Photo Voltaic Powered Voltage Source Inverter for Single Phase Induction motor with MPPT Algorithm

A.Nandha kumar, R.Senthilkumar, T.Alex Stanley Raja, K.V.Santhoshkumar

Abstract –With fast decaying of fossil fuels and increased demand of electrical energy, the utilization of renewable energy sources have been increased in large extent during the recent years. Among various renewable energy sources solar energy plays a vital role, because it is used assolar powered street lights, solar water heater,and solar cooker and to derive induction motor using inverter circuit. Due to this reason, this paper is proposed to develop a model which consists of 1 ϕ induction motor driven by multi stages of power conversion circuit. The first stage is DC – DC boost converter where the duty cycle is controlled by Maximum power point tracking algorithm. The second stage is voltage source inverter, with open loop sub synchronous speed control method to achieve high performance during various operating speeds. A pulsewidth modulation strategy is developed to supply the pulses to the switches in the inverter so that the output voltage can be controlled based on the V/F method. The speed torque performance characteristics of the 1ϕ induction motor based on the developed control method is determined by using MATLAB simulation and also hardware results are obtained using PIC microcontroller.

Keywords: Pulse Width Modulation, Perturb and Observe Algorithm, maximum solar power point tracking algorithm

I. INTRODUCTION

In domestic and industrial areas single phase induction motors are widely used because of its simple in construction. The parts of single phase induction motor are auxiliary winding and main winding. Since single phase induction motors are not self-starting a capacitor and mechanically operated type centrifugal switch is connected in series with the auxiliary winding. Due to this the current flowing through the starting winding is leading at an angle of α with respect to main winding (usually the value of α = 90^o) [1]. Many speed control methods are available for the single phase induction motor. Among that the simplest methods are (a) stator voltage control and (b) variable voltage variable frequency control In the stator voltage control method the voltage applied to the stator is varied in steps in order to control the speed of the motor.

But due to the cost of auxiliary voltage changing equipment this method is rarely used in practice [2].

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The second method of speed control is VVVF method, in this type, since the speed of the ***1ϕ*** induction motor is directly proportional to frequency [3].

The speed of the motor can be controlled by varying both the supply frequency and voltage. In order to obtain VVVF supply on DC source fed with voltage source inverter is connected to the single phase induction motor. The switches in the inverter are controlled by suitable PWM technique [4] – [6]. Based on the turn on and turn off sequence of the switches the speed of the motor can be controlled. The constant DC source is provided by the solar panel. However the output voltage of the solar panel is not enough to drive the two legs of VSI coupled to the induction motor load hence an DC-DC boost converter is used which increases the supply voltage and it is controlled by maximum power point tracking algorithm. Among various power point tracking algorithm the simplest and easiest method is perturb and observe algorithm [7] – [10]. Thus the paper proposes a VSI fed single phase induction motor along with PV powered DC source with boost converter controlled by MPPT algorithm [8]. The first section of this paper covers the operation of ***1ϕ*** induction motor with VSI and DC – DC converter. The second section covers the MPPT control algorithm used for DC – DC boost converter and in the third section the PWM technique used for VSI are briefed using relevant diagrams. Finally the hardware result and software result were analyzed.

II. SOLAR PV SYSTEM FOR *1 Φ* INDUCTION MOTOR

The figure 1 shows a single phase induction motor coupled to two leg VSI where the speed control is done using conventional method. i.e. the variable speed of operation is obtained by constant DC source with MPPT algorithm. The speed torque characteristics of the single phase induction motors can be improved by using sinusoidal pulse width modulation.

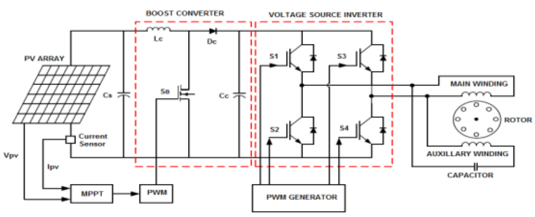

Fig.1 Solar PV System for Single Phase Induction Motor

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In the stage 1 the solar panel supplies dc voltage and it is fed to the DC-DC boost converter after filtering it through a L-C filter. The low voltage DC output of solar panel is increased to a constant DC voltage using boost converter. The DC-DC boost converter consists of switch S_s along with diode and output capacitor filter. The switch S_s is turned on and off based on the switching pulse provided through the MPPT algorithm. In order to provide variable voltage variable frequency supply to the induction motor, the constant DC source voltage from the boost converter is connected to a two leg operated single phase VSI.

