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Modelling Of Three Phase Inverter for Voltages Using Switching Function

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ABSTRACT
In this paper, a model for voltage-source inverter (VSI) using switching function concept have been made and studied.For the purpose of modelling MATLAB software is being used. With the developed functional model, the simplification of the static power circuits can be achieved so that the convergence and long run-time problems can be solved

Keywords: *Functional model; transfer function; sinusoidal pulse width modulation; switching function; voltage source inverter*

I. INTRODUCTION

In an industrialized nation today, Power electronics has already found an important place in modern technology and has revolutionized control of power and energy. As the voltage and current ratings and switching characteristics of power semiconductor devices keep improving, the range of applications continues to expand in areas such as lamp controls, power supplies to motion control, factory automation, transportation, energy storage and electric power transmission and distribution.

The technological advances made in the field of power semiconductor devices over the last two decades, have led to the development of power semiconductor devices with high power ratings and very good switching performances. Some of the popular power semiconductor devices available in the market today include Power MOS Field Effect Transistors (Power MOSFETs), Insulated Gate Bipolar Transistors (IGBTs) and Gate Turn off Thyristors (GTOs)**.**Three-phase voltage source inverters are widely used in variable speed ac motor drives applications since they provide variable voltage and variable frequency output through pulse width modulation control. Continuous improvement in terms of cost and high switching frequency of power semiconductor devices and development of machine control algorithm leads to growing interest in more precise PWM techniques. The most widely used PWM method is the carrier-based sine-triangle PWM method due to simple implementation in both analog and digital realization. The improvements in semiconductor technology, which offer higher voltage and current ratings as well as better switching characteristics. On the other hand, the main advantages of modern power electronic converters, such as high efficiency, low weight, small dimensions, fast operation, and high power densities, are being achieved through the use of the so-called switch mode operation, in which power semiconductor devices are controlled in ON=OFF fashion.In this paper, a functional model for voltage-source inverter (VSI) using switching function concept is studied and the actual implementation of the model is proposed with the help of MATLAB Simulink.

II. GENERAL THEORY OF SWITCHING FUNCTION

The static power converters inverters can be modeled as a black box with the input and output ports. The dc and ac variables can be input and output according to the operation mode. Then, the transfer function is obtained to describe the task to be performed by the circuits. Especially, the transfer function can be used to compute a dependent variable in terms of its respective independent circuit variable. Also, in Pulse Width Modulation (PWM), the waveform to be modulated is considered the independent variable and the resulting modulated waveform is the dependent variable. For example, in case of VSI, the output voltage is dependent variable and it depends on the input voltage, which is independent variable. Therefore, the general transfer function can be defined as

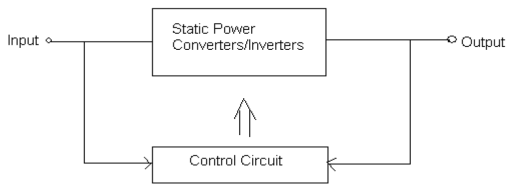

Fig. 1 Block diagram of static power conversion system

$$Transfer\ Function = \frac{Dependent\ Variable}{Independent\ Variable}$$

With the applied control strategy, each transfer function consists of the various particular switching functions. Using the switching function theory, the detailed relationship between the input and output variables can be obtained. Therefore, obtaining the proper switching function is very important in order to describe the role of the static power Con verters/inverters. The detailed theoretical explanation of the switching function is well addressed in the references.

III . PROPOSED FUNCTIONAL MODEL FOR THREE PHASE VOLTAGE SOURCE INVERTER

Fig. 2(a) shows the circuit configuration of VSI and also Fig. 2(b) designates the input and output variables to be considered in analyzing and designing the circuit. Based on the transfer function theory, in VSI, input current (Iin) and output voltage (vab, Vbc, Vca) are the dependent variables and input voltage (Vd) and output current (Ia, Ib, Ic) are the independent variables. Therefore, the relationship between the input and output variables can be expressed as

[Vab, Vbc, Vca] = TF .Vd

Iin = TF $[Ia, Ib, Ic]^T$

Where TF is the transfer function of VSI. Generally, the transfer function is consisted of the several switching functions as

TF = [SF1, SF2, SF3 ...]

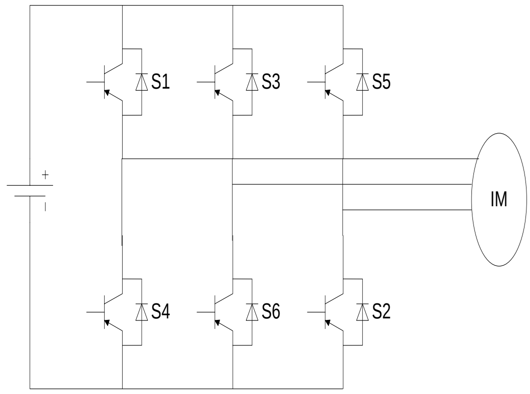

Fig. 2 . Circuit Configuration of VSI.

