SVPWM Controller for three phase UPS system operating under highly nonlinear load

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ABSTRACT : *The distortion obtained in the Uninterruptible Power Supply (UPS) output due to increasing use of rectifiers in critical loads an effective strategy is needed to control the output of UPS system. Sinusoidal pulse width modulation (SPWM) and space vector pulse width modulation (SVPWM) are the most popular PWM techniques for three phase UPS system. As compared to SPWM, SVPWM is much effective in reducing harmonics and distortions caused by highly non linear loads. In this paper space vector based control strategy is presented for three phase UPS system that are operating under highly nonlinear load. The proposed controller generates gating signals and guarantees high quality output at the load. SIMULINK is used to design and analyse the controller for three phase ups system.*
Keywords : UPS, non linear load, Space Vector PWM

I. INTRODUCTION

The increase in use of rectifiers in critical loads such as in medical and military instruments, there is a need to improve the quality of power obtained from the UPS system. Due to advancement in the field of power device technology in recent years have paved the way for modern fast switching PWM techniques for DC- AC conversion.

Pulse Width Modulation (PWM) is a popular technique used for controlling the width of the gate pulse by various mechanism. The DC-AC inverters usually operates on pulse width modulation technique (PWM). The traditional inverter output voltage changes according to changes in the load. The PWM inverter irrespective of the output load, keeps the output voltage of the inverter at the rated voltage. The pulse width and switching frequency adjusted according to the value of the load to provide constant rated output.

SPWM and SVPWM are the most popular and widely used modulation techniques. In SPWM the width of each pulse is varied in proportion to the amplitude of the sine wave. The gating signal for the inverter are generated by comparing a sinusoidal reference signal with a triangular wave carrier. It is obtained by taking repeating sequence (triangular wave) as the control signal and comparing it with reference wave (sinusoidal signal). The frequency and amplitude of the reference or modulating voltage is varied to get the desired output voltage. [10]

Space vector method is an advanced computation-intensive PWM method and possibly the best PWM techniques for three phase inverters. Space vector modulation was originally developed as a vector approach to pulse width modulation for three phase inverters. It is more sophisticated technique for generating sine wave to that provides higher voltage to the load with low harmonic distortion. 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 clarke'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 to provide more efficient use of dc input voltage. Because of its superior performance characteristics, it has been finding widespread application in recent years.[8]

II. SYSTEM DESCRIPTION

Fig 1. Shows the single-line diagram of a typical three phase four wire UPS system. The controlled rectifier converts the three phase mains voltage into a constant DC voltage and used to charge the batteries shown in fig.1. the three phase inverter with the help of controller converts DC voltage into desired AC voltage. In this paper the controller which is used to control the inverter is designed using space vector PWM technique. The LC low pass filter is used to remove the harmonics generated by PWM technique. The load connected at the output of the UPS system can be single or three phase and can be linear or non linear load.[7]
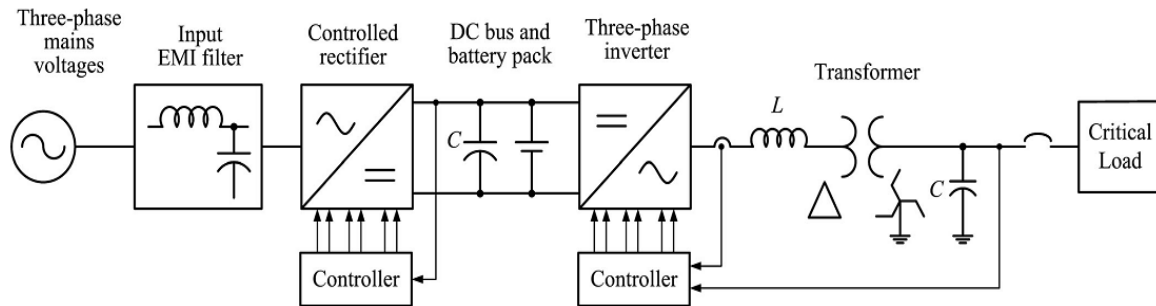
Fig 1. Single-line diagram of a typical three phase four-wire UPS system.

