International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-2 Issue-2, January 2013

Comparison and Implementation of Different PWM Schemes of Inverter in Wind Turbine

Nitin Adhav, Shilpa Agarwal

Abstract: ***As the conventional sources are limited, world has to move towards new sources of energy and they are renewable sources like wind, solar etc. Wind technology has been started many years ago, as it is clean and free energy source worldwide. In this paper the variable wind turbine, how they interface with power electronics and with interface and different control techniques of wind able to reduce fluctuations in variable speed wind turbine, sinusoidal electrical energy to be penetrated in to the load/grid. This paper discuss the most emerging renewable energy source, wind energy, which by means of power electronics is changing from being a minor energy source to be acting as an important power source in the energy system. By that wind power is also getting an added value in the power system operation [2].***

Keywords: Wind Generator, SPWM, HCC, SVPWM Power Quality, PSIM

I. INTRODUCTION

Due to the increasing demand on electrical energy and environmental concerns, a considerable amount of effort is being made to generate electricity from renewable sources of energy. The major advantages of using renewable sources are abundance and lack of harmful emissions. Wind is one of the most abundant renewable sources of energy in nature. The wind energy can be harnessed by a wind energy conversion

System (WECS) composed of a wind turbine, an electric generator, a power electronic converter and the corresponding control system [4].

In classical power systems, large power generation plants located at adequate geographical places produce most of the power, which is then transferred towards large consumption centers over long distance transmission lines. The system control centers monitor and control the power system continuously to ensure the quality of the power, namely the frequency and the voltage [2]. Energy storage in an electricity generation and supply system enables the decoupling of electricity generation from demand. In other words, the electricity that can be produced at times of either low-demand low-generation cost or from intermittent renewable energy sources is shifted in time for release at times of high-demand high-generation cost or when no other generation is available [3].

Manuscript published on 30 December 2012.
***Correspondence Author(s)**
Nitin Adhav, Department name, Affiliation, City, State, Country
Shilpa Agarwal

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license http://creativecommons.org/licenses/by-nc-nd/4.0/

The continued growth and expansion of the wind power industry in the face of a global recession *and* a financial crisis is a testament to the inherent attractiveness of the technology. 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 [1].

II. WHY INVERTERS IN WIND TURBINE?

In this paper, will first discuss the why and where inverters used in wind turbine. The use of Variable-speed wind turbines in recent years progressed. Variable-speed operation can only be implemented by dissociate the electrical grid frequency and mechanical rotor speed. To such end connection power-electronic inverters are used as interface such as an ac–dc–ac inverter combined with advanced control systems. Pulse Width Modulation variable speed drives are tremendously applied in many new industrial applications that require superior performance. Variable voltage and frequency supply to ac drives is 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).Simulation results are obtained using P-SIM [1].

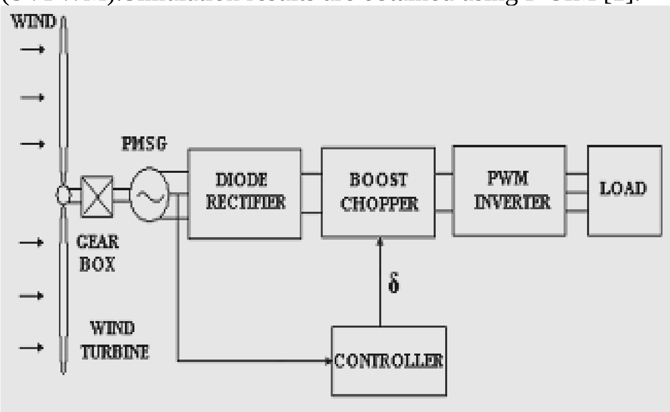


Figure 1 Wind Energy Conversion System

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 shown in fig.1.There are two basic two types of wind turbines. 1 .Fixed Speed Wind Turbines
2. Variable Speed Wind Turbines

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

I. Fixed Speed Wind Turbines

A fixed speed turbine consists of a rotor and a squirrel cage induction generator, connected via a gearbox. The generator stator winding is connected to the grid. The generator slip varies with the generated power, so the speed is not, in fact, constant; how- ever, as the speed variations are very small (just 1-2%), it is commonly referred to as a 'fixed speed' turbine. A squirrel cage generator always draws reactive power from the grid, which is undesirable, and reactive power is compensated by capacitor as shown in fig.2 [5]

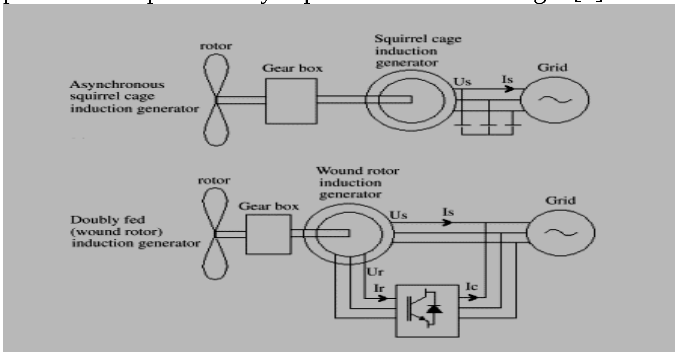


Figure 2.Fixed speed wind turbine system

Vestas and Nordic Wind power supply a variation of this design, the semi-variable speed turbine, in which the rotor resistance of the squirrel cage generator can be varied instantly using fast power electronics. So far, Vestas alone has succeeded in commercializing this system, under the trade name OptiSlip®. A number of turbines, ranging from 600 kW to 2.75 MW, have now been equipped with this system, which allows transient rotor speed increases of up to 10% of the nominal value. Variable speed wind turbines have progressed dramatically in recent years. Variable speed operation can only be achieved by decoupling electrical grid frequency and mechanical rotor frequency. To this end, power electronic converters are used, such as an AC-DC-AC converter combined with advanced control systems [5].

