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Some Aspects on 3-Phase Bridge Inverter (180 Degree Mode)

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ABSTRACT: This paper presents the Simulink model for 3 phase inverter in 180 degree mode. The three-phase square wave inverter can be used to generate balanced three-phase ac voltages of desired (fundamental) frequency. Moreover, harmonic voltages of 5th, 7th and other non-triplet odd multiples of fundamental frequency distort the output voltage. In many cases such distortions in output voltages may not be tolerable and it may also not be practical to use filter circuits to filter out the harmonic voltages in a satisfactory manner. The main objective of this paper is to overcome these problems by using a square wave PWM inverter with 6 thyristors.

KEYWORDS: Simulink, Thyristor, Pulse Width Modulation

I. CONCEPT AND MOTIVATION:

Simulink is a block diagram environment for multidomain simulation and model based design. It supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modelling and simulating dynamic systems. It is integrated with MATLAB enabling us to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis. Multilevel inverters have gained more attention in high power applications because it has got many advantages . It can realize high voltage and high power output by using semiconductor switches without the use of transformer and dynamic voltage balance circuits. [1,3,5,6].

In this paper we highlight the Simulink program in MATLAB for 3 phase bridge inverter for 180 degree mode. Frequency and output voltage can be changed using slider gains block. For providing adjustable-frequency power to industrial applications, three-phase inverters are more common than single-phase inverters. Three-phase inverters, like single-phase inverters, take their dc supply from a battery or more usually from a rectifier. A basic three-phase inverter is a six-step bridge inverter. It uses a minimum of six thyristors. In inverter terminology, a step is defined as a change in the firing from one thyristor to the next thyristor in proper sequence. For one cycle of 360 degrees, each step would be 60 degrees interval for a six-step inverter. This means that thyristors would be gated at regular intervals of 60 degrees in proper sequence so that a 3-phase ac voltage is synthesized at the output terminals of a six-step inverter, [3, 5, 8, 9]. All this has motivated our objective of research.

II. FUNDAMENTAL THEORY:

A 3-phase bridge type VSI with square wave pole voltages has been considered. The output from this inverter is to be fed to a 3-phase balanced load. This circuit may be identified as three single-phase half-bridge inverter circuits put across the same dc bus. The individual pole voltages of the 3-phase bridge circuit are identical to the square pole voltages output by single-phase half bridge or full bridge circuits. The three pole voltages of the 3-phase square wave inverter are shifted in time by one third of the output time period. These pole voltages along with some other relevant waveforms have been plotted. The horizontal axis of the waveforms has been represented in terms of 'ωt', where 'ω' is the angular frequency (in radians per second) of the fundamental component of square pole voltage and 't' stands for time in second. In the figure the phase sequence of the pole voltages is taken as V_{AN}, V_{BN} and V_{CN}.

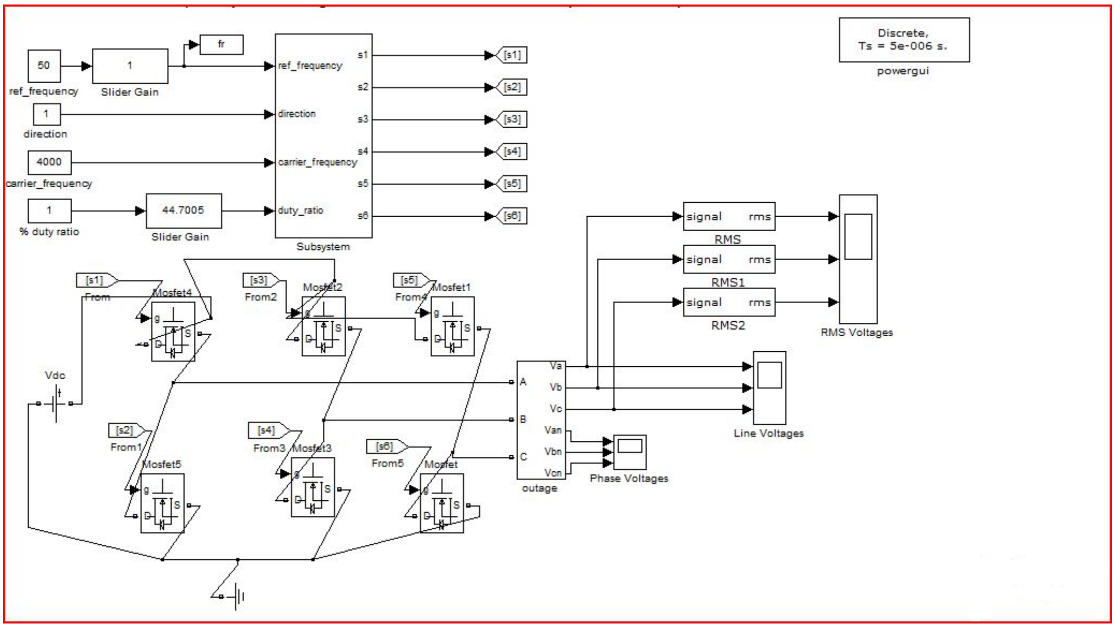
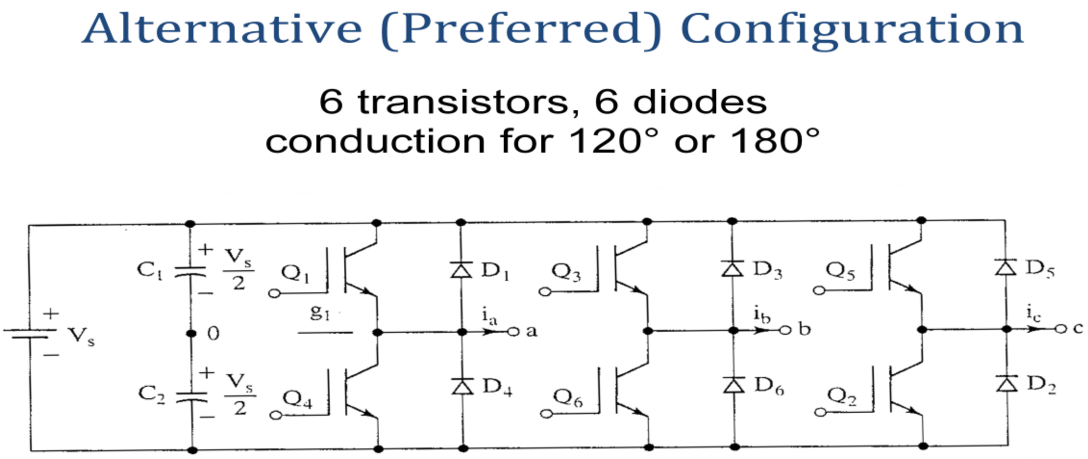