III. SVPWM CONTROLLER DESIGN

3.1 Park's Transformation

In space vector PWM the three phase quantities are converted into two phase quantities by park's transformation. These two phase quantities are used to generate the reference vector and the angle by which it is rotating in d-q frame which modulates the inverter output.
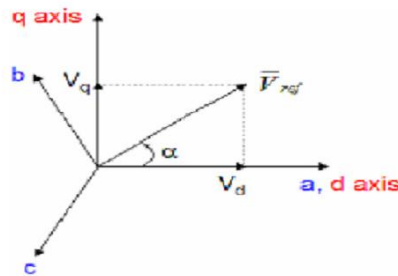

Fig 2. Voltage space vector and its component in d-q.

The park's transformation equations which transforms three phase (abc) quantities to two phase quantities (d-q) are given below:

$$V_d = \frac{2}{3}[V_a \sin(wt) + V_b \sin(wt - \frac{2\pi}{3}) + V_c \sin(wt + \frac{2\pi}{3})] \tag{1}$$

$$V_q = \frac{2}{3}[(V_a \sin(wt) + V_b \cos(wt - \frac{2\pi}{3}) + V_c \cos(wt + \frac{2\pi}{3})] \tag{2}$$

$$V_0 = \frac{1}{3}(V_a + V_b + V_c) \tag{3}$$

3.2 Generation of V-Reference And Angle

The two phase quantities (d-q) which are generated from above equations are used to generate reference vector and its equivalent angle as shown in fig 2.
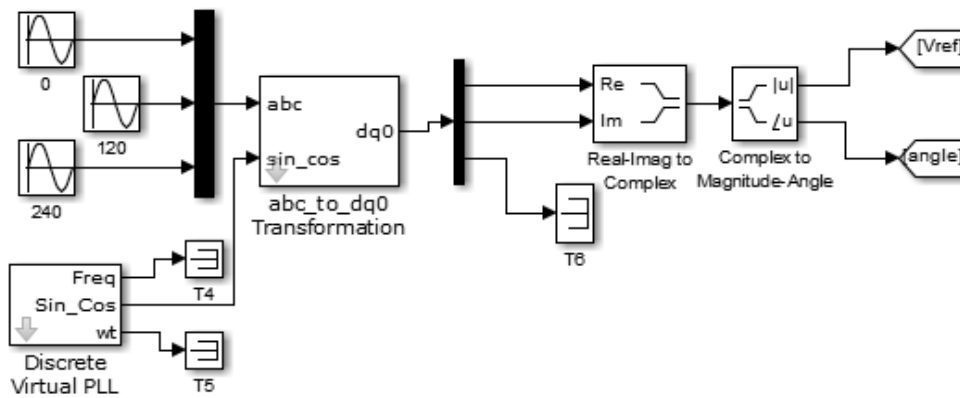
Fig 3. Simulink model for Generation of V-reference and angle.

3.3. Sector Formation

Fig 4 shown below is the typical diagram of three phase voltage source inverter. The switches 1,3,5 are upper switches and if these are 1 it turns the upper inverter leg ON. The switches 2,4,6 are lower switches and if these are 0 it turns the lower inverter leg ON.
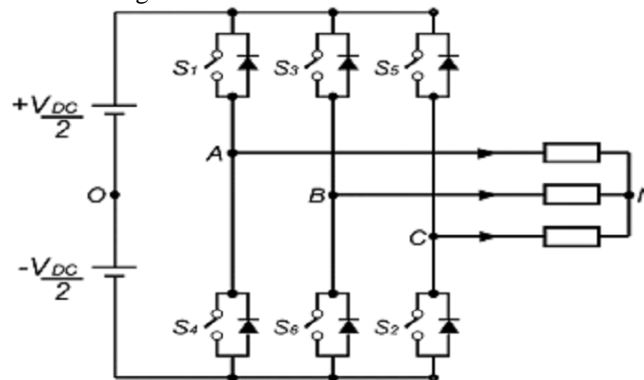

Fig 4. Three phase voltage source inverter configuaration.

