

Utilization of Non-Conventional Energy Resources Connected to Grid

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Abstract:- As the conventional energy resources are decreasing and energy demand is increasing with time, the future of power generation depends on the non-conventional energy resources. The performance analysis and installation of a power system using Non-Conventional Energy Resources have been time-consuming and uneconomical. The major problem with non-conventional energy resource is to analysis the availability of solar energy in any geographical area, initial cost estimation and inaccurate calculations of energy demand. In this paper, an analogy is presented to estimate the solar energy available using ATMEGA-16 and MATLAB platform. The proposed scheme has been tested on a virtually designed PV-Array and very efficient MPPT technique. All the generated power then converted from DC to AC using 3-level VSC and fed to an On-Grid System. Analysis of generated power of PV array and electric energy transferred to the grid also has been done to study the performance of solar power plant on changing environmental conditions like temperature, irradiance, and humidity.

analyze the plant behavior at that particular location with the help of MATLAB simulation. In this work, design and analysis of a 100kW PV Array system with 25 kV grid system is considered.

II. METHODOLOGY

Designed hardware is used to get the real-time sun data and send data into MATLAB simulation using a Bluetooth serial port communication system. In MATLAB simulation we use curve fitting tool to generate a real-time curve of temperature and irradiance of a particular location. Further, this data sends to the virtually designed PV system. PV array converts the solar power in DC voltage. This DC voltage then boosts using DC to DC boost converter with powerful MPPT algorithms. A VSC controlled inverter is used to convert supply from DC to AC. For grid compatibility, we use a transformer to step up the transformer [2]. The flow diagram of the proposed methodology is shown in Fig. 1.

Keywords:- Converters; MATLAB; MPPT; PV Array; Solar Energy; Transformers.

I. INTRODUCTION

The irradiance and temperature of the sun on different location of the earth change differently because of the environmental conditions and appearance of the sun during the day time. Because of this irregularity of temperature and irradiance, it is difficult to predict the power which can be generated using the PV array of solar cell and also creates difficulty in the analysis of the solar module characteristics. To counter these difficulties, a hardware system is designed to estimate and analyze the generated power of the solar power system using MATLAB/Simulink platform.

This paper presents the design of a virtually created solar power system with the help of hardware components and MATLAB software. Use of real-time sun condition gives an accurate design analysis of the system. The temperature and irradiance data of the sun fed to the designed virtual system in MATLAB. The virtual environment of solar power plant uses virtually designed PV arrays with accurate algorithms and MATLAB simulation blocks give dc voltage generation like a real PV array [1]. The proposed work gives near to accurate prediction of the behavior of solar plat before installing it at any place. It will only require to set the designed hardware at a different location to get the sun data of that particular location and

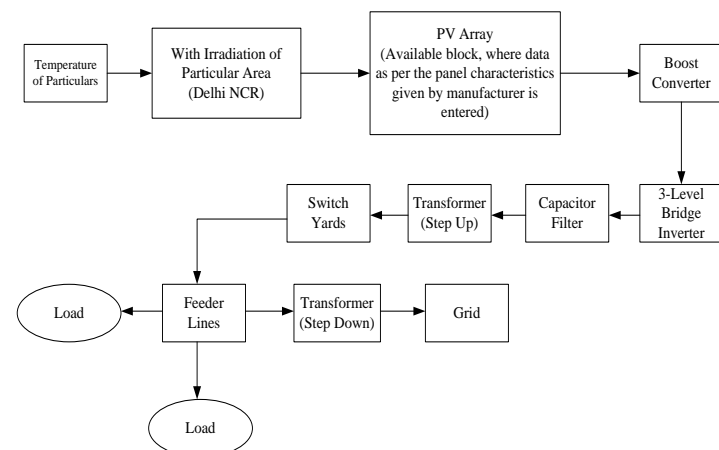


Fig. 1:- Block Diagram of the Designed System

III. HARDWARE

Collecting run time data from the sun of a defined area, a designed hardware PCB is used. The main components of the PCB are ATMEGA-16 IC, LDR, LM-35 temperature sensor and a Bluetooth module. LM-35 is used to determine the real-time temperature of the sun and LDR is used to determine the real-time irradiance of the sun. ATMEGA-16 IC is used to perform the ADC conversions and communication platforms for communication. Bluetooth module uses serial port UART communication to send data in MATLAB/Simulation. This data is sent to the MATLAB curve fitting tool and a graph is generated for real-time

temperature and irradiance of the sun. The hardware setup shown in Fig. 2 is powered by a 5V power supply.