A squirrel cage induction generator has a principal characteristic that it always consumes reactive power. To establish the rotating magnetic field of the stator, reactive power must be supplied from the network to the stator winding of the induction generator. In most cases, this is undesirable, particularly for large turbines and weak grids. Therefore, the reactive power consumption of the squirrel cage induction generator is nearly always partly or fully compensated by a capacitor bank to achieve a power factor close to one in the steady state. As a result, during load flow calculation this reactive power, Q_C, supplied by the capacitor bank should be considered system including a wind turbine generator system (WTGS) that can be used for load flow study. [26].

II. Variable Speed Wind Turbine

Alternatively, variable speed configurations provide the ability to control the rotor speed. This allows the wind turbine system to operate constantly near to its optimum tip-speed ratio. The following advantages of variable-speed over constant-speed can be highlighted: [27]

I. the Annual Energy Production (AEP) increases because the turbine speed can be adjusted as a function of wind speed to maximize output power. Depending on the turbine aerodynamics and wind regime, the turbine will on average collect up to 10% more annual energy. [27]

II. The mechanical stresses are reduced due to the compliance to the power train. The turbulence and wind shear can be absorbed, i.e., the energy is stored in the mechanical inertia of the turbine, creating a compliance that reduces the torque pulsations [27].

III. The output power variation is somewhat decoupled from the instantaneous condition present in the wind and mechanical systems. When a gust of the wind arrives at the turbine, the electrical system can continue delivering constant power to the network while the inertia of mechanical system absorbs the surplus energy by increasing rotor speed [27].

IV. Power quality can be improved by reduction the power pulsations. The reduction of the power pulsation results decreases voltage deviations from its rated value in the point of common coupling (PCC). This allows increasing the penetration of the wind power in the network [27].

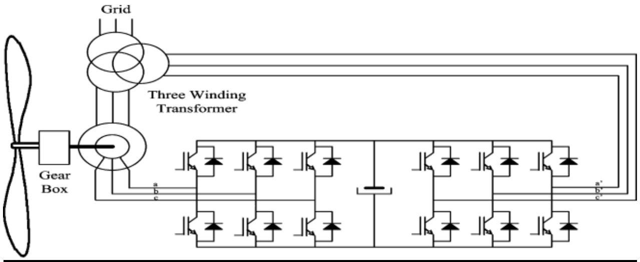


Figure 3.Variable speed wind turbine system (DFIG)

Wind energy has matured to a level of development where it is ready to become a generally accepted utility generation technology. Wind-turbine technology has undergone a dramatic transformation during the last 15 years, developing from a fringe science in the 1970s to the wind turbine of the 2000s using the latest in power electronics, aerodynamics, and mechanical drive train designs. In the last five years, the world wind-turbine market has been growing at over 30% a year, and wind power is playing an increasingly important role in electricity generation, especially in countries such as Germany and Spain. The legislation in both countries favors the continuing growth and installed capacity wind power is quite different from the conventional electricity generation with synchronous generators. Further, there are differences between the different wind-turbine designs available in the market. These differences are reflected in the interaction of wind turbines with the electrical power system. An understanding of this is, therefore, essential for anyone involved in the integration of wind power into the power system [3]. Moreover, a new technology has been developed in the wind- power market introducing variable-speed working conditions depending on the wind speed in order to optimize the energy captured from the wind. The advantages of variable-speed turbines are that their annual energy capture is about 5% greater than the fixed-speed technology, and that the active and reactive powers generated can be easily controlled. There is also less mechanical stress, and rapid power fluctuations are scarce because the rotor acts as a flywheel (storing energy in kinetic form). In general, no flicker problems occur with variable-speed turbines.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Variable-speed turbines also allow the grid voltage to be controlled, as the reactive-power generation can be varied. As disadvantages, variable-speed wind turbines need a power converter that increases the component count and make the control more complex. The overall cost of the power electronics is about 7% of the whole wind turbine [3].

III. CURRENT WIND-POWER TECHNOLOGY

1) Variable-Speed Concept Utilizing Doubly Fed Induction Generator (DFIG): In a variable-speed turbine with DFIG, the converter feeds the rotor winding, while the stator winding is connected directly to the grid. This converter, thus decoupling mechanical and electrical frequencies and making variable-speed operation possible, can vary the electrical rotor frequency. This turbine cannot operate in the full range from zero to the rated speed, but the speed range is quite sufficient. This limited speed range is caused by the fact that a converter that is considerably smaller than the rated power of the machine is used. In principle, one can say that the ratio between the size of the converter and the wind-turbine rating is half of the rotor-speed span. In addition to the fact that the converter is smaller, the losses are also lower. The control possibilities of the reactive power are similar to the full power-converter system. For instance, the Spanish company Gamesa supplies this kind of variable-speed wind turbines to the market [3].

The forced switched power-converter scheme is shown in Fig.3.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.

