PLL based method for control of grid connected inverter for unbalanced grid frequency

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***Abstract*— The increase interest in renewable energy production together with higher and higher demand from the energy distribution companies regarding grid energy injection and grid support in case of a failure raises new challenges in terms of control for DC systems. Due to the above mentioned, grid side inverter control is one of the main issues in decentralized power production units. In order to feed power to utility a GCI is required as interfacing equipment. This paper deals with the design and implementation of PLL based control method for the grid connected inverter. The control method should give less THD in inverter O/P current and the inverter O/P current should be in phase with grid voltage so it gives unity power factor operation. The PLL based control technique for grid-connected inverter is simulated using MATLAB software. The case of unbalanced grid frequency is considered and simulated using MATLAB software package. This method works well with variation in grid frequency and give minimum THD and Unity Power Factor.**

***Index Terms*— Phase Lock Loop (PLL), Grid Connected Inverter (GCI), Unbalance Frequency**

I. INTRODUCTION

Solar, wind and hydro are renewable energy sources that are seen reliable alternative to conventional energy sources. Consequently, the control structures of grid connected inverter as an important section for energy conversion and transmission should be improved to meet the requirements to grid interconnection. Alternative energy sources such as fuel-cell, photovoltaic, wind power etc. requires a grid-connected inverter as interfacing, equipment to feed the AC power to utility. Now-a-days renewable energy sources are becoming more popular just because of their various advantages & applications. In order to generate power to utility, a grid connected inverter is required.

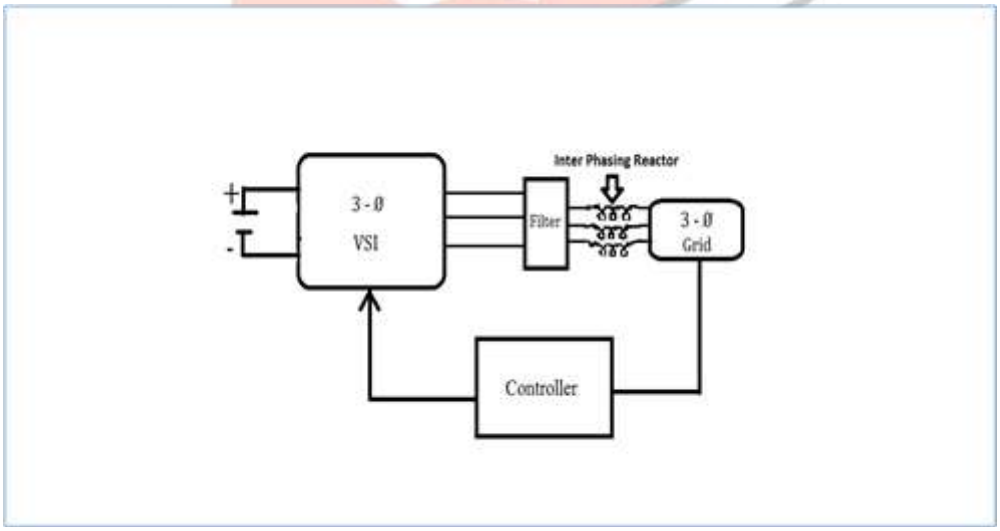

Fig.1 Grid connected inverter

As shown in Fig.1 DC voltage source is connected to voltage source inverter (VSI) and LC filter is connected to the output side of the VSI to reduce the output current harmonics. Inter phasing reactor is connected in series with LC filter to limit the high starting current and the output is supply to the grid. [6]

A. Features of grid connected inverters:

- Low line current distortion and high power factor. Usually the inverter is controlled so as to generate the output current in phase with the grid voltage to achieve the maximum active output power by minimizing the reactive output power.
- High efficiency. The overall efficiency of alternative energy generation will be highly dependent on the efficiency of the inverter.
- High switching frequency. The inductors of the output filter can be smaller.
- Simple circuitry. Low cost and high reliability should be achieved.[6]

II. CONTROL METHOD

Fig.2 shows the control method based on PLL to control grid connected inverter.

