‘’Analysis Droop Control Strategy for Parallel Solar Inverters-off Grid Mode’’

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Abstract: Over the years, power converters have found wide application in grid interfaced systems, including distributed power generation with renewable energy sources. In distributed energy systems like solar, hydro or any diesel generation where the output of the system is DC and is expected to be converted in AC, an inverter is used. There are various modes to have a controlled output of inverter. This output is to be controlled such that there should be balanced supply when inverters are connected in parallel. It is consists of three phase Voltage Source Inverter control scheme which is called as Proportional controller. In PI control, the stationary reference frame is used to transfer the feedback quantities from load side to source side. In this process, the decoupling of *d* and *q* components arises which is little complex. The PI controller is adopted in the most familiar dqo reference frame. The three phase system is simulated in the matlab-simulink environment with the controller and experimental results are given to prove the correctness and feasibility of the system. The droop control technique is all about sharing of the Active and Reactive powers between parallel connected inverters connected in Mini-Grid system. The sharing of power will be based on the ratings of the inverter when they are subjected to any change in load. The renewable Energy sources can meet the new load requirement in manner determined by its frequency and Voltage Droop Characteristics, The focus on a control Strategy that will be for the operation of Parallel inverter based micro-grid. This technique is important because, there is no external link is required between the inverters to share the load.

Index Terms - : PI controller; d- alphabetic character reference frame; alpha beta reference frame; reference tracking; Droop control; Three loop control; wireless communication, mini-grid.

I. INTRODUCTION

One of the world’s fastest increasing major economy is upcoming international energy market. It has also successfully a range of energy market changes and carried out a huge amount renewable energy development, the especially in solar energy. Looking ahead, the government has laid out an inspired vision to transport secure, reasonable and sustainable energy to all these nations. This is in-depth purpose to support the government in summit its energy policy objectives by setting out range of recommendations in each area. With the focus on energy system transformation of energy security affordability. The analysis also highlights a number of significant lessons from the quick growth of India’s energy sector that could inform the plants of other nations around the world. The government of India has maintained greater interconnections through the country and now needs the current coal fleet to operate more flexibly. It is also encourage in reasonable battery storage. The International experience suggests that varied mix of flexibility investments needed to successful system integration of wind and solar PV

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In order to control the renewable energy sources more effectively and fulfill power quality requirement, micro-grid concept is proposed more recently. A micro-grid is a cluster of RES and loads, which can operate in both grid-connected mode and islanded mode. All the renewable energy sources are parallel connected to an ac common bus through inverters or ac-to-ac converters. The key functional element of an AC Micro-Grid system is a Voltage Source Inverter (VSI). The different Renewable Energy Sources (RES) within the Micro-Grid system can operate independently or interconnected to a common DC link which supplies constant input to the VSI. These systems are to be properly controlled in order to provide the reliable power system to the utility network [2-4].

This paper focuses on a control strategy that is used for the operation of a parallel inverters based micro-grid. First, the power flow in a network system is investigated, based on which the droop control method for micro-grid is presented. Furthermore, inverter control techniques are discussed and combined with the droop method for proper power sharing. Droop control is a concept which is done for active and reactive power sharing between the parallel inverters. For droop control technique, there is a need of at least two parallel connected inverters [5]. As the main objective is to observe power sharing between the two inverters, droop control technique is mainly used for micro grid systems where main grid in islanded. This control method is used for the regulation of the voltage and the frequency on AC micogrids, fed by voltage source inverters. In order to avoid a complex communication network for the synchronization of the various VSI on a micro grid, a conventional method called Droop Control issued.

