A Concept Of Smart Grid And Control Schemes In Variable Power Source Wind Turbine

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Abstract— There are lots of meanings of Smart Grid and definitions as well. Some how Smart Grid concept is the use of new emerging technology and devices to make efficient the transmission and distribution system as well the quality of power to the consumer at lower rate is supplied. The wind turbine technology is one of the most emerging renewable technologies. It started in the1980'es with a few tens of kW production power to today with Multi-MW range wind turbines that are being installed. This also means that wind power production in the beginning did not have any impact on the power system control but now due to their size they play an active part in the grid. The technology used in wind turbines was in the beginning based on a squirrel-cage induction generator connected directly to the grid. By that power pulsations in the wind are almost directly transferred to the electrical grid. Furthermore there is no control of the active and reactive power, which typically is important control parameter to regulate the frequency and the voltage. As the power range of the wind turbines increases these control parameters become more important and it is necessary to introduce power electronics as an interface between the wind turbine and the grid. The implementation of power electronics device is changing the basic characteristic of the wind turbine from being an energy source to be an effective active power generation source. The electrical technology used in wind turbine is not new. It has been discussed for several years but now the price produced kWh is so low, that solutions with power electronics are very attractive.

Keywords:-Smart Grid, Wind Generator, Control techniques, Power Quality, PSIM

I.   INTRODUCTION

Wind energy is a prominent area of application of variable-speed generators operating on the constant grid frequency. Wind energy is now firmly established as a mature technology for electricity generation and over 13,900 MW of capacity is now installed, worldwide. It is one of the fastest growing electricity generating technologies.
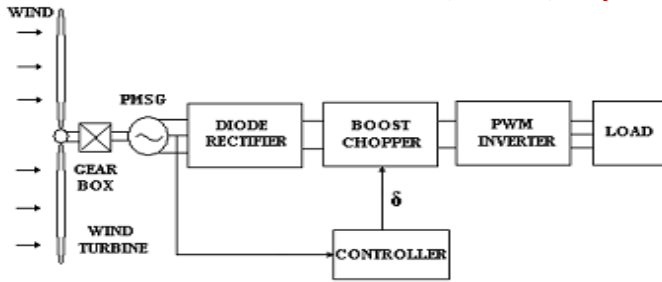
II.   SMARTGRID CONCEPT

Now days, the world is suffering from the problem of constantly increasing demand of electrical power, the limited resources are available to generate electrical power by coal, fossil fuels. Again the emission of carbon leads world to global warming effect. So, most of the country of the world have diverted towards the non-renewable energy sources to full fill the demand of greatly increasing electricity. Smart grid is a concept to full fill the demand of electricity as needed by the consumer at any time at lowest possible rates and the reliability issues, power quality issues to be completed. In this paper by the concept of Smart Grid the biggest source of non-renewable energy Wind is considered, and the fluctuations cause in the output power of the wind turbine generator are greatly reduced to low level by using new control techniques. So that the power which is sent to the grid /load has sinusoidal characteristics leads to better power quality. By using inverter in between the wind turbine and grid and implementation of power electronics techniques the output power has negligible fluctuations..

Why and where inverters used in wind turbine?

In this paper will first discuss the why and where inverters used in wind turbine.
Variable-speed wind turbines have progressed dramatically in recent years. Variable-speed operation can only be achieved by decoupling the electrical grid frequency and mechanical rotor frequency. To this end, power-electronic inverters are used, such as an ac–dc–ac inverter combined with advanced control systems. Pulse Width Modulation variable speed drives are increasingly applied in many new industrial applications that require superior performance. Variable voltage and frequency supply to a.c. drives is invariably obtained from a three-phase voltage source inverter. A number of Pulse width modulation (PWM) schemes are used to obtain variable voltage and frequency supply. The most widely used PWM schemes for three-phase voltage source inverters are carrier-based sinusoidal PWM, Hysteresis type modulation and space vector PWM (SVPWM). Nowadays generally hysteresis type modulation is used in inverters but, There is an increasing trend of using space vector PWM (SVPWM) because of their easier digital realization and Better dc bus utilization. This project focuses on step by step development SVPWM implemented on an Induction generator. The model of a three-phase a voltage source inverter is discussed based on space vector theory. Simulation results are obtained using PSIM.