IV. MODELING

The system is designed in MATLAB/Simulink environment using Power System Block set as shown in Fig. 3. For capturing the serial port data, Signal Builder block, PV- array block, designed boost converter with MPPT techniques are used. The DC voltage available at the output terminals of the Boost converter is fed to 3-level VSC controlled inverter block for DC to 3 phase AC conversion. This AC voltage is stepped up with the help of the transformer block designed in MATLAB/Simulink. To send this data to the power grid system, ABCD parameter block is used. The output of the ABCD block is fed to the Grid Block. Three display subsystems are used to display the boost voltage, Inverter voltage and grid transferred voltage. These three blocks are very important for the analysis of the overall system.

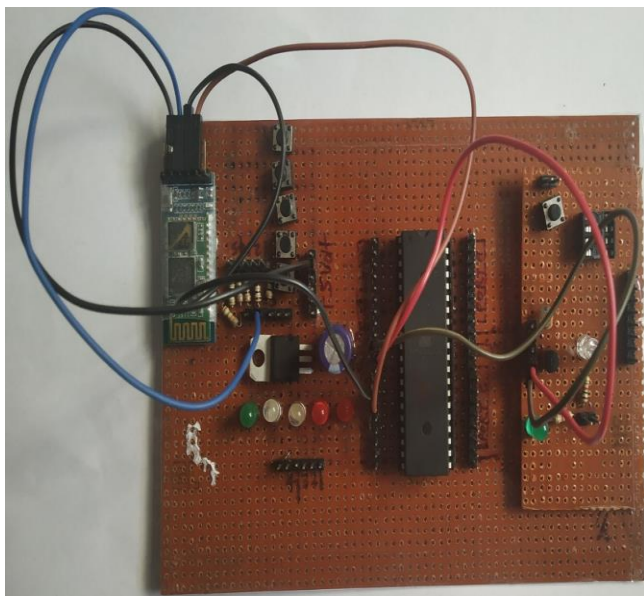


Fig. 2:- Designed Hardware for Real-Time Sun Data Analysis

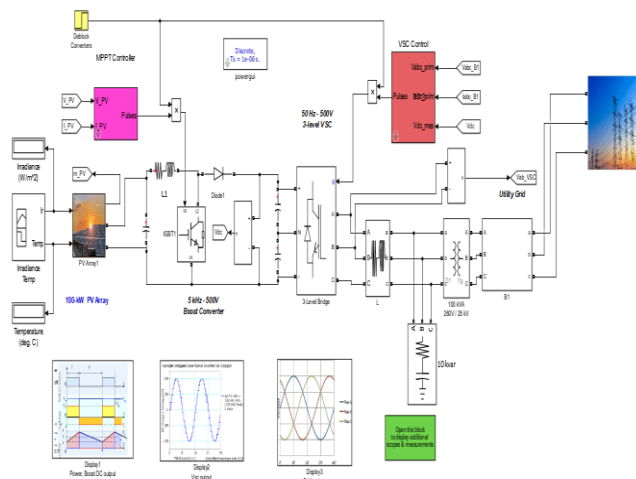


Fig. 3:- Simulation of Solar System in MATLAB/Simulink

A. Signal Builder

Signal builder block is used to draw the changes of the sun temperature and irradiance, which monitor how it changes during the days or months. With the help of hardware data, which is sent by the serial port Bluetooth communication to Matlab terminal, temperature and irradiance curve is drawn. Signal Builder Block output data is shown in Fig. 4. Further, this data sends to the virtually designed PV-array.