A. *Solar Power Point Tracking Method*

Usually the amount of power required by the load depends mainly on the operating voltage of the PV panel. Generally the change in the solar irradiation and atmospheric temperature affects the output voltage of the solar panel which in turn reduces the maximum power point. The speed of operation of induction motor is very poor during the reduced MPP. To find the maximum point of operation an MPPT algorithm was used. i.e. Perturb and observable algorithm . Many methods to develop to find the MPP such as a) the transmission lines are incremental conductance b) Fuzzy logic c) PSO d) and other algorithm [11] – [13].

This paper implements perturb and observe algorithm because of its simplicity in algorithm and high reliable tracking algorithm. The fig.2 showsVI characteristics of solar array at constant irradiance and temperature. The output characteristics of the solar PV module are shown in figure 4. Assume that from the point of MPP the solar PV array is far away. The operating voltage is perturbed i.e. increased in small step and corresponding change in output power is mainly observed. If the output power is increased then the operating point of solar array is moved to the maximum point. Then once again the change in voltage is monitored and the operating point is again shifted towards the maximum power point. If there is a decrease in power due to the change in voltage then the operating point is moved away from the maximum power point, The follow chart of the algorithm is shown in figure.5

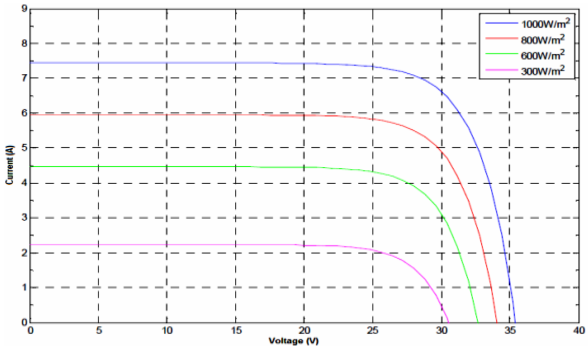

Fig.3 Output characteristics of PV array

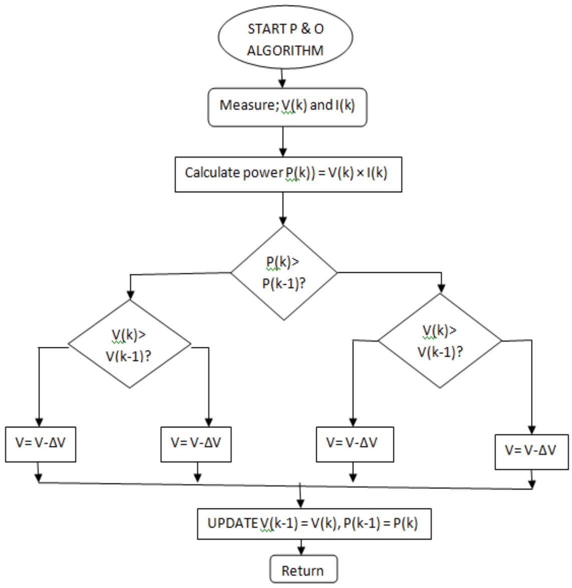

Fig.5 Graphical Image of P and O process

The duty cycle of the DC-DC boost converter between the solar panel and the inverter is controlled by the MPPT algorithm. The average output voltage of the DC-DC converter is given by Eq. (1) [14].

$$\frac{V_{Out}}{V_{Supply}} = \frac{1}{1-D_1} \qquad (1)$$

Where $V_{Out}$and $V_{Supply}$are the output voltage and supply voltage of the boost converter and $D_1$is the duty cycle of the switch (S_s). The operating point of solar panel is controlled by the duty cycle using MPPT algorithm.

The simulationresults of the VSI fed single phase Induction motor are presented.

B. *Single Phase Induction Motor with VVVF*

In the V/F control method gradual change in the supply frequency causes increase or decrease in speed. However if the speed control is done by changing the input supply frequency the supply voltage should also be changed because if the frequency decreases, keeping the supply voltage constant, the flux is increased , if flux is increased core losses are increased. Hence it is necessary to increase the supply voltage with respect to increase in frequency or decrease in supply voltage with respect to decrease in frequency. [15].