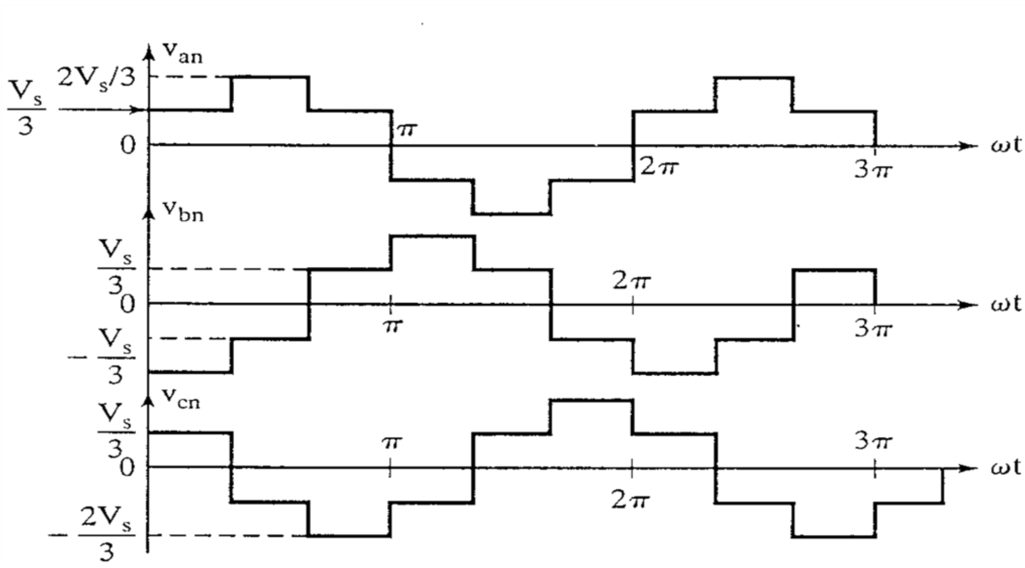
Fig 1 Simulink Model

To appreciate the particular manner in which the switches have been numbered, the conduction-pattern of the switches marked in the figure may be noted. It may be seen that with the chosen numbering the switches turn on in the sequence:- S1, S2, S3, S4, S5, S6, S1, S2, ….and so on. Identifying the switching cycle time as 360 degrees (2π radians), it can be seen that each switch conducts for 180^0 and the turning on of the adjacent switch is staggered by 60 degrees. The upper and lower switches of each pole (leg) of the inverter conduct in a complementary manner. To reverse the output phase sequence, the switching sequence may simply be reversed. Considering the symmetry in the switch conduction pattern, it may be found that at any time three switches conduct. It could be two from the upper group of switches, which are connected to positive dc bus, and one from lower group or vice-versa (i.e., one from upper group and two from lower group). According to the conduction pattern indicated in the figure there are six combinations of conducting switches during an output cycle:- (S5, S6, S1), (S6, S1, S2), (S1, S2, S3), (S2, S3, S4), (S3, S4, S5), (S4, S5, S6). Each of these combinations of switches conducts for 60^0 in the sequence mentioned above to produce output phase sequence of A, B, C. As will be shown later the fundamental component of the three output line-voltages will be balanced. The load side phase voltage waveforms turn out to be somewhat different from the pole voltage waveforms. [6, 7, 8].