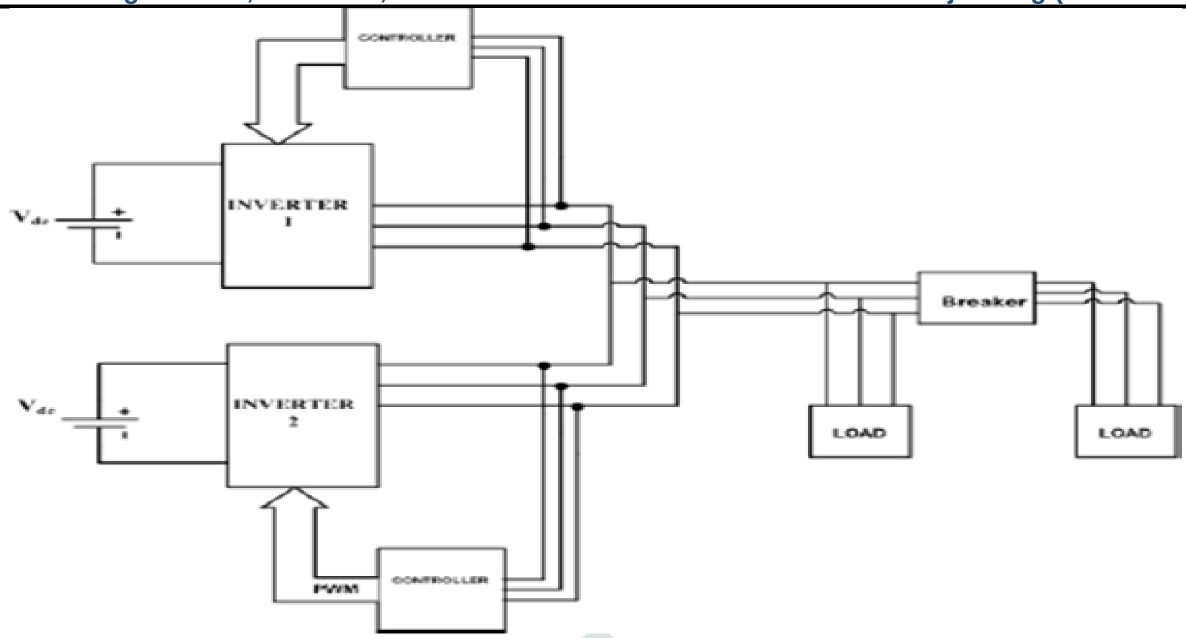

Figure 1. Block diagram of droop controlled inverters

- To maintain amplitude and frequency of the voltage in a micro-grid within a normal range when operating in autonomous mode;
- To share adequate active power and reactive power from energy sources to the loads when operating in autonomous mode;
- To perform optimal power exchange between micro-grid and the main power grid when operating in grid- connected mode;
- To ensure a smooth transfer between inverter and grid in autonomous mode and grid connected mode.

To satisfy of these needs, we'd like a bearing system which is able to maintain these parameters at desired value. It's important to possess a really reliable power offer and for that, the system desires, a decent controller. This will be achieved by PI controller. The general conclusion is that, several of the controllers for this explicit system are either bowed down due to the advanced network or they're terribly tough to implement. Hence the controller selection and its implementation become very important [5].

The straight forward PI controller is employed for dominant the electrical converter output. The most advantage of the PI controller is that there are no remaining management error when a set-point modification or a method disturbance. An obstacle of PI controller is that there's a bent for oscillations. PI management is employed once no steady-state error is desired [3]. There is a use of synchronous frame in PI control, where abc quantities are converted to dqo quantities and then error signal is fed to the PI controller

II. SYSTEM DESCRIPTION

The micro-grid will be connected either in grid connected mode or autonomous (islanded) mode. Ordinarily the small sources act as constant power sources, once they are operated in grid connected mode, which means that they are controlled to inject the demanded power in to the network .In autonomous mode the micro sources are controlled to supply all the power needed by the local loads while maintaining the voltage and frequency within the allowed limits. The system shown in Fig. 1 is the parallel operation of two inverters It comprises filter and electrical converter block whose specifications are given within the table no one. The controller blocks given in Fig. one are enforced by PI controller. This controller is analysed and enforced in following sections.

III PROPOSED SYSTEM

The frequency and voltage droop controls in Fig 2 can be employed in each dispatchable generator to maintain the micro grid frequency and voltage within the specified standards. However, the non dispatchable generators in the micro grid are operated in maximum power tracking mode to enhance the benefits of renewable energy sources, the interaction between different types of DGs in an autonomous micro grid is investigated by means of droop. Represent the non-inertial source. In the first case, the behaviour of inertial DGs is analyzed. The response of micro grid with non-inertial [7] DGs is presented next. Finally, both inertial and non-inertial DGs are considered to propose better drop control strategies for a hybrid micro grid.

