# Simulation for Single-Phase SVPWM Inverter fed Motor Speed Control

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***Abstract-In this paper the transient performance of single phase motor supplied by the single phase SVPWM voltage source inverter is studied emphatically. And then, voltage space vector of the single phase cascaded H-bridge inverter is analyzed and the SVPWM whose control algorithm is deduced. Moreover, a simulation model of variable frequency speed control system of single phase SVPWM inverter fed single phase motor is built by MATLAB/SIMULINK. Finally, by the simulation calculated to the actual case, the result is consistent with the theoretical analysis. Thus, it would be of a certain practical significance and reference value in the design of SVPWM inverter and speed control system of single-phase motor.***

***Keywords- Inverter; single-phase SVPWM control technique; single-phase motors; simulation.***

## I. INTRODUCTION

With the development of modern power electronic technology, the digitized Pulse Width Modulation (PWM) technology is constantly optimizing and renovating, which passed from the Sine Pulse Width Modulation (SPWM) to the widely used Space Vector Pulse Width Modulation (SVPWM) at present. The SVPWM is a special combination of the switch trigger order and the pulse width of the three-phase voltage source inverter power device. It is proved both by the theory and practice that SVPWM is an advanced and accurate calculated PWM method, compared with the SPWM method. As the best of the inverter's PWM methods, the SVPWM was known by its low low-order harmonic component of the output voltage, high utilization of the DC power, low switch loss and simple algorithm, which can be achieved easily by the digital control scheme. Owing to the superior performance, the SVPWM has been widely used in all kinds of three-phase inverter circuits. However, there is no practical application of the SVPWM technology in the ingle-phase inverter source. There isn't quite a few papers which refer to the SVPWM technology in the single - phase inverter source. Dehbonei [1] gave an algorithm of the single-phase inverter SVPWM, modeled after the three-phase SVPWM principle, and proved the correctness through the simulation. Pinheiro, Shao and Michels [2-4] did further research. They pointed out that the achievements in the 3-phase SVPWM technology could also used in single-phase SVPWM method, and reached a admirable control result. A simple way to estimate the filter parameters of the single-phase SVPWM voltage source. The single-phase SVPWM technology, nonetheless, is not now entered actual application, nor in the AC transmission system. In the rural areas, small industrial sectors and small power users like home users even the electric traction of the railway the single -phase power supply is applied. Consequently it is important for us to pay attention to the single-phase SVPWM technology.

The single-phase Smith induction motor [5] has small start torque, which is applicable to drive the loads like pumps, air compressors, freezers, fridges and fans, etc. The single-phase Smith induction motor is a high efficiency motor with distinct energy saving effect, specially compared with the single-phase induction motor. As there isn't any paper of the application of the single-phase SVPWM inverter in the three-winding single-phase capacitor motor, it is with practical significance to make a research of the SVPWM inverter-Smith single phase motor speed control system.

## ➢ ANALYSIS OF VOLTAGE SPACE VECTOR

Fig.1 shows the equivalent circuit of the single-phase whole-bridge inverter. L is the output filter inductance and C is the filter capacitance. In this circuit, it is assumed that the Voltage of the DC power Vdc is a constant, and the inverter's switch device is the ideal switch.

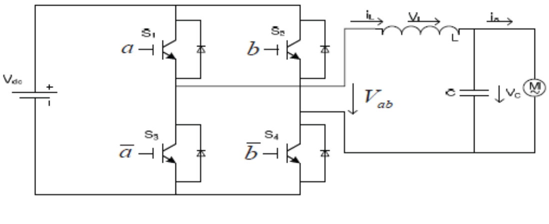


Figure 1.Circuit of the single-phase cascaded H-bridge inverter

It's possible to get the technological principle of the single-phase SVPWM technology which imitate the principle of the three-phase inverter SVPWM technology. It is easier to achieve the control of the single-phase SVPWM than the three-phase. In the three-phase modulation we should consider the interaction between the phases and transform, using the Park transformation, the interaction to the static $\alpha - \beta$ coordinate system. It is only need to analysis the technology in the static $\alpha - \beta$ coordinate system without special transformation. In the Fig.1 the inverter generates four types of the voltage vectors, as shown in table 1. In Fig.1 a , b is the switching variable, '0' represents off and '1' represents on.

