the observations are tabulated below.

Table 2 After 6 seconds.

Source/Load	Power (kW)
Grid power	0
DC Load Power	150
AC Load	610
Interlinking Load Power	80
DC source 1 Power	90
DC Source 2 Power	90
AC source 1 Power	380
AC source 2 Power	200

Grid Disconnected mode

In this mode of operation the grid is disconnected from the AC-DC microgrid.So the microgrids has no option of absorbing deficient power from the main grid.



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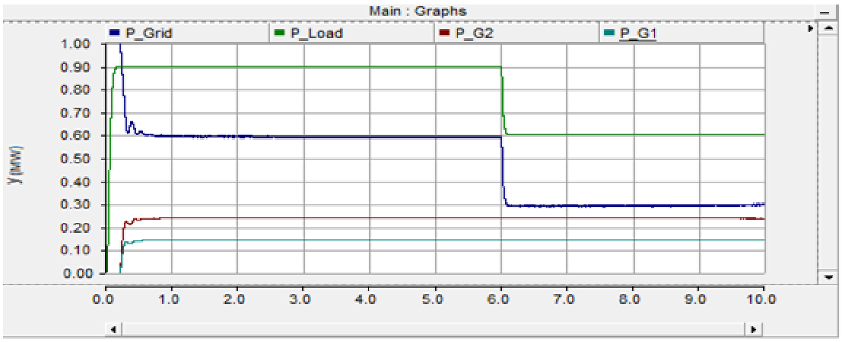

Fig5:Grid connected mode

In the grid connected mode the AC microgrid is directly connected to the grid while the DC microgrid is connected via the Interlinking converter.Whatever power is deficient in the system is absorbed from the main grid.At six seconds the load at the AC microgrid is reduced and it can be seen that the grid power has decreased.This validates that the grid is responding to the load changes.

Table 3 Till 6 seconds.

Source/Load	Power (kW)
Grid power	600
DC Load Power	145
AC Load	900
Interlinking Load Power	-40
DC source 1 Power	50
DC Source 2 Power	50
AC source 1 Power	220
AC source 2 Power	120

After 6 seconds the load at the AC microgrid is decreased by means of switched breaker circuits and the corresponding changes can be observed in the system.

Table 4 After 6 seconds

Source/Load	Power (kW)
Grid power	0
DC Load Power	150
AC Load	610
Interlinking Load Power	80
DC source 1 Power	90
DC Source 2 Power	90
AC source 1 Power	380
AC source 2 Power	200

Feeding power to grid mode.

Whenever there is excess power in the AC-DC hybrid microgrid the excess power will be fed back to the grid.This mode of operation has been simulated and the graphs and obsevations are tabulated below.

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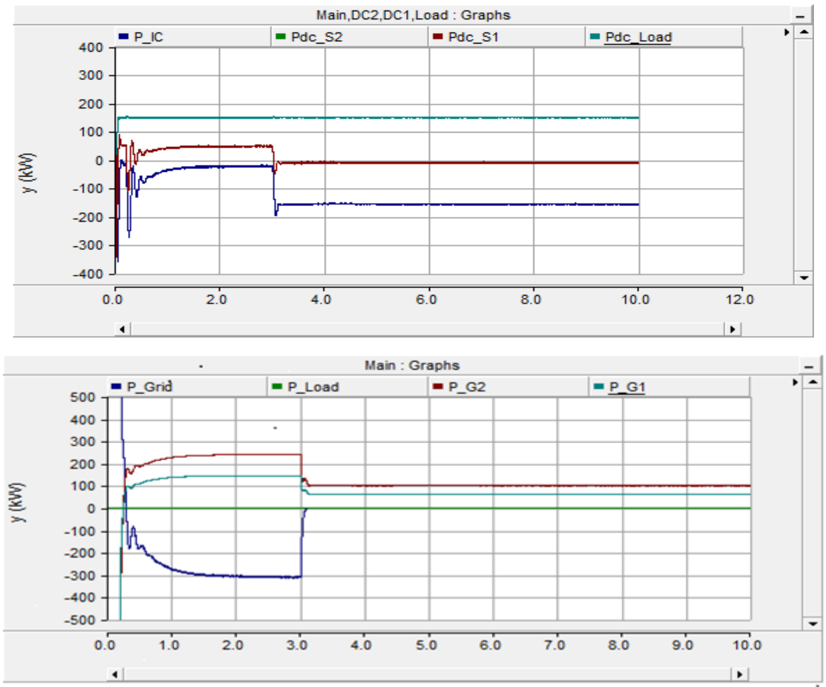