***2) Variable-Speed Concept Utilizing Full-Power Converter: in* this concept**, the generator is completely decoupled from the grid [3] [5]. The energy from the generator is rectified to a dc link and after is converted to suitable ac energy for the grid. The majority of these wind turbines are equipped with a multi-pole synchronous generator, although it is quite possible (but rather rare) to use an induction generator and a gearbox. There are several benefits of removing the gearbox: reduced losses, lower costs due to the elimination of this expensive component, and increased reliability due to the elimination of rotating mechanical components. Enercon supplies such technology.

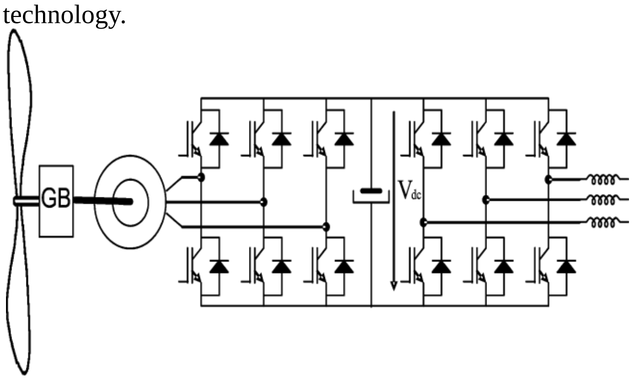


Figure 4 Variable Speed concepts using full power converter

Fig.4 shows the scheme of a full power converter for a wind turbine. The machine-side three-phase converter works as a driver controlling the torque generator, using a vector control strategy. The grid-side three-phase converter permits wind- energy transfer into the grid and enables to control the amount of the active and reactive powers delivered to the grid. It also keeps the total-harmonic-distortion (THD) coefficient as low as possible, improving the quality of the energy injected into the public grid. The objective of the dc link is to act as energy storage, so that the captured energy from the wind is stored as a charge in the capacitors and may be instantaneously injected into the grid. The control signal is set to maintain a constant reference to the voltage of the dc link V_{dc} [3].⟶

Different control methods of Inverter used in wind Turbine.

- SPWM [Sinusoidal pulse width modulation]
- Hysteresis Current Controller
- SVPWM [space vector pulse Width modulation]

⟶**<u>Sinusoidal Pulse Width Modulation in Inverters</u>**

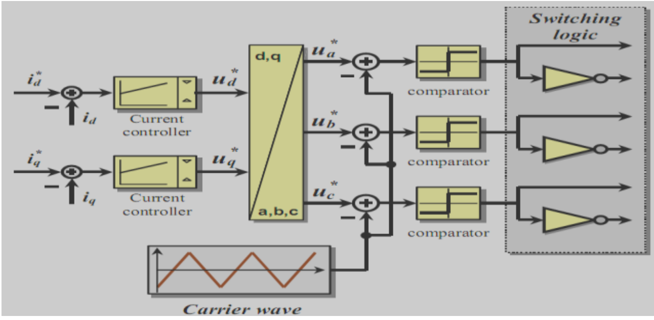


Figure5Sinusoidal PWM, current control and switching logic.

Three-phase reference voltages of variable amplitude and frequency are compared in three separate comparators with a common triangular carrier wave of fixed amplitude and frequency (figure). Each comparator output forms the switching-state of the corresponding inverter leg [Dub 89], [Leo 85]. In torque controlled ac motor drives using sinusoidal PWM, the reference voltages (u^*_a, u^*_b, u^*_c) are usually calculated by an additional current control loop (FOC). [6]

As shown in figure 6, a saw-tooth- or triangular-shaped carrier wave, determining the fixed PWM frequency, is simultaneously used for all three phases. This modulation technique, also known as PWM with natural sampling, is called sinusoidal PWM because the pulse width is a sinusoidal function of the angular position in the reference signal.

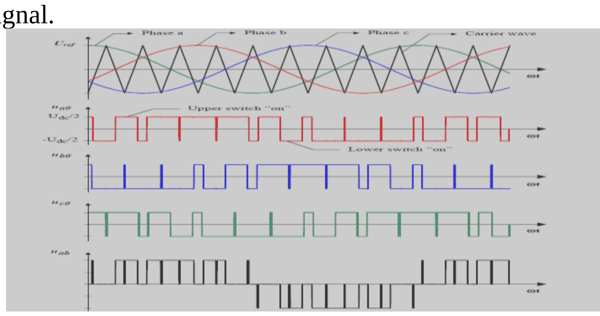


Figure 6 Principle of sinusoidal PWM generation

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Since the PWM frequency, equal to the frequency of the carrier wave, is usually much higher than the frequency of the reference voltage, the reference voltage is nearly constant during one PWM period T_{PWM}. This approximation is especially true considering the sampled data structure within a digital control system. Depending on the switching states, the positive or negative half dc bus voltage is applied to each phase. At the modulation stage, the reference voltage is multiplied by the inverse half dc bus voltage compensating the final inverter amplification of the switching logic into real power supply 6].