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

Six non zero vectors shapes the axes of hexagonal and supplies power to the loads shown in fig 5. Two zero vector V_0 and V_7 are at the origin and apply zero voltage to the load. These eight vectors are called basic space vector are denoted by ($V_0,V_1,V_0,V_2,V_3,V_4,V_5,V_6,V_7$).The objective of the SVPWM Technique is to approximate the reference vector using eight switching pattern.
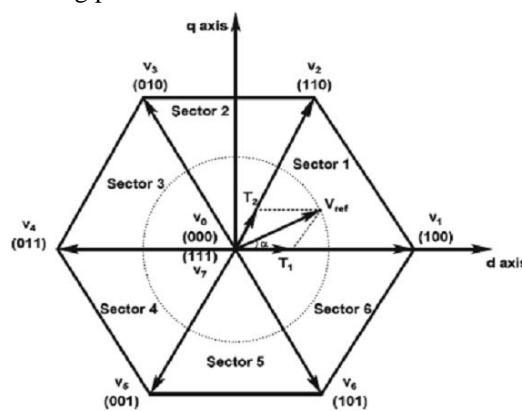

Fig 5. Basic switching vectors and sectors.

As shown in fig 5 there are six sectors which are formed by switching of a typical three phase inverter inverter. Each sector consists of 60 degree. The logic behind reference vector (Vref) lying in which sector is

designed in above simulink model. The sectors are defined as, sector 1 is 0- 60 degree, sector 2 is 60- 120 degree, sector 3 is 120- 180 degree and so on. The logic says that, suppose the angle which is generated with Vreference is 130 degree then it lies in sector 3 as shown in fig 6.
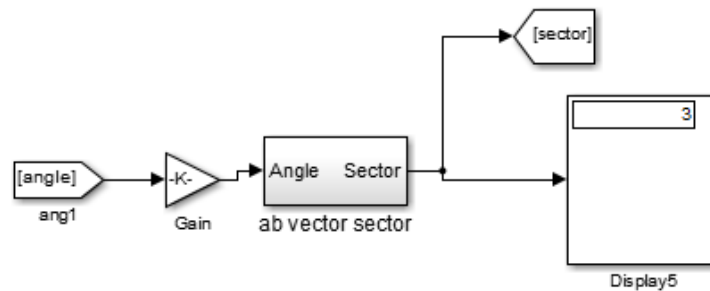
Fig 6. Simulink model for Sector formation.

3.4. Calculation of Dwell time

Consider the reference vector lying in sector 1 as shown in fig 7. T1 is the time for active vector 100 (+ - -) is applied and T2 is the time for active vector 110(+ + -) is applied. Alpha (α) is an angle through which reference vector is rotating. By applying T1 and T2 for appropriate time we get the value of reference vector. Ts is the total time for which active vector and null vector(Tz) are applied. Calculation of T1, T2, Ts and Tz are given below.[5]
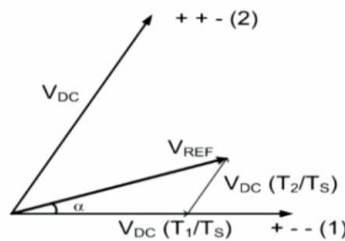
Fig 7. Referenece vector in sector 1.

