MODELING, ANALYSIS AND CONTROL OF DISTRIBUTED GENERATION INTERFACING TO THE UTILITY GRID

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ABSTRACT:

This paper presents a three phase grid connected DC/AC inverter with active power control for medium size renewable and distributed DC energy sources. A grid synchronization method was introduced to generate direct and quadrature components of the grid voltage and to generate a synchronized current reference for the current loop control. One of the important issues of the Distributed power generation system connected to the utility network is the synchronization with the grid voltage vector. The detection of the positive sequence voltage component at fundamental frequency is required for the control of distributed generation. The magnitude and phase angle of the positive sequence voltage is used for the synchronization of the converter output variables. the technique used in the system detection i.e. Phase Locked Loop (PLL), the amplitude and the phase angle of the positive sequence component must be fast and accurately obtained, even if the utility voltage is distorted or unbalanced. The phase-locked loop (PLL)-based techniques are the state-of-the-art techniques in detecting the phase angle of the grid voltages. The proportional-integral controllers, sinusoidal pulse-width modulation (SPWM) control technique and Clarke and Park transformation, the inverter control system, phase locked loop are the basic requirements for archive the goal.So we can synchronizing between the DG and utility Grid.

Index Terms— Disributed power generation system, phase locked loop ,grid synchronization, Simulation results

1-INTRODUCTION

Now recent days, the continuously increasing the load demand, overburden on the grids that's way create some issue for example blackouts, instability of grid, degradation of power quality, power security etc. To balance these load demand and generation, renewable energy resources such as Photovoltaic (PV), Wind, and Biomass could be a good solution. From these renewable energy, solar energy is considered to be one of the most useful sources because it is free, pollution free and maintenance free. We required inverter for converting DC to AC voltage from PV, fuel cell before connecting it to grid. Because the voltage from renewable energy source (PV and Fuel cell) are DC. Grid is a voltage source of infinite capability. The output voltage of inverter and frequency of inverter should be same as that of grid frequency and voltage. The output of grid connected inverter can be controlled by the voltage source or current source and sine pulse width modulated (SPWM). Voltage source inverters (VSI) are most widely used in renewable source for converting the DC to AC .

➢ **Meaning of distributed generation**

The word distributed generation is used as indication of a medium scale electricity generation system. When conventional energy sources are use then pollution is occur in the environment and those are limited, but the utilization of renewable energy sources such as wind energy, fuel cells and solar energy, these sources are non-polluted. To meet rapidly increase the load demand, Distributed power generation system (DPGS) is the solution to meet the load demand. These DPGS are not suitable to be joined straightforwardly to the primary utility grid. Fast advancement of power electronic devices and innovation, dual converters are utilized to interface between distributed power generation system and utility grid as they match the ch/cs of the distributed power generation system and the requirements of the grid. With the help of the Power electronics enhancement ,we can improves the performance of distributed power generation system and improve the system control capacity, power quality issues, system's stability. Quickly increment in number of DGPS's prompts complexity in control while incorporation to grid. Subsequently necessities of grid connected converters get to be stricter and stricter to meet high power quality principles like unity power factor, reduction the total harmonic distortion, less individual harmonic distortion, voltage control and frequency control, real and imaginary power control, quick response during time of transients. Thus the control procedures connected to DGPS happen to high interest and need to further researched and created. In this section, a virtual grid flux arranged vector control (external circle controller) and three differents types of current controllers, for example, hysteresis current controller, current regulated delta modulator, modified ramp type current controller (internal current circle) strategies are proposed, with principle concentrate on current control loop , harmonic distortion,constant switching frequency , unity power factor operation of inverter. Vector control of grid connection of inverter is like vector control of electric machine. Vector control uses decoupling control of real and imaginary power. The control of grid for the vector control converter comprises of two control loop.

- The inner control loop- controls the real and imaginary grid current parts.
- The outer control loop- decides the real current reference by controlling the DC link voltage.