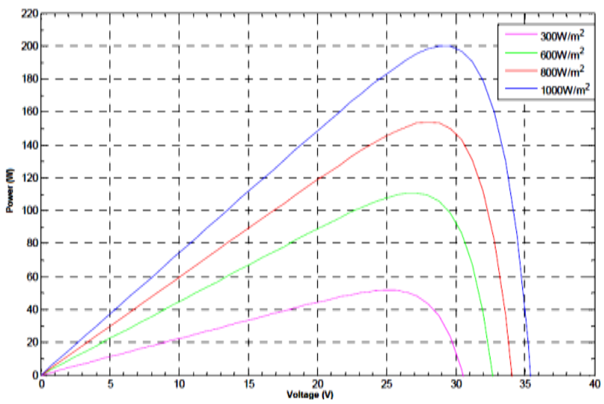

Fig.2 V-I Characteristics of Array

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The induced emf of an induction motor is

$$E_{ph} = 4.44 f \Phi T_{ph} \qquad (2)$$

$$\frac{E_{ph}}{4.44 T_{ph} f} = \Phi \qquad (3)$$

The value of 4.44 $\times T_{ph}$ is considered to be constant

Since $E_{ph} = V$

$$\frac{V}{f} = \Phi \qquad (4)$$

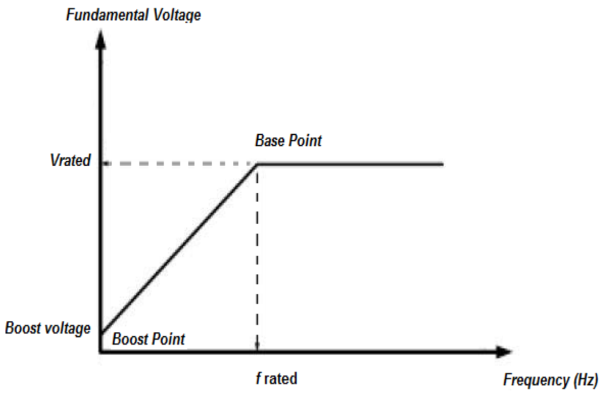

Fig.4 Volt per hertz control method

The above figure shows the operation of induction motor where the base point is reached. i.e. above which increase in frequency does not causes increase in fundamental voltage. But below the base point there is linear increase in fundamental voltage with increase in frequency. This method of speed control is named as open loop speed control drive.

III.PWM CONTROL METHOD

In order to control te output voltage and frequency of VSI, the single phase PWM technique is used. In this Technique the triangular wave is called the carrier signal and the square wave is called the control signal. Both these signals are compared and the gate pulses are generated based on the comparison [16]-[17].The value of the output signal is given by $V_o = V_s\sqrt{2\delta}$.

The amplitude modulation index is given by

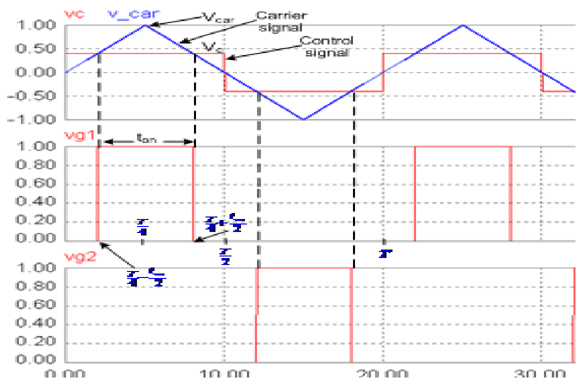

Fig.6 Gating signals of Single pulse-width modulation

$$m_a = \frac{V_C}{V_{car}}$$

The rms ac output voltage

$$V_o = \left\{ \frac{2}{T} \int_{\left(\frac{T}{4}-\frac{t_{on}}{2}\right)}^{\left(\frac{T}{4}+\frac{t_{on}}{2}\right)} V_s^2\, dt \right\}^{1/2} = V_s \sqrt{\frac{2t_{on}}{T}} = V_s\sqrt{2\delta}$$

where

$$\delta = \text{duty ratio} = \frac{t_{on}}{T}$$

By varying the amplitude of the control signal V_c the pulse width can be controlled which in turn controls the speed of the motor.

