SVPWM controller for three phase inverter using PI controller operating under non linear load

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Abstract: In the past several years, there is rapid increase of power electronics-based loads connected to low and medium voltage power distribution systems. As these loads draw non sinusoidal current from the mains, it degrades the power quality by causing Harmonic distortion. So to reduce harmonics and to increase power quality Space vector control strategy is presented for three phase inverter system operating under highly nonlinear loads. Pulse width modulation are mainly used in industrial application for better performance. Proportional Integral (PI) controller is used to design SVPWM in closed loop. The proposed controller design generates gating signals which drives inverter and guarantees high quality output with less distortion for non linear load. MATLAB/SIMULINK is used for designing and development of SVPWM based three phase inverter.

Keywords: Inverter , non linear load, PI controller, Space Vector PWM.

I. INTRODUCTION

With the increasing use of rectifiers in critical loads improvement in the quality of power obtained from the UPS system is required. In the recent years, due to advancement in the field of power electronics technology, it paved the way for modern fast switching PWM techniques for DC to AC conversion. Output voltage from an inverter can be adjusted by changing a control within the inverter itself. The most prominent method of doing this is by using pulse-width modulation control within an inverter. In this method, a dc input voltage is given to an inverter and a controlled ac output voltage is obtained by changing the on and off periods of inverter switches. This is the most popular method of controlling the output voltage of an inverter and this method is termed as Pulse - Width Modulation (PWM) Control.

The most widely used and popular modulation techniques are SPWM AND SVPWM. The widths of the voltage pulses, over the output cycle, vary in a sinusoidal manner in SPWM. The scheme involves comparison of a high frequency triangular carrier voltage with a sinusoidal modulating signal which gives the desired fundamental component of the voltage waveform. the peak magnitude of modulating and reference waveform generates the gating pulse which drives the inverter switches.

Space vector method is an advanced computation PWM method and possibly the best PWM techniques for three phase inverters. This technique uses vectors to be applied according to region where the output voltage vector is located. This technique is more sophisticated for generating sine wave which can provide higher voltage to the load with low harmonic distortion. SVPWM approach is different from PWM modulation. it is based on space vector representation of the voltages in the α-β plane. The α-β components are obtained by clarke's transformation. Space Vector PWM (SVPWM) uses a special switching sequence of the upper three transistors of a three -phase inverter. Space Vector Modulation increases the capability of the output of Sinusoidal PWM (SPWM) with reduced distortion in output voltage waveform and also prevents un-necessary switching.

II. SVPWM IMPLEMENTATION

A. Park's transformation

In space vector PWM the first step is to convert the three phase quantities into two phase quantities by park's transformation formulae. These two phase quantities are then used for generation of the reference vector and its equivalent angle by which it is rotating in d-q frame which modulates the inverter output.
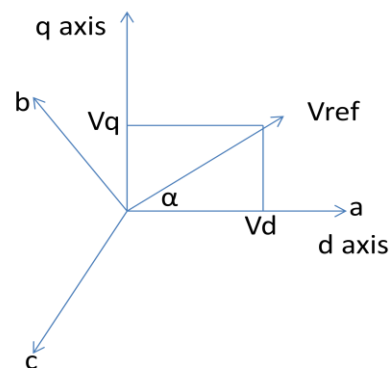

Fig 1 park's transformation

The equations of park's transformation which converts three phase quantities to two phase quantities are given below.

$$V_d = 2/3[V_a \sin(\omega t) + V_b \sin\left(\omega t - \frac{2\pi}{3}\right) + V_c \sin\left(\omega t + \frac{2\pi}{3}\right)]$$

$$V_q = 2/3[V_a \sin(\omega t) + V_b \cos\left(\omega t - \frac{2\pi}{3}\right) + V_c \cos\left(\omega t + \frac{2\pi}{3}\right)]$$

$$V_0 = 1/3(V_a + V_b + V_c)$$

B. Vref and its equivalent angle

The two phase quantities generated from the above equations are further used to generate reference vector and its equivalent angle as shown in fig 2.
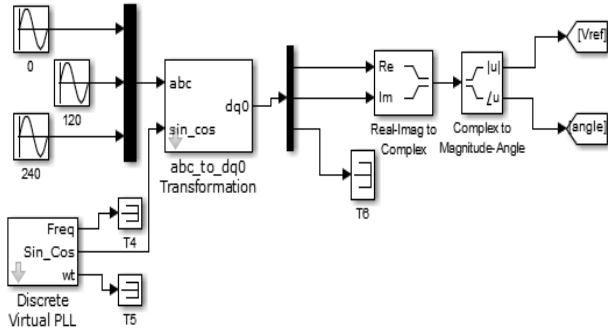

Fig 2. Simulink model for V-reference and angle.

