Research Paper Engineering

Simulation of Line and Phase Voltages of Inverter Using Switching Function Concept

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ABSTRACT

In this paper, a functional model for voltage-source inverter (VSI) using switching function concept is studied. Proper converter design requires that maximum current and voltage ratings are known so that components with adequate safety margins can be selected. The switching functions are obtained using MATLAB simulink and are used to get line and phase voltages. The general switching function concept is reviewed in brief and the implementation using MATLAB Simulink are explained in detail.

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, multi megawatt industrial drives, 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). As a result of these rapid advancements in power semiconductor technology, substantial amount of research is being devoted to the area of static power converters. The input and output currents and voltages of static power converters are generally associated with harmful low-order harmonics.

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.

Application areas of power converters still expand thanks to 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 (no operation in the active region).

In this paper, the switching functions are obtained using sinusoidal PWM method and are used to get line and phase voltages of voltage source inverter.

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

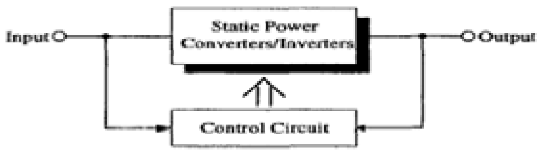


Fig. 1 Block diagram of static power conversion system

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

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 Converters/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

[Vbc, Vca Vab,] = 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 ...]

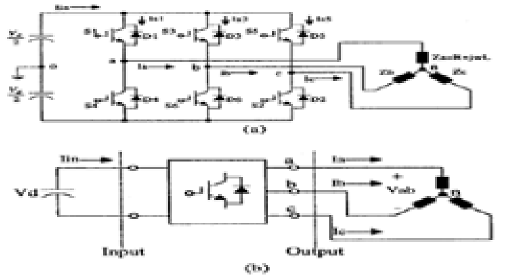
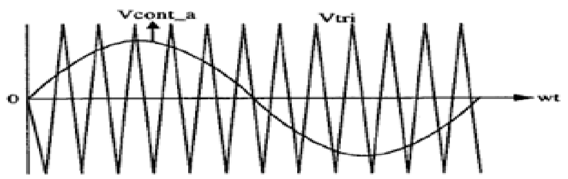
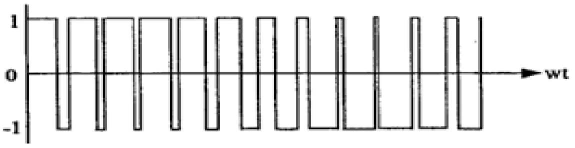


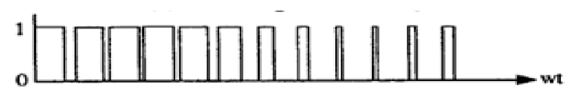
Fig. 2 a) Circuit Configuration of VSI. b) Input and output variables of VSI



(a) Carrier (Vtri) and control (cout_a) Signals



(b) Switching function SF1



(c) Switching function SF2
Fig. 3 SPWM control strategy and switching function

In order to define the switching functions, a control strategy to be applied should be selected. In this paper, the Sinusoidal Pulse Width Modulation (SPWM) technique as shown in Fig. 3(a) is considered as a control strategy. Based on the SPWM, Figs. 3(b) and (c) express the two switching functions (SFI, SF2). The switching function SF1 expresses the Vao, Vbo, and Vca and it is used to calculate the inverter line-to-line voltages (Vab,Vbc,Vca) and phase voltages (Van, Vbn, Vcn). On the other hand, the switching function SF2 designates the voltage across the switch and the load currents (Ia, Ib,Ic)are derived as ratios of voltages and respective impedances using the switching function SF2. Mathematical representation SFl and SF2 are given

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

$$SF2 = B_0 + \sum_{n=1}^{\infty} Bn\ Sin(n\omega t)$$

IV. 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.

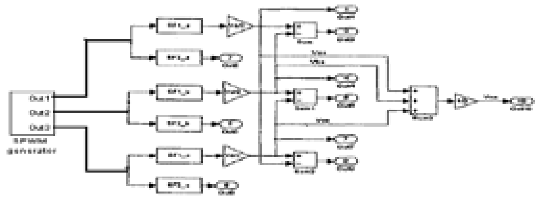


Fig 4. Proposed model for calculating the inverter line-to-line voltages and phase voltages.