$$V_{ref}T_s = V_1T_1 + V_2T_2 + V_zT_z \qquad (4)$$

$$T_s = T_1 + T_2 + T_z \qquad (5)$$

$$T_1 = \frac{V_{ref}\sin(60-\alpha)}{V_{dc}\sin(60)}T_s \qquad (6)$$

$$T_2 = \frac{V_{ref}\sin(\alpha)}{V_{dc}\sin(60)}T_s \qquad (7)$$

$$T_z = T_s - T_1 - T_2 \qquad (8)$$

Modulating signal is generated by applying these vectors (V_1, V_2, V_z) for appropriate time. By comparing this modulating signal with carrier wave triggering pulses are generated. These pulses used as a gating signal for inverter switches.
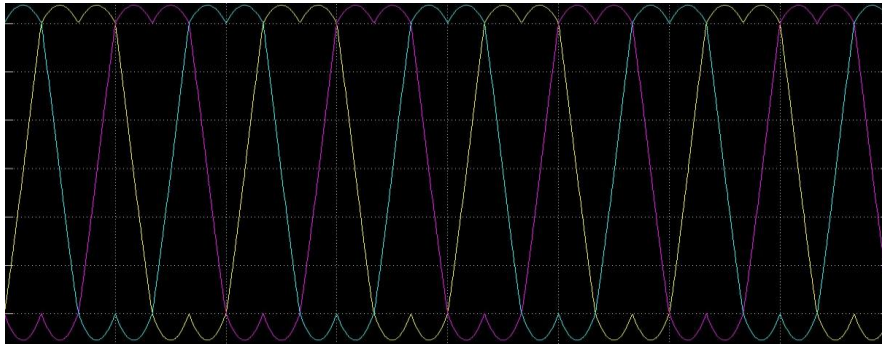
IV. SIMULATION RESULTS
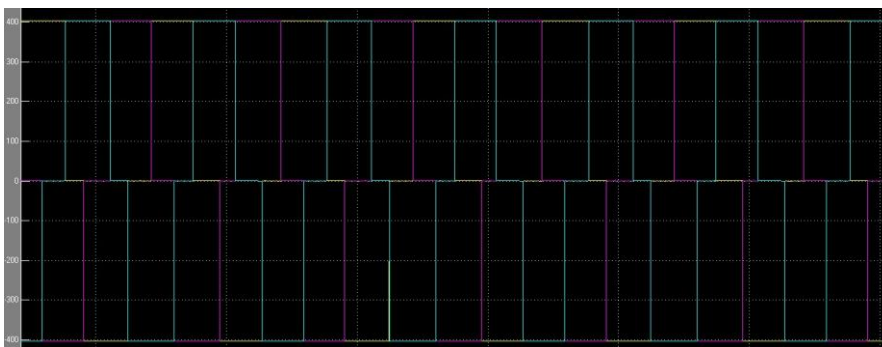