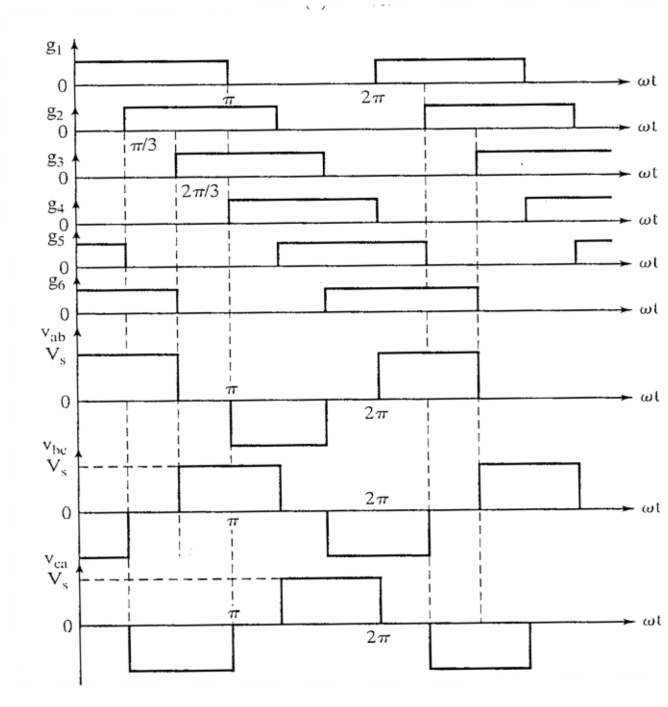
III. CIRCUIT DIAGRAM & WAVEFORMS:



Phase Voltages for 180° Conduction



Waveforms for 180° Conduction



IV. DERIVATION AND CONCLUSION:

The three-phase square wave inverter as described above can be used to generate balanced three-phase ac voltages of desired (fundamental) frequency. However harmonic voltages of 5th, 7th and other non-triplet odd multiples of fundamental frequency distort the output voltage. In many cases such distortions in output voltages may not be tolerable and it may also not be practical to use filter circuits to filter out the harmonic voltages in a satisfactory manner. In such situations the inverter discussed here will not be a suitable choice. Fortunately there are some other kinds of inverters, namely pulse width modulated (PWM) inverters, which can provide higher quality of output voltage.

The square wave inverter may still be used for many loads, notably ac motor type loads. The motor loads are inductive in nature with the inherent quality to suppress the harmonic currents in the motor. The example of a purely inductive load discussed in the previous section illustrates the effectiveness of inductive loads in blocking higher order harmonic currents. In spite of the inherent low-pass filtering property of the motor load, the load current may still contain some harmonics. These harmonic currents cause extra iron and copper losses in the motor. They also produce unwanted torque pulsations. Fortunately the torque pulsations due to harmonic currents are of high frequencies and their effect gets subdued due to the large mechanical inertia of the drive system. The motor speed hardly changes in response to these torque pulsations. However in some cases torque pulsations of particular frequencies may cause unwanted resonance in the mechanical system of the drive. A special notch filter may then be required to remove these frequencies from the inverter output voltage.

The input dc voltage to the inverter is often derived from an ac source after rectification and filtering. A simple diode bridge rectifier followed by a filter capacitor is often the most cost-effective method to get dc voltage from ac supply. In some applications, like in un-interrupted power supplies, the dc input may be coming from a bank of batteries. In both these examples, the input dc magnitude is fairly constant. With fixed input dc voltage the square-wave inverter can output only fixed magnitude of load voltage. This does not suit the requirement in many cases where the load requires a variable voltage variable frequency (VVVF) supply. In order that ac output voltage magnitude is controllable, the inverter input voltage will need to be varied using an additional dc-to-dc converter. However a better solution will be to use a PWM inverter, which can provide a VVVF output with enhanced output voltage quality.

In spite of the limitations, discussed above, the square wave inverter may be a preferred choice on account of its simplicity and low cost. The switch control circuit is very simple and the switching frequency is significantly lower than in PWM inverters. This results in low switching losses. The switch cost may also be lower as one may do away with slower switching devices and slightly lower rated switches. Another advantage over PWM inverter is its ability to output higher magnitude of fundamental voltage than the maximum that can be output from a PWM inverter (under the given dc supply condition). Listed below are two applications where a 3-phase square wave inverter could be used.

(i) A low cost solid-state frequency changer circuit: This circuit converts the 3-phase ac (input) voltages of one frequency to 3-phase ac (output) voltages of the desired frequency. The input ac is first converted into dc and then converted back to ac of new frequency. The square wave inverter may be used for dc to ac conversion. Such a circuit may, for example, convert 3-phase ac voltages of 50 Hz to 3-phase ac voltages of 60 Hz. The input to this circuit could as well have come from a single-phase supply, in which case the single-phase ac is first converted into dc and then converted back to 3-phase ac of the desired frequency.

(ii) An uninterrupted power supply circuit: Uninterrupted power supply circuits are used to provide uninterrupted power to some critical load. Here a critical load requiring 3-phase ac supply of fixed magnitude and frequency has been considered. In case ac mains supply fails, the 3-phase load may be electronically switched, within few milliseconds, to the output of the 3-phase square wave inverter. Input dc supply of the inverter often comes from a battery bank.

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