C. Defining sector

The diagram of three phase voltage source inverter is shown fig below. The switches 12,21,31 are upper switches and the switches 12,22,32 are lower switches. if the upper switches are 1 it turns upper inverter leg ON and similarly if lower switches are 0 it turns lower inverter leg ON.
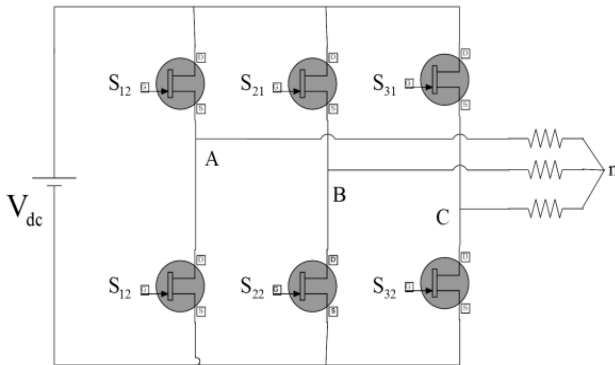
Fig 3. Three phase inverter configuuration.

The upper switches are complementary to lower switches, so the only possible combination for the switching states are (000,001,010,011,100,101,110,111). There are total eight switching states out of which two states are null states and remaining six are active states.
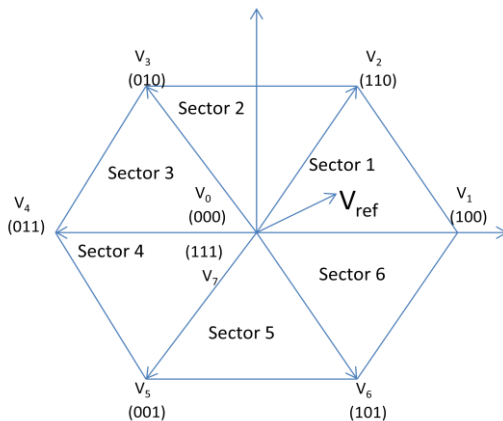

Fig 4. Basic switching vectors.

Six active vectors shape the axes of hexagonal and are used to supply power to the loads shown in fig 4. Two zero vector V0 and V7 are at the origin and supply zero voltage to the load. These eight vector are called as basic space vectors and are denoted by $(V_0, V_1, V_2, V_3, V_4, V_5, V_6, V_7)$. The objective of the SVPWM technique is to estimate the reference vector using eight switching pattern.
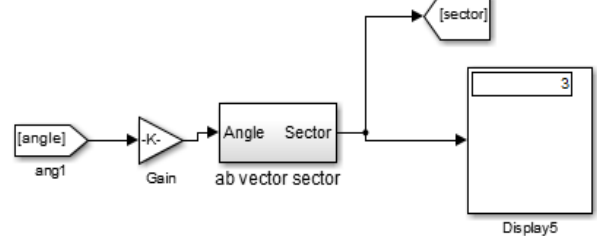

Fig 5. Simulink model for Sector definition.

In the ab vector sector block sectors are defined. there are six sectors out of eight which are obtained by switching of a typical three phase inverter shown in fig 5. Each sector is made up of 60 degree. The logic for reference vector (V_{ref}) is in which sector is designed in above simulink model. The sectors are defined such as, sector 1 means 0- 60 degree, sector 2 is 60- 120 degree, and so on. The above logic says that, if the angle which is generated with $V_{reference}$ is 140 degree then it lies in sector 3 as shown in fig 5.