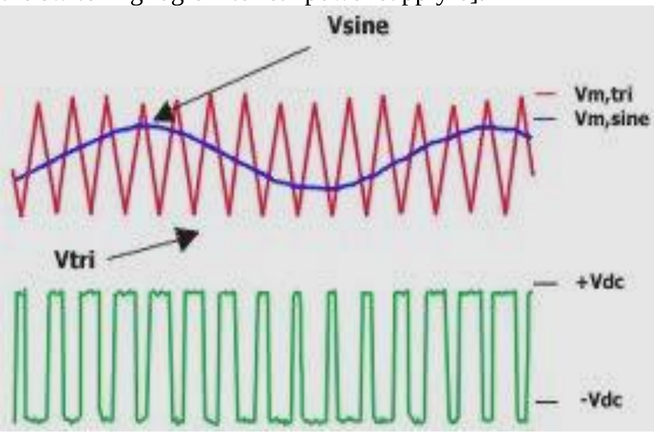


Figure 7 PWM for Inverter Single Phase

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

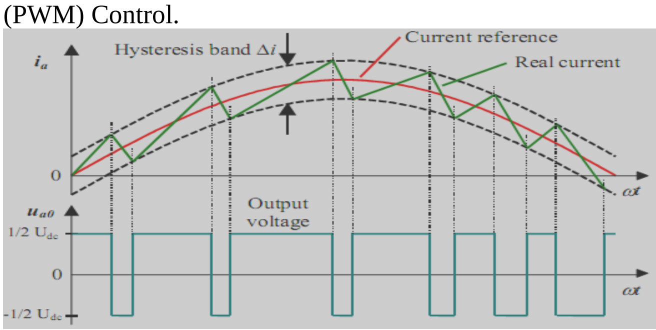


Figure 8.Actual Waveforms in P-sim single phase

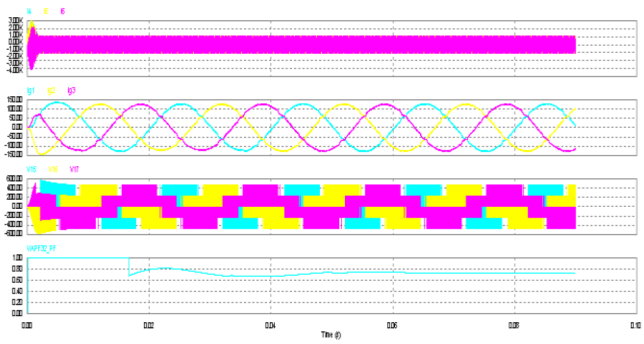


Figure 9.waveforms for three phases in P-sim(a) generator output(b)inverter output current (c) three phase voltage of inverter (d) power factor of load

Hysteresis PWM current controller

Hysteresis current control is a PWM technique, very simple to implement and taking care directly for the current control. The switching logic is realized by three hysteresis controllers, one for each phase (figure 11). The hysteresis PWM current control, also known as bang-bang control, is done in the three phases separately. Each controller determines the switching-state of one inverter half-bridge in such a way that the corresponding current is maintained within a hysteresis band Δi [6].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 11, and is usually implemented using two level switching so that each phase leg output is the mirror image of the other.

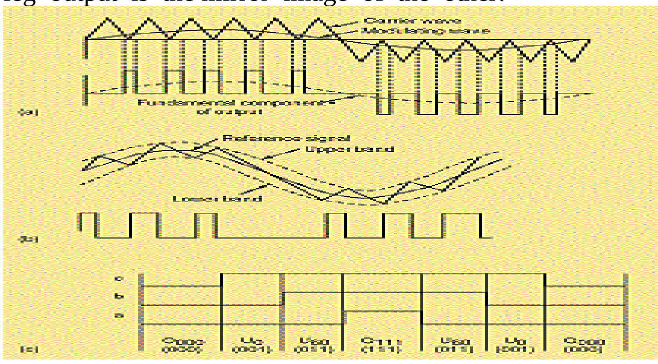


Figure 11.Wave forms of HCC

In HCC technique the error function centered in a preset hysteresis band. When the error exceeds the upper or lower limit the hysteresis controller makes an appropriate decision to control the error within the preset band and send the pulses to VSI to produce the reference current as shown in fig.11.[6]

It generates the PWM Pulses as it touches the upper and lower hysteresis band.

- Working of HCC

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

$$v_{uv} = Ri_o + L\frac{di_o}{dt} + e \qquad \text{.......... (1)}$$

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

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

$$i_o = i_o^r + \tilde{i}_o \qquad \text{............. (2)}$$

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

$$\bar{v}_{uv} + \tilde{v}_{uv} = R(i_o^r + \tilde{i}_o) + L\frac{d}{dt}(i_o^r + \tilde{i}_o) + e \qquad \text{............ (3)}$$

As the average and ripple components on the left-hand and Right-hand sides of (3) must be equal, the following Equations can be obtained

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

$$\tilde{v}_{uv} = R i_o^* + L\frac{di_o^*}{dt} + e$$

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

………….. (4)

The ripple voltage drop across the load resistance R~ io is Usually small and can be neglected and, hence, (4) can be simplified into

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

….. (5)

Thus, the output current ripple can be calculated as follows

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

……. (6)

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

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

…… (7)

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 (6), the following Expression can be obtained.