Controlling a wind turbine involves both fast and slow control. Overall the power has to be controlled by means of the aerodynamic system and has to react based on a set-point given by dispatched center or locally with the goal to maximize the production based on the available wind power.

Below maximum power production the wind turbine will typically vary the speed proportional with the wind speed and keep the pitch angle fixed. At very low wind the speed of the turbine will be fixed at the maximum allowable slip in order not to have over voltage. A pitch angle controller will limit the power, when the turbine reaches nominal power. The generated electrical power is done by controlling the doubly-fed generator through the rotor-side converter. The control of the grid-side converter is simply just keeping the dc-link voltage fixed. Internal current loops in both converters are used which typically are linear PI-controllers, as it is illustrated in Fig. 1. The power converters to the grid-side and the rotor-side are voltage source inverters.
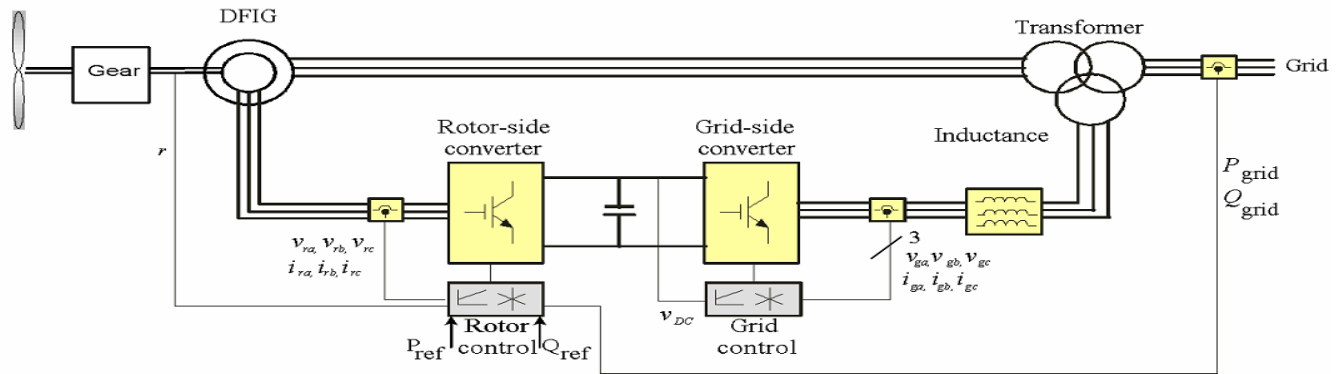

Fig 1. Doubly fed Induction generator system

Another solution for the electrical power control is to use the multi-pole synchronous generator. A passive rectifier and a boost converter are used in order to boost the voltage at low speed. The system is industrially used today. It is possible to control the active power from the generator. The topology is shown in Fig. 2 A grid inverter is interfacing the dc-link to the