D. Dwell Time

Consider suppose the reference vector is lying in sector 1 as shown in fig 6. T1 is the time for which active vector 100 (+ - -) is applied and T2 is the time for which active vector 110(+ + -) is applied. Alpha (α) is an angle by which reference vector is rotating in. Applying T1 and T2 for suitable time we get the appropriate value of reference vector. Ts is the total time for which null vector (Tz) and active vector are applied. T1, T2, Ts and Tz calculations are given below.
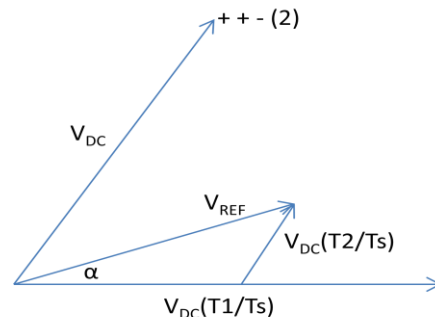

Fig 6. Reference vector in sector 1.

$$V_{ref} T_s = V_1 T_1 + V_2 T_2 + V_z T_Z$$

$$T_s = T_1 + T_2 + T_z$$

$$T_1 = \frac{V_{ref} \sin(60 - \alpha)}{V_{dc} \sin(60)} T_S$$

$$T_2 = \frac{V_{ref} \sin(\alpha)}{V_{dc} \sin(60)} T_S$$

$$T_z = T_s - T_1 - T_2$$

By applying these vectors (V1,V2, Vz) for appropriate time Modulating signal is generated. compare this modulating signal with carrier wave to generate triggering pulses. These pulses used as a gating signal to drive inverter switches.

E. *Proportional Integral(PI) controller*

When a load is connected to the inverter output, the output voltage is sensed and is given to a comparator which compares this load output with the reference signal i.e desired signal and it produces the error signal. This instantaneous error is given to a (PI) controller. PI controller has two elements namely Proportional (P) and Integral (I). Proportional part is used to reduce the error while Integral part helps in reducing the offset. P depends on present error and I depends on past errors. So, step response of a system can be better improved with the use of PI controller. Also the integral term in the PI controller helps to improve the tracking by reducing the instantaneous error between reference and the actual value or desired value. The resulting error signal is compared with a triangular carrier signal and intersections decide the switching frequency and pulse width.
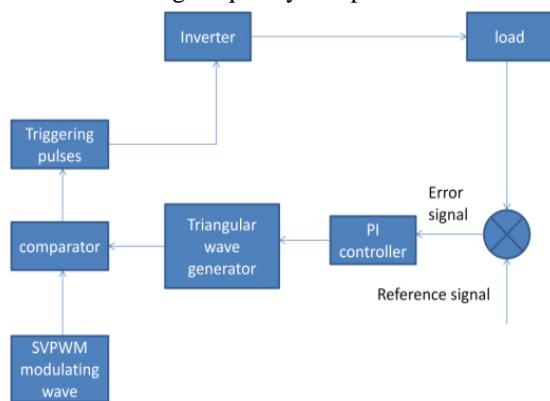

Fig 7 Block diagram of SVPWM controller using PI control logic.

III. SIMULATIONS AND RESULTS

Fig 8, 9, 10 shows behavior of SVPWM controller with PI control logic when non linear load is diode bridge rectifier. Fig 11,and 12 shows the harmonics spectrum for current and voltage respectively. Fig 13 shows three phase inverter stage with non linear load.
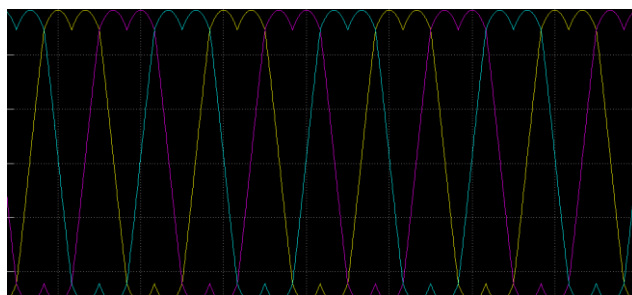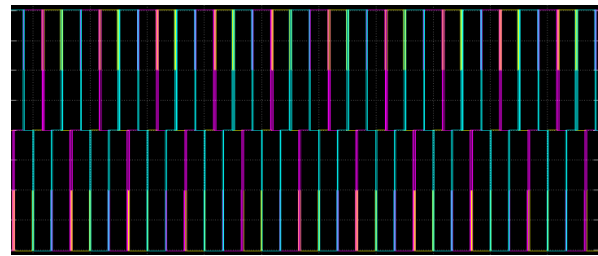