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

…. (8)

Where TON is the ON period of switches Q1and Q4. Based on (8), the ON period can be obtained as follows

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

….. (9)

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

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

….. (10)

Based on (10), the OFF period can be calculated as

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

….. (11)

Based on (9) and (11), the switching period can be calculated as

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

… (12)

By using (8) and (12), the switching frequency can be obtained as

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

……. (13)

The average switching frequency over one fundamental period is

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

………… (14)

Where

$$f_{sm}^s = \frac{E_d}{4hL}$$

……... (15)

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

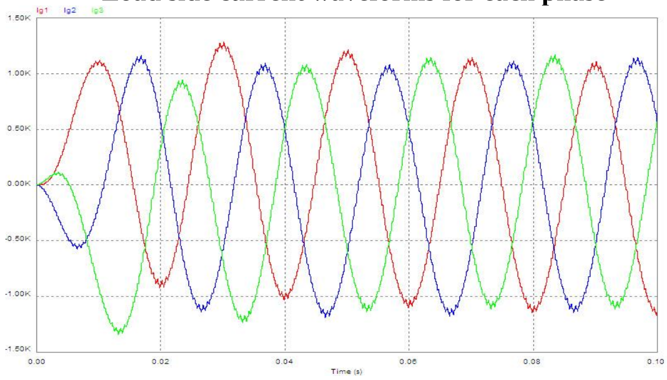
$$\tilde{I}_{o,av} = h/\sqrt{3}$$

……………. (16)

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



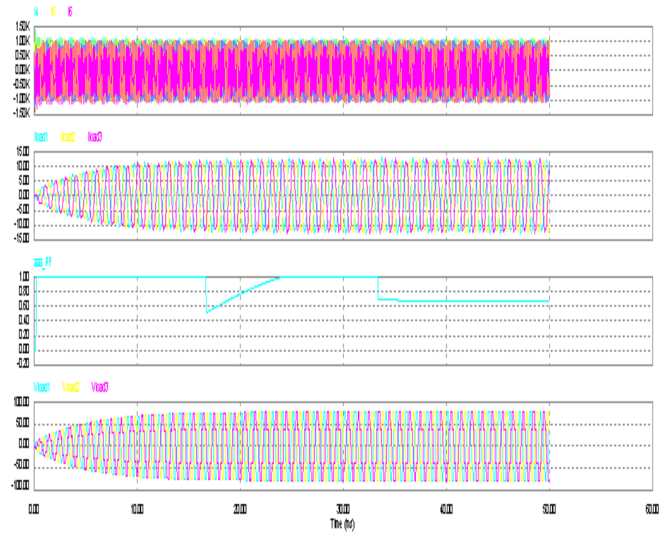
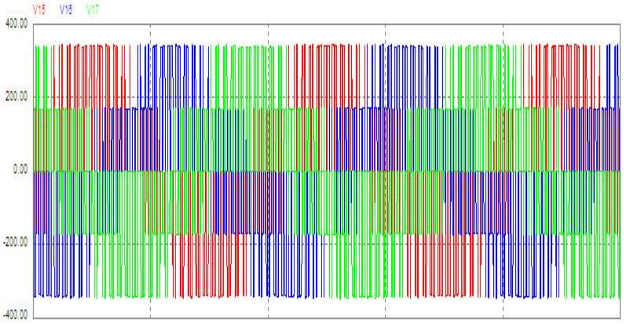
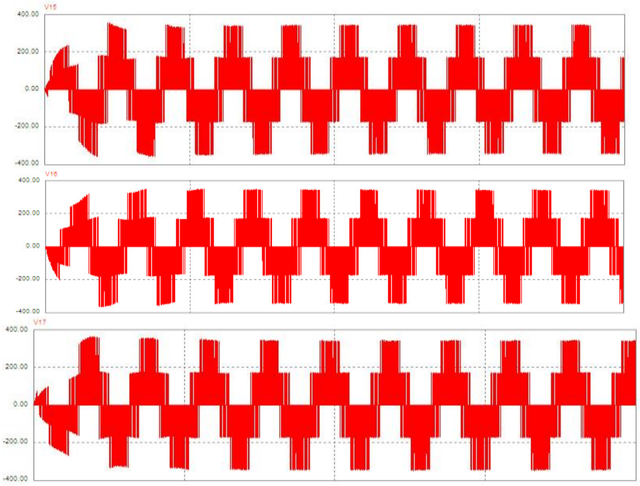


Figure 12.HCC waveforms in PSIM (a) Generator Output (b) with inverter control –single phase (c) power factor (d) load voltage

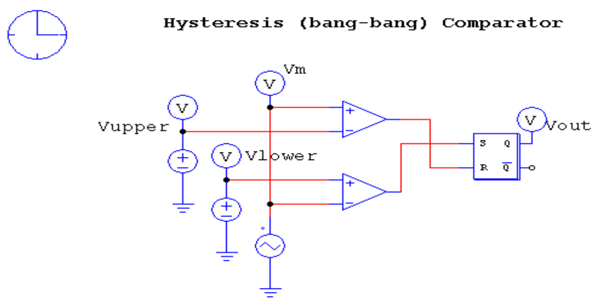
Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.