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)

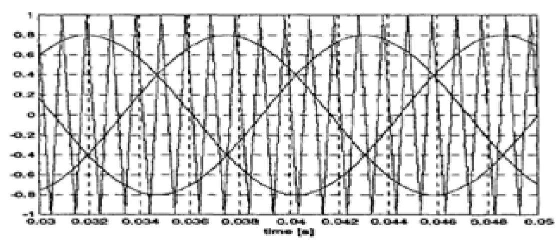
And the phase voltages as
Van =Vao –Vno

Vbn =Vbo –Vno

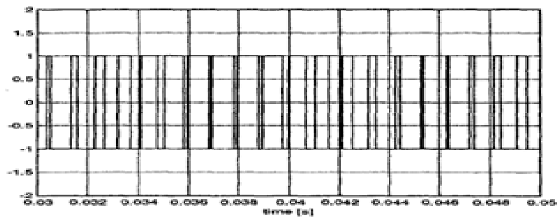
Vcn =Vco –Vno

IV. 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.

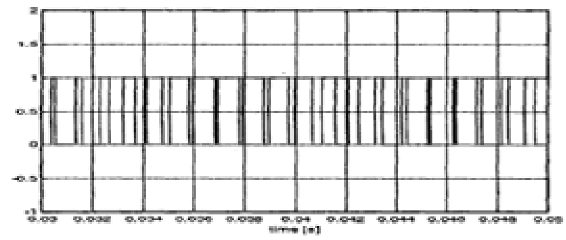
Fig. 5, from the SPWM control strategy, the switching functions SFl and SF2 are obtained. Then, the inverter line-to-line voltage (Vab) and phase voltage (Van) can be successfully derived by the action of switching function block



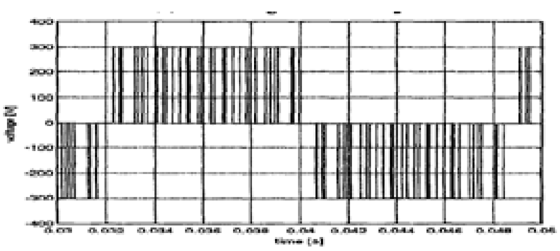
a) Carrier signal and control signal in SPWM.



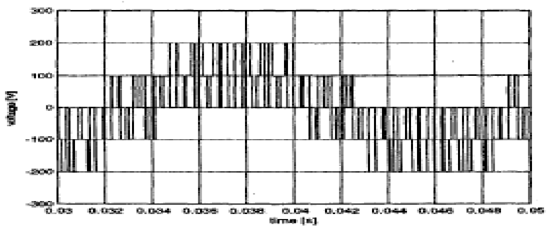
b) Switching function SF1



c) Switching function SF2



d) Inverter line-to-line voltage (Vab)



e) Inverter phase voltage (Van)

Fig. 5. Simulation voltage waveforms of VSI with SPWM Strategy

(Vd=300V, fs=lkHz, fc=50Hz, Ma=0.8**)**

Conclusion

In this paper, a functional model for voltage-source inverter (VSI) using switching function concept is studied. The switching functions are obtained using MATLAB simulink and are used to get line and phase voltages. The general switching function concept is reviewed in brief and the implementation using MATLAB Simulink are explained in detail**.**

REFERENCES

[1] Shingare,D., (2009).Satara Industrial and power electronics, (4th ed.), Electrotech publication,. [2] Mohan,N.,Undeland,T.,Robbins,W.(2006), Power electronics converters, applications and design (3rd Edition), John wiley and sons. [3] Lee,B.K.,& Ehsani,M.., (1999).A simplified functional model for 3-phase voltage source inverter using switching function concept", IEEE,pp462-467. [4] Wiechmann,E.,p., Ziogas,P.,D.,& Stefanovic,V.,R., (1985)Generalized functional model for three phase PWM inverter rectifier converters", in Proc. IEEE IAS'85 pp. 984-993. [5] Wood,P., (1981)Theory of switching power converter, New York. Van Nostrand-Reinhold, [6]. alazar,L., G. joos,(1994Jan.) PSPICE simulation of three-phase inverters by means of switching functions", IEEE Trans, Power Electron., 9(1), 35-42 [7]. Ziogas,P.,D.. Wiechmann, E,. P.&,. Stefanovic, V., R.,(1985Sep/Oct) A computer-aided analysis and design approach for static voltage source inverter", IEEE Trans. Ind. Applicat., vol., 21(5) 1234-1241 [8] EnjetiP.,N.,& Ziogas,P.,D.,(1990 Feb). Analysis of a static power converter under unbalance: A novel approach", IEEE Trans. Ind. Electron., 37(1), 91-93.