➢ **What are the difficulties?**

- Financial cost
- Less choice between different (costly) primary fuels
- Predictability of power output
- Effect on power quality

➢ **Someother problems are associated with DG grid interfacing:**

- Damping of harmonics
- Voltage control
- The behaviour of DG units during grid faults
- Frequency control

➢ **Grid connected system requirements:**

The fundamental requirements of interfacing with the grid are as follows,

- The voltage magnitude and phase must equal to that required for the desired magnitude and direction of the power flow.
- The voltage is controlled by the transformer turn ratio and/or the rectifier inverter firing angle in a closed-loop control system.
- The frequency must be exactly equal to that of the grid, otherwise the system will not work. The requirementof this the exacting frequency, use the utility frequency as a reference for the inverter switching frequency.

Prior, control and adjustment of the power system as taken care only by large power system for example hydro power plant, bio gas power plant, coal power plant, and so on. Requirement of grid interconnection is differ from nation to nation. Nations like India where the wind farm energy system fast expanding , a wind farm must have the capacity to add to control task on the same level as ordinary power plants, regulated by limit of existing wind conditions. As a rule the prerequisites are expected to guarantee that the DPGS have the control and dynamic properties required for operation of the power system concerning both short time and long time security of supply, voltage quality and stability of the power system.

2-Configuration ofDistributed Power Generation System and Control

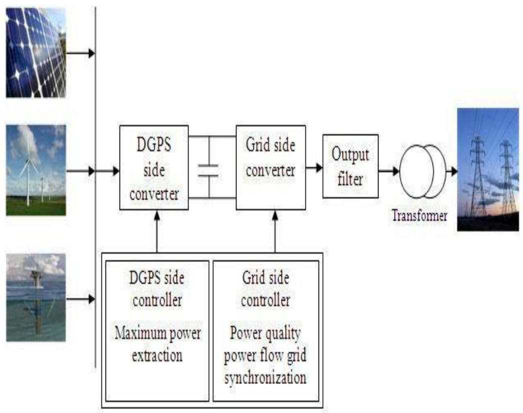


Fig: 1- Fundamental Structure of DPGS

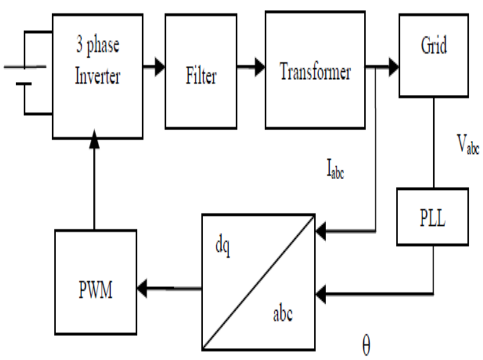


Fig: 2-Basic connection scheme

The given diagram is the grid and inverter synchronization block diagram. In this block diagram we require the transformation theory ,clark's transformation and park's transformation theory. Then for frequency estimation we use the phase locked loop, and after that transformation means abc to dq transformation ,we convert it in sinusoidal wave, that is archived by inverse park's and clark's transformation.

In current controller that controlled sine wave is compare with the triangular wave means it is a SPWM controller. In SPWM controller the sin Wave is compared with the triangular wave and generate the gate pulse and that gate pulse is give into inverter and finally according to the gate pulse output is generate. That generated output voltage and grid voltage have same magnitude and same frequency. So as that is done then the proper synchronization is archived between utility grid and inverter.

