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Grid Synchronized Voltage Source Inverter Controlled By Using PI Controller

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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. The paper consists of the study of three phase Voltage Source Inverter in grid connected mode. In PI control is the stationary reference frame is used to transfer the feedback quantities where the decoupling of component requirement increases some complications. The main advantage with this controller is the reduction in steady state DC error. The PI controller is adopted most familiar dqo reference frame. The three phase system is simulated in the matlab-simulink environment with both the controllers and experimental results are given to prove the correctness and feasibility of the system.

Keywords—PI controller; d-q reference frame; reference tracking; Grid synchronization.

I. INTRODUCTION

Due to rapid depletion of fossil fuels and the rising demand of electricity power, the interconnection renewable energy sources (RES) including wind turbines, photovoltaic (PV), and other distributed generation etc. has raised concern in the last few years. Hence it become general trend to increase the electricity production using renewable power system. According to the survey, in the last few years there is a great increase in the use of solar and other renewable energy systems. This increase is nearly from 5% to 20% of the total energy used. Also in the year 2008 - 2009 there is a drastic increase in use of solar energy compared to the last decade [1]. In order to control this 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 common bus is then connected to the utility/grid. The 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 the properly controlled in order to provide the reliable power system to utility network [1]. Fig. 1 shows the block diagram of the photovoltaic grid interfaced system. It gives the general idea of distributed generation system consisting a boost converter and inverter. The renewable energy source used is photovoltaic system. As the output of Photovoltaic system is very low as compared to the grid utility voltage the boost converter is required to boost low level output of PV system. The output of the Boost converter is thus fed to the three phase voltage source inverter.

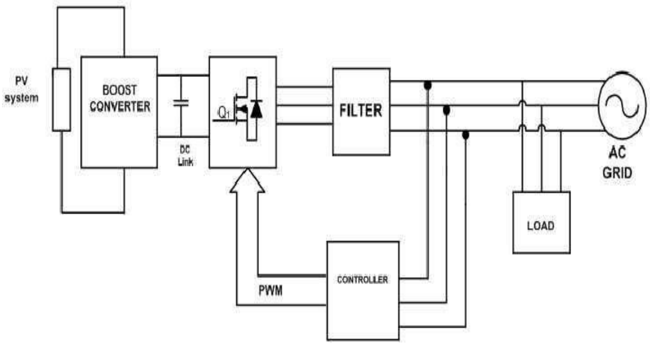

Figure 1. Block diagram of grid connected RE System

The output of the inverter is given to the grid utility through the filter. The control block, as shown in Fig.1, is implemented with suitable control schemes. The sinusoidal pulse width modulation (SPWM) technique is adapted to send pulses to the inverter. DC link capacitor is used for regulate the output of boost converter so these inverter will get constant DC input [2].

The grid connected voltage source inverter may have following problems to face:-

- 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 the micro-grid and main power grid when operating in grid-connected mode;
- To ensure a smooth transfer between inverter and in the grid autonomous mode and grid connected mode.

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To satisfy all these requirements, we need a control system which will maintain these parameters at desired value. It is very important to have a very reliable power supply and for that the system needs a good controller. This can be achieved by PI controller. The general conclusion is that many of the controllers for this particular system are either over burdened because of the complex network and they are very difficult to implement. Hence the controller select ion and its implementation becomes very important. The simple PI controller is used for controlling the inverter output. The main advantage of the PI controller is that there will be no remaining control error after a set-point change or a process disturbance. A disadvantage of PI controller is that there is a tendency for oscillations. PI control is used when no steady-state error is desired [3]. There is a use of synchronous frame in PI control but to reduce the complications of decoupling in it. The stationary reference frame (α−β transformation) is used in PR (proportional resonant) controller.

• The new controller proposed, to overcome above disadvantages of PI controller, is Proportional Resonant (PR) Controller [2], [4]. The main advantage of PR controller is to reduce DC steady state error to zero by forcing the ideally infinite gain at the resonating frequency. Also due to use of α − β transformation, the reference tracking system is improved [4].

II. SYSTEM DESCRIPTION

The micro-grid can be connected either in grid connected mode or an autonomous (islanded) mode. Normally the micro sources act as constant power sources, when 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 RES is connected to voltage source inverter and then it is fed to grid. It consist of filter and inverter block whose specifications are given in the table no 1. The controller block given in Fig. 1 is implemented by PI controller. This controller is analyzed and implemented in following sections.

III. CONTROLLER

This paper reviews the control schemes for controlling the grid connected VSI. The current controller can significant effect on quality of the current supplied to grid by the inverter, and therefore it is important that the controller provides a high quality sinusoidal output with minimal distortion to avoid harmonics. The controllers which are used to control inverters are the PI controller with the grid voltage feed-forward path as described below.

PI CONTROLLER

For three phase systems, synchronous frame simple PIcontroller can be used as shown in fig.2. The main advantage of the PI controller is that there will be no remaining control error after a set-point change or a process disturbance. But the main problem with PI controller is that, there will be steady state error for three phase system, whereas, for single phase systems, PI controller is the most effective and easier to implement. Fig. 2 shows the PI controller implementation block diagram. PI controller requires abc to dqoreference transformation. As shown in Fig. 2 the voltage after the filter is sensed and phase lock loop is used to extract systems angular frequency from it.

