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Simulative Analysis of Power Conversion System for Hybrid Electric Vehicles Based on Dual Input Sources Including Charging from Solar Panel

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Abstract- **Renewable energy sources are highly recommended in hybrid electric vehicles (HEV) applications. The power converters play an important role in hybrid electric vehicle system. The design of control system for such converters is discussed in the paper. The design of both DC-DC dual input converter and 3 phase VSC is done using MATLAB simulation. The design of SVPWM technique is presented for three phase VSC and PI control is for DC-DC converter. By the integration of this system a 3 phase induction motor will be operated, which in turn can be utilized for running of shaft of any vehicle. The dual input converter feed by two sources one is PV system and other is battery which is being charged by the PV system**

Index Terms-- **HEV, PID, RES, SVPWM**

I. INTRODUCTION

Due to the disadvantages of fossil fuel such as emission of CO2 and global warming the demand of renewable energy sources have been increased now a days [1], [2], [3]. Because of its environment friendly the RES can be used in more interesting field of HEV applications. These Types of converters can be used in in automotive applications, residential purposes, aerospace and when multiple sources of energy required for any application [4]. The multiple input converter's applications for hybrid electric vehicle are presented in [5-7].

Recently the three phase voltage source inverters (VSIs) are mostly used for the variable speed drives and supplying variable voltage and variable frequency through controlling of any PWM technique [8]. The purpose of modulation technique is to gain the maximum fundamental frequency component with varying output and mitigate the other harmonics. After an advent of microprocessor the SVPWM become one of the most precious PWM technique [9, 10,]. The magnitude of the peak fundamental frequency of the SVPWM based 3 phase inverter which is approximately about 90.6% increase in maximum voltage by comparing it with conventional PWM techniques [11]. It is more sophisticated PWM technique for the generation of sine wave with higher voltage to motor and with lower harmonics distortion [12-16].

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II. INTEGRATION OF TWO BUCK CONVERTERS

The circuit diagram of integrated dual input DC-DC buck-boost converter consisting of two input voltage sources with one input having higher voltage than other input source as shown in figure below [14]. The source of energy can be of any form whether its battery, ultra capacitor, etc. When the MOSFETS are off then diodes D1 and D2 will be turned on and current through inductor can easily flow. Since the flow of power from sources depends only on operation of MOSFETS. If MOSFET 1 is on then power flows from source 1, also converter will step down the voltage and behaves as a buck converter and power flows from source 2 when MOSFET 2 will be turned on and converter operates in buck-boost. In [11] the different modes of operation of this converter are discussed.

$$V_o = \frac{d_1}{1-d_2} * V_1 + \frac{d_2}{1-d_2} * V_2 \quad (1)$$

The circuit diagram of this converter is depicted in Fig. 1. By using the two buck converter concept this new topology can be obtained. The two input sources can be used simultaneously in Mode.

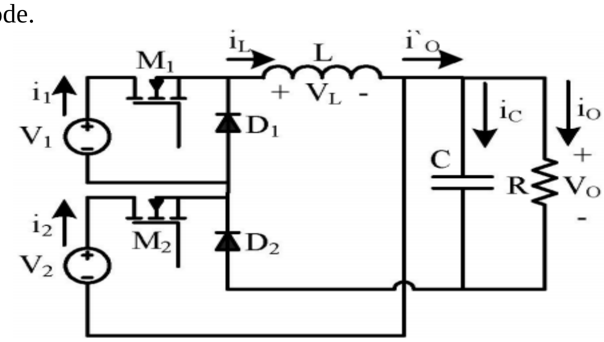

FIGURE 1: Integration of two buck-boost converters [13]

Four different modes of operation based on the status of the switches are explained below.

Mode I: In this mode the MOSFET M1 is on and MOSFET M2 is off. When MOSFET1 is conducting then, diode D1 will be reverse biased while Diode D2 will bypass the inductor current. In this mode only one source V1 will feed to inductor and load.