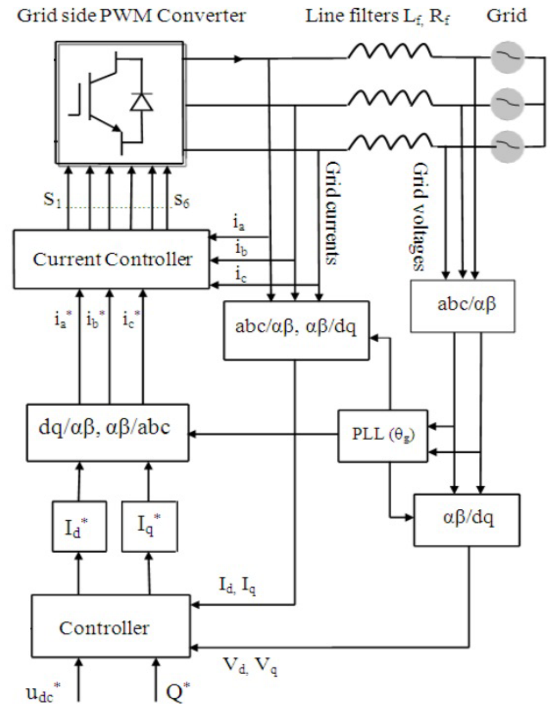


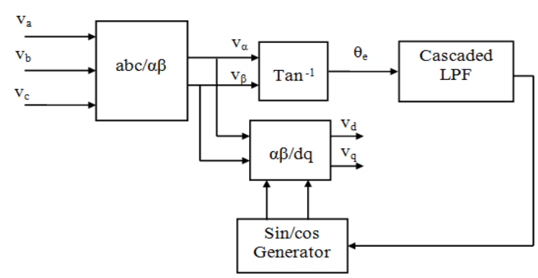
Fig:3- Block diagram of grid connected inverter

➢ Phase Locked Loop (PLL)

The execution of the grid voltage requires the exact of the phase angle of the grid voltage waveform. Generally this is filed by phase locked loop (PLL). PLL decides the position of the grid flux vector and gives point of angle (θ). That point is utilized to produce unit vectors cos(θ), sin(θ). This unit vector is utilized as a part of referance frame theory for changing over stationary

Figure:4-Instantaneous PLL circuit

two phase quantities from rotating two phase quantities in rotating referance frame. PLL gives



unity power component .So PLL has the phase angle between grid voltages and currents is zero.Here two PLL are consider and comparision of these PLL are present.

- SRF PLL
- DSOGI PLL

3-Simulation Work

our aim is the proper synchronization between grid and inverter ,so we can transmit the power to utility grid as well as load, which are connected on the same line. With the help of the MATLAB Simulation , some results are observed, follow.

Before go to simulation study. Analyses the parameter what are taken into consideration in the simulation.

➢ **System Parameters:**

System parameters	Value
Grid voltage	380 V (Phase to phase)
Grid Frequency	50 Hz
DC link coltage	600V
Switching frequency	15 KHz
Filter inductance	5 mH

Table:1-System parameters

Inverter can flow maximum 30 Amp current,so inverter can flow approximately 4500 Watt power.so load demand is below inverter capacity then inverter provide the power and remaining power is fed into the grid. When load demand is above the inverter capacity then extra requirement of power is provided by grid.

➢ **Waveform of simulation Result:**

Inverter current :

Without filter:

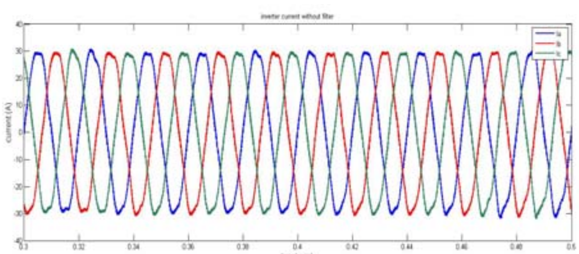


Fig:5- inverter current without filter

Inverter Phase Voltage:

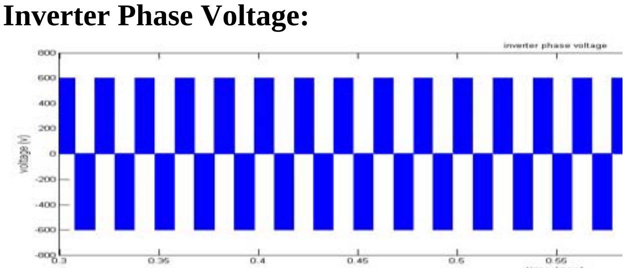
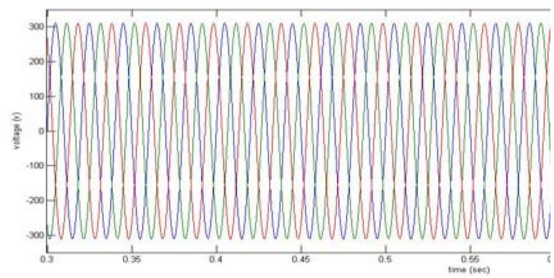


Fig:6-Inverter Phase voltage



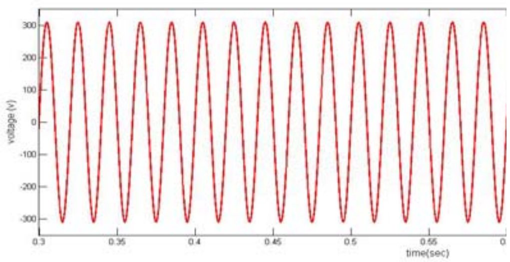


Fig:7 and Fig:8- Grid voltage(3 phase and 1 phase

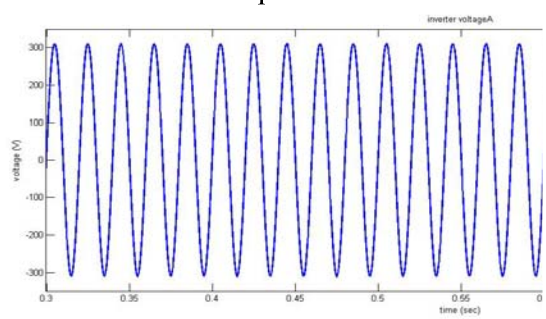


Fig:9- Inverter voltage(1- phase)

In Fig:8 and Fig:9 ,we show that the inverter voltage and grid voltage both are in phase ,means the proper synchronization are done between grid and inverter.

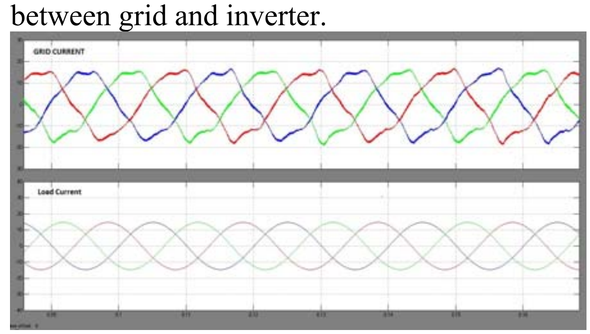
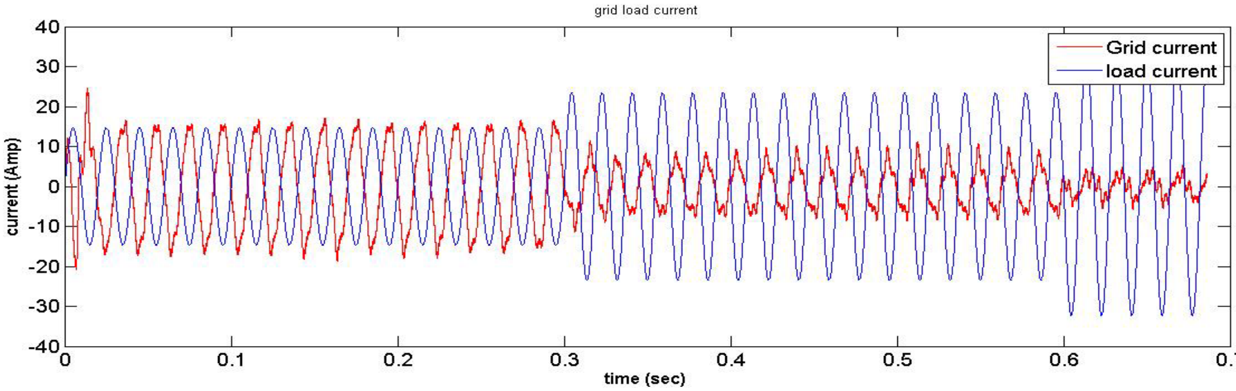


