Power Control in a Hybrid Isolated Power System with Better Power Quality

Dr. B. Mouli Chandra,
Professor and HoD, Department of EEE, QIS College of Engineering and Technology, Ongole
email:bmoulichandra@gmail.com

Dr. B. Venkata Prasanth,
Professor in EEE, QIS College of Engineering and Technology, Ongole, email:
bvenkataprasanth@gmail.com

Dr. Ahmad Syed,
Assistant Professor in EEE, Chaitanya Bharathi Institute Of Technology,
ahmadsyed_eee@cbit.ac.in

Dr. Prakash Y.,
Department of EEE, QIS College of Engineering and Technology, Ongole

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Abstract
Hybrid power systems are the combination of different renewable energy conversion systems like solar energy, fuel cell, wind energy, tidal energy, geothermal energy etc,. They are considered as a reliable and viable option for the electrification of rural villages which are beyond the reach of proper grid electricity. The control of power among different renewable sources while maintaining the power quality of supply is important for the reliable and sustainable operation of these isolated systems. This idea proposes a flexible and versatile solution to voltage quality problems is offered by active power filters APF. Where the reactive power, harmonics and unbalance in the load power are always supplied by one photovoltaic inverter, while the active power is shared by another photovoltaic inverter and fuel cell based on the load requirement. This power sharing control increases the power reliability and power quality of isolated village hybrid power systems. The detailed simulation is studied in MATLAB SIMULINK
Index Terms—Hybrid power system, Active Power Filter, Power sharing control

I. Introduction

A major part of world population lives in villages where the extension of grid electricity is difficult. Distributed generation (DG) has become an important energy option due to utility restructuring, technology evolution, public environmental policy, and an expanding electricity market. Many such renewable based power systems working in different parts of India and the world are generating power which are not at par with the grid power. The improved quality and reliability in the supply definitely results an increase in power demand and hence the reduction in cost of electricity.

Load compensation and power injection using the grid interactive inverters in microgrid do exist in literature [2]- [4]. The main focus of this work is to realize a dual functionalities in an inverter that would provide the active power injection from solar photo voltaic system and also works as an active power filter, compensating unbalances and the reactive power generated by other loads connected to the system. The proposed system consists of PV and Fuel cell. The active power of load is properly shared among the two inverters and the Fuel cell, whereas the reactive, unbalance and harmonic power of load is taken care by Inv-1. This decoupled active and reactive power sharing among inverters increases the efficiency and overall reliability of the system[6]-[7].

Parallel inverter power sharing scheme available in literatures are of two types. The first method is based on the drooping of output voltage amplitude and frequency as a function of active and reactive power delivered by the inverter [8]-[9]. This scheme does not require any control communication and is well suited for power sharing among parallel inverters which are situated at different geographic locations. However, it has some drawbacks such as slow dynamic response, high dependency on inverter output impedance, active and reactive power coupling and unequal unbalance and harmonic power sharing. The other control scheme is based on the active load sharing techniques such as centralized, master slave, average load sharing and circular chain control [10]. These active load sharing schemes require control communication but provide good voltage regulation and dynamic responses.

The active power is shared by the two PV inverters. But because of the intermittent nature of the solar irradiation the power may not be sufficient to supply the load. As the load increases, the active power demand increases. This additional active power demand is supplied by the Fuel cell. By this way the power management is done to meet the load requirements. The power quality problems like reactive power, harmonics, and unbalance in the load voltage due to nonlinear loads are compensated by the p-q theory control strategy. Hence we can say that PV-I inverter will compensate the power quality issues apart from supplying the active power. But the PV-II inverter and Fuel cell will only supply the active power demand by the load.