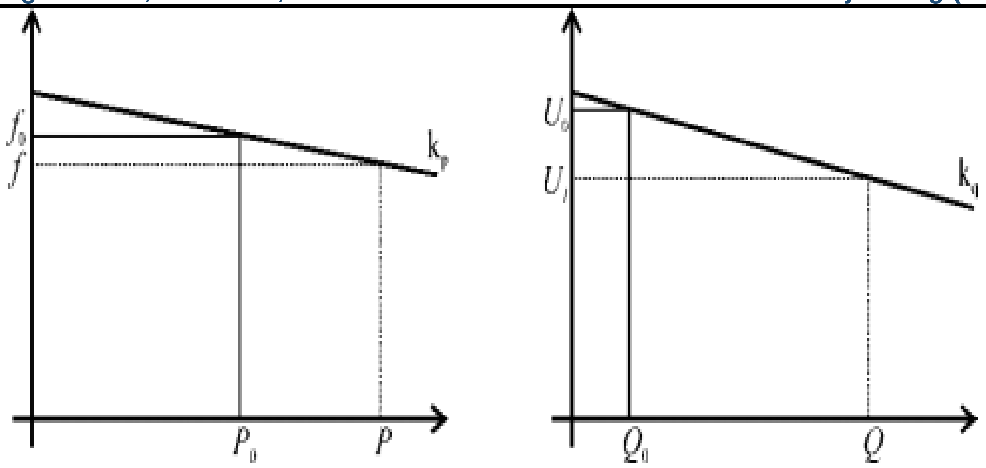

Fig.2 Frequency and Voltage Droop Control Characteristics

IV THREE PHASE INVERTER

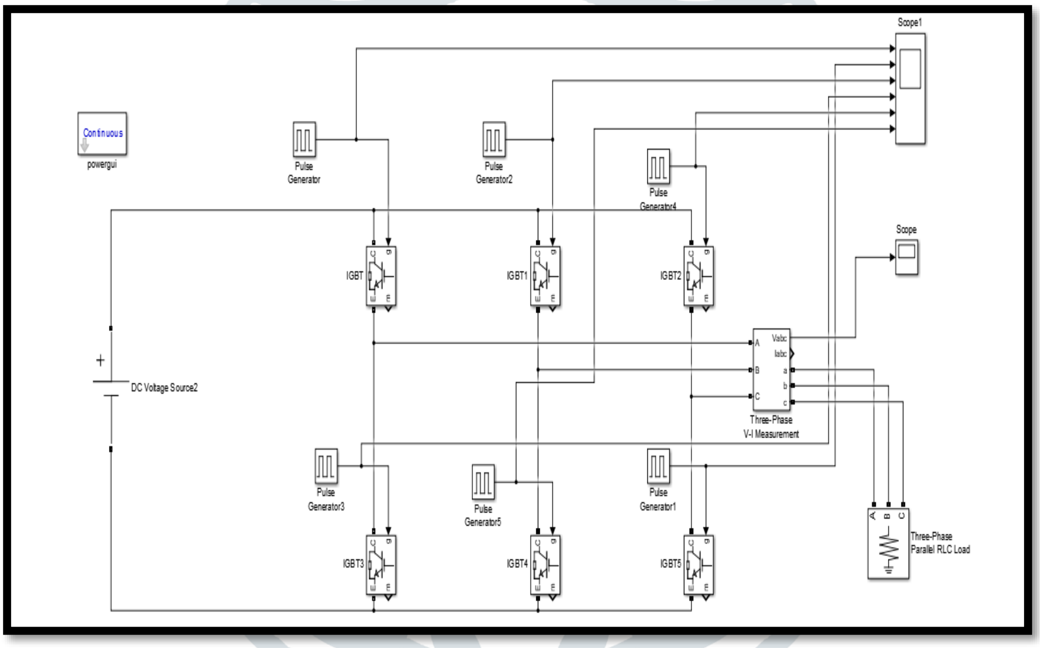

Fig. 3 Block Diagram of three phase inverter in Matlab simulation

Three-phase inverters are normally used for high power applications. The advantages of a three-phase inverter are:

- The frequency of the output voltage waveform depends on the switching rate of the switches and hence can be varied over a wide range.
- The direction of rotation of the motor can be reversed by changing the output phase sequence of the inverter.
- The ac output voltage can be controlled by varying the dc-link voltage.

The general configuration of a three-phase DC-AC inverter is shown in Circuit Diagram. Two types of control signals can be applied to the switches:

• 180° conduction • 120° conduction

In this mode of conduction, every device is in conduction state for 180° where they are switched ON at 60° intervals. The terminals A, B and C are the output terminals of the bridge that are connected to the three-phase delta or star connection of the load. The operation of a balanced star connected load is explained in the diagram below. For the period 0° − 60° the points S1, S5 and S6 are in conduction mode. The terminals A and C of the load are connected to the source at its positive point. The terminal B is connected to the source at its negative point. In addition, resistances R/2 is between the neutral and the positive end while resistance R is between the neutral and the negative terminal.