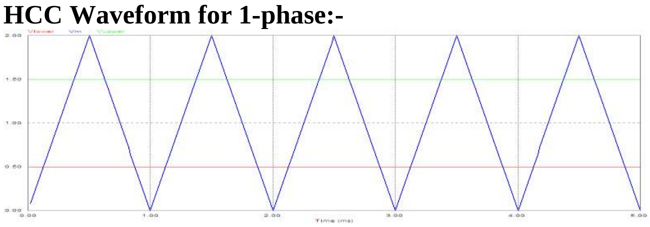
Individual waveforms from load side



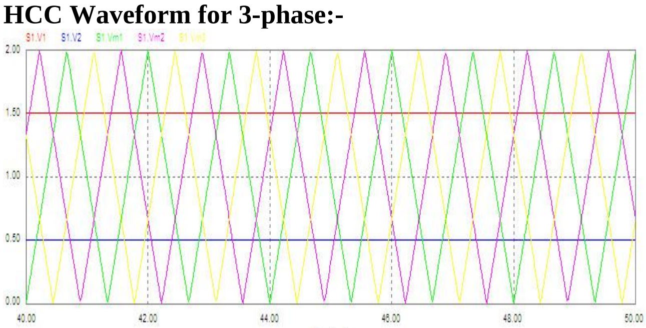
Hysteresis Current Controller Power Circuit (HCC):-



HCC Waveform for 1-phase:-



HCC Waveform for 3-phase:-



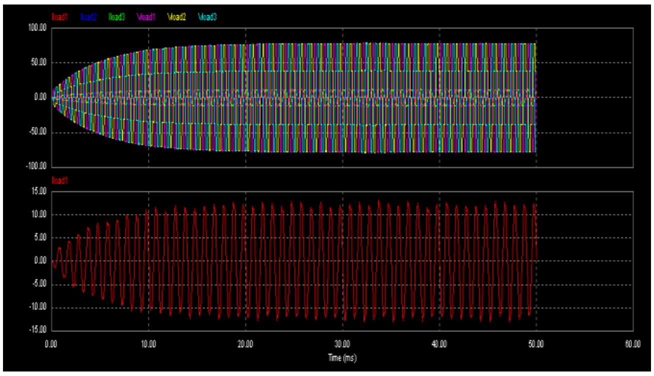


Figure 13.Actual Wave form- 3 phase HCC in P-SIM

IV. SPACE VECTOR (SVPWM)

Space Vector Modulation (SVM) was originally developed as vector approach to Pulse Width Modulation (PWM) for three phase inverters. It is a more sophisticated technique for generating sine wave that provides a higher voltage to the load with lower total harmonic distortion. The main aim of any modulation technique is to obtain variable output having a maximum fundamental component with minimum harmonics. Space Vector PWM (SVPWM) method is an advanced; computation intensive PWM method and possibly the best techniques for variable frequency drive application [11].

A space vector PWM

The circuit model of a typical three-phase voltage source PWM inverter is shown in Figure-14. S_1 to S_6 are the six power switches that shape the output, which are controlled by the switching variables a, a', b, b', c and c'. When an upper switch is switched on, i.e., when a, b or c is 1, the corresponding lower transistor is switched off, i.e., the corresponding a', b' or c' is 0. Therefore, the on and off states of the upper switch S_1, S_3 and S_5 can be used to determine the output voltage. SVPWM is a different approach from PWM modulation based on space vector representation of the voltages in the α-β plane. The α-β components are found by Clark's transformation. Space Vector PWM (SVPWM) refers to a special switching sequence of the upper three power transistors of a three-phase power inverter. It has been shown to generate less harmonic distortion in the output voltages and/or currents applied to the phases of an AC motor and to provide more efficient use of dc input voltage. Because of its superior performance characteristics, it has been finding widespread application in recent years [11].

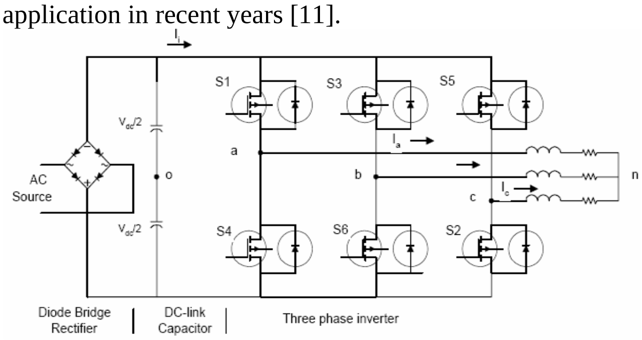


Figure 14.Tree phase voltage source inverter

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

V. PRINCIPLE OF SPACE VECTOR PWM

As illustrated in Fig. 14, there are eight possible combinations of on and off patterns for the three upper power switches. The on and off states of the lower power devices are opposite to the upper one and so are easily determined once the states of the upper power transistors are determined. According to equations and, the eight switching vectors, output line to neutral voltage (phase voltage), and output line-to-line voltages in terms of DC-link V dc, are given in Table 4 and Fig. 31 shows the eight inverter voltage vectors (V0 to V7). [20].

The relationship between the switching variable vector $[a, b, c]^t$ and the line-to-line voltage vector is given $[V_{ab}\ V_{bc}\ V_{ca}]^t$ by eq in the following:

$$\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = V_{dc} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} \quad \text{..................... (17)}$$

Also, the relationship between the switching variable vector $[a, b, c]^t$ and the phase voltage vector $[V_{ab}\ V_{bc}\ V_{ca}]^t$ can be expressed below.

$$\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = V_{dc} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} \quad \text{............. (18)}$$