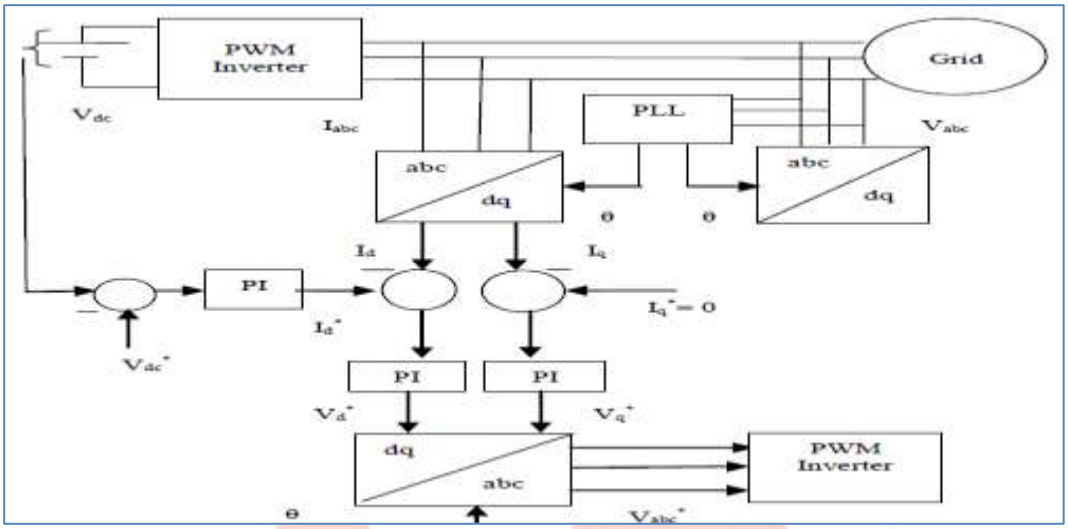

Fig. 2 Control block diagram

In this control method the inverter output current and grid voltage are taking as reference into the abc to dq block, this abc to dq block known as a Park transformation. This Park Transformation is converted three phase reference frame into two phase rotating frame. The two phase current component is Id, First Id taking a zero as reference and second Id is taking a Vdc as reference, then it's two components are taken into the PI controller. PI controller is use into the PLL as a error tuning. Then it will be connected with the Dq to abc block. This block known as an inverse Park Transformation. It is converted two phase rotating frame into the three phase reference frame and it will supply to the PWM inverter.[2]

A. PLL

The words PLL means "Phase- Locked Loop", PLL is a control system that generates an output signal whose phase is related to the phase of an input signal. While there are several differing types, it is easy to initially visualize as an electronic circuit consisting of a variable frequency oscillator and a phase detector. The oscillator generates a periodic signal, and the phase detector compares the phase of that signal with the phase of the input periodic signal, adjusting the oscillator to keep the phases matched. Bringing the output signal back toward the input signal for comparison is called a feedback loop since the output is "fed back" toward the input forming a loop.

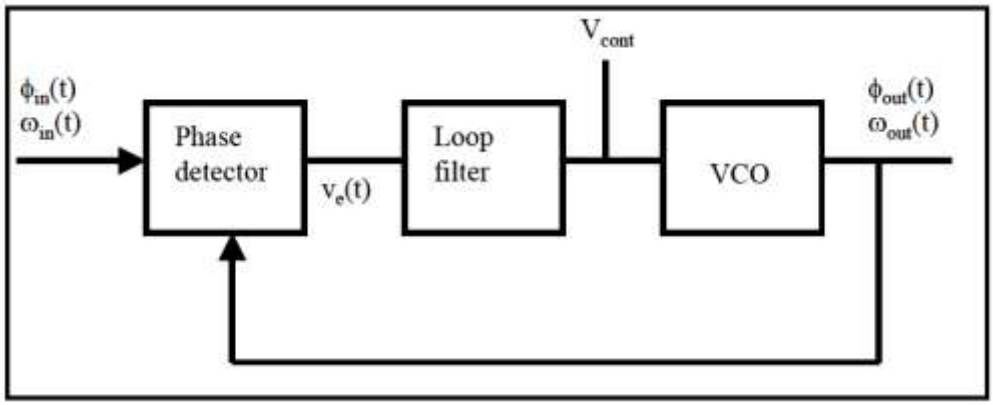

Fig. 3 PLL

A PLL is a feedback system that includes a VCO, phase detector, and low pass filter within its loop. Its purpose is to force the VCO to replicate and track the frequency and phase at the input when in lock. The PLL is a control system allowing one oscillator to track with another. It is possible to have a phase offset between input and output, but when locked, the frequencies must exactly track.[5]

B. Benefits of PLL

- Eliminates the problem of frequency drift.
- Increase battery life of product
- Less manufacturing cost
- PLL System are very important in generating accurate and stable frequency.