Mode II: In this mode the MOSFET M1 is off and MOSFET M2 is on. In this pattern the diode D1 is forward biased but diode D2 is reversed biased. In this mode only one source V2 will feed to the inductor and load.

Mode III: The both MOSFETs M1 and M2 will be off in type of mode of operation. Then both diode D1 and D2 will be in conducting state to which will bridge the current through inductor. The converter in this state is now out of both supply sources. The magnetic energy stored in is now dissipate into the load.

Mode IV: The MOSSFETs M1 and M2 are on and both diodes D1 and D2 will be reversed biased and both sources of energy V1 and V2 will be in series which will energize the inductor and supply to the load.

The working of this converter is simple when each source of energy operates individually, then its working will be same as like conventional buck converter.

III. INTEGRATION OF TWO BUCK-BOOST CONVERTER

The above integrated buck-buck converter topology will save one inductor will feeding two input sources of energy. This converter has circuit diagram as show in Fig. 2. This converter will operate in 3 modes instead of 4 modes as in buck-buck converter. Both MOSFET M1 and MOSFET M2 cannot be turned on simultaneously.

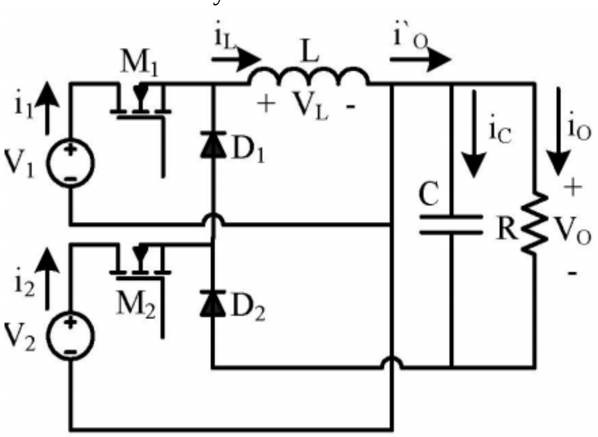

FIGURE 2: Integration of two buck-boost converters [14]

The other modes are:

Mode I: MOSFET M1 is on and MOSFET M2 is off in this mode of operation. Diodes D1 and D2 will be reversed biased therefor source V1 supplies to inductor.

Mode II: When MSOFET M1 if off and M2 is on. The diode D1 conducts only and V2 supplies to inductor.

Mode III: When both MSOFETS are off then diodes D1 and D2 will be conducting and both sources of energies will be cut out. Only stored energy in inductor will supply to the load.

IV. DESIGN OF SVPWM TECHNIQUE FOR THREE PHASE VOLTAGE SOURCE INVERTER

In the modulation technique the three phase quantities are converted into stationary frame or synchronously rotating frame. The magnitude of reference vector can calculated from two phase components [11, 12]. Let three phase sinusoidal components be:

$$V_a = V_m \sin wt \qquad (2)$$

$$V_b = V_m \sin\left(wt - \frac{2\pi}{3}\right) \qquad (3)$$

$$V_c = V_m \sin\left(wt - \frac{4\pi}{3}\right) \qquad (4)$$

The formula for interchanging the switching vector [a b c] and the line-to-line voltage vector [Vab Vbc Vca] is given by.

$$K_s = \frac{2}{3}\begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{-\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \qquad (5)$$

Also the formulae for calculating switching variable vector [a b c] from the phase voltage vector [Van Vbn Vcn] is:

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \frac{V_{dc}}{3}\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \qquad (6)$$

There are 8 switching combinations of on and off conditions for upper switches of each phase leg of three phase VSI. While for lower switches the pattern is just opposite as that of upper switches so they can be easily calculated if for upper switches is calculated as shown in Tab. 1.