IV.SIMULATION RESULTS OF THE NEWLY PROPOSED SYSTEM

The performance of the two leg voltage source inverter is initially checked by the simulation using MATLAB/SIMULINK for single phase induction machine. In the simulation circuit a DC source is used instead of solar panel and is connected to the boost converter through the inductor filter. Then the output of DC-DC converter is connected to the capacitor link in order to obtain the output voltage of $V_{dc}/2$. This voltage is fed to the diode four diode circuit with MOSFET combination in order to obtain the five level output across the load. The inverter is designed using four MOSFET switches and its output is fed to the induction motor drive.

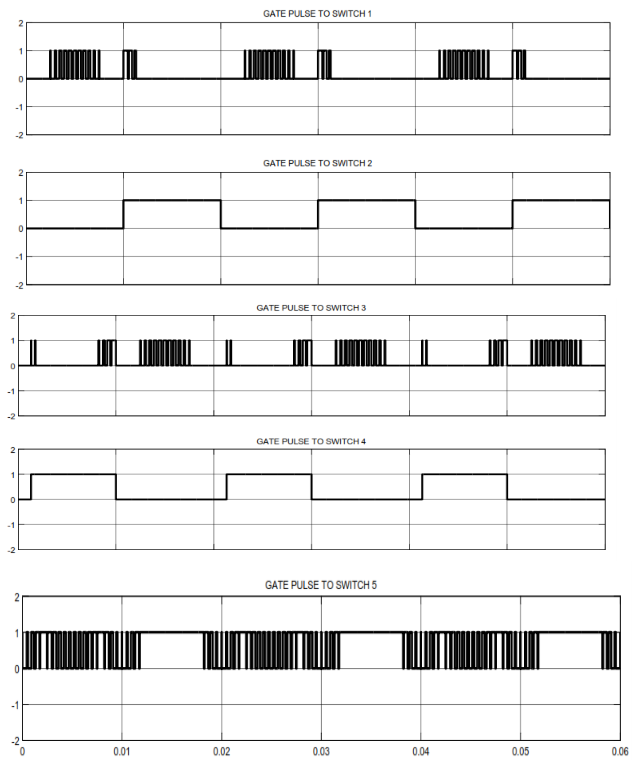

Fig. 9 Gate Pulses for the switches S_{11}, S_{12}, S_{13}, S_{14}, S_{15}

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The gate pulses generated for the four switches are shown in Fig.9. The subsystem of the switches pulse circuit is shown in Fig.10. The simulation result shows that the output voltage V_m=200 V and the output current is I_{peak}= 35 A. In the simulation setup the DC voltage input applied is 200 V. The overall MATLAB circuit is shown in Fig.11 and the simulated waveforms are shown in Fig. 12 and 13.