III. Simulation and Results

A. Simulink model

Fig.4 shows the Simulink model of grid connected inverter control using PLL. Constant DC voltage is given as an input. In three phase voltage source inverter, 6 IGBTs are used. L-C filter is used to reduce harmonics. Interfacing reactor is used and inverter currents are fed to the grid as shown in Simulink model.

In control method PLL is used to track the desired frequency, Park and clarke transformations are done in order to individually control the inverter current and input DC voltage. SPWM method is used for generation of gate pulses.

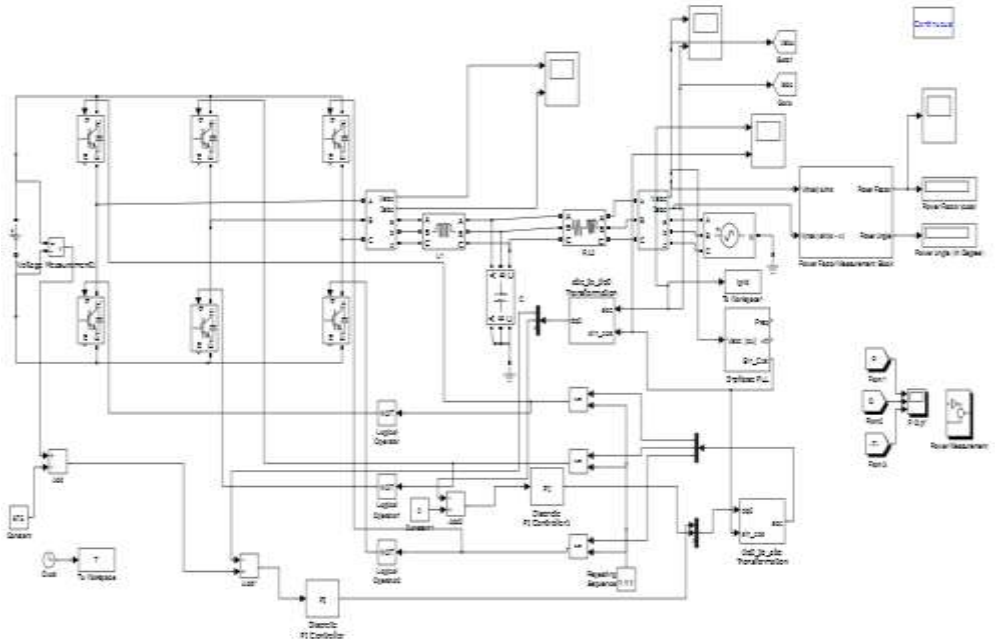

Fig.4 Simulink model

B. Waveforms and results for constant DC and balanced grid frequency

I. Parameters

- Vdc=676V;
- Vac=230v;
- f=50Hz
- R=0.4ohm;
- C=0.01 microF;
- L1=200 mH
- L2=0.1mH;