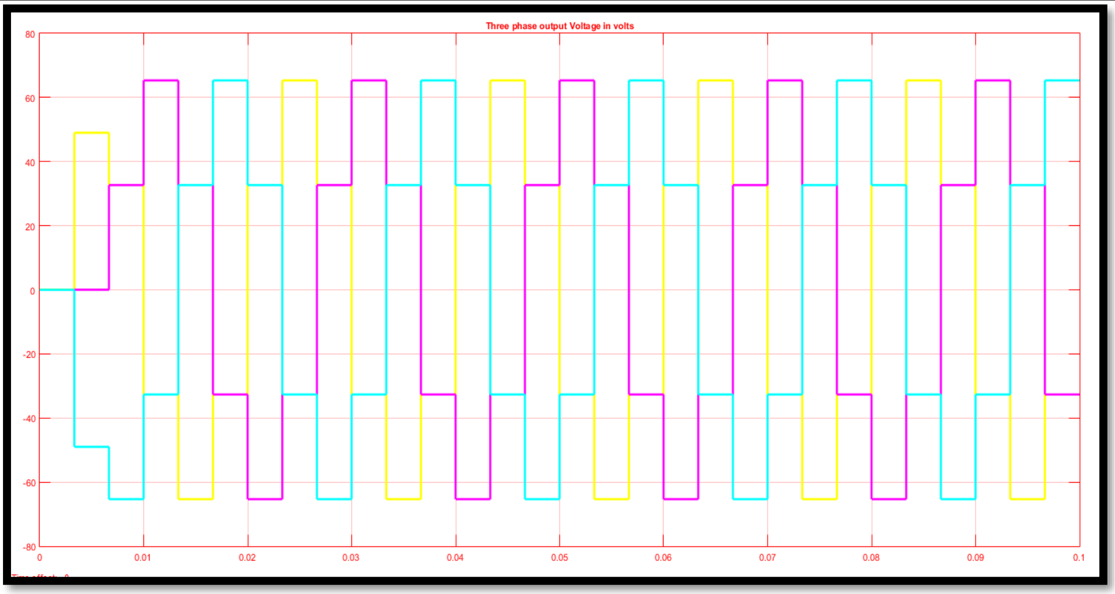

Fig4. Three Phase Output Voltage of 3 Phases VSI

Fig. 4 shows that the waveforms of phase voltage, it can be observed that there are six changes in magnitude during one cycle of voltage, as marked on the voltage V_{AS}. Thus, the VSI is frequently called a *six-step inverter*. Because the waveform is periodic, it contains a fundamental component of voltage as well as higher-order harmonics whose harmonic numbers are given by h=6n±1h=6n±1 Where *n* is an integer from 1 to infinity. Thus, the waveform contains the 5th and 7th, 11th and 13th, 17th and 19th harmonics, and so on.

V ANALYSIS OF CHANGE IN LOAD ON VOLTAGE SOURCE INVERTER

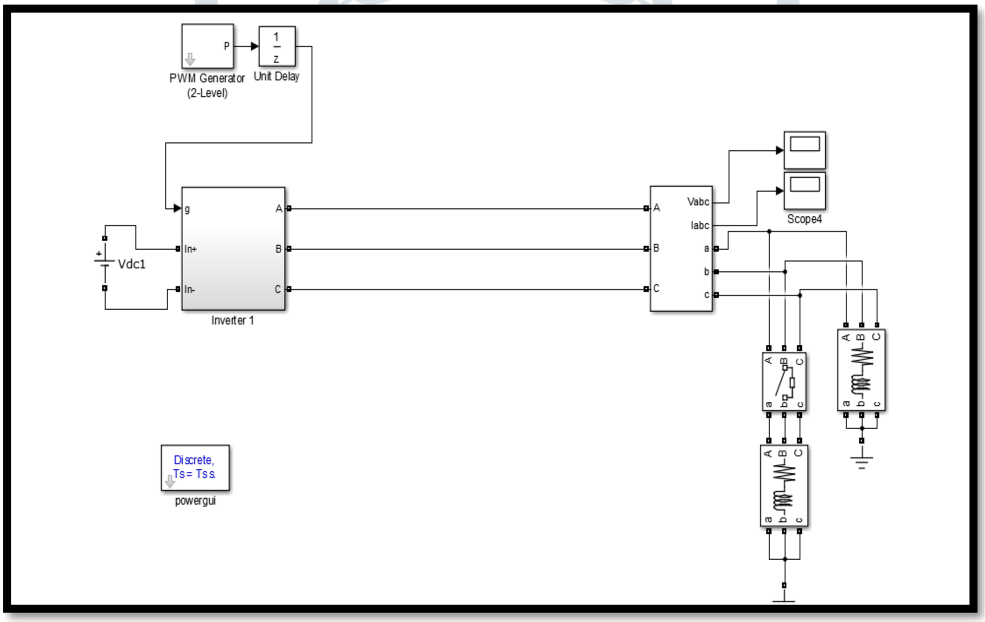

Fig. 5 Block Diagram of Inverter Circuit Along With RL Load in Matlab Simulation

Fig 5 shows that the block diagram of inverter circuit along with RL load, the inverter is a three phase inverter, the function of the inverter is that it converts the dc supply into ac supply as we know about that, then there is a gate signal also given to the inverter circuit for triggering purpose. A PWM Generator (level 2) is used Simulating the inverter in Simulink sometime requires manual PWM generation of signal which can be manually controlled by some other signal inputs. The design includes only two blocks adder and comparator to generate the PWM wave. By changing amplitude of the saw tooth wave or sine wave the output PWM generation can be controlled