Grid. Here it is also possible to control the reactive power to the grid. Common for both systems are they are able to control reactive and active power very fast and thereby the turbine can take part in the power system control.
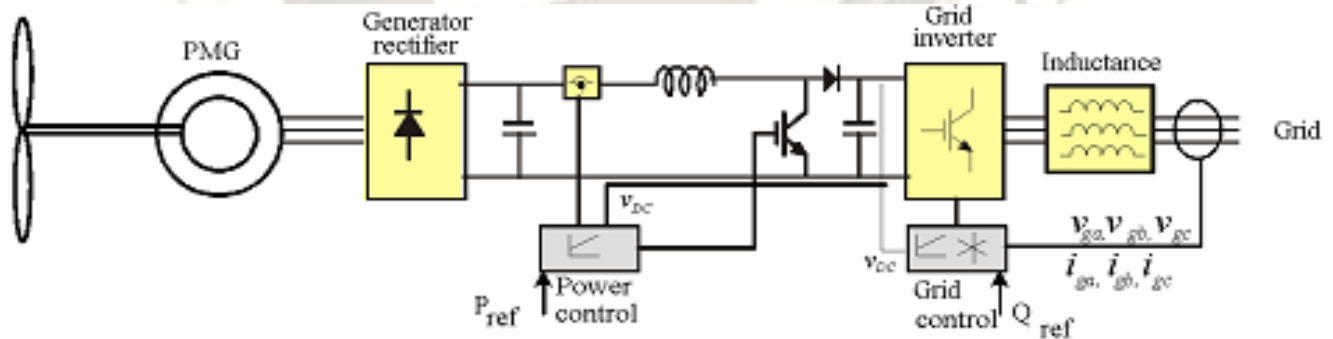

Fig 2. Control scheme for Permanent magnet generator

The power control system should also be able to limit the power.

An example of an overall control scheme of a wind turbine with a doubly-fed generator system is shown in Fig. 3

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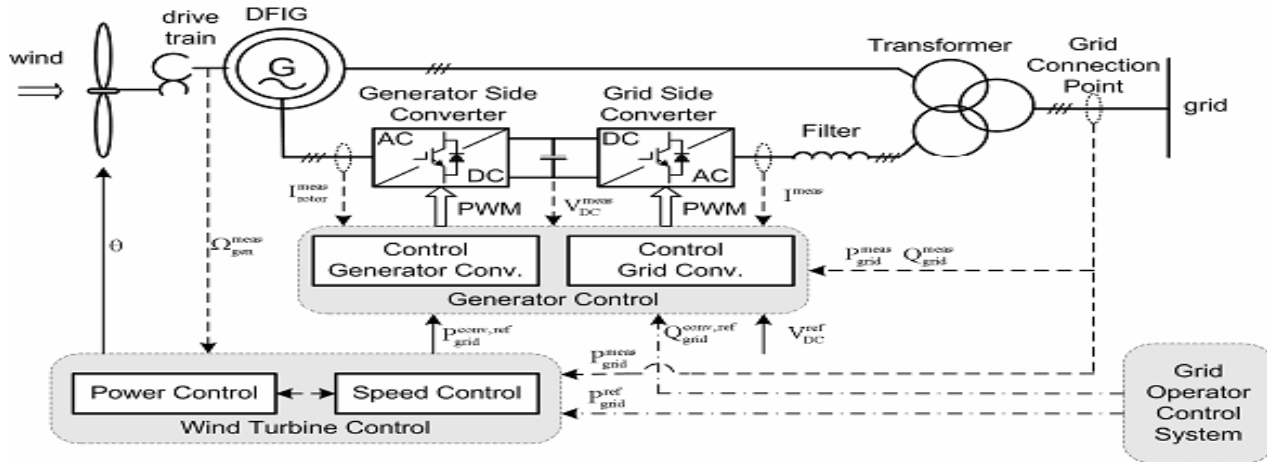Vol. 2, Issue 4, July-August 2012, pp.579-584**