Fig:10-Grid current and Load current



As shown in fig:10 ,each phase of grid current and load current are completely opposite to each other,when load demand is below inverter power capacity.

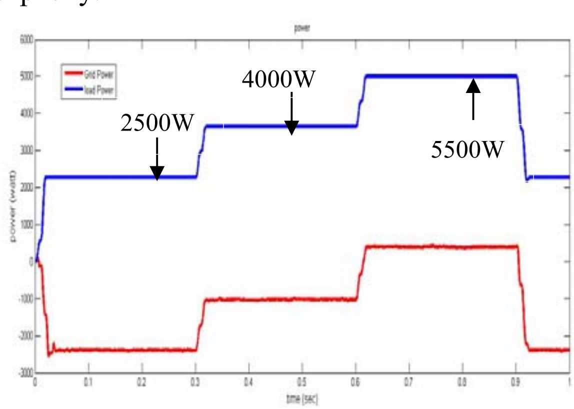
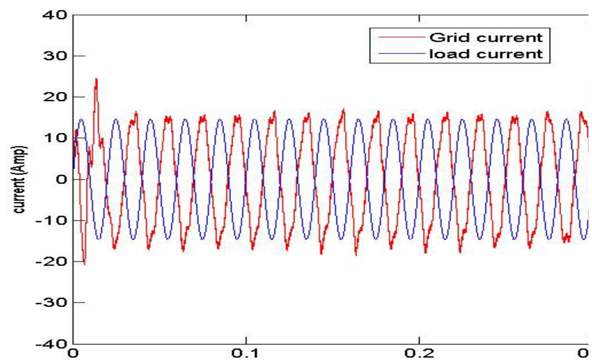


Fig:11- inveter power (Blue) and Grid Power(Red)

Here as shown in fig:11 the RED colour is present the grid power and BLUE colour is present the load power.when load is 2500W then inverter provide power,then at 0.3 sec load demand is increase and load is becomes to 4000 W,at that time inverter provide power, at 0.6 sec load demand is increase and load is becomes to 5500 W,then inverter can not provide the total load demand at that time, grid is provide required power for satisfied the load demand,as shown in fig:12.



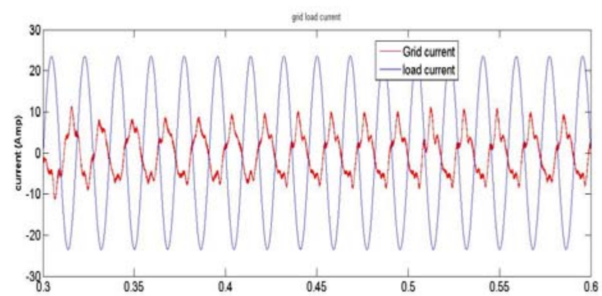


Fig:12-Phase voltage,current and grid current

THD of inverter current :

- **Without filter:**

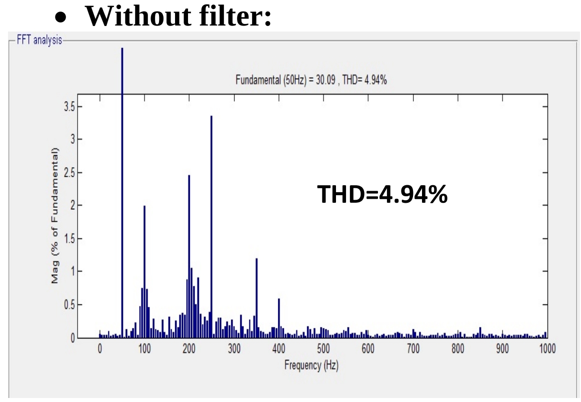


Fig:13-THD of inverter current without filter

➢Comparison of PLL:

As the study of the DSOGI PLL and SRF PLL, carry out some simulation result for change in frequency. At that time whichPLL is take less time for stable operation is analyse .follow.