Vectors Of Voltage.	Switching Vectors			Phase Voltage			Line Voltage		
	A	B	C	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
V_{-0}	*Low*	*Low*	*Low*	0	0	0	0	0	0
V_{-1}	*High*	*Low*	*Low*	0.66	-0.33	-0.33	1	0	−1
V_{-2}	*Low*	*High*	*Low*	0.33	0.33	-0.66	0	1	−1
V_{-3}	*Low*	*High*	*Low*	-0.33	0.66	-0.33	−1	1	0
V_{-4}	*Low*	*High*	*High*	-0.66	0.33	0.33	−1	1	1
V_{-5}	*Low*	*High*	*High*	-0.33	0.33	0.66	0	−1	1
V_{-6}	*Low*	*Low*	*High*	0.33	-0.66	0.33	1	−1	0
V_{-7}	*High*	*Low*	*High*	0	0	0	0	0	0

Table No.01 Switching_Vectors, Phase voltage and line_voltages.

DESIGN AND IMPLEMENTATION OF SVPWM

With the help of following steps SVPWM inverter can be design and implemented:

1. Calculate the V_d, V_q, V_{ref} and alpha angle.
2. Calculate duration of time T_1, T_2 and T_o.
3. Calculation of the switching time (T_z) of different switches.

Step-1: Calculation of V_d, V_q, V_{ref} and angle (α)

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3} \cdot \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \qquad (7)$$

$$\therefore \left| \overline{V}_{ref} \right| = \sqrt{\left(V_d^2 + V_q^2\right)} \qquad (8)$$

Step-2

$$\Rightarrow T_Z . \left|\overline{V}_{ref}\right| * \begin{bmatrix} \cos(\alpha). \\ \sin(\alpha). \end{bmatrix} = T_1 * \frac{2.}{3.} * V_{dc} \begin{bmatrix} 1. \\ 0. \end{bmatrix} + T_2 * \frac{2.}{3.} * V_{dc} \begin{bmatrix} \cos\left(\frac{\pi}{3}\right). \\ \sin\left(\frac{\pi}{3}\right). \end{bmatrix} \qquad (9)$$

$$\therefore T_1 = T_z . a . \frac{\sin\left(\frac{\pi}{3} - \alpha\right)}{\sin\left(\frac{\pi}{3}\right)} \quad (where, 0 \leq \alpha \leq 60^0) \qquad (10)$$

$$\therefore T_2 = T_z . a . \frac{\sin\left(\frac{\pi}{3}\right)}{\sin\left(\frac{\pi}{3}\right)} \qquad (11)$$

$$\therefore T_0 = T_z - (T_1 + T_2) \left(where, T_z = \frac{1}{f_z} \; and \; a = \frac{\left|\overline{V}_{ref}\right|}{\frac{2}{3} . V_{dc}} \right) \qquad (12)$$

Step-3: Switching time of each switch from 1 to 6.

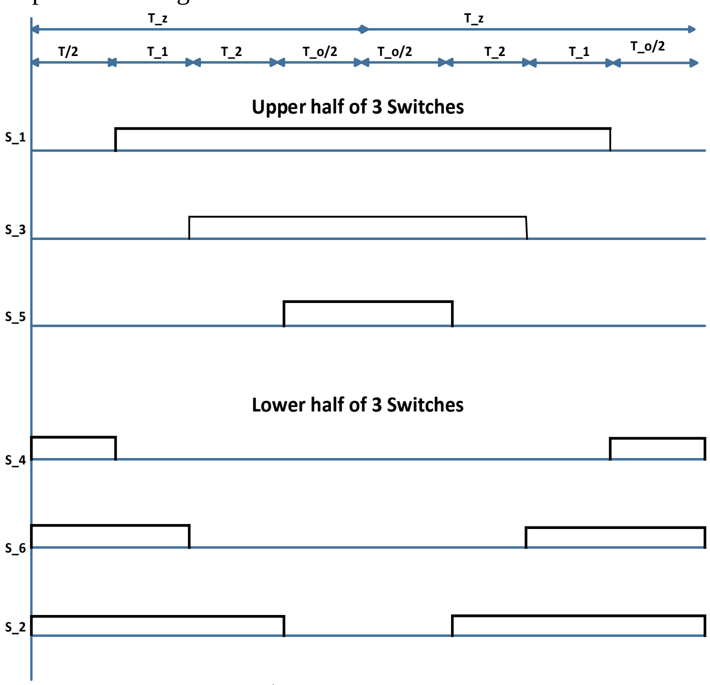

FIGURE 3: Sector 1st switching sequence and time [14]

Sector 01: All switches operation in First sector: In this sector the upper half of 3 switches operates as: The switch S1 is closed while switch S3 and S5 will remain opened. But lower half of 3 switches will operates as complementary to each switch in their respective phase leg as in Fig. 3.