Fig 3. Control scheme of DFIG

The forced switched power-inverter scheme is shown in Fig. 4. The converter includes two three-phase ac–dc converters linked by a dc capacitor battery. This scheme allows, on one hand, a vector control of the active and reactive powers of the machine, and on the other hand, a decrease by a high percentage of the harmonic content injected into the grid by the power converter.
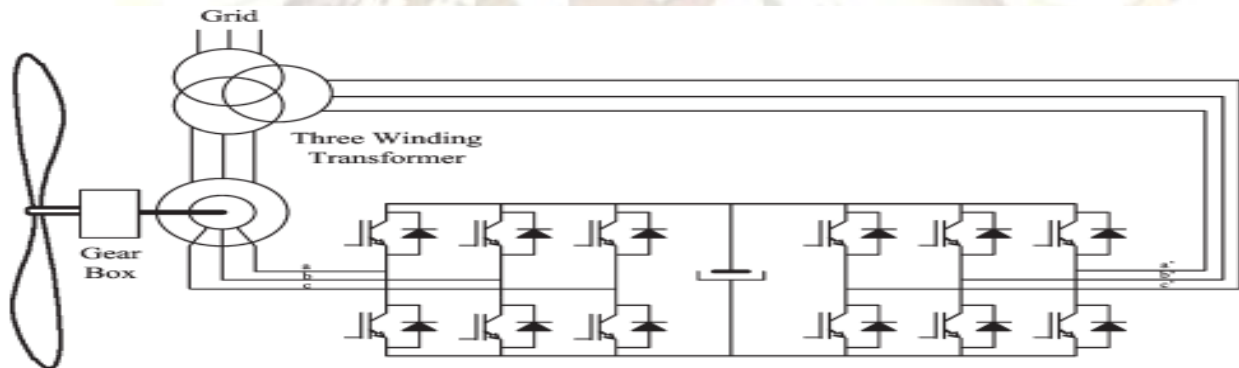
Fig. 4 Single doubly fed induction machine with two fully controlled ac–dc power inverters.

→ Different control techniques of Inverter used in wind Turbine.
- SPWM [Sinusoidal pulse width modulation]
- Hysteresis Current Controller
- SVPWM [space vector pulse Width modulation]
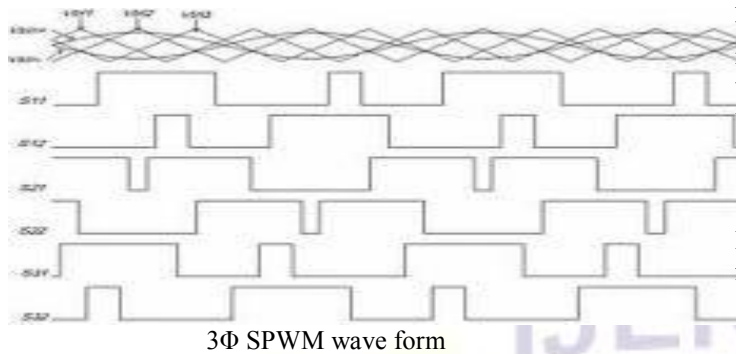
→**Sinusoidal Pulse Width Modulation in Inverters**
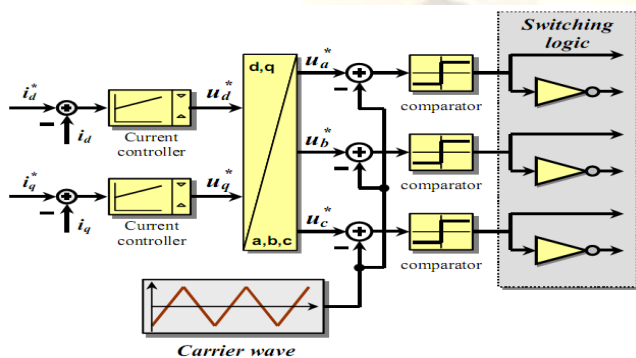
In SPWM the most straightforward implementation, generation of the desired output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave as depicted schematically in Fig.
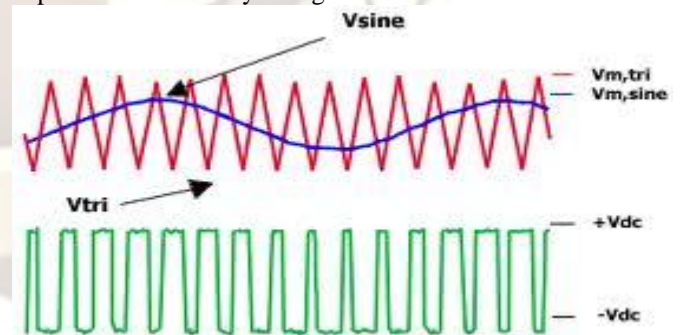
Output voltage from an inverter can also be adjusted by exercising a control within the inverter itself. The most efficient method of doing this is by pulse-width modulation control used within an inverter. In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and

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this method is termed as Pulse-Width Modulation (PWM) Control.