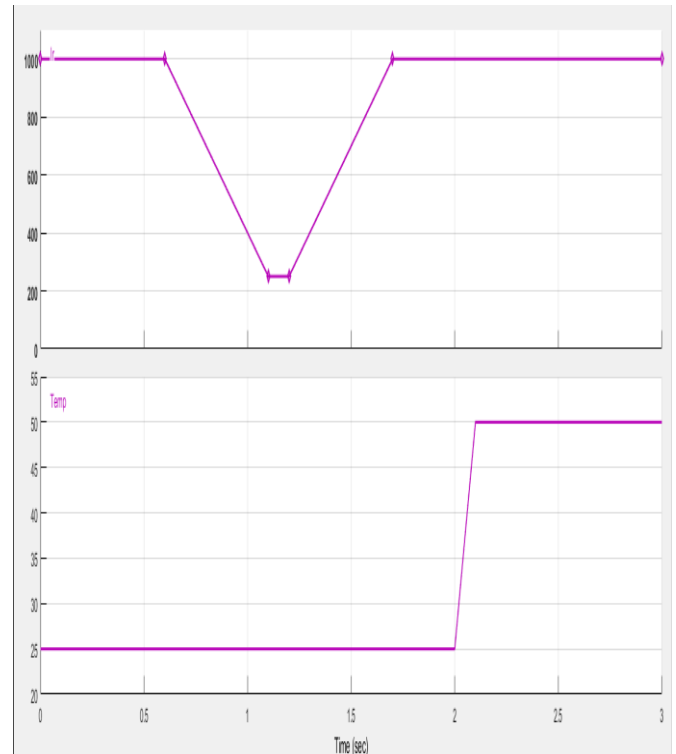


Fig. 4:- Signal Builder- Temperature and Irradiance Graph

B. PV Array

PV Array Block is used to design the analogy of real PV system. The variable quantity of the PV system is temperature and the irradiance which are fed in the block using signal builder. The equations (1)-(6) used to design the system are mentioned below. [2] The calculated values are given in the block as shown in Fig. 5.

$$I_{sh} = \frac{V + IR_s}{R_p} \quad V_t = \frac{kT_{op}}{q} \tag{1}$$

$$I_{ph} = [k_i(T_{op} - T_{ref}) + I_{sc}] \frac{S}{S_n} \tag{2}$$

$$I_{rs} = \frac{I_{sc}}{\exp\left(\frac{V_{oc}}{V_t C_n} - 1\right)} \tag{3}$$

$$I_s = I_{rs} \left(\frac{T_{op}}{T_{ref}}\right)^3 \exp\left[\frac{qE_g}{Kn} \left(\frac{1}{T_{op}} - \frac{1}{T_{ref}}\right)\right] \tag{4}$$

$$I_d = N_p I_s \left[\exp\left(\frac{V + IR_s}{N_s V_t n C}\right) - 1\right] \tag{5}$$

$$I = I_{ph} N_p - I_{sh} - I_d \tag{6}$$

Where

- V_t : Thermal voltage in volts
- k, q : Boltzmann’s constant (1.38e-23J/K), Electronic charge (1.6e-19C)
- T_{op}, T_{ref} : Operating Temperature of the module in Kelvin, Reference temperature of 250 C
- I_{sh} : Shunt current in Ampere
- S, S_n : Irradiation in device surface in W/m², Reference irradiation of 1kW/m²
- I_{ph}, I_d : Light generated current in Ampere, Diode current in Ampere.
- I_{sc}, V_{oc} : Short circuit current in Ampere, Open circuit voltage in Volt
- I_{rs} : Reverse saturation current at reference temperature in Ampere
- I_s : Diode saturation current in Ampere
- k_i : Temperature coefficient of short circuit current
- E_g, n : Band gap energy of cell (1.12eV), Diode ideality factor
- R_s, R_p : Resistance in series in ohm, Resistance in parallel in ohm
- N_s, N_p : Number of modules in series, Number of modules in parallel
- C : Number of cells in the module
- I, V : Module current in Ampere, Module voltage in Volts