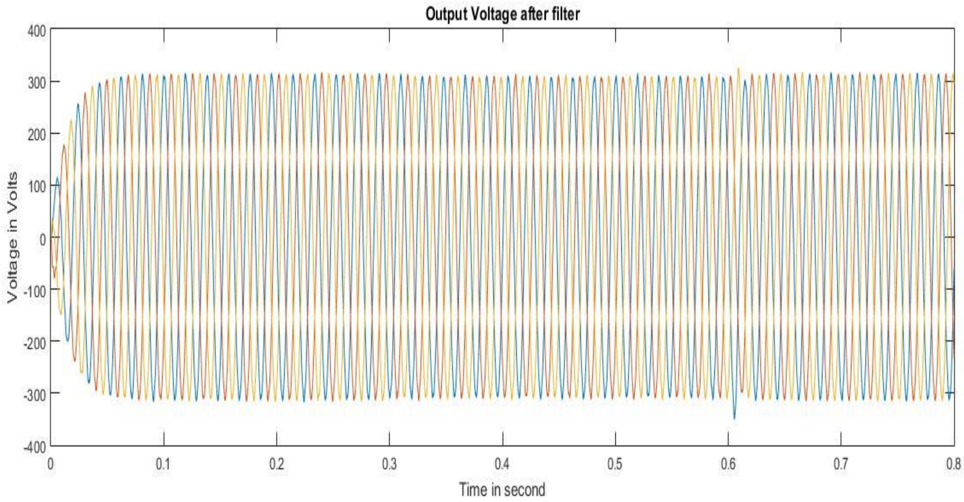

Fig 6 Three Phase Output Voltage after Filter

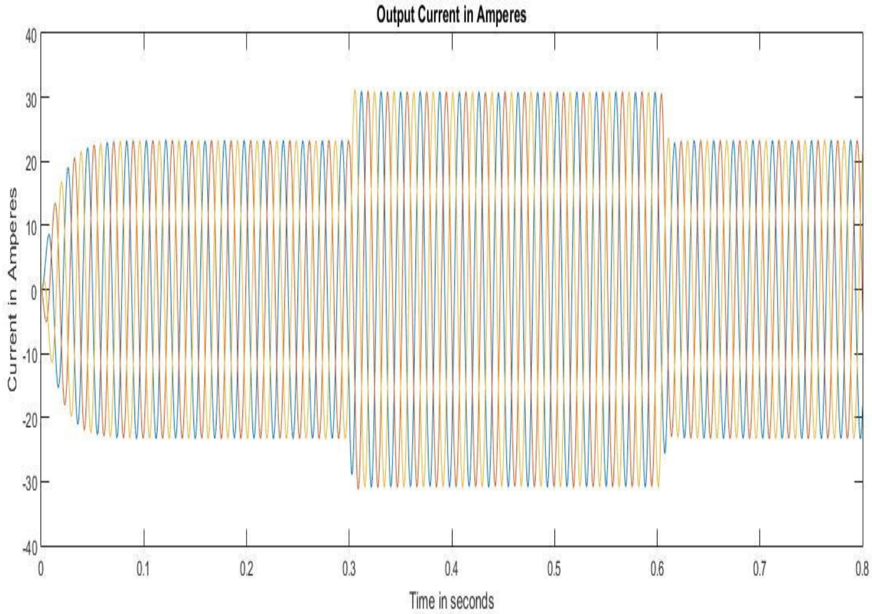

Fig 7 Three Phase Output Current after Filter

Fig. 6 shows the output voltage waveforms of three phase voltage inverter after filter circuit. In this waveform we can see that the distortion is reduced by the filter circuit which is a LC type filter. Due to this filter output waveform is distortion less. In this waveform is plotted output voltage with respective of time seconds.

Fig. 7 shows the output current waveforms of three phase voltage inverter after filter circuit. In this waveform we can see that the distortion is reduced by the filter circuit which is a LC type filter. Due to this filter output waveform is distortion less. In this waveform is plotted output current with respective of time seconds. From 0 to 0.3 seconds it is smooth due to switching this distortion from 0.3 second to 0.6 second is reduced, it will be done by filter circuit

VI CONTROLLER

This paper reviews the management schemes for dominant the droop controlled VSI. The current controller will have a vital impact on the standard of the present equipped to the load by the electrical converter, and thus it's necessary that the controller provides a top quality curving output with minimal distortion to avoid harmonics. The PI controller development is explained in detail below.