➢ **Output voltages of three-phase inverter (3)**

• **The eight inverter voltage vectors (V_0 to V_7)**

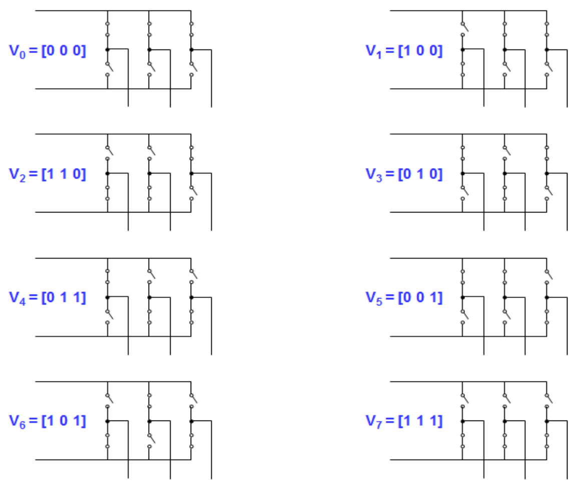


Figure 15.Sequences of switching states [20]

Voltage Vectors	Switching Vectors			Line to neutral voltage			Line to line voltage		
	a	b	c	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
V_0	0	0	0	0	0	0	0	0	0
V_1	1	0	0	2/3	-1/3	-1/3	1	0	-1
V_2	1	1	0	1/3	1/3	-2/3	0	1	-1
V_3	0	1	0	-1/3	2/3	-1/3	-1	1	0
V_4	0	1	1	-2/3	1/3	1/3	-1	0	1
V_5	0	0	1	-1/3	-1/3	2/3	0	-1	1
V_6	1	0	1	1/3	-2/3	1/3	1	-1	0
V_7	1	1	1	0	0	0	0	0	0

Figure 16.Output phase and line voltages [20]

VI. SIMULATION OF SVPWM IN PSIM

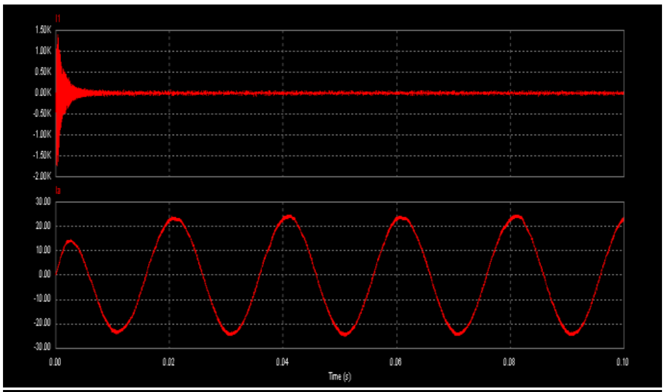


Fig 17 single phase waveform (a) without inverter control (b) with inverter control-SVPWM

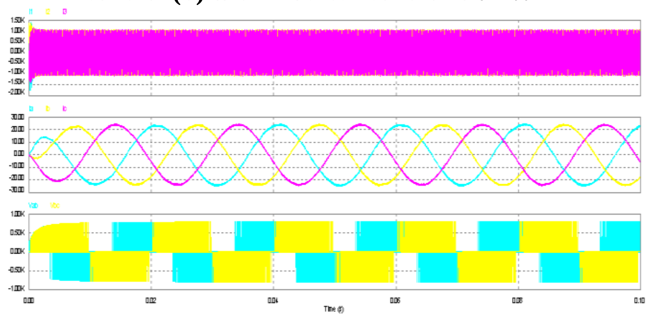


Figure 18 output current and voltage-3 phase

⟶ Conclusion

After study of these kinds of variable speed wind turbines, and how the control techniques actually work on power electronic interface shows really interesting results. All the PWM methods mentioned in this paper are far best for wind turbines to reduce THD and to produce sinusoidal electrical energy.

As study reveals Space vector PWM generates less harmonics distortion in current or voltage in comparison with sine PWM.

Space vector provides more efficient use of supply voltage in comparison with Sine PWM.

Sine PWM

➢ Locus of the reference vector is the inside of a circle with radius of 1/2 V_{dc}

Space vector PWM

➢ Locus of the reference vector is the inside of a circle with radius of $1/\sqrt{3}\ V_{dc}$

Voltage Utilization: Space Vector PWM = $2/\sqrt{3}$ times of Sine PWM.

REFERENCES

1. Nitin Adhav " A concept of Smart grid and control Schemes in variable power source wind turbine International journal of engineering and research Application " Vol. 2, Issue 4, July-August 2012, pp.579- 584
2. F. Blaabjerg, Z. Chen, R. Teodorescu, F. Iov Aalborg University institute of Energy Technology "Power Electronics in Wind Turbine Systems" 1-4244-0449-5/06/$20.00 ©2006 IEEE
3. Juan Manuel Carrasco, Jan T. Bialasiewicz,, Ramón C. Portillo Guisado, José Ignacio León, "Power-Electronic Systems for the Grid Integration of Renewable Energy Sources: A Survey" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 53, NO. 4, AUGUST 2006