II. Waveforms

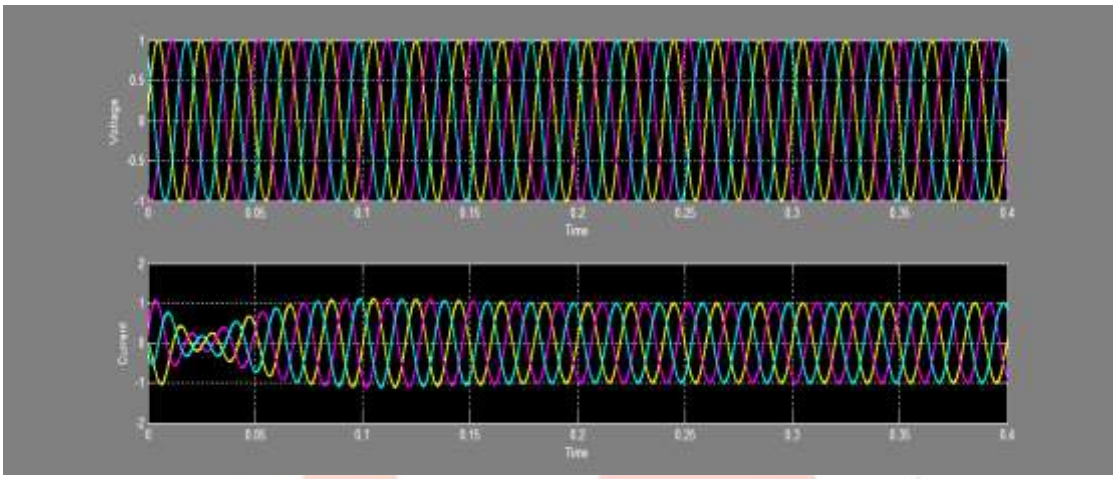

Fig.5 Inverter output current and grid voltages

III. Results:

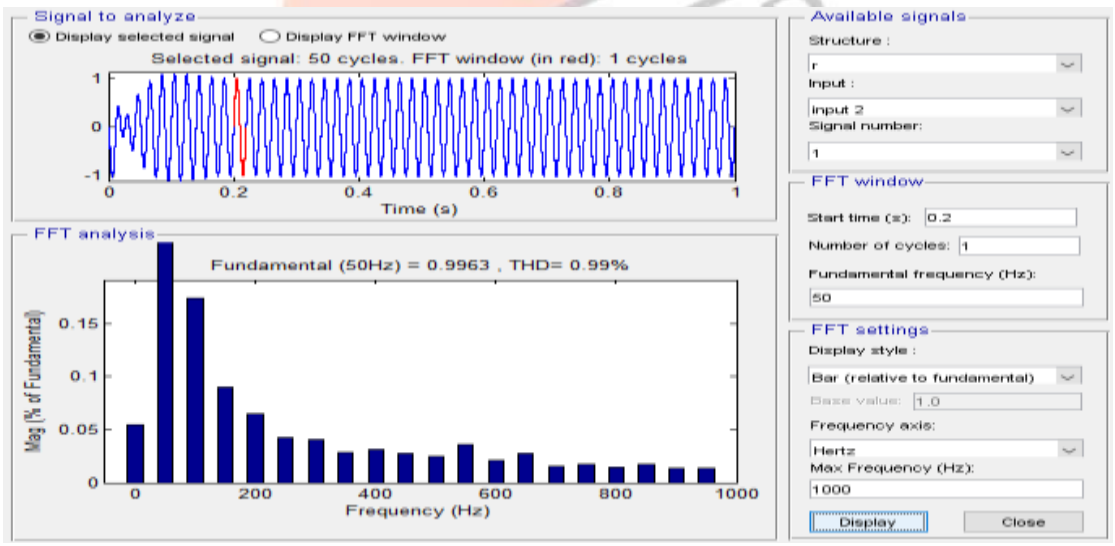

Fig.6 THD analysis

As shown in Fig.5, grid voltages and inverter output currents are inphase and unity power factor operation is achieved and form Fig.6 THD of inverter output current is only 0.99 %.

C. Waveforms and results for unbalanced grid frequency

I. Parameters

- Vdc=676V;
- Vac=230v;
- f1=50Hz at time 0 to 0.2 sec.
- f2=48/52Hz at time 0.2 to 0.3 sec.
- R=0.4ohm;
- C=0.01 microF;
- L1=200 mH
- L2=0.1mH;