A] PI CONTROLLER

For 3 part systems, synchronous frame easy PI controller will be used as shown in Figure two. The most advantage other PI controller is that there'll be no remaining control error when a set-point modification or a method disturbance. However the most drawbacks with PI controller is that, there'll be steady state error for 3 part system, whereas, for single part systems, PI controller is the most effective and easier to implement. Figure two shows the PI controller implementation block diagram. PI controller needs abc to dqo reference transformation. As shown in figure two, the voltage when the filter is detected and part lock loop is employed to extract systems angular frequency from it.

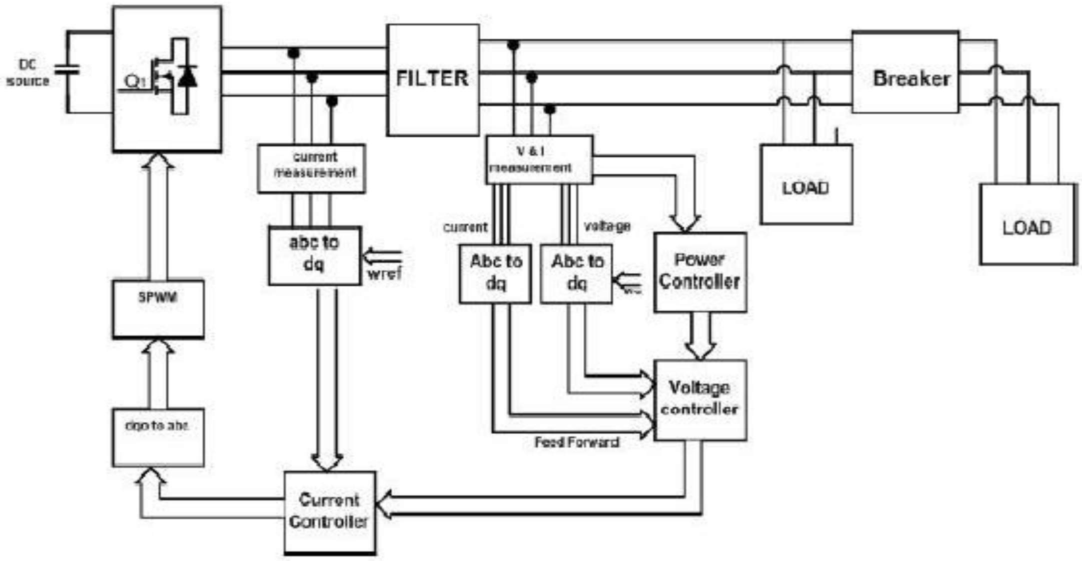

Figure 8. Block diagram of droop control technique using PI controller

The stationary dq0 transformation is finished to trace the error signal then the inverse reworked signal is provided to PWM detected before the filter and therefore the reference signal generated by voltage detected when the filter. The reference generator block shown in Fig. two is enforced on the idea of (5) and (6). This block takes output voltage or grid voltage in dq0reference system (Vod and Voq), as input signals. therefore it generates reference current signals (idref and iqref) which are compared with actual current signals.
The active power (P) and reactive power (Q) supplied to grid can be given in synchronous reference frame as

$$P = 1.5(Vod\ id + Voq\ iq) \quad (1)$$

$$Q = 1.5(Vod\ iq + Voq\ id) \quad (2)$$

Where the Vod, Voq, id, iq are the voltages and currents after the filter in dqo reference frame and P, Q are the active and reactive power respectively.

Assumed Voq = 0, and hence (1) and (2) can be written as

$$P = 1.5(Vod\ id) \quad (3)$$

$$Q = 1.5(Vod\ iq) \quad (4)$$

From above equations, id and iq can be extracted as-

$$id = 2P/3Vod \quad (5)$$

$$iq = 2Q/3Vod \quad (6)$$

These current signals are compared with actual and given to the PI controller. As PI controller requires feed forward path to improve reference tracking, grid voltage is fed to it. Then these signals are again transformed to abc frame and from SPWM, it is fed to the inverter switches [8].

B] REFERENCE QUANTITIES*:*

The reference quantities required for the simulation of droop controlled parallel inverters are reference frequency And reference voltage according to the demand or load. These signals can be extracted from load side of filter. For frequency, an angular frequency can be extracted from active power and voltage can be extracted from reactive power as stated below.

Active Power (P) ἀ Supply Frequency (f) (7)

$$mp = -\Delta w/p \quad (8)$$

$$mp = -(Wref - Wactual)/P \quad (9)$$

$$\omega ref = \omega actual - mpP \quad (10)$$

Reactive Power (Q) ἀ Voltage (V) (11)

$$nq = \Delta V/Q \quad (12)$$

$$nq = -(Vref - Vactual)/Q \quad (13)$$

$$Vref = Vactual - nqQ \quad (14)$$

Supported the higher than equations, reference quantities will be extracted. The P vs. f droop loop permits parallel connected generators to control in an exceedingly safe method sharing variations within the load/demand in an exceedingly pre-determined method while not any dedicated communication means that. Similarly, the Q vs. V droop loop is employed to reduce the circulation currents that would seem if the electrical resistance between the generators and a typical load weren't identical.