1. Waveform of load voltage and current when frequency is change.

- **When frequency is 50 Hz.**

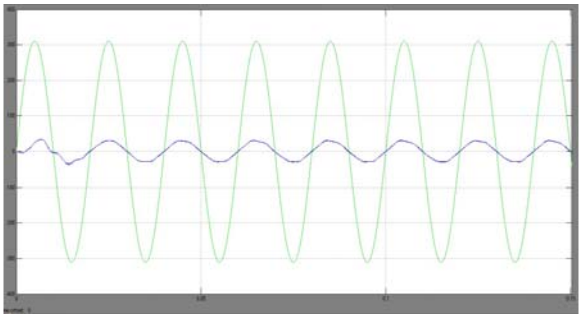


Fig:14-Load voltage and current in SRF PLLat 50 Hz Frequency

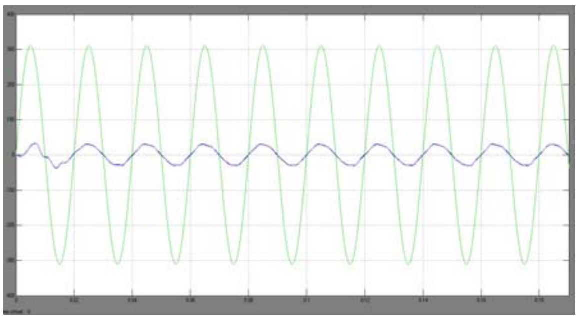


Fig:15-Load voltage and current in DSOGI PLLat 50 Hz frequency.