II. Waveforms for frequency= 48 Hz

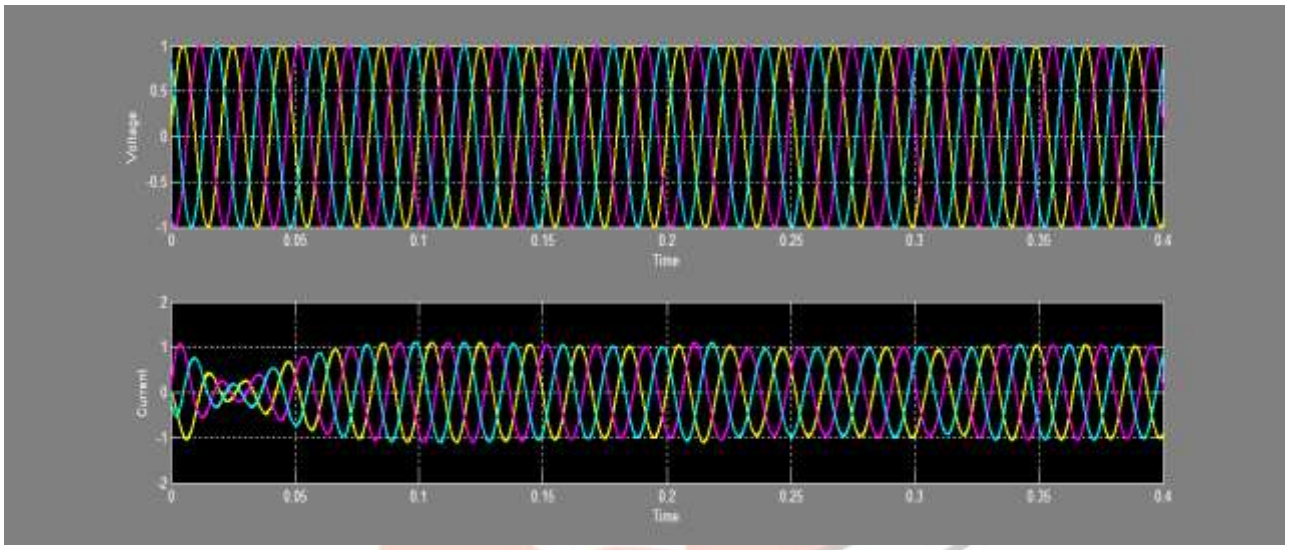

Fig. 7 Inverter output current and grid voltages for f=48 Hz

III. Waveforms for frequency= 52 Hz

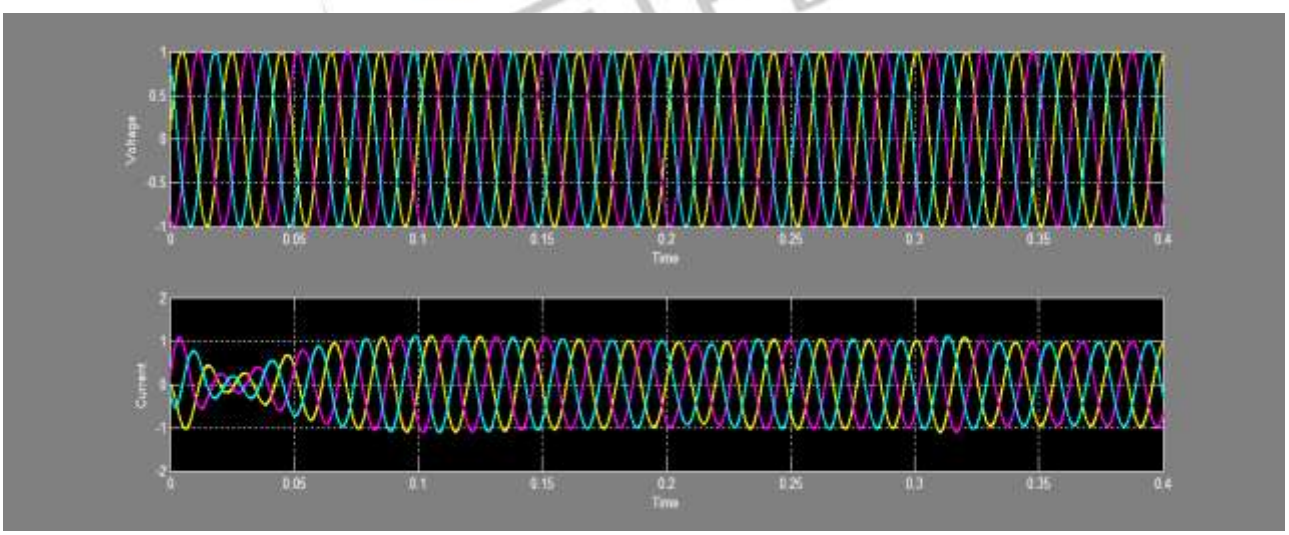

Fig. 8 Inverter output current and grid voltages for f=52 Hz

IV. Results

In case of unbalance grid frequency, this control system gives near to unity power factor operation, as inverter output currents are in phase with grid voltages as shown in waveforms.

IV. CONCLUSION

This control method based on PLL gives THD less than 5% and power factor is unity. Also in case of grid frequency Unbalance, SPWM control with PLL method gives power factor near to unity.

ACKNOWLEDGEMENT

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