SINUSOIDAL PULSE WIDTH MODULATION

In SPWM, the gating signals are generated by comparing a sinusoidal reference signal of frequency fr with a triangular carrier wave of frequency fc. By comparison of the common carrier signal with three reference sinusoidal signals Va, Vb, Vc, the logical signals, which define the switching instants of the power transistor are generated.

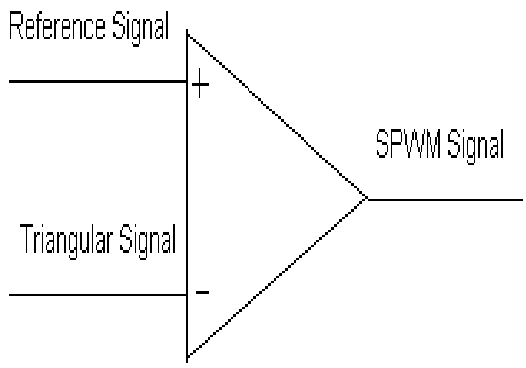

Fig 3.Comparison of reference and triangular signal

- When Vr < Vc = Output is low
- When Vr > Vc = Output is high

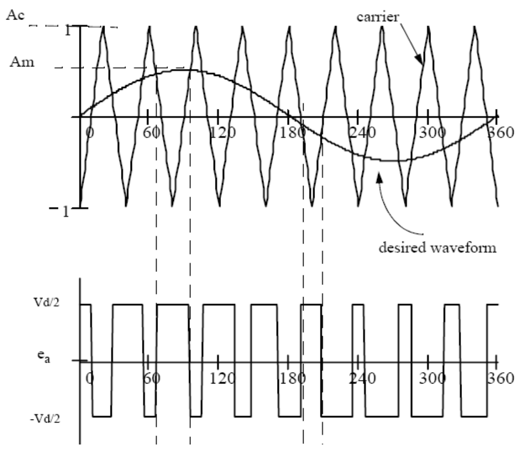

Fig 4 Principal of Pulse Width Modulation

The over modulation region occurs above M>1 and a PWM converter, which is treated like a power amplifier, operates in the nonlinear part of the characteristic. The number of pulses per half cycle depends on carrier frequency.Sinusoidal pulse width modulation or SPWM is the most common method in industrial applications i.e. motor control and inverter application.

IV. GENERAL SWITCHING FUNCTION CONCEPT

Let us consider the single phase voltage source inverter for explanation of general switching function concept. The same concept is then applied to three phase voltage source inverter. The only difference between single and three phase inverter is the modes of operation of inverter.The output of the converter depends on the switching pattern of converter switches and input voltage or current.Based on the transfer function theory, output quantities of converter are expressed as input quantities.