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

4. S. M. Barakati, M. Kazerani, *Senior Member, IEEE*, and X. Chen "A new wind turbine system based on matrix converter"0-7803-9156-X\\05\$20.00@2005 IEEE
5. Inside Wind turbine fixed Vs. Variable james and james Science publishers ltd.
6. Voltage Source-PWM inverter
7. A.M.Gole 2000 "power electronics" Sinusoidal Pulse Width Modulation
8. Power Electronics and Drives (Version 2): Dr. Zainal Salam, 2002 4.4.1 SPWM
9. D.Dujic, E.Levi, M.Jones Liverpool John Moores University School of Engineering G.Grandi, G.Serra, A.Tani University of Bologna Department of Electrical Engineering 40136 - Bologna, Italy Liverpool L3 3AF, UK "Continuous PWM Techniques for Sinusoidal Voltage Generation with Seven-Phase Voltage Source Inverters" 1-4244-0655-2/07/$20.00©2007 IEEE
10. Tariq MASOOD.CH Qatar Petroleum Dukhan Qatar, Dr. Abdel-Aty Edris (Manager Power Delivery R & D) EPRI USA, Prof. Dr. RK Aggarwal University of Bath Bath _ UK, Prof. Dr. Suhail A. Qureshi University of Engineering & TechnologyLahore Pakistan, Prof. Dr. Abdul Jabber Khan Rachna College of Engineering &Technology Gujranwala Pakistan, Yacob Y. Al-Mulla IEEE Chair Doha Qatar" Space Vector (PWM) Digital Control and Sine (PWM) Pulse Width Modulation modelling, simulations Techniques & Analysis by MATLAB and PSIM (Powersys)"
11. K. Vinoth Kumar, Prawin Angel Michael, Joseph P. John and Dr. S. Suresh Kumar School of Electrical Sciences, Karunya University, Coimbatore, Tamilnadu, India "SIMULATION AND COMPARISON OF SPWM AND SVPWM CONTROL FOR THREE PHASE INVERTER" ARPN Journal of Engineering and Applied Sciences VOL. 5, NO. 7, JULY 2010
12. M.B.B. Sharifian, R. Rahnavard, Y. Ebrahimi "Variable Hysteresis Band Current Controller of Shunt Active Filter Based Fuzzy logic Theory under Constant Switching Frequency" International Journal of Computer and Electrical Engineering, Vol. 1, No. 2, June 2009 1793-8163
13. B.Chitti Babu , K.B.Mohanty"Doubly-Fed Induction Generator for Variable Speed Wind Energy Conversion Systems- Modeling & Simulation" International Journal of Computer and Electrical Engineering, Vol. 2, No. 1, February, 2010 1793-8163
14. Mansour Mohseni, *Student Member, IEEE*, and Syed M. Islam, *Senior Member, IEEE "*A New Vector-Based Hysteresis Current Control Scheme for Three-Phase PWM Voltage-Source Inverters" IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 25, NO. 9, SEPTEMBER 2010
15. Seung-Ho Song, Shin-il Kang Div. of Electronics & Information Engineering Chonbuk National University, Nyeon-Kun Hahm* Intech-FA Co Ltd* Youngin , Gyungi, Korea "Implementation and Control of Grid Connected AC-DC-AC Power Converter for Variable Speed Wind Energy Conversion System" 0-7803-7768-0/03/$17.00 (C) 2003 IEEE
16. S. Seman, *Student Member, IEEE*, J. Niiranen, S. Kanerva, and A. Arkkio "Analysis of a 1.7 MVA Doubly Fed Wind-Power Induction Generator during Power Systems Disturbances "
17. Nikolay N. Lopatkin, Maria I. Kraskova *Biysk Teacher-Training State University after S.M. Shukshin (BTTSU),Biysk, Russia"* Simple PSIM-model of Vector Formation of the Phase-to-Phase Voltage of a Multilevel Inverter" 9th INTERNATIONAL WORKSHOP AND TUTORIALS EDM'2008, SESSION IV, JULY 1-5, ERLAGOL
18. Mohamayee Mohapatra, B.Chitti Babu, *Member IEEE* Department of Electrical Engineering, National Institute of Technology, Rourkela, INDIA "Fixed and Sinusoidal-Band Hysteresis Current Controller for PWM Voltage Source Inverter with LC Filter IEEE students' Technology symposium,IIT kharagpur,03\04.
19. Dalessandro, U. Drofenik, S. D. Round and J. W. Kolar Swiss Federal Institute of Technology (ETH) Zurich Power Electronic Systems Laboratory" A Novel Hysteresis Current Control for Three-Phase Three-Level PWM Rectifiers"
20. Lecture 25 prof.Ali Keyhani Department of Electrical And Computer Engineering The Ohio State University"Pulse Width Modulation Techniques"
21. Dorin O. Neacsu" SPACE VECTOR MODULATION–An Introduction Tutorial at IECON2001" IECON'01: The 27th Annual Conference of the IEEE Industrial Electronics Society
22. Dr.Rafael K.Jardan"Supporting text for the E-learning Material chapter 3.4.Control in Power Electronics Part B:-Space Vector Theory
23. Dong-Choon Lee, *Member, IEEE*, and G-Myoung Lee "A novel modulation technique for Space Vector PWM inverter" IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 13, NO. 6, NOVEMBER 1998
24. Abdallah Saadoun, Ali Yousfi, Yacine Amirat "AN IMPROVED SPACE VECTOR MODULATOR MODEL FOR HIGH PERFORMANCE AC DRIVES"
25. Abdul Rahiman Beig G.Narayanan Lab Department of Electrical Enginner Indian Institute of Science Bangalore, V.T. Ranganathan "Space Vector Based Synchronized PWM Algorithm for Three Level Voltag Source Inverters: Principles and Application to VlfDrives Chapter 2 Wind Turbine Modelling
26. J. Marques, H. Pinheiro, H. A. Gründling, J. R. Pinheiro and H. L. Hey Federal University of Santa Maria – UFSM Group of Power Electronics and Control – GEPOC UFSM/CT/NUPEDEE, Campus Universitário, Camobi "A survey on variable speed wind turbine"

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.