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Indigenous Technique for Generation of Gate Pulse by Space Vector Pulse Width Modulation with Two Level Switching

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***Abstract*: This Paper explains gate pulse generation technique for IGBT switching to generate variable and constant flux three phase power signal with RPM variation of a squirrel cage asynchronous induction machine. To generate SVPWM, complicated mathematical calculations are used and it may take quite more time for execution of those equation in micro-controller. In many cases, if calculation time of micro-controller is comparably high w.r.t switching time, the entire operation got disturbed and cause fatal error in the inverter. This paper also elaborate the pulse generation technique from a pre-calculated lookup table.**

***Keywords*: Power converter, Two Level Switching, motor drives, vector control.**

I. INTRODUCTION

The trend of energy requirement is ever growing. Due to same, it is required to find an alternative solution rather than the conventional energy & purposefully the importance of renewable energy like solar, nuclear, wind etc. are gaining its importance day by day. Mainly in case of solar energy, DC power is to be converted in AC for distribution through grid and the necessity of power converter seeks a heavy demands.

In addition to the above, Flow and torque control are very essential in power and process industries. This may easily be achieved by controlling speed of prime mover as flow is directly proportional to RPM. In this context, VFD is the best tool for electric prime mover like asynchronous induction motor. Three phase power signal with required flux is generated from a d.c source with a proper switching technique called pulse width modulation. Several techniques were adopted earlier to control the RPM. In earlier scenario, voltage controlled rectifier and frequency controlled inverter were used to control flux where variable flux generation is quite difficult and synchronous control are required for voltage controlled rectifier and frequency controlled inverter. Among the several PWMs, space vector control is the best alternative for better RPM and torque control. In SVPWM, rectifier control may not be required. Voltage and frequency both may be controlled by controlling the switching of IGBT. A universal technique of SVPWM generation is elaborated below,

II. POINT VECTOR GENERATION

In Fig. 1, each phase leg has top and bottom switches. If top switch closes, phase voltage attains a positive voltage and if bottom switch closes, phase voltage attains a negative voltage (with respect to fictitious ground point of DC sources). In this calculation, ‘1’ is denoted as top switch is closed and ‘0’ is denoted as bottom switch is closed.

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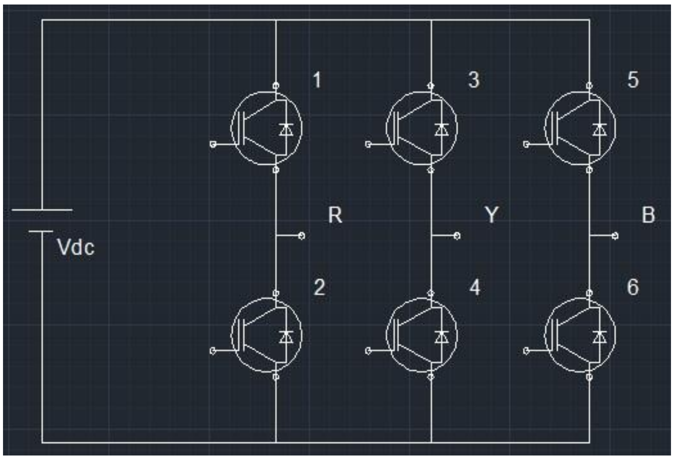

Fig. 1: Circuit diagram

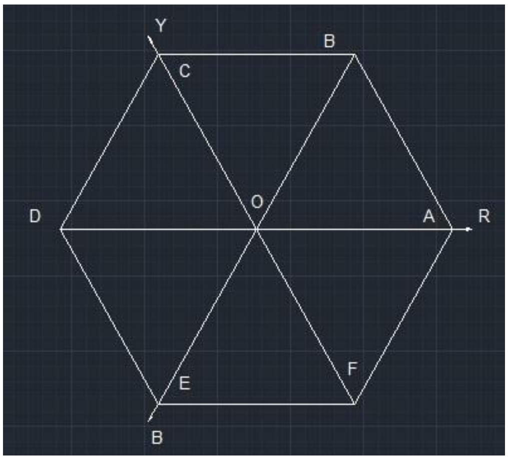

Fig. 2: Space vector distribution

Space vector distribution for the circuit in Fig. 1 are shown in Fig.2

In three phase system, summation of amplitudes of all the three phases at given time is zero. Hence, if switch (1, 3, 5) or (2, 4, 6) are ON at same time, system voltage attains zero voltage, these switching sequences are called redundant zero vectors. So, zero vectors are situated at point 'O' in Fig. 2, the vector notations are (0, 0, 0) and (1, 1, 1).