II. System topology

In this section, the topology of the hybrid system is discussed. The proposed system consists of two parallel PV inverters and a Fuel cell. The block diagram of the system is shown in Fig. 1. During the day time, when there is enough solar irradiation, the two parallel inverters are able to meet the load demand. The operating duty of Fuel cell can therefore, be scheduled during peak load demand or based on the power balance between inverters output power and the load power. So the operation of the plant can be divided into two modes, mode-I and mode-II. In mode-I, two parallel inverters are supplying active power to the load and Inv-I compensates the reactive, unbalance and harmonic power of load During mode-II operation, the active power is shared among two inverters and a Fuel cell. The non active power required by the load is supplied by the InvI as in mode-I operation. As the non active power of the load is fully supplied by a PV inverter, the full capacity of the Fuel cell can be used for supplying the active power. Moreover, because of the use of solar PV inverter, the Fuel cell need to operate only during peak hours. The another advantage of the scheme is, the unbalance in source currents and THDs in source voltage and current are getting minimised. Thus the entire system would generate power which are on par with the grid power. Thus an off grid village energy system becomes more efficient, reliable and economic. In the proposed system, the nonlinear load compensation and power sharing among different sources are controlled by APF and p-q theory

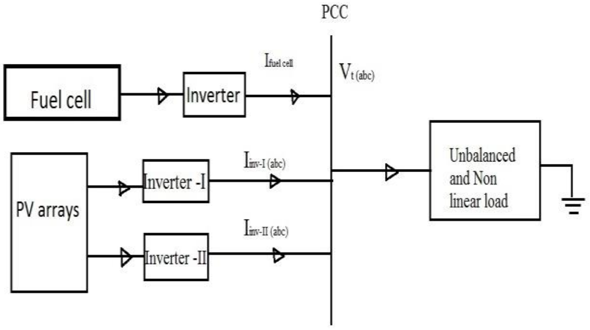

Fig. 1 Block diagram

III. P-Q CONTROL THEORY

p-q theory(or d-q) was developed primarily for an non linear load compensation by active power filters. The system topology is shown in Fig.2

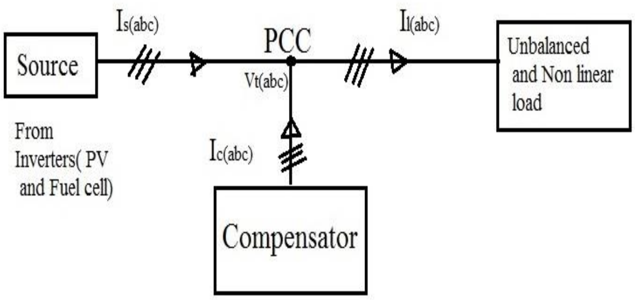

Fig.2 Non linear load compensation

The theory of load compensation is derived out by the following conditions

a). The average real power demand by the utility grid should be met. Shown as,

$$V_{ta}\, I_{sa} + V_{tb}\, I_{sb} + V_{tc}\, I_{sc} = P_l \qquad (1)$$

b) The neutral current must be zero. Therefore,

$$I_{sa} + I_{sb} + I_{sc} = 0 \qquad (2)$$

The three phase currents are drawn and are converted to two phase components such that it becomes easy for the analysis. As the three phase components are having the mutual inductance effect between them and are displaced at any angle of 120 degrees from each other i.e time varying in nature. It is not easy with the three phase components to compensate the power quality problems like reactive power compensation, harmonics, and unbalance in the load components because of non linear loads. To make it easy the three phase components are transformed to two phase components by removing the mutual inductance effect and making it time invariant. Hence we get α-β components after removing the mutual inductance effect and to make it time invariant the α-β components are transformed to p-q or d-q components.

The three phase components transformation to α-β and to p-q or d-q components are shown below.