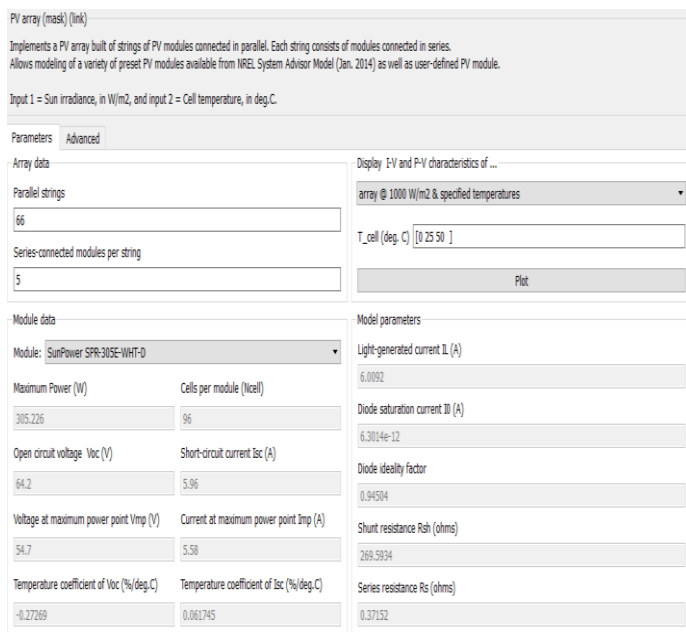


Fig. 5:- Setting up the parameters for PV- array

C. Boost Converter

The output of the PV array is 220V DC. As the grid support the 3-phase supply but for the conversion from DC to 3 phase AC requirement of voltage is 500V DC for VSC based 3 level bridge converter. For that purpose, DC to DC step-up boost converter is used. Boost converter uses highly efficient incremental and integral conductance MPPT technique. Primarily use of boost converter in this project is to find out the maximum power point of PV- array on the running condition which maximize the efficiency of PV modules and convert the voltage from 220V to 500V. Boost

converter consists one IGBT, one diode, one series combination of inductor and resistor, one capacitor at the input side and two capacitors at the output side. For setting up the firing angle of IGBT, the incremental and integral technique of MPPT is used [3]. Simulink model of the Boost Converter is given in Fig. 6.

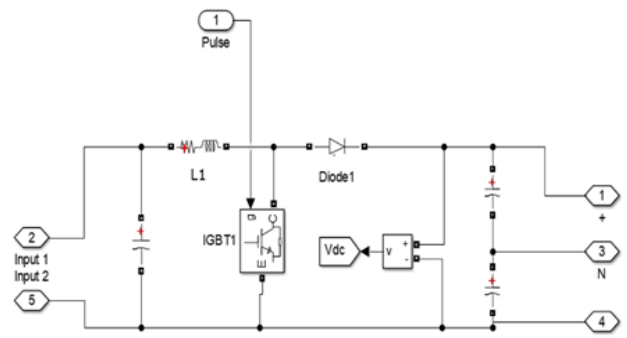


Fig. 6. Simulation of Boost Converter

D. Maximum Power Point Tracking (MPPT) Technique

MPPT stands for Maximum Power Point Tracking which means to track the operating point where the maximum power can be drawn. The process of maintaining the operating point at the maximum power point of the PV Panel is called Maximum Power Point Tracking [4]-[5]. The Simulink model is shown in Fig. 7 is designed using the equations (7)-(10) [6]-[7]. The typical characteristic of MPPT is also shown in Fig. 8.