Point 'A' of Fig. 2 basically represent 'R' phase is positive and other two phases are negative, the equivalent vector for the same is (1, 0, 0). Similarly for point 'B', 'R'&'Y' are positive 'B' phase is negative which can be denoted as a vector (1,1,0). Likewise point C,D,E & F are represented as (0,1,0),(0,1,1),(0,0,1) & (1,0,1). So the vectors situated at the vertices of the hexagon of Fig. 2 are called the active vectors and the switching sequences are (2,3,6),(2,3,5),(2,4,5) & (1,4,5) respectively. The space vectors are symbolically denoted as (r,y,b) which implies $\vec{V} = r.e^{j.0} + y.e^{j.\frac{2\pi}{3}} + b.e^{j.\frac{4\pi}{3}}$. So, the vector at point D(0,1,1) is same as $\vec{V} = e^{j.\frac{2\pi}{3}} + e^{j.\frac{4\pi}{3}}$.

Now let us consider the switching of triangle OAB. Here zero vector is denoted as V1 (any one vector may be considered from the redundant zero vectors, in this case vector (0,0,0) is considered) and active vectors at pointy A&B are denoted as V2 & V3 which are nothing but (1,0,0) and (1,1,0) respectively.

III. REFERENCE VOLTAGE GENERATION

Reference voltage vector for the SVPWM generation is denoted by $\overrightarrow{Vref}$ is given by,

$$\overrightarrow{Vref} = \left|\overrightarrow{Vref}\right| e^{j\theta} \quad (1)$$

Where,

$\left|\overrightarrow{Vref}\right| = kf_r$

k = v/f ratio of the machine

v = rated voltage of the motor

f = rated frequency of the motor

f_r = running frequency of the machine

$\theta = 2\pi f_r nTs$

Ts= 1/fs = sampling time

fs = sampling frequency(switching frequency of IGBT/ MOSFET)

n is a counter [if Tr/6Ts is fraction, then n varies from 0 to m and if Tr/6Ts is integer, then n varies from 0 to (Tr/6Ts -1)]

m = round off figure of Tr/6Ts (if Tr/6Ts = 9.8 or 7.3 then the value of m will be 9 or 7)

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IV. VOLT-SEC BALANCE CALCULATION

$$\begin{pmatrix} \vec{V1} \\ \vec{V2} \\ \vec{V3} \end{pmatrix} = \begin{pmatrix} r1 & y1 & b1 \\ r2 & y2 & b2 \\ r3 & y3 & b3 \end{pmatrix} \begin{pmatrix} e^{j.0} \\ e^{j.2\pi/3} \\ e^{j.4\pi/3} \end{pmatrix}$$

$\equiv [V] = [RYB][\theta]$ (2)

So, [RYB] matrix for ΔOAB is given by,

$$\begin{pmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 1 & 0 \end{pmatrix}$$

Let us consider, T1, T2, T3 are the time duration for which $\vec{V1}$, $\vec{V2}$, $\vec{V3}$ are switched. Consider the following matrix equation,

$$Ts' \begin{pmatrix} 1 \\ Re(\overrightarrow{Vref}) \\ Im(\overrightarrow{Vref}) \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ Re(\vec{V1}) & Re(\vec{V2}) & Re(\vec{V3}) \\ Im(\vec{V1}) & Im(\vec{V2}) & Im(\vec{V3}) \end{pmatrix} \begin{pmatrix} T1 \\ T2 \\ T3 \end{pmatrix}$$

If Tr/6Ts is float,

Then, Ts' = (n+1)Ts – nTs where n varies from o to (m-1)

And Ts'= Tr/6Ts – nTs where n=m

If Tr/6Ts is integer,

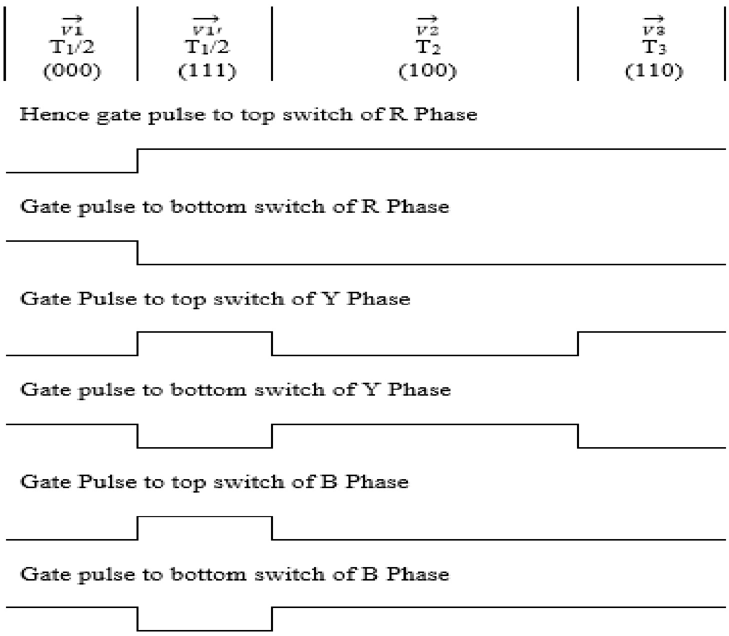
Then, Ts'=Ts for all n

The above matrix equation denoted as follows,

$[\overrightarrow{Vref}]=[V'][T]$

$[T]=[V']^{-1}[\overrightarrow{Vref}]$ (3)

V. SWITCHING PULSES TO IGBT



[T1 divided in equal two values as at the corresponding point, two redundant vectors exists.

$\overrightarrow{V1'}$ is the other redundant vector at point 'O'.]

The same calculations may be applied to next remaining five triangles to complete the cycle.

VI. OUTPUT VOLTAGE EQUATIONS

In this calculation, each phase leg voltage is measured with respect to DC negative terminal and the relations between line and phase voltage is given by,

Vd.c.(min) = 2Vref/√3; where Vref = $\left|\overrightarrow{Vref}\right|$

Vleg(peak to peak) = 2Vref/√3; VLine(peak) = VR-Leg – VY-Leg

VPhase(peak) = VLine(peak)/ √3;

Vref = 1.5 VPhase(peak); A typical output for 415V(rms), 50Hz machine simulated in MATLAB is given below:

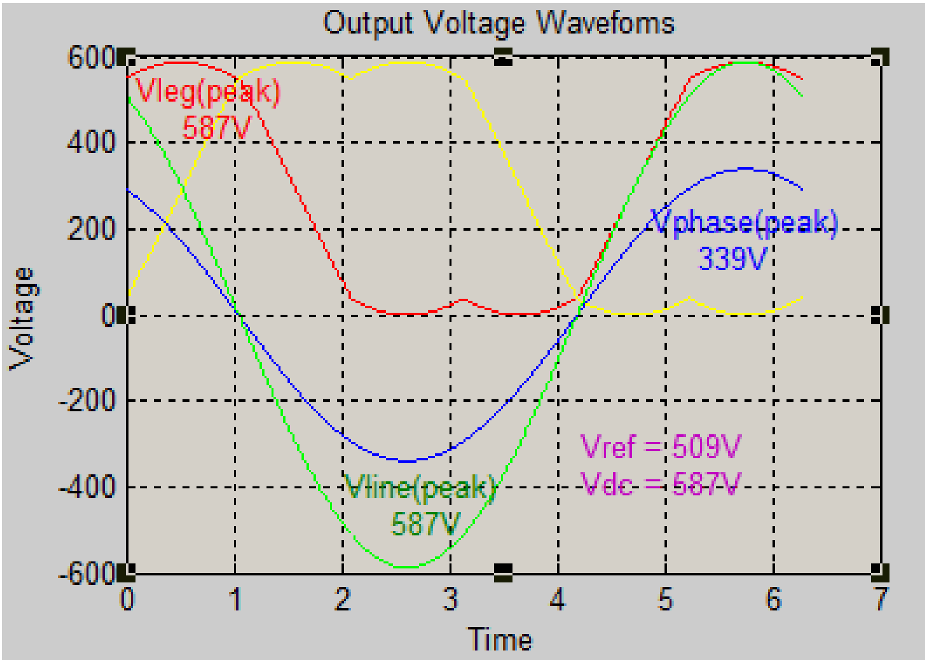


Fig. 3: Output Voltage Waveforms

VII. CONCLUSION

The above switching topology was successfully implemented in a 30kW variable frequency drive. A three level system is also developed using the same switching topology. The switching pulses generated using dsPIC microcontroller.

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