The three phase currents are as shown below

$$I_a = I_m \cos\omega t \quad (3)$$

$$I_b = I_m \cos(\omega t - 2\pi/3) \quad (4)$$

$$I_c = I_m \cos(\omega t - 4\pi/3) \quad (5)$$

Hence we get

$$I_\alpha = \sqrt{(2/3)} \times (i_a + (-1/2)i_b + (-1/2)i_c) \quad (6)$$

$$I_\beta = \sqrt{(2/3)} \times (\sqrt{3}/2(i_b) + -\sqrt{3}/2(i_c)) \quad (7)$$

To get the time invariant components the α-β components are transformed to p-q or d-q components hence we get

$$I_d = i_\alpha \cos\theta + i_\beta \sin\theta \quad (8)$$

$$I_q = -i_\alpha \sin\theta + i_\beta \cos\theta \quad (9)$$

IV. CONTROL STRATEGY OF MODE 1 OPERATION

Control strategy is explained separately for two modes of operation of the plant. In mode-I, a Fuel cell is working in parallel with two inverters to supply the load. In mode-II, two PV inverters are operating in parallel. The schematic model of control strategy is shown in Fig 3

A. **Mode: I** Operation of parallel PV inverters and Fuel cell

In this mode, the control strategy is developed in such a way that, the Fuel cell and the two PV inverters together share the average active power demand, while Inv-I supplies rest of the power components such as reactive, harmonic and unbalanced power demanded by the load.
The reference current generation of Inv-I and Inv-II are separately described in the following sections.

$$I_{load(abc)} = I_{inv1(abc)} + (I_{inv(abc)} + I_{inv2(abc)}) \quad (10)$$

Thus Inv-I supplies all reactive and harmonic components of load current and an active component that corresponds to the available microgrid power at the DC bus. The reference current generated by using (10) is tracked by using hysteresis band current controller and switching pulses are thus generated.

B.Mode II Operation of two parallel inverters

If the solar insolation is high so that the PV power output is sufficiently enough to meet the total demand, two parallel inverters are operating in parallel to supply the load. During this mode, Inv-I provides compensation to the nonlinear load as well as supplies a fraction of active power.

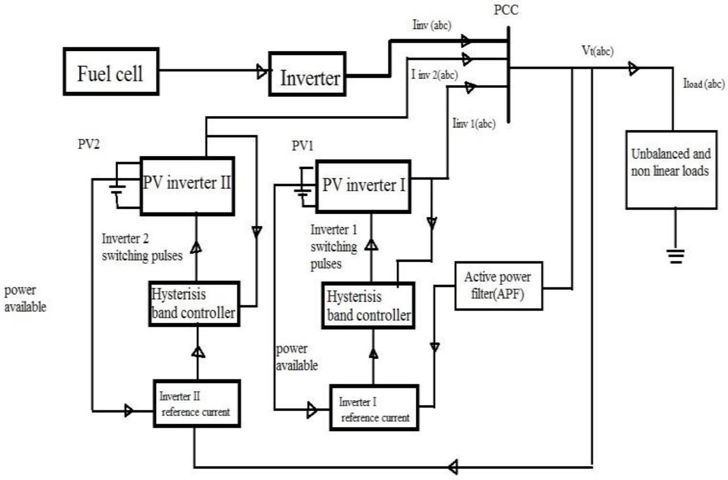

Fig 3 Schematic model

In this mode, Inverter-II is controlled in voltage controlled mode. The inverter is made to track a reference voltage and current of desired magnitude and frequency with the help of a hysteresis band controller, thus regulating the magnitude and frequency of the PCC voltages.

Table 1

PARAMETER VALUES FOR SIMULATION STUDIES

Sno	Parameter	Value
1	Inverter 1 DC voltage	800v
2	Inverter 2 DC voltage	800v
3	Fundamental frequency	50Hz
4	Load resistance	50ohm
5	Load inductance	30mH
6	Hysteresis Band(+or-)h	0.1A

V. SIMULATION STUDIES

The parallel inverter operating with a Fuel cell is simulated using MATLAB simulation. The various parameters of the system under study are given in Table. I. The voltage at the DC bus of inverter is decided by PV power output.

The simulation results are shown in the following graphs Fig 4. The source voltage, source current and load currents are as shown below.