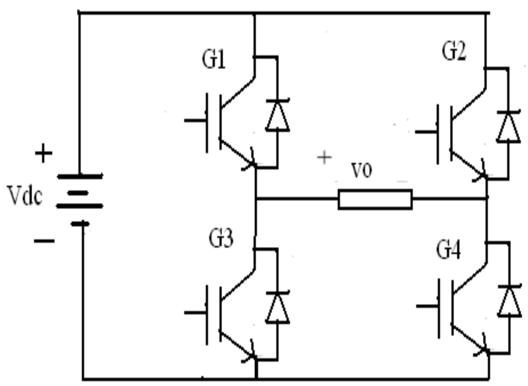

Fig 5 Single phase voltage source inverter

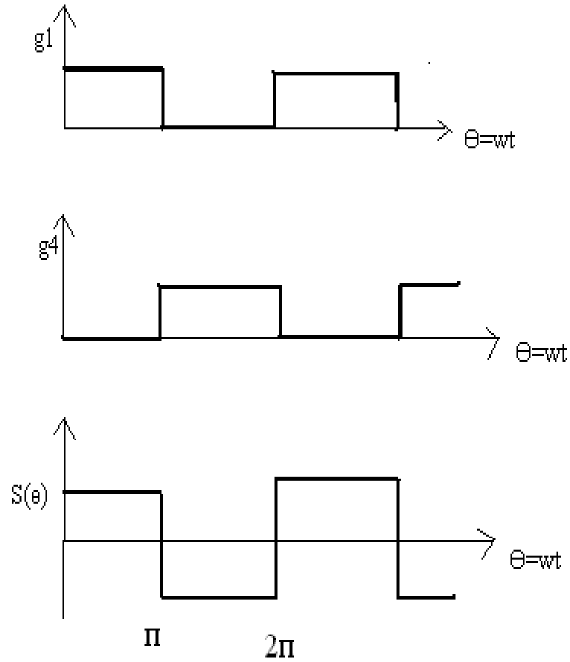

Fig 6 Switching function

Therefore the switching function is given by

$S(\theta) = g1 - g4$

$= 1$ for $0 \le \theta \le \pi$

$= -1$ for $\pi \le \theta \le 2\pi$

And output voltage is related to input voltage by

$V0(\theta) = S(\theta)\, Vdc(\theta)$

$S(\theta)$ depends on the type of converter and gating pattern of the switches.

V. ANALYSIS METHOD

Based on the switching functions SF1and SF2 a functional model for VSI is built by using MATLAB Simulink. Fig. 4 shows the proposed overall functional model for calculating the design parameters of VSI. As shown in Fig. 4, it consists of four functional blocks: SPWM generator, switching function block, load block, and pure switch and diode current generating block. In the SPWM block, the carrier signal (Vtri) is compared with three different control signals (Vcont-a, Vcont-b, Vcont-c) and it inputs to the switching function block to generate inverter line to line voltages and phase voltages.

Block Diagram is as follows

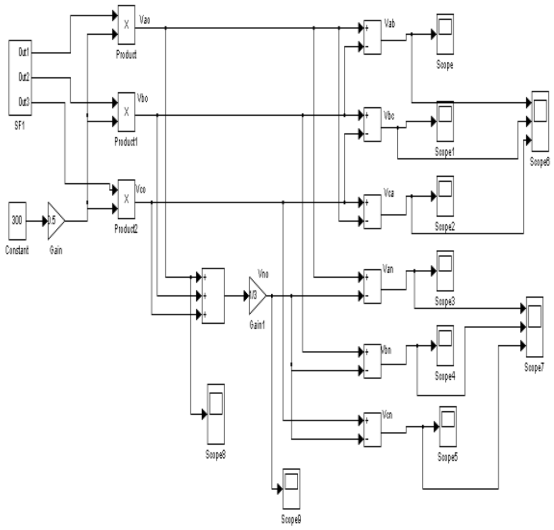

Fig.7 Block Diagram

Each phase has two switching functions such as SF1_a, SF2_a, SF1_b, SF2_b, SF1_c, and SF2_c. Using the switching function SF1_abc, the Vao, Vbo, and Vco can be obtained as

$$Vao = \frac{Vd}{2} SF1\_a = \frac{Vd}{2} \sum_{n=1}^{\infty} An\ Sin(n\omega t)$$

$$Vbo = \frac{Vd}{2} SF1\_b = \frac{Vd}{2} \sum_{n=1}^{\infty} An\ Sinn(\omega t - 120)$$

$$Vco = \frac{Vd}{2} SF1\_c = \frac{Vd}{2} \sum_{n=1}^{\infty} An\ Sinn(\omega t + 120)$$

Then, the inverter line-to-line voltages (Vab, Vbc, Vca) can be derived as

$$Vab = Vao - Vbo = \frac{\sqrt{3}}{2} Vd \sum_{n=1}^{\infty} An\ Sinn(\omega t + 30)$$

$$Vbc = Vbo - Vco = \frac{\sqrt{3}}{2} Vd \sum_{n=1}^{\infty} An\ Sinn(\omega t - 90)$$

$$Vca = Vco - Vao = \frac{\sqrt{3}}{2} Vd \sum_{n=1}^{\infty} An\ Sinn(\omega t + 150)$$

Also, the inverter phase voltages (Van, Vbn, Vcn) And Vno is calculated as

Vno= 1/3(Vao +Vbo + Vco)

And the phase voltages as

Van =Vao –Vno

Vbn =Vbo –Vno

Vcn =Vco –Vno

VI. SIMULATION RESULT AND DISCUSSION

The simulation parameters are as follows; input voltage Vd=300V, R=5Ω, L=20mH, carrier signal frequency=l kHz, control signal frequency (fc) =50Hz, modulation index Ma=0.8. Fig. 5, from the SPWM control strategy, the switching functions SFl and SF2 are obtained. Then, the inverter line-to-line voltage (Vab) and phase voltage (Van) can be successfully derived by the action of switching function block