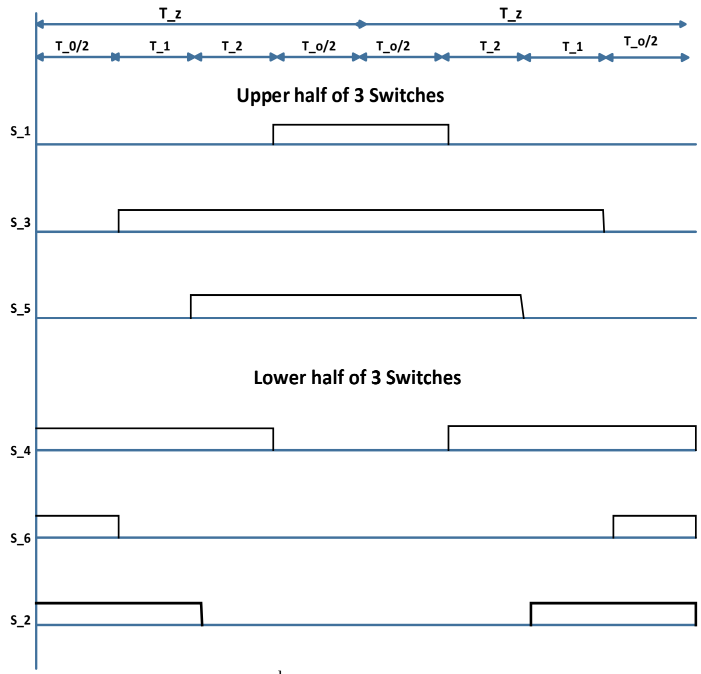

FIGURE 4: Sector 2nd switching sequence and time [14].

Sector 02: Operation of all switches in second sector: In this sector the upper half of 3 switches operates as: switch S3 is closed while switch S1 and S5 will remain opened. But lower half of 3 switches will operates as complementary to each switch in their respective phase leg as in Fig. 4.

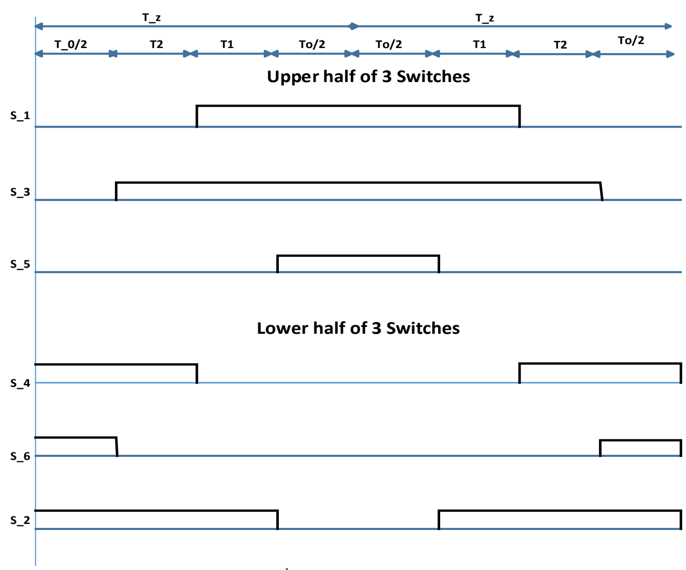

FIGURE 5: Sector 3rd switching sequence and time [14].

Sector 03: Operation of all switches in third sector: In this sector the upper half of 3 switches operates as: switch S1 and S3 will be closed while switch S5 will remain opened. But lower half of 3 switches will operates as complementary to each switch in their respective phase leg as in Fig. 5.