3Φ SPWM wave form

HYSTERESIS CURRENT CONTROLLER

Conventional hysteresis current control operates by comparing a current error (i.e. the difference between the demanded and the measured phase current) against fixed hysteresis bands. When the error exceeds the upper hysteresis band, the inverter output is switched low, and when the error falls below the lower hysteresis band, the inverter output switches high. This process is illustrated in Figure 1, and is usually implemented using two level switching so that each phase leg output is the mirror image of the other.

Wave forms of HCC

The basic scheme of a single-band hysteresis current controller is shown in Fig In this case; the inverter will produce a Positive output voltage when the current error touches the Lower hysteresis limit. On the other hand, a negative output Voltage is produced when the current error touches the Upper hysteresis limit. The output voltage waveform under this current controller is shown below.

- Working of HCC

In general, the output voltage expression can be written as follows

$$v_{uv} = Ri_o + L\frac{di_o}{dt} + e$$

The output voltage and current can be decomposed into the Average (averaged over one switching cycle) and ripple components as follows

$$v_{uv} = \bar{v}_{uv} + \tilde{v}_{uv} \tag{2}$$

$$i_o = i_o^r + \tilde{i}_o \tag{3}$$

For the current, the average value is equal to the reference and the ripple component is equal to the error component. If (2) and (3) are substituted into (1), then the following is obtained

$$\bar{v}_{uv} + \tilde{v}_{uv} = R(i_o^r + \tilde{i}_o) + L\frac{d}{dt}(i_o^r + \tilde{i}_o) + e \tag{4}$$

As the average and ripple components on the left-hand and Right-hand sides of (4) must be equal, the following Equations can be obtained

$$\bar{v}_{uv} = Ri_o^r + L\frac{di_o^r}{dt} + e \tag{5}$$

$$\tilde{v}_{uv} = R\tilde{i}_o + L\frac{d\tilde{i}_o}{dt} \tag{6}$$

The ripple voltage drop across the load resistance R~ io is Usually small and can be neglected and, hence, (6) can be simplified into

$$\tilde{v}_{uv} \simeq L\frac{d\tilde{i}_o}{dt} \tag{7}$$

Thus, the output current ripple can be calculated as follows

$$\tilde{i}_o = \frac{1}{L}\int \tilde{v}_{uv}dt = \frac{1}{L}\int (v_{uv} - \bar{v}_{uv})dt \tag{8}$$

The average value of the output voltage can be assumed to Vary sinusoidally at the fundamental output frequency