Fig6:Power feeeding to grid

Table 5 Till 3 seconds

Source/Load	Power (kW)
Grid power	0
DC Load Power	150
AC Load	0
Interlinking Load Power	-150
DC source 1 Power	0
DC Source 2 Power	0
AC source 1 Power	100
AC source 2 Power	50

After 3 seconds the grid was disconnected from the system and hence the effective load on the Hybrid AC-DC microgrid model reduces and hence the generated power is reduced.The power flow results are tabulated below.

Table 6 After 3 seconds

Source/Load	Power (kW)
Grid power	0
DC Load Power	150
AC Load	610
Interlinking Load Power	80
DC source 1 Power	90
DC Source 2 Power	90
AC source 1 Power	380
AC source 2 Power	200

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Active Shunt Filter Graphs

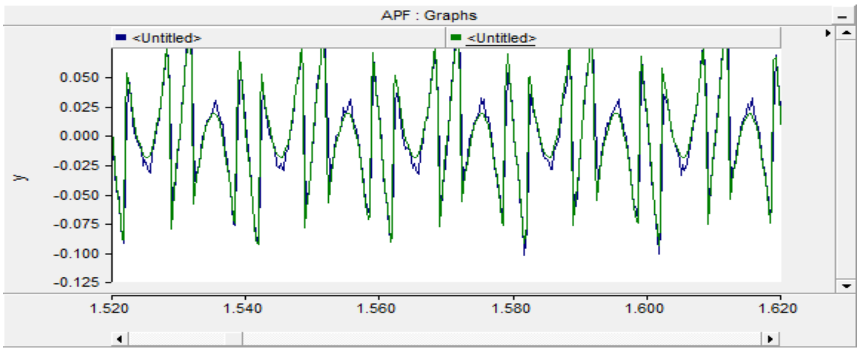

Fig7:Tracking of extracted harmonics by hysteresis Conrol

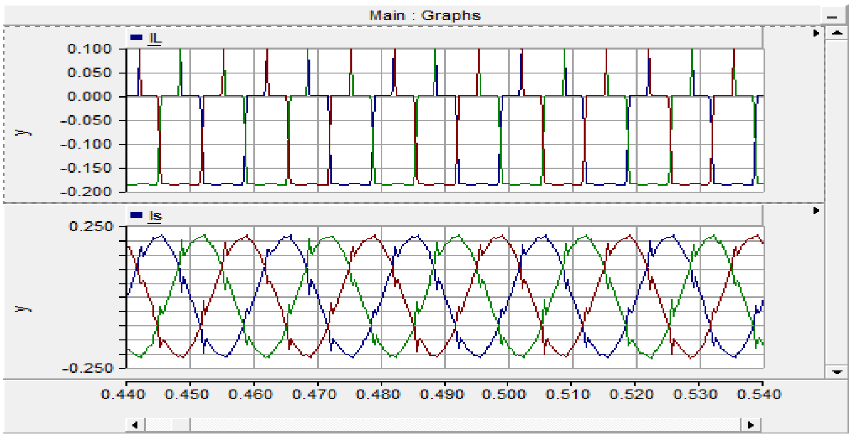

Fig8:Improvement in Harmonics

IV. CONCLUSION

The proposed AC-DC hybrid Grid connected model has been developed in the PSCAD software platform,and an aactive shunt filer has been modelled to suit the devoloped microgrid model,so as to eliminate harmonics if any generated by non;linear loads.The simulation results have been plotted and observations have been tabled.It could be observed that the theactive shunt filter,The interlinking converter working on coordinated control loop is responding well to different grid scenarios.

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BIOGRAPHY

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