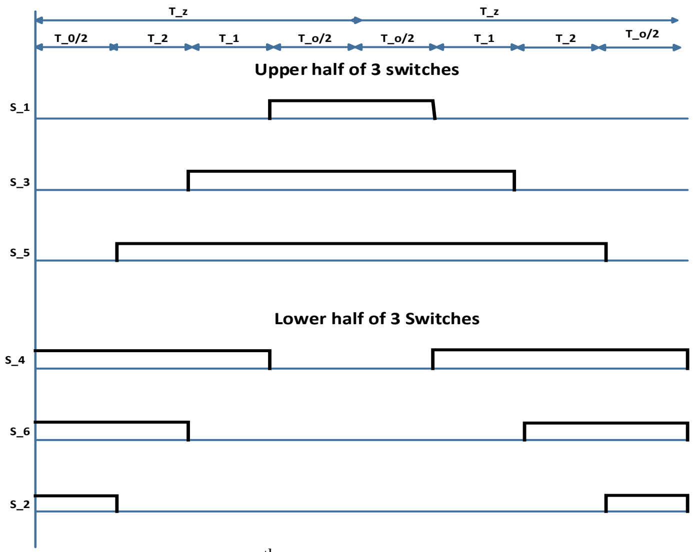

FIGURE 6: Sector 4th switching sequence and time [14]

Sector 04: Operation of all switches in fourth sector: In this sector the upper half of 3 switches operates as: The switch S5 is closed while switch S1 and S3 will remain opened. But lower half of 3 switches will operates as complementary to each switch in their respective phase leg as in Fig. 6.

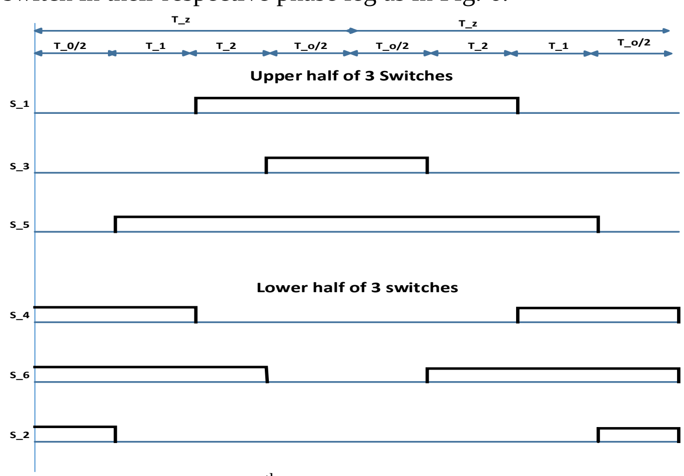

FIGURE 7: Sector 5th switching sequence and time [14].

Sector 05: Operation of all switches in fifth sector: In this sector the upper half of 3 switches operates as: The switch S1 and S5 will remain closed while switch S3 will remain opened. But lower half of 3 switches will operates as complementary to each switch in their respective phase leg as in Fig. 7.

Sector 06: Operation of all switches in sixth sector: In this sector the upper half of 3 switches operates as: The switch S1 is opened while switch S3 and S5 will remain closed. But lower half of 3 switches will operates as complementary to each switch in their respective phase leg as in Fig. 8.

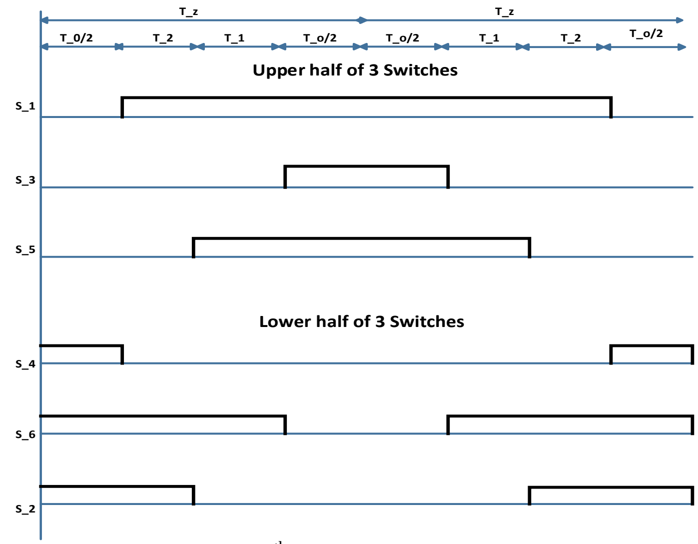

FIGURE 8: Sector 6th switching sequence and time [14]