VII. SIMULATION RESULTS

The 3 part inverters are connected in parallel as explained in earlier section and are controlled by PI Controller in droop control mode. The simulations are allotted for numerous load conditions and therefore the system is therefore examined at the modification of load. The DC offer is fed to the electrical converter as a distributed generation supply. The LC filter is used to eliminate the harmonics when the electrical converter. The similar formed electrical converter output is therefore regenerate to curving wave. The filter output is fed to the load. The parameter values employed in the simulation are given within the table no one. The droop coefficients are ought to be per analysis. These coefficients are needed to extract reference quantities as given in equations 9-14

Table 1: System parameters

Sr No	Parameter	Inverter 1	Inverter 2
1	Line to line peak voltage	330V	330 V
2	DC supply	650V	650V
3	Supply frequency f_s	50 Hz	
4	Switching frequency f_s	8kHz	8kHz
5	Filter Inductance L_f	3 mH	3 mH
6	Inductor internal resistance r_f	0.05 Ω	0.05 Ω
7	Filter capacitance	30μF	30μF
8	Capacitor resistance	0.5Ω	0.5Ω
9	Cable resistance	0.45 Ω	0.40 Ω
10	Cable inductance	1.25mH	1.175 mH
11	$Load_1$ power	8000W	
12	$Load_2$ power	4000W	

Fig. five shows the 3 part load voltage fed from electrical converter. The grid is taking care of the voltage hyperbolic and controller maintains the voltage constant despite the fact that load is hyperbolic at instant 0.3sec. The Fig. six shows the 3 part load current once electrical converter is controlled by PI control