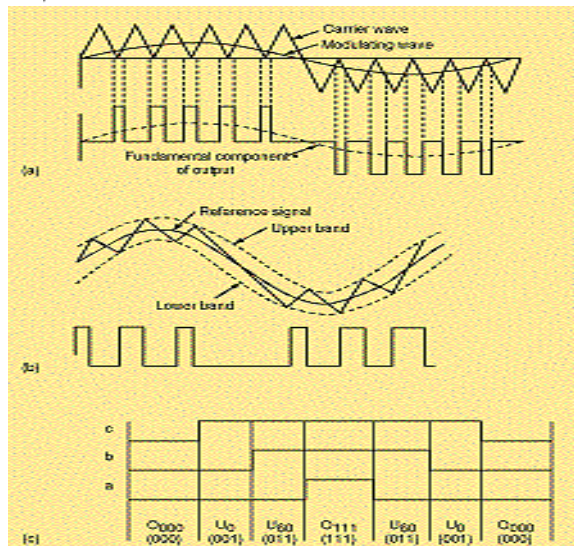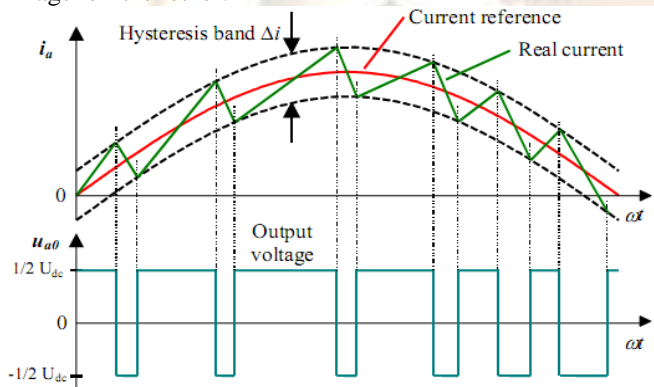$$\bar{v}_{uv} = V_m \sin\theta = kE_d \sin\theta \tag{9}$$

Where k ¼ Vm/Ed is the modulation index.
When the transistors Q1and Q4 receive ON signals, a Positive output voltage is produced, vuv ¼ Ed. This ON Period lasts until the output current error reaches the upper Hysteresis limit. Thus, during the ON period, the current error is changing from 2h to þh. Based on (8), the following Expression can be obtained.

$$h = \frac{E_d - \bar{v}_{uv}}{L}T_{ON} - h \tag{10}$$

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Where TON is the ON period of switches Q1and Q4. Based on (10), the ON period can be obtained as follows

$$T_{ON} = \frac{2hL}{E_d - \bar{v}_{uv}} \qquad (11)$$

During the OFF period, that is, when transistors Q1and Q4 receive OFF signals (transistors Q2and Q3 receive ON signals), the output voltage is negative, Vuv ¼ Ed. During this period denoted by TOFF, the current ripple changes from h to 2h, that is

$$-h = \frac{-E_d - \bar{v}_{uv}}{L} T_{OFF} + h \qquad (12)$$

Based on (12), the OFF period can be calculated as

$$T_{OFF} = \frac{2hL}{E_d + \bar{v}_{uv}} \qquad (13)$$

Based on (11) and (13), the switching period can be calculated as

$$T_s = T_{ON} + T_{OFF} = \frac{4E_d hL}{(E_d - \bar{v}_{uv})(E_d + \bar{v}_{uv})} \qquad (14)$$

By using (9) and (14), the switching frequency can be obtained as

$$f_s = \frac{1}{T_s} = \left(\frac{E_d}{4hL}\right)(1 - k\sin\theta)(1 + k\sin\theta) \qquad (15)$$

The average switching frequency over one fundamental period is

$$f_{s,av} = f_{sm}^s \left(1 - \frac{k^2}{2}\right) \qquad (16)$$

Where

$$f_{sm}^s = \frac{E_d}{4hL} \qquad (17)$$

Is the maximum switching frequency? The rms value of the current ripple is constant at