V. RESULTS AND DISCUSSION

The flow of whole system is explained here by this statement and also shown in Fig. 9. The DC-DC converter takes power from two different input sources of energy and regulate out voltage at desired output voltage. Again this out is feed to a three phase voltage source inverter (VSI) which will supply it to the three phase induction motor to drive any application.

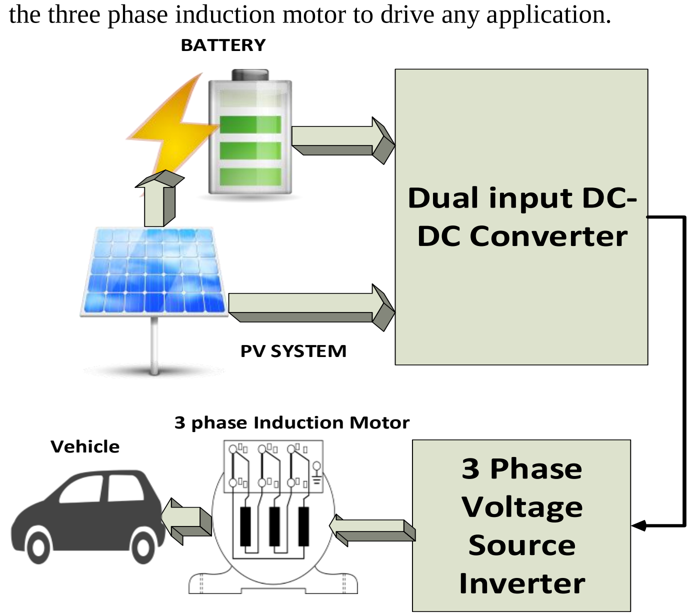

FIGURE 9: Circuit of whole system operating 3 phase Induction Motor

The design of SVPWM for 3 phase (Ø) is shown in Fig. 10:

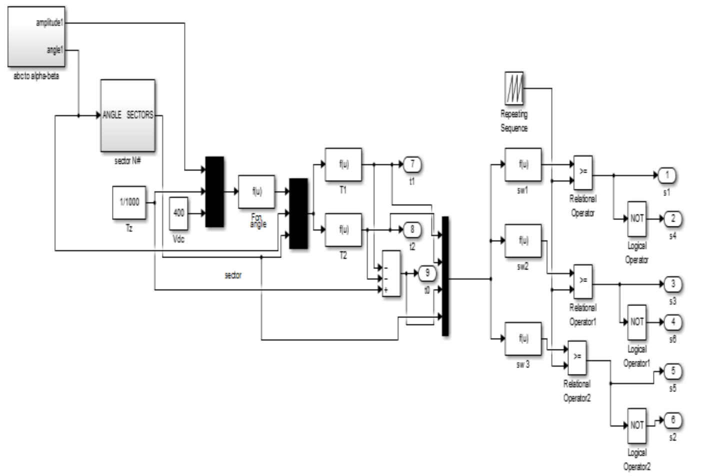

FIGURE 10: Step 01: conversion from three phase into two phase sing MATLAB Simulink