Fig 8. Modulating signal waveform.
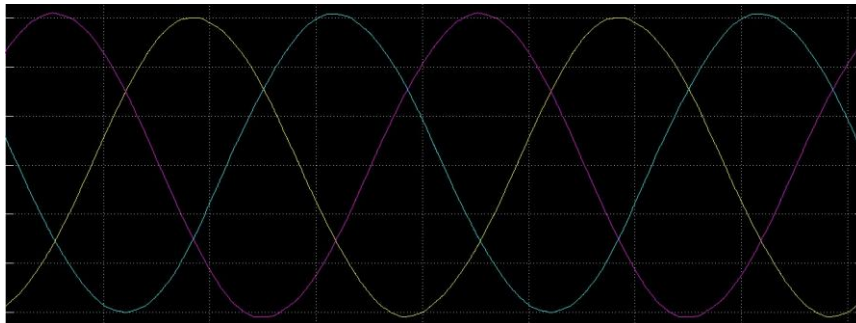

Fig 9. Three phase square wave output
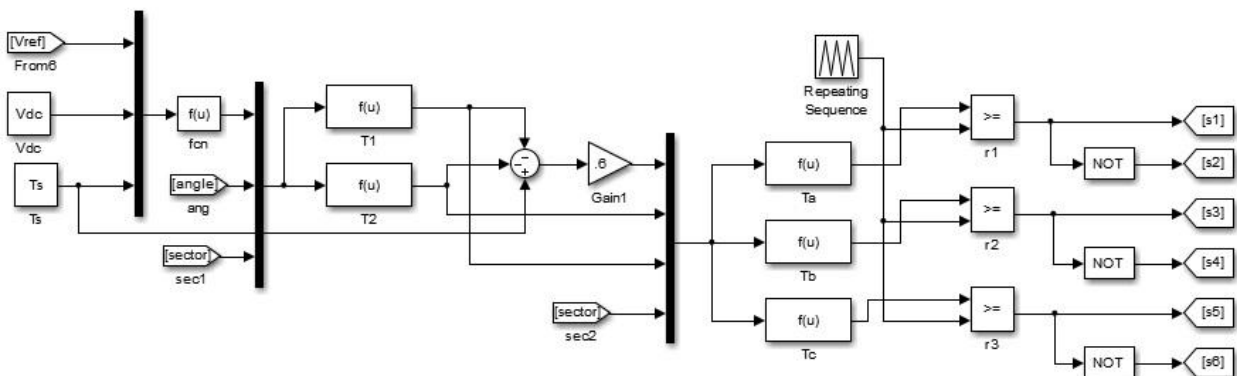

Fig 10. Three phase filtered output waveform

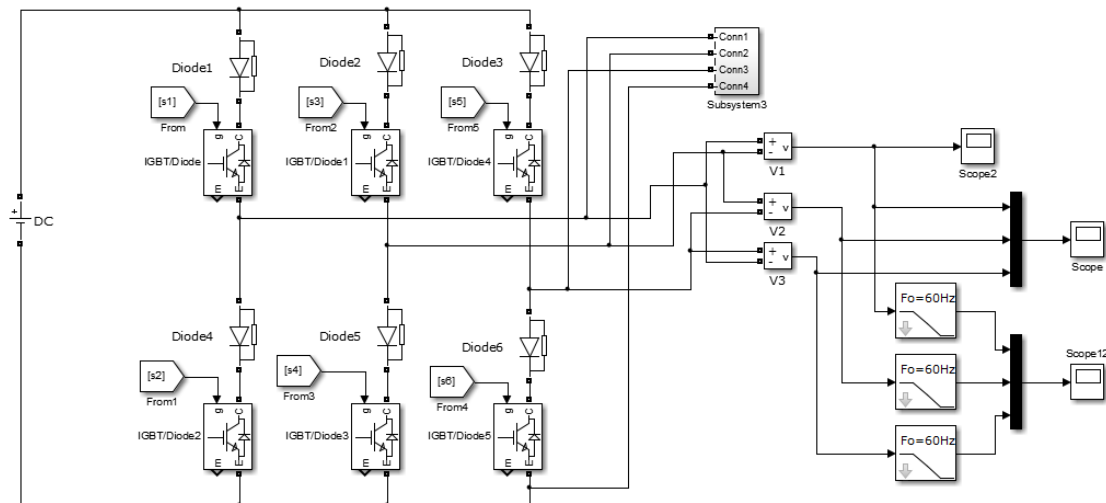Fig 11.Simulink model for calculation of dwell time and generation of gating signal

Fig12. Simulink model for inverter stage with non linear load.

V. CONCLUSION

In this paper, a high-performance control strategy for UPS system was described that is able to compensate for distortion and unbalance generated by nonlinear loads or by nonlinearity in the inverter. SVPWM is much better in reducing harmonics and controlling the RMS magnitude of output voltage. It gives 15% enhanced fundamental output with better quality than SPWM.

REFERENCES

[1]   M Ozaki, Y. Adachi, Y. Iwahori, and N. Ishii, Application of fuzzy theory to writer recognition of Chinese characters, *International Journal of Modelling and Simulation, 18(2),* 1998, 112-116.
[2]   P.S Verma and G narayanan, "Space vector PWM as a modified form of sine triangle PWM for simple analog or digital implementation", *IEEE Journal of research*, Dec 2006.
[3]   H.W. Van der broeck, H.C. Skudelny and G.V Stanke, **"**Analysis and realization of a pulse width modulation based on voltage space vectors", *IEEE Trans. Industry application*, 1988.
[4]   D G Holmes and T A Lipo, "Pulse width modulation for poor convertors", principle and practice IEEE *PRESS,* 2003.
[5]   G.Narayanan and V .T.Ranganathan, "Traingular comparison approach and space vector approach to pulse width modulation in inverter fed drives", *journal to the indian institute of science*, sep/oct 2000.
[6]   H.Dheng, R.Oruganti and D. Shrinivasan, "Analysis and design of iterative learning control strategies for UPS inverter", *IEEE trans june 2007*.
[7]   Bunyamin Tamyurek, " A high performance SPWM controller for three phase UPS system operating under highly non linear load" in *IEEE transactions on power electronics, vol.28 no.8,* August 2013
[8]   Mettam K.Mounika ,B.Kiran Babu, "Sinusoidal and Space Vector Pulse Width Modulation For Inverter" in *International Journal of Engg and Technology(IJETT) vol.4. issue4-*April 2013.
[9]   M. J. Ryan, W. E. Brumsickle, and R. D. Lorenz, "Control topology options for single-phase UPS inverters," *IEEE Trans*. *Ind. Appl., vol. 33, no. 2*, pp. 493–501, Mar./Apr. 1997.
[10] Augistina Hernandez, Ruben Tapia, Member, IAENG, Omar Aguilar, and Abel Garcia, "Comparison of SVPWM and SPWM techniques for Back to Back Converters in PSCAD" in *World Congress on Engineering and Computer Science , Vol I*, October -2013.