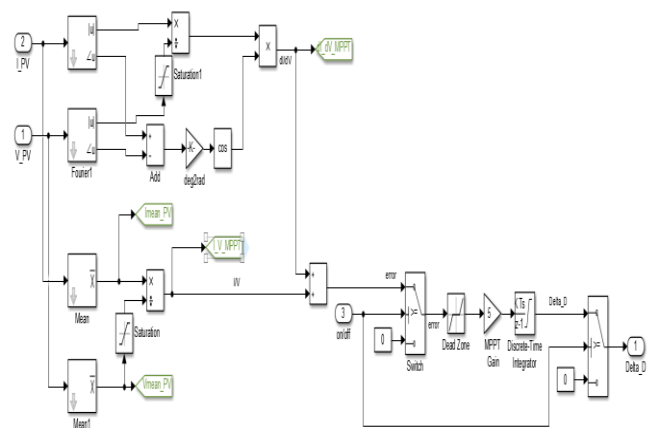


Fig. 7:- Simulation of MPPT

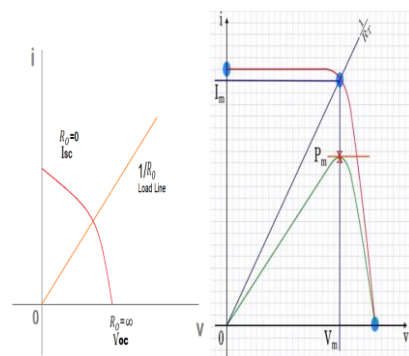


Fig. 8:- Characteristics of MPPT

Maximum power point is obtained when $\frac{dP}{dV} = 0$,
 $P = V \times I$ (7)

$$\frac{dP}{dV} = 0$$
 (8)

$$\frac{d(V \times I)}{dV} = I + V \times \frac{dI}{dV} = 0$$
 (9)

$$\frac{dI}{dV} = \frac{-I}{V}$$
 (10)

where $dI dV$ = fundamental components of I and V ripples measured with a sliding time window T_MPPT
 I, V = mean values of V and I measured with a sliding time window T_MPPT

The integral regulator minimizes the error $(\frac{dI}{dV} + \frac{I}{V})$
 Regulator output = Duty cycle correction

E. Voltage Source Converter

Three-level three-phase voltage source inverter is used to convert the output of boost converter 500V DC to the 450V line-to-line AC. Simulation of voltage source converter consists of six IGBTs and six diodes. Switching of IGBT is controlled by VSC main control block. The setting parameter is shown in Table I:

Parameter	values
Nominal power	100e3
Frequency	50
Nominal dc voltage	500
Total transformer leakage impedance	0.002+j0.06
Choke impedance	2e-3+j250e-6
Vdc regulator gain	Kp=7, ki=800
Current regulator	Kp=0.3, ki=20

Table 1:- Parameter Of VSC Controller

The values of snubber resistance, snubber capacitance, internal resistance, and forward voltages for Three phase 3-level bridge converter are calculated and fed to the block parameters as shown in Fig. 9.

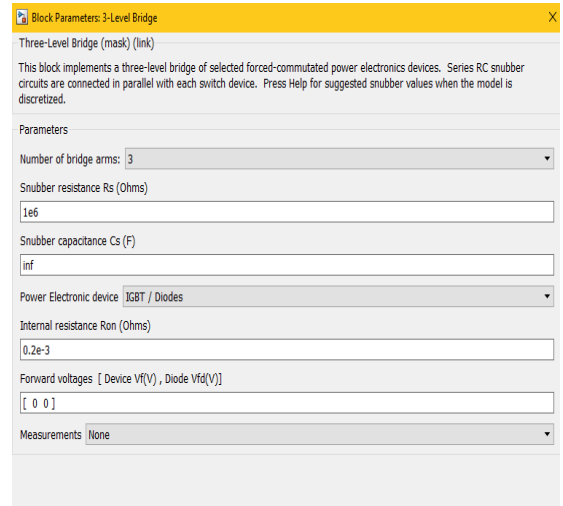


Fig. 9:- Block parameter of Three-Level Bridge Converter

F. Transformer

The high transmission voltage has low losses and high transmission capacity, hence a step-up transformer is used to convert the AC voltage level obtained from Voltage Source Inverter i.e. 250V to 25KV, which is to be connected to the grid. A transformer of rating 100KVA, 250/25KV is simulated to connect the converted solar power on to the grid system as shown in Fig. 10. [8]-[9]