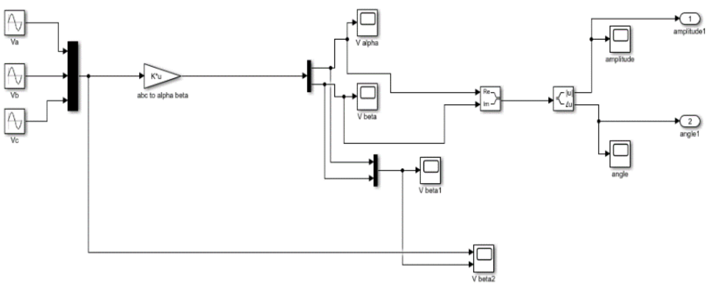

FIGURE 11: Step02: Design of a Sector using MATLAB Simulink

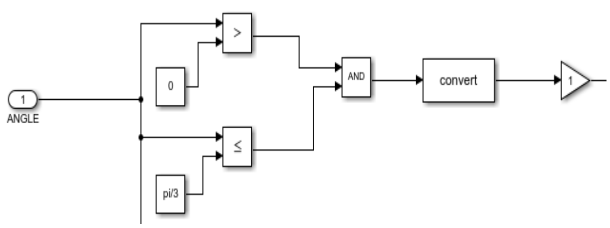

FIGURE 12: Step 03: Implantation of time equations in MATLAB Simulink

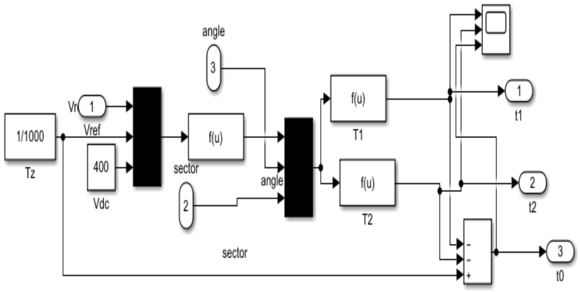

FIGURE 13: Step 04 Switches operation in different sectors

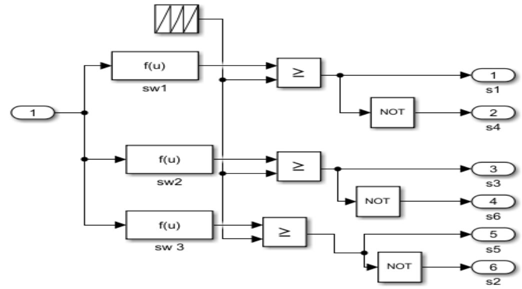

FIGURE 14: Output voltage waveform of 3 phase (∅) VSI

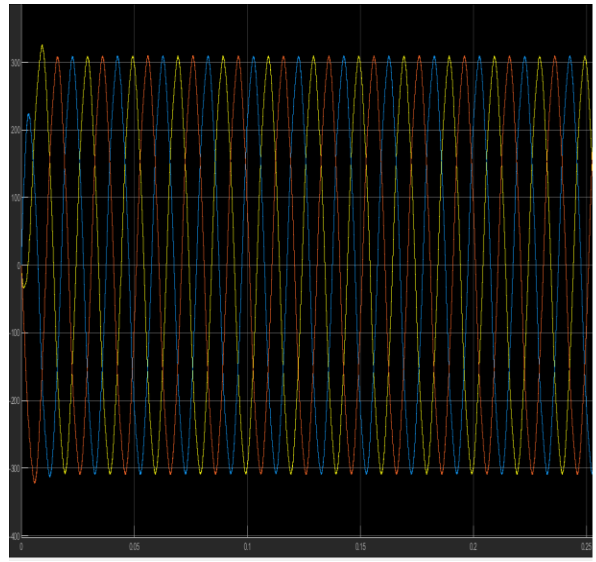

FIGURE 15: Output Voltage waveform of 3 phase (∅) VSI

VII. CONCLUSION

The voltage source inverter (VSI) is designed using SVPWM techniques. The result is tested through supplying a load of three phase induction motor which can used in any applications of automotive vehicle. The design of SVPWM is done step by step. While Dual input DC-DC converter is designed using voltage mode control technique with the help PID controller. The two DC sources can integrated to supply vehicle can be accessed easily on an automotive vehicle like solar, wind or fuel cell etc. they can supply both DC motor as well as AC motor drive the shaft easily

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