$$\tilde{I}_{o,av} = h/\sqrt{3} \qquad (18)$$

Under a hysteresis current controller, the output current ripple is constant but the average switching frequency varies with the modulation index. The average switching frequency will be maximum when the modulation index is zero.
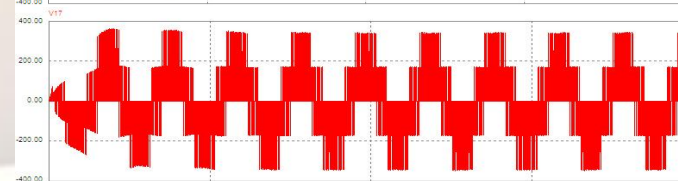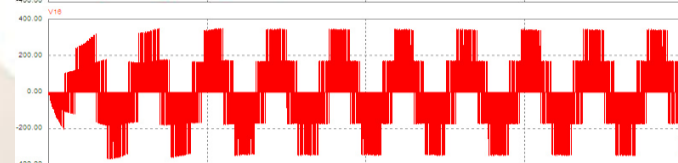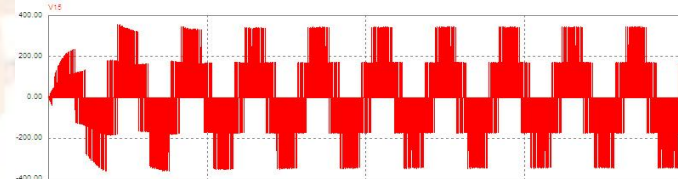
→ **Simulation Results in PSIM environment:-**
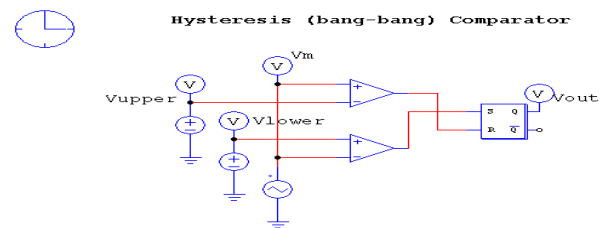
Load side current waveforms for each phase
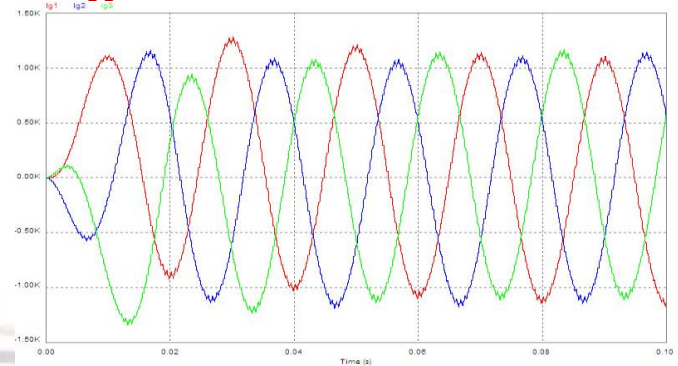
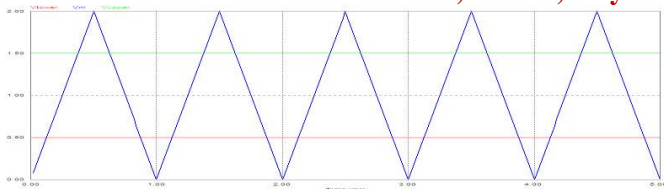**Load side voltage waveforms for each phase**
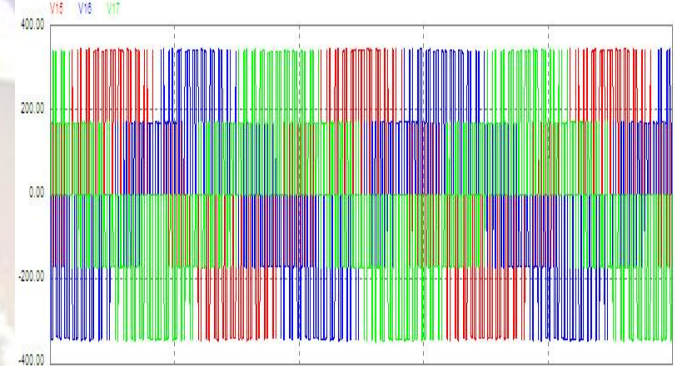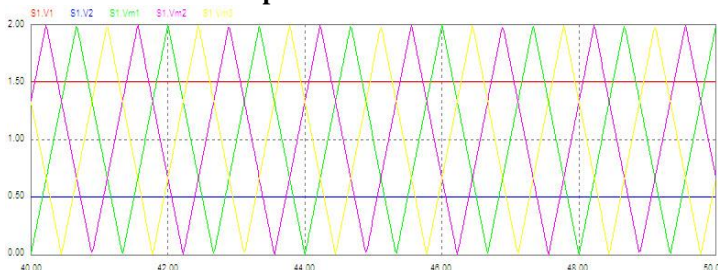