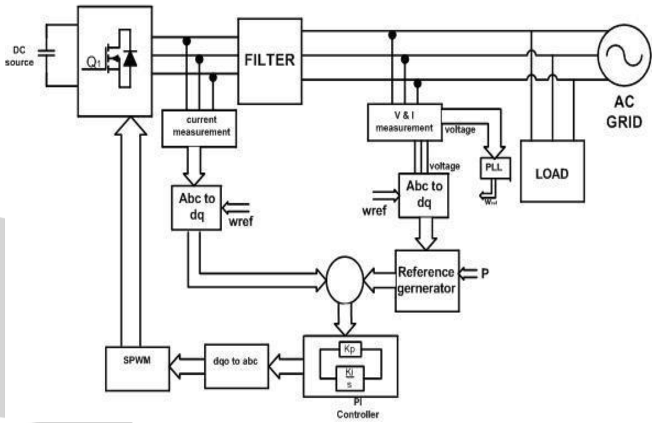

Figure 2. PI controller block diagram

The stationary dq0 transformation is done to track the error signal and then the signal is again transformed into abc quantities and is provided to PWM generator. The PI controller is used to minimize the error signal between actual current quantities sensed before the filter and the reference signal generated by voltage sensed after the filter. The reference generator block shown in Fig. 2 is implemented on the basis of (5) and (6). This block takes output voltage or grid voltage in dq0 reference frame (Vod and Voq) as input signals. Thus it generates reference current signals (id ref and iq ref) 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

$$P = 1.5(Vod\ id + Voq\ iq)(1)$$
$$Q = 1.5(Vod\ iq + Voq\ id)(2)$$

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

$$P = 1.5(Vod\ id)(3)$$
$$Q = 1.5(Vod\ iq)(4)$$

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

$$id = 2P/3Vod\ (5)$$
$$iq = 2P/3Vod(6)$$

These current signals are compared with actual and given to the PI controller. 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.

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Table No. 1 **System Parameter For Grid Connected System**

Sr No.	Parameter	Value
1	Three phase peak voltage	330V
2	Grid voltage	230V
3	DC supply	650V
4	Supply frequency fs	50HZ
5	Switching frequency fsw	8kHZ
6	Filter Inductance Lf	3 Mh
7	Inductor internal resistance rf	0.05Ω
8	Filter capacitance	25µF
9	Capacitor resistance	0.5Ω
10	Load1 power	6000W
11	Load2 power	3000W

IV. SIMULATION RESULTS

The three phase voltage source inverter connected to the grid and is controlled by the Proportional Integral (PI) controller. The simulations are carried out for various load conditions and the system is thus examined. The DC supply is fed to the inverter as a distributed generation source. The LC filter is used to eliminate the harmonics after the inverter. The quasi shaped inverter output is thus converted to sinusoidal wave. The filter output is fed to the load with grid connected in parallel. The parameter values used in the simulation are given in the table no 1.

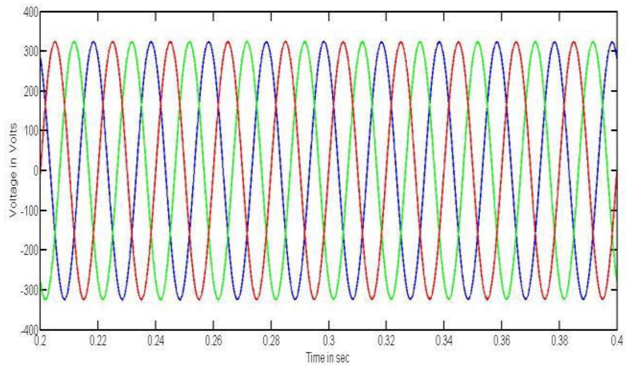

Figure 3. Three phase load voltage using PI controller

Fig. 3 shows the three phase load voltage fed from inverter. The grid is taking care of the voltage increased and controller maintains the voltage constant even though load is increased at instant 0.3sec. The Fig. 4 shows the three phase load current when inverter is controlled by PI controller.

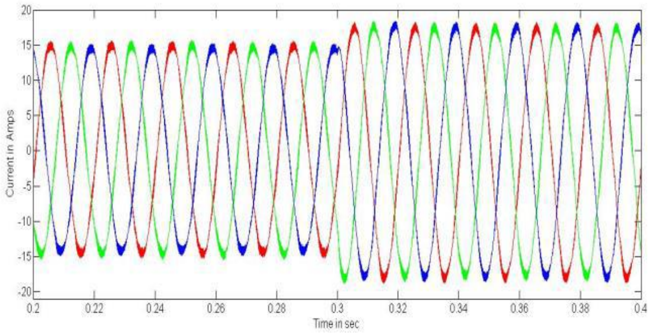

Figure 4. Three phase load current using PI controller

From Fig. 5 and Fig. 9 it can be seen that, during transient PI controller need some settling time, which can be improved by increasing order of controller. The settling time required by the PI controller is nearly 0.06 sec to reach to the steady state.

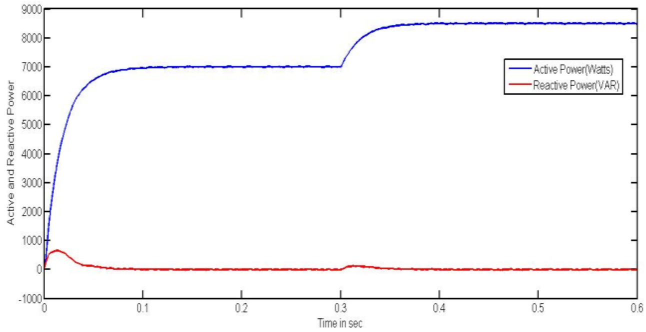

Figure 5. Active and Reactive power supplied by inverter to the load using PI controller.

V. CONCLUSION

In this paper the main attempt made for showing the simulation results of PI controlled grid synchronized inverter. This paper proposes the detail analysis of the basic control strategy used for voltage source inverter and also gives the study of Photovoltaic grid interconnected system. The shortcomings of PI controller as more settling time inadequate reference tracking system and complicated implementation can be overcame in second order controllers. Hardware results will be tested and published with next paper.

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