The value of current is being changed at the time t=0.1sec with additional load. As the load is further increased at t=0.15sec, hence the PV inverters alone cannot meet the load demand so the Fuel cell energy is added to meet or compensate the extra demand.

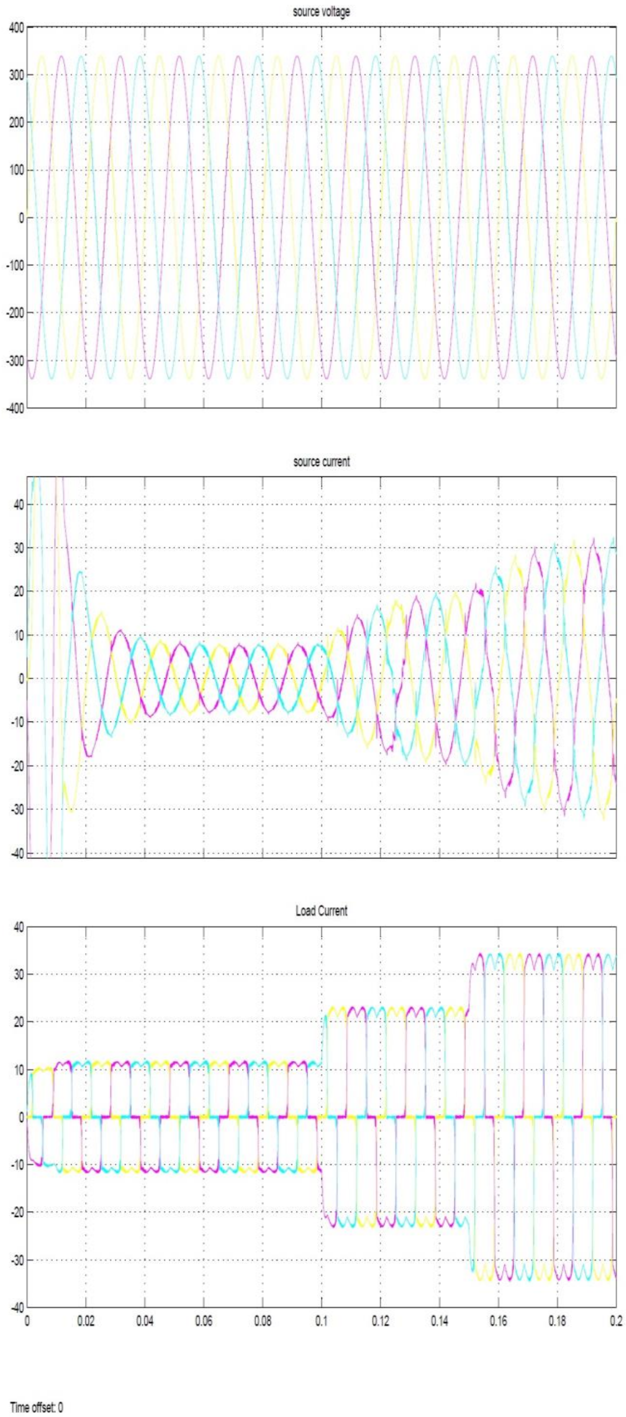

Fig. 4. Source voltage, Source current, Load Current

VI. Conclusion

There are many renewable based off-grid power system for village electrification. This can have a wide spread application, if the supply reliability and the power quality are improved. This work proposes a hybrid topology with two parallel inverters and a Fuel cell. The sharing of active and non active powers are controlled by Active Power Filter. The proposed system has increased reliability as three power sources are available for active power sharing and a dedicated inverter for supplying the non active power. In this hybrid scheme, as one inverter and Fuel cell are supplying only active power, the full capacity of the inverter and the fuel cell respectively can be utilised to inject the real power to the off grid. The improvement in the power quality definitely brings an off-grid system to generate power which are on par with grid power supply.

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