Individual waveforms from load side
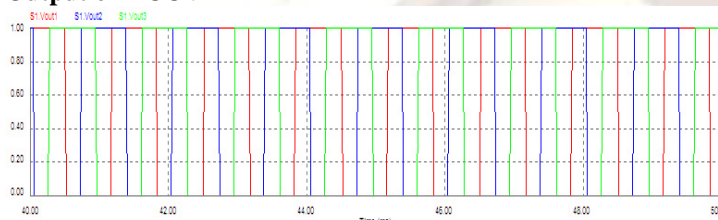

Hysteresis Current Controller Power Circuit (HCC):-
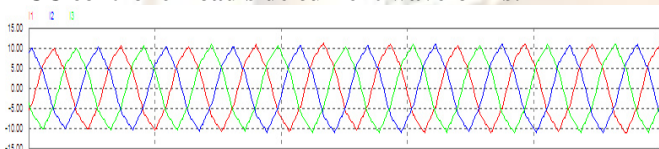

HCC Waveform for 1-phase:-

HCC Waveform for 3-phase:-

Output of HCC :-
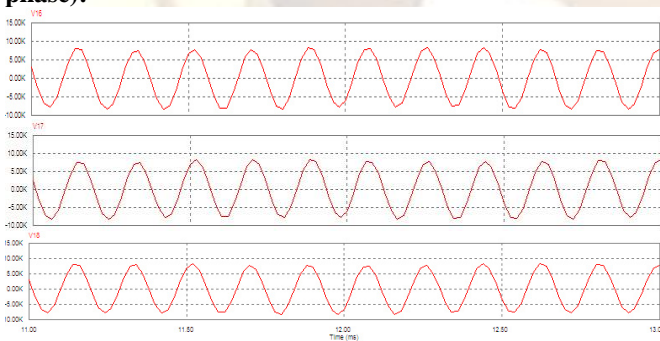

HCC controller load side current waveforms: -

HCC controller load side voltage waveforms(for each phase):-

→ Conclusion

This study has discussed the two most popular control methods for Grid Connected Inverters, 1) SPWM, 2) Hysteresis Current Controller technique. In comparison the SPWM technique is more difficult in large Grid Connected Inverters, where switching frequency is not high enough, as the result filtering of output may difficult and expensive in SPWM. For this reason the Hysteresis Controller is used.

With the use of Smart-Grid concept, that enables the power transmission, distribution and utilization of qualified power by using power electronics devices. ultimately by the concept of smart grid we can be able to reduce losses on power network, quality of power is maintained up to the mark by using power electronics devices, faster protection system based on communication network and information technology.

Regardless of undesirable harmonic spectrum, if null wire connection be accessible, Hysteresis Controllers can be implemented easily, and will be good choice due to its transient response.

A new hysteresis current controller that is suitable for a single-phase full-bridge inverter has been proposed in this paper. The proposed hysteresis current controller has successfully combined the advantages of both the conventional double-band hysteresis current controller (fast response) and symmetrical unipolar PWM (better waveform). Switching frequency expressions that are useful in the design of hysteresis current controllers have been derived. For the same hysteresis band, the average switching frequency of the
inverter under the proposed hysteresis current controller is much lower than that of conventional hysteresis controllers. By using the proposed current controller, the capability of inverter switching devices can be fully utilized to improve the inverter output current waveform. Simulated and experimental results have verified the effectiveness of the proposed current controller under transient and steady- state conditions. Applications of the proposed current controller to bidirectional rectifiers, UPSs, and multilevel inverters are under investigation.

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