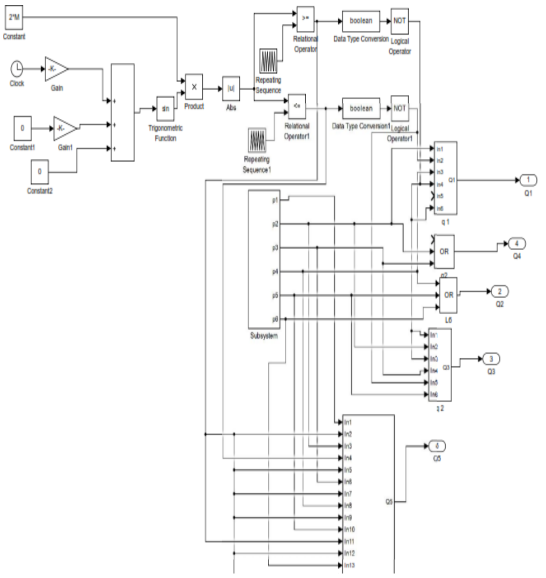

Fig.10 Simulation of PWM circuit using MATLAB/SIMULINK

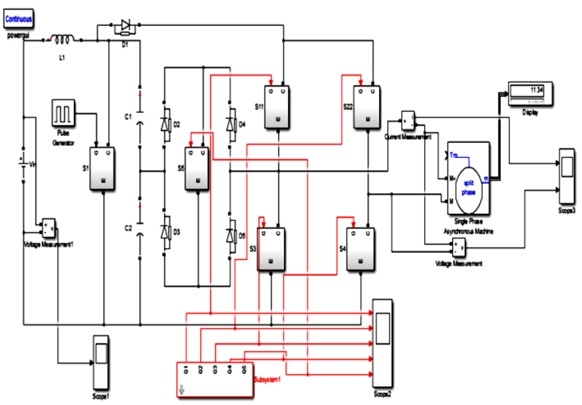

Fig. 11 Simulation of inverter with SPIM using MATLAB/SIMULINK

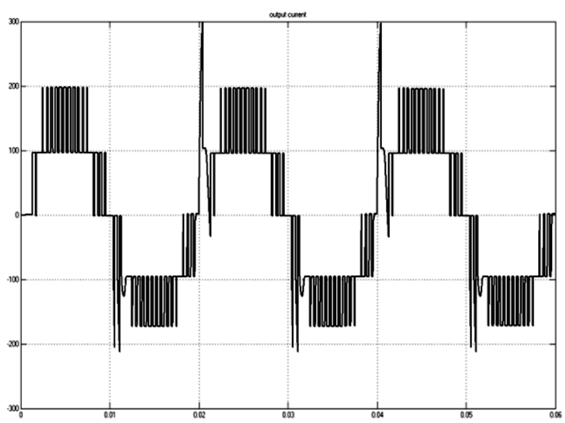

Fig.12Output voltage of the inverter with SPIM load

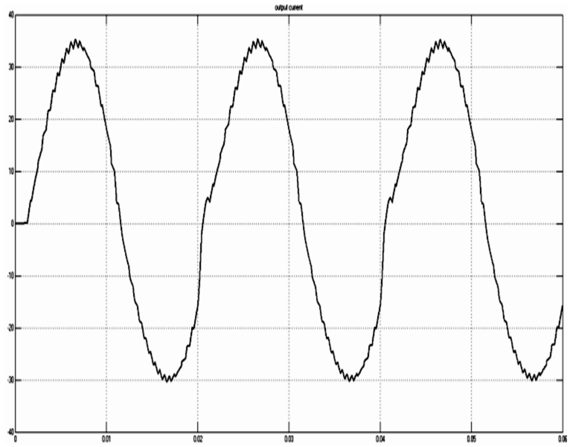

Fig. 13 Output current of the inverter with SPIM load

V .HARDWARE RESULTS

The hardware circuit consists of a rectifier circuit with step down transformer and regulator to give supply voltage of 5V PIC micro controller and the inverter circuit with single phase induction motor used in Exhaust fan. The pulses are generated using Peripheral Interface microcontroller.

Initially the circuit is designed using proteus and the PCB layout of the model is developed. Using the layout the components are soldered and the output terminal is connected to SPIM. The description of the motor is shown in table I.

Type	Voltage	Current	Speed
Shaded pole with Squirrel cage rotor	230V	0.35A	1350rpm