- **Change in frequency at 0.3 sec from 50 Hz to 55 Hz**

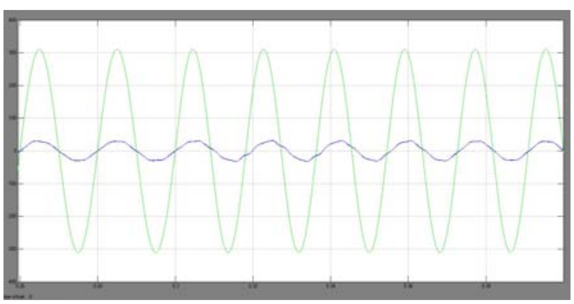


Fig:16-SRF PLLat 50 to 55 Hz frequency

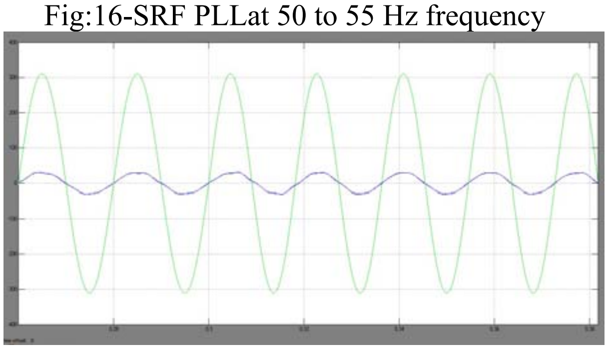


Fig:17-DSOGI PLLat 50 to 55 Hz frequency

- **Change in frequency at 0.3 sec from 50 Hz to 60 Hz**

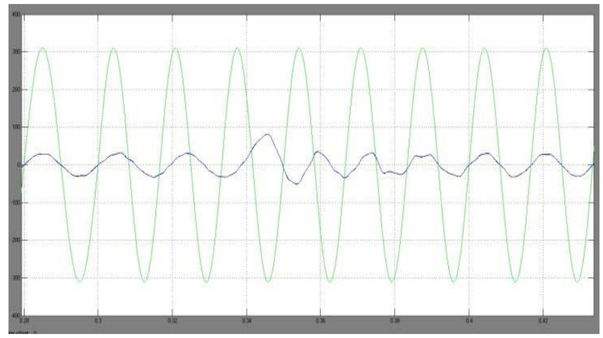


Fig:18-SRF PLL at 50 to 60 Hz frequency

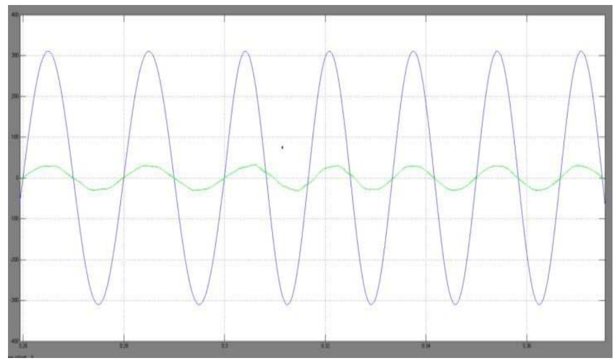


Fig:19-DSOGI PLL at 50 to 60 Hz frequency

2. Change in frequency at 0.3 sec from 50 Hz to 70 Hz

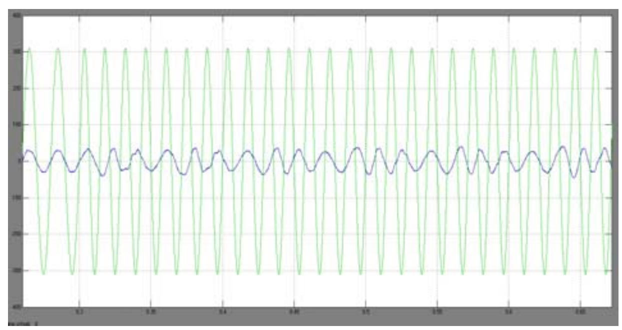


Fig:20- SRF PLLat 50 to 55 Hz frequency

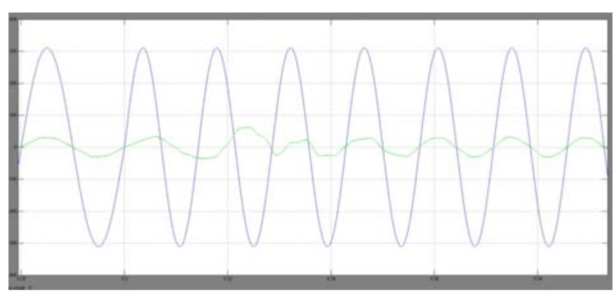


Fig:21-DSOGI PLLat 50 to 70 Hz frequency

Table:2-Comparison between SRF & DSOGI PLL when frwquency is change.

Frequency change	**SRF PLL**	**DSOGI PLL**
50 Hz	-	-
50 to 55 Hz	4 cycle	**1 cycle**
50 to 60 Hz	7 cycle	**2 cycle**
50 to 70 Hz	**Not stable in 25 cycle**	**4 cycle**
50 to 80 Hz	**Not stable**	**6 cycle**

Table:3-Power factor of DSOGI PLL when frequency variation is apply.

Step of frequency from 50 Hz	**Power factor**	**Power Factor IEEE standard**
0	**0.9995**	**>0.85**
5	**0.9994**	**>0.85**
10	**0.9993**	**>0.85**
20	**0.9846**	**>0.85**
30	**0.9799**	**>0.85**

Conclusion:

As the load demand is increase then the stress is increase on the grid.at that time, the inverter is connect with the grid with proper synchronization and that proper synchronization is archived by phase locked loop which gives frequency estimation of the grid .As result the stress on the grid is decrease means inverter provide some amount of power .Using PLL observe the different abnormality on the grid and analyse the different abnormalities.

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