Fig 8 modulating waveform
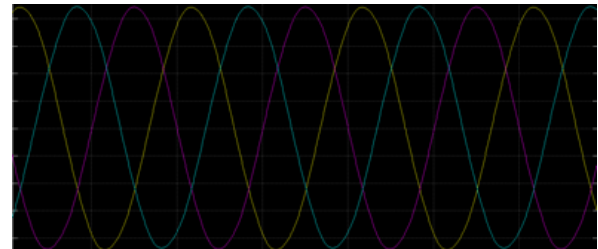

Fig 9 Three phase output.
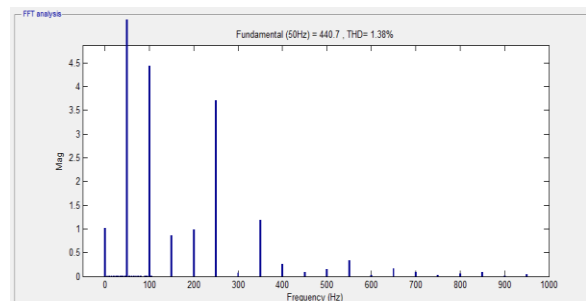

Fig 10 Three phase filtered output

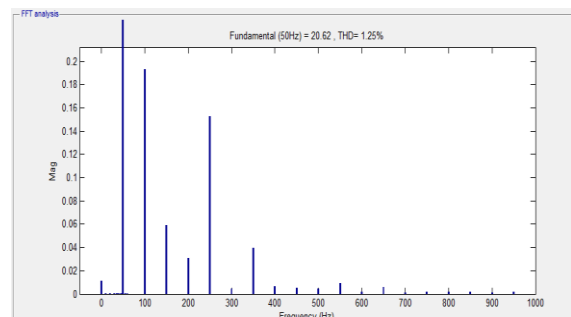Fig 11 voltage harmonics spectrum

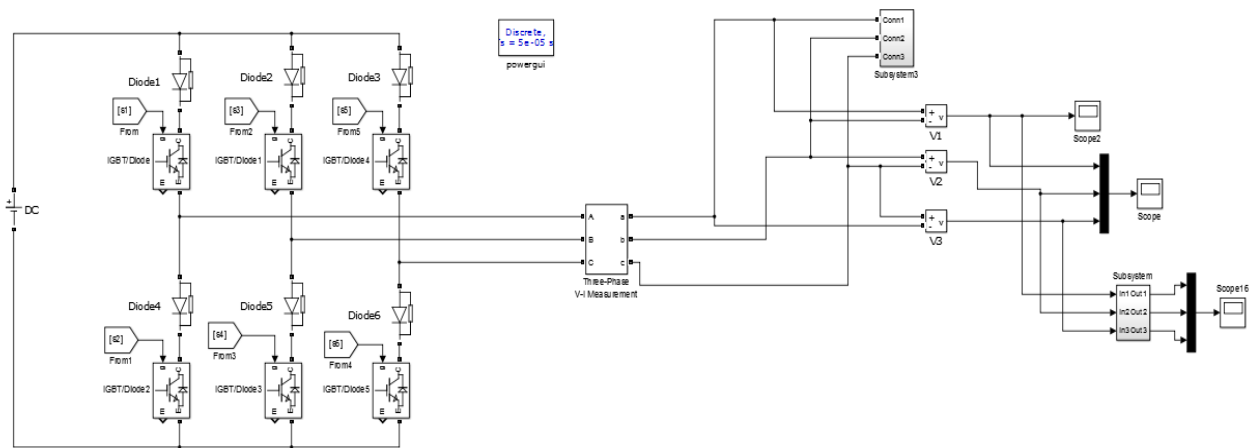Fig 12 current harmonics spectrum

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Fig 13. Simulink model for three phase inverter stage.

IV. CONCLUSION

In this paper SVPWM controller with PI control logic for three phase inverter is proposed. The simulation and results are analysed using MATLAB/SIMULINK software. The harmonic spectrum under non-linear load conditions shows that reduction of harmonics is better with the use of PI controller. It is useful in increasing DC bus utilization than that of other methods. The THD for load current under non linear load is reduced.

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