Table: I Single phase Induction motor

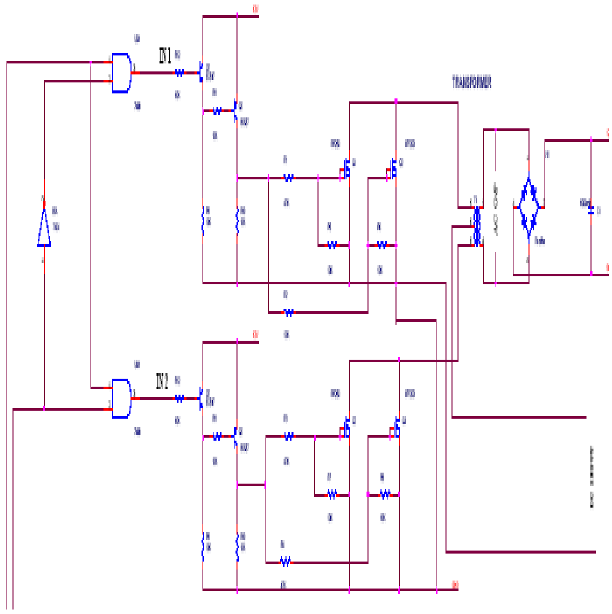

Fig.14 PWM based MOSFET driver circuit

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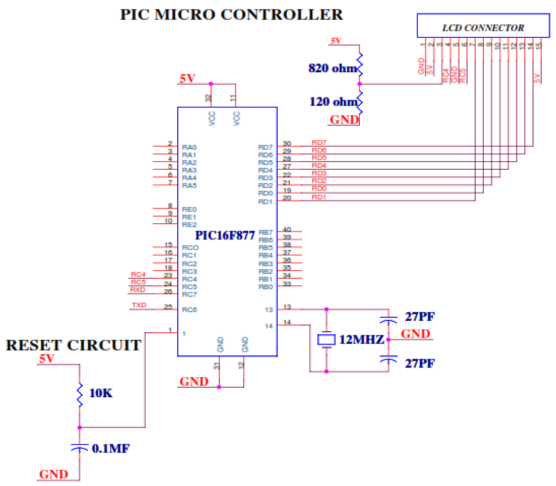

Fig.15 PIC Microcontroller with LCD display and pulses to inverter circuit

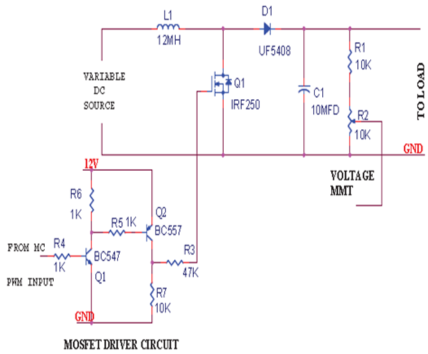

Fig.16 Boost converter driver circuit

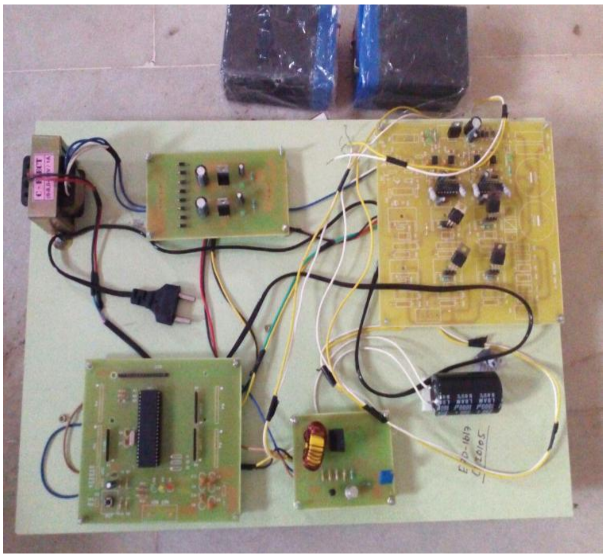

Fig. 17 Hardware model of Inverter

The output voltage obtained from the inverter after hardware implementation is 81 V. The difference between the simulation result and hardware result is varying because in hardware circuit we used single phase induction motor. The speed of the motor is low at a range of 850 rpm measured using tachometer.

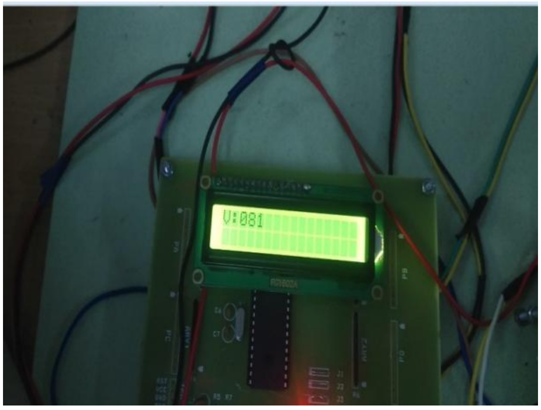

Fig.18 Output voltage of the inverter with SPIM load.

VI. CONCLUSION

Thus the single phase induction motor driven by single phase VSI using MPPT algorithm was simulated using MATLAB/SIMULINK model. The output obtained indicates that there is more distortion in output voltage but however the current waveform is more or less sinusoidal. The harmonics are larger and filter circuit should be designed to reduce the harmonics or artificial intelligence technique should be used to generate the pulses for IGBT which in turn reduces the harmonics.

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