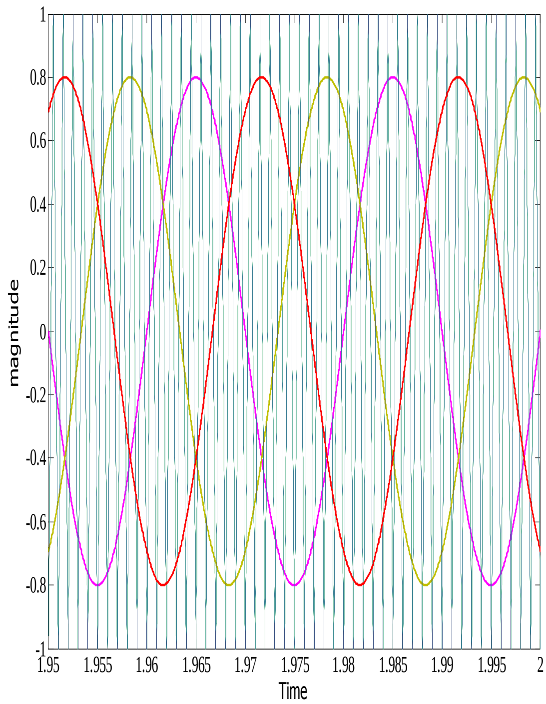

Fig.8 **Result of Sinusoidal PWM Signal**

It shows the result for SPWM Signal for all three phases. Here amplitude of sinusoidal signal is 0.8 and for carrier signal it is 1 thus making the modulation index equal to 0.8.

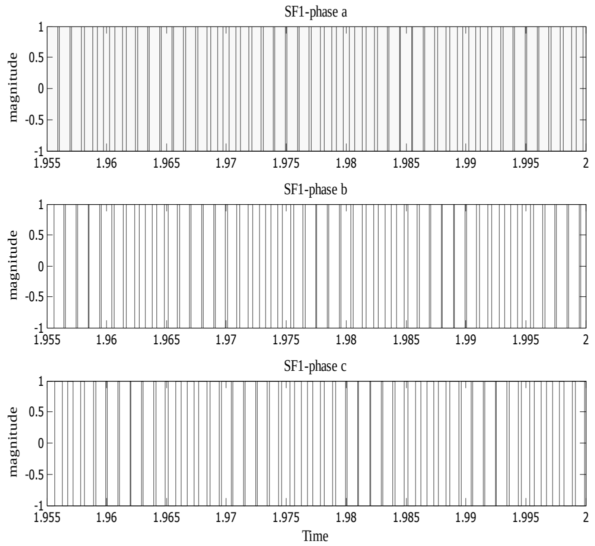

Fig.9 **Result of Switching Function 1**

Switching Function 1 shown in Figure 4.6 is the bipolar type of Switching Function as it is having both positive and negative pulses. Applying Fourier transformation to the pulses of Switching Function 1

We get,

SF1 = $\sum_{n=1}^{\infty} An\ Sin(n\omega t)$

This equation is the Fourier transformation of the pulses obtained from Switching function SF1.

In this there is no 'a0' because both positive and negative pulses are present and are equal so the average value of the function is zero i.e. dc component is absent.

Switching function SF1 is then used to expresses the Vao, Vbo and Vco.

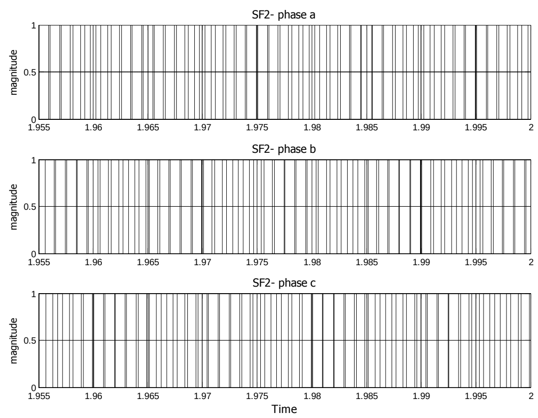

Fig10 **Result of Switching Function 2**

Switching Function 2 shown in Figure 4.8 is the unipolar type of Switching Function as it is having only positive pulses. Applying Fourier transformation to the pulses of Switching Function 2

We get, SF2 = B0 + $\sum_{n=1}^{\infty} Bn\ Sin(n\omega t)$

In this there is 'B0' because it is having only positive pulse so the average value of the function i.e. dc component is present. It also used to calculate switch current.