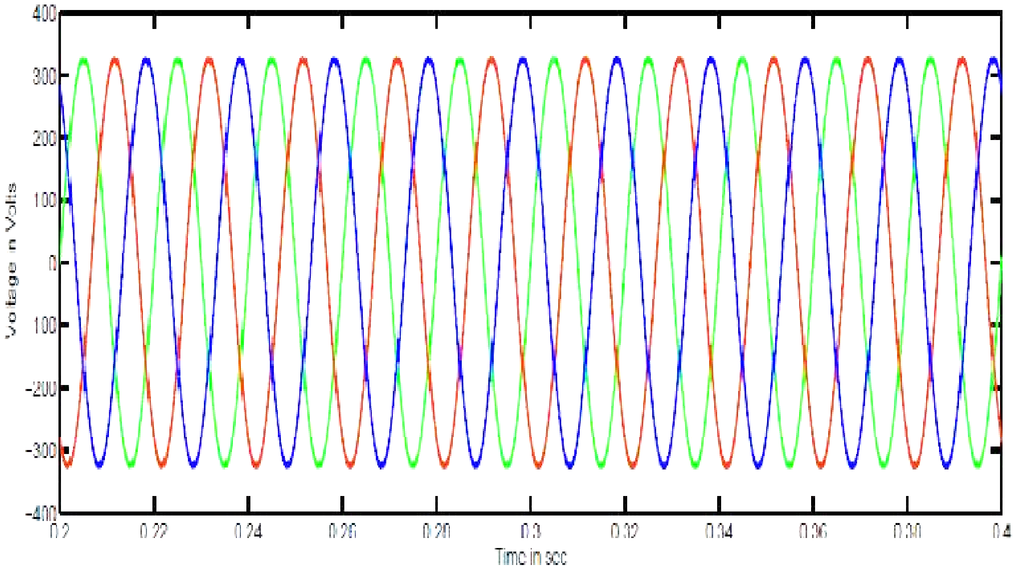

Figure 9. Three phase load voltage using PI controller

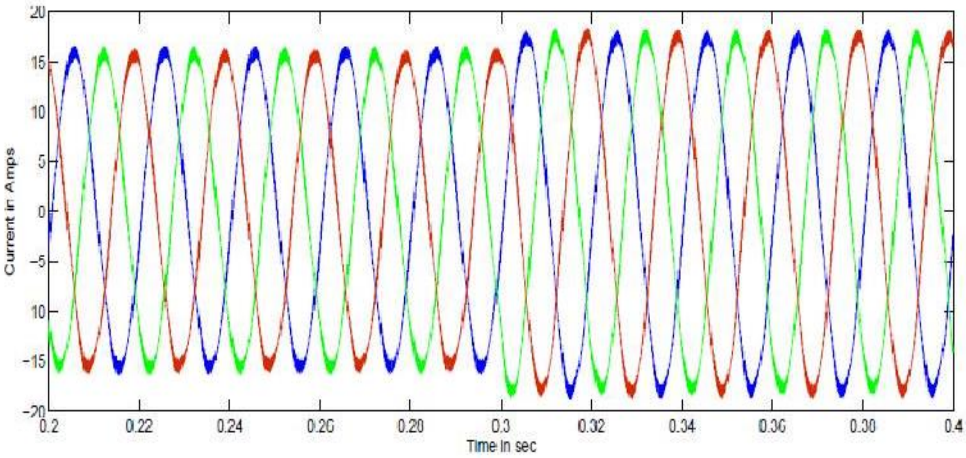

Figure 10. Three phase load current using PI controller

From Fig. 11 and Fig. 12, it will be seen that, throughout transient PI controller takes very little longer for subsiding, as it takes nearly zero.06 sec to succeed in to the steady state. These figures are the waveforms of active and reactive powers equipped by each the inverters once the system is subjected to a modification in load from 0.3sec to 0.6sec.

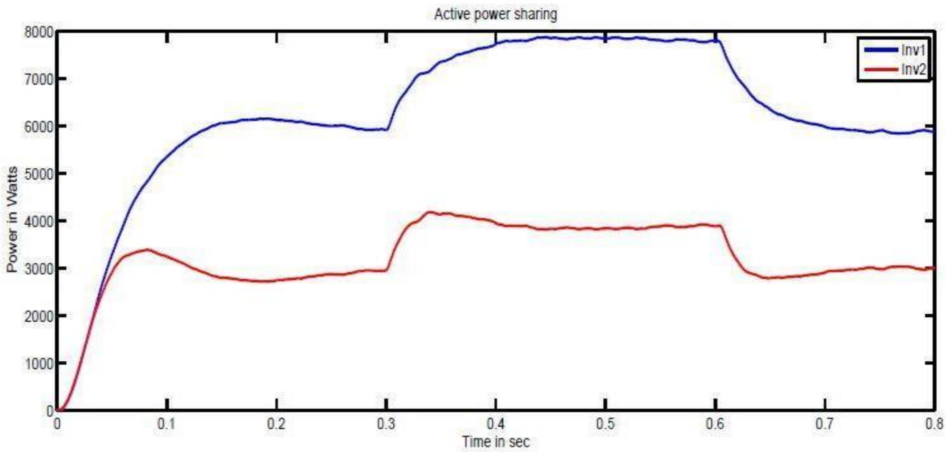

Figure 11. Active power supplied by both the inverters to the load

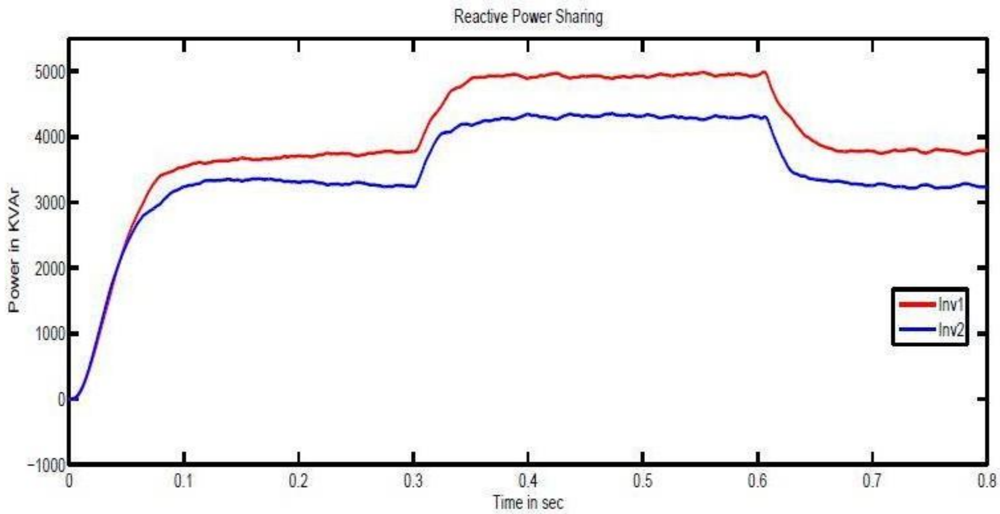

Figure 12. Reactive power supplied by both the inverters to the load

VI. CONCLUSION

In this paper, the main attempt is made of droop controlling of three phase parallel connected inverters. For this, PI controller is used to synchronize load and the system. The system is examined in matlab simulink and hence the results are depicted in figures 9-12.

Droop control technique is the active and reactive power sharing between the parallel inverters according to the demand of load. This is excellently achieved in the above system and can be analyzed in Figure 11 and 12.

This work of PI controlled Droop mode inverters can be extended to PR (Proportional resonant) controller, where system response can be improved [7].

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