TABLE 1. FOUR SWITCHING STATES

| S.no | a | b | $V_{ab}$ | Voltage vector |
|---|---|---|---|---|
| 1 | 0 | 0 | *0* | *V0* |
| 2 | 0 | 1 | $-V_{dc}$ | *V1* |
| 3 | 1 | 0 | $V_{dc}$ | *V2* |
| 4 | 1 | 1 | *0* | *V3* |

The Fig.1 can be expressed as the switching function:

$$\begin{bmatrix}V1\\V2\end{bmatrix}=V_{dc}\begin{bmatrix}1 & -1\\-1 & 1\end{bmatrix}\begin{bmatrix}a\\b\end{bmatrix}\text{----------------------------------- (1)}$$

From the four voltage vector we know the output voltages of the inverter corresponding toV0 and V3 are zero, which we record them as zero vector. V1 and V2 are recorded as non-zero vector. Although the composition of the sine wave is not affected by zero vector, it is possible to reduce the switching frequency of the switching devices, the corresponding switching loss and the harmonic wave component trough distributing zero vector properly. Fig.2 shows the space voltage vector of the whole bridge inverter. There is only 2 variable voltage space vector and 2 invariable voltage space vector.

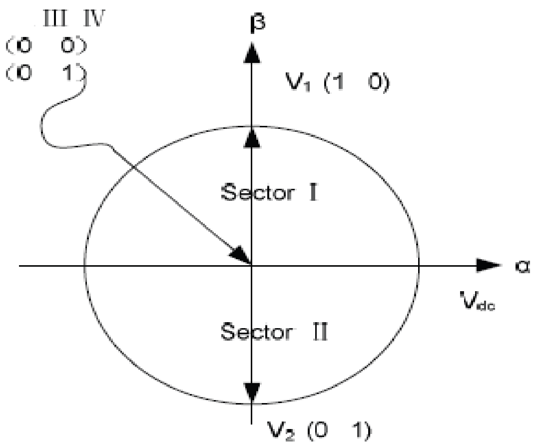


Figure 2.The space voltage vector of the H-bridge inverter.

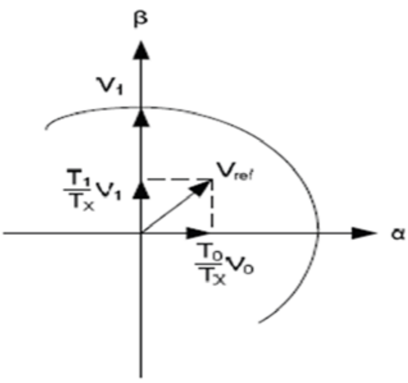


Figure 3. The Vref and space vector of part I.

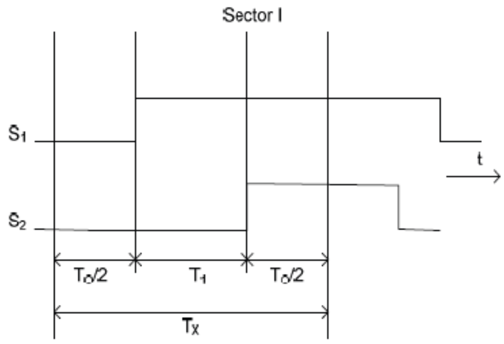


Figure 4. PWM modes of sector I

Obviously, the output states of the inverter are continuously toggled among V0 and V3 by the principle of the equal average voltage. It is accessible to obtain the equivalent sine wave voltage vector by way of controlling the action time of the voltage space vector of the inverter. The adjacent voltage space vectors merge at the average output voltage when they have similar switching cycle time, and get the Vref . as shown in Fig.3.

The output voltage $V_{ab}$ is from $(T_1/T_x)V_1$ added by $(T_0/T_x)V_0$.

Where $Tx= (1/2f_s)$ and $f_s$ is the switching frequency.

$$\int_0^{Tx} Vref\ dt = \int_0^{T1} V1\ dt + \int_0^{Tx} V0{,}3\ dt\text{-----------------}$$
(2)

The rest time $(T_x - T_1)$ is the duration of the zero voltage Vector (*V0 & V3*). The output voltage can be shown as Fig.4, when the reference voltage is the sector I.

- ALGORITHM OF THE SINGLE-PHASE SVPWM

The expected output voltage of the inverter is:

$$V_{ab} = U_m \sin \omega t\text{---------------------(3)}$$

It is known from the Fig.3 that it is impossible to merge equivalent sine wave voltage vector if $V_{ab} > V_{dc}$ , from which we can define the modulation M as:

$$M = \frac{Um}{Vdc} \qquad \text{-------------------- (4)}$$

It is supposed *Tx* is the PWM carrier cycle of the system,*T0* is the action time of the zero voltage vector. The algorithm of the single-phase SVPWM is obtained from the analysis above.

$$\left.\begin{aligned} Tx\,\overrightarrow{Vab} &= T1.Vx + T0.V(0{,}3) \\ Tx &= T1 + T0 \end{aligned}\right\}\text{-------------------------- (5)}$$

Where *Vab* is the expected output voltage vector and Vx is one of *V1* and *V2* , determined by Vab .When ωt belongs to sector I, *Vx* = *V2* :

$$\left.\begin{aligned} T1 &= M.Tx.\sin \omega t \\ T0 &= Tx - T1 \end{aligned}\right\} \text{-------------------------------- (6)}$$

$$\left.\begin{aligned} T1 &= M.Tx.\sin \omega t\text{-}\pi \\ T0 &= Tx - T1 \end{aligned}\right\} \text{--------------------------------}$$

(7)

Especially, kinds of optimized algorithm can be obtained for the single-phase SVPWM, by changing the timeallotment and the position distribution. This is familiar with the three phase SVPWM.

## II. SIMULATION

The fig 5 represents mathematical model SVPWM FOR SINGLE PHASE CASCADED H-BRIDGE INVERTER FED SINGLE PHASE INDUCTION MOTOR. In fig 5 SVPWM block represents pulse generation of two level algorithm. When the output of svpwm gives to h- Bridge and get two level output. The modulation index is taken as 0.8 and L C filter connected at bridge output .by using filter output we can control the single phase induction motor.

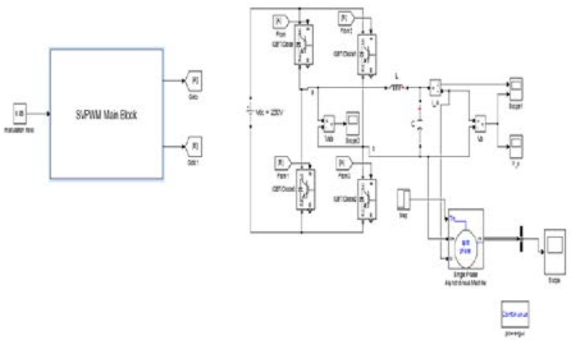


Fig 5 Simulation Overview

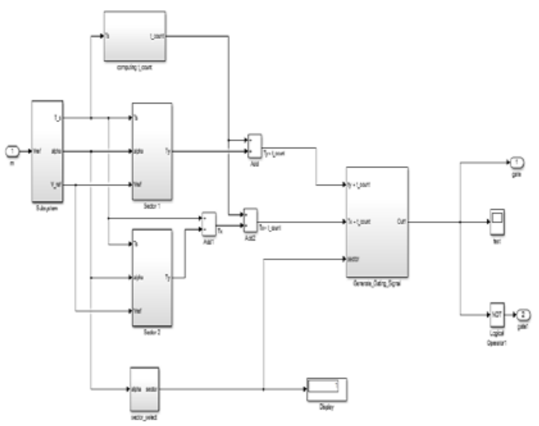

Fig 6 SVPWM Generation Block

fig. 6 represents SVPWM generation four switches full bridge inverter. According to Perks transformation analogy.

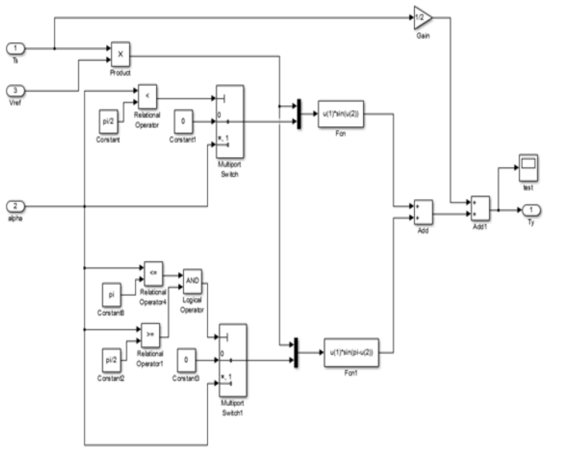

Fig 7 SVPWM sector I

From Fig.7 SVPWM Sector 1 shows that the process of input took from remain blocks and producing sector based logics are 00, 10, and 11 as following sequences producing a square pulse from svpwm block .finally it illustrates the generation of pulses from both combinations of active and non active vectors from sector 1.

## III. EXPERIMENTAL RESULTS

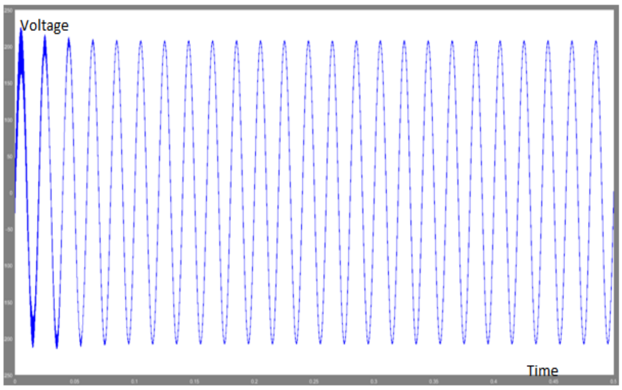


Fig 8 filtered output voltage

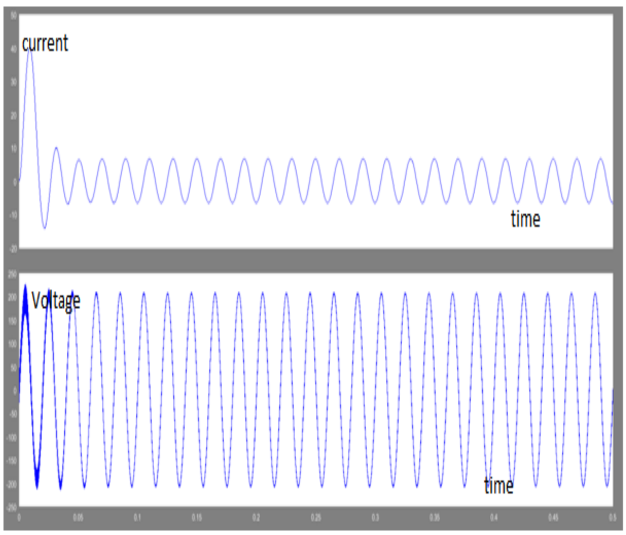


Fig 9 Output current and voltages

## IV. CONCLUSION

The speed control performance of the SVPWM for cascaded h-bridge inverter fed single-phase induction motor was obtained. The mathematical model of single-phase SVPWM control algorithm was obtained. The simulation model was created based on MATLAB / SIMULINK. According to the simulation computation the results match the theoretical analysis. A MATLAB/Simulink based model for implementation of SVPWM is presented. The step development is reported. The presented model gives an insight into SVPWM.

## V. FUTURE SCOPES

Further this can be enhanced by using IGBT instead of MOSFET for higher voltage power operations. The speed control of motor can also be achieved by V/F method.

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