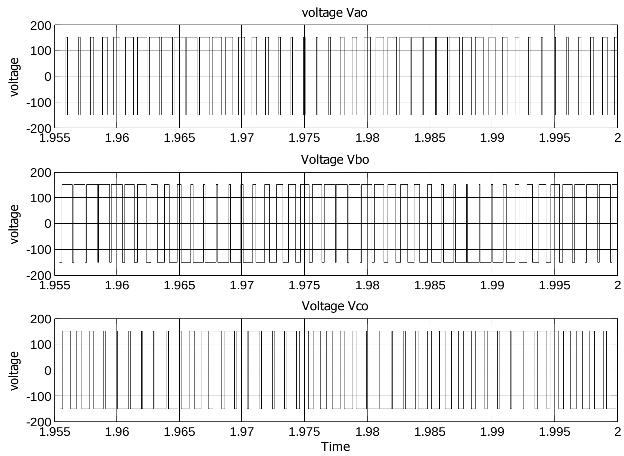

Fig.11 **Voltages Vao, Vbo, Vco**

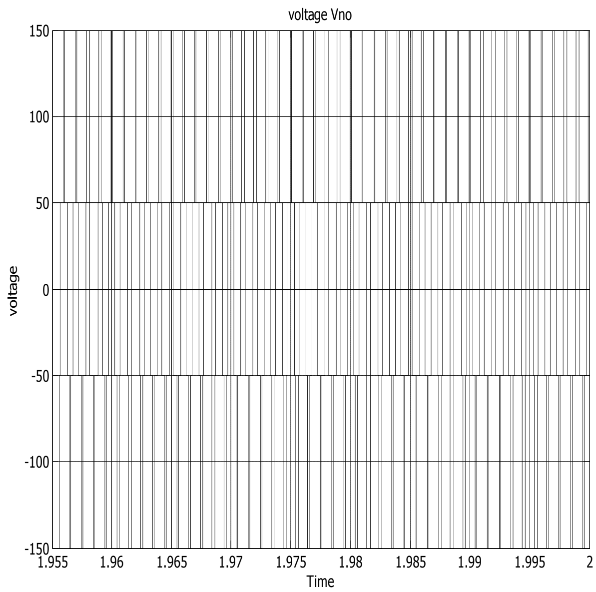

Fig. 12 **Voltage Vno**

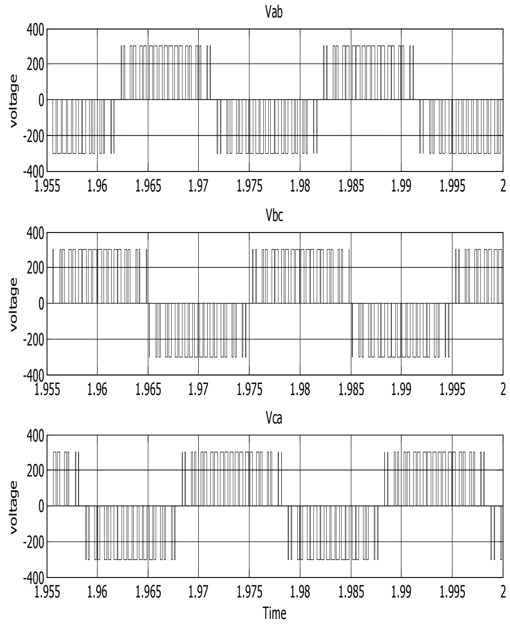

Fig 13 **Line Voltages Vab, Vbc, Vca**

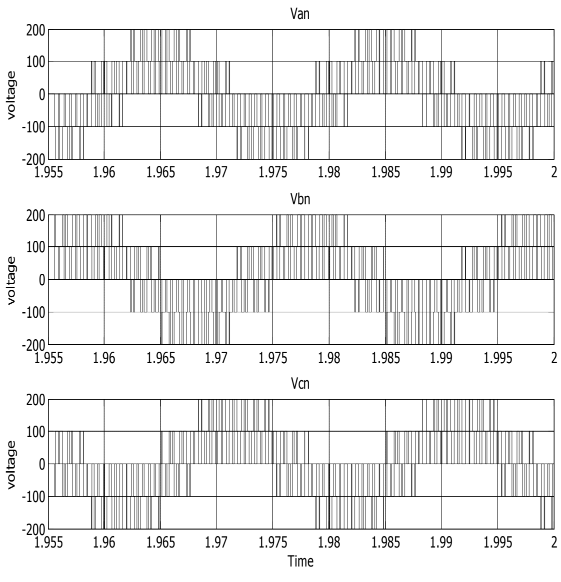

Fig. 14 **Phase Voltages Van, Vbn, Vcn**

VII. CONCLUSION

In this paper, the switching functions are studied & obtained and the implementation using MATLAB Simulink are explained in detail and are used to get line and phase voltages. . Furthermore, the control strategy to be applied to VSI can be easily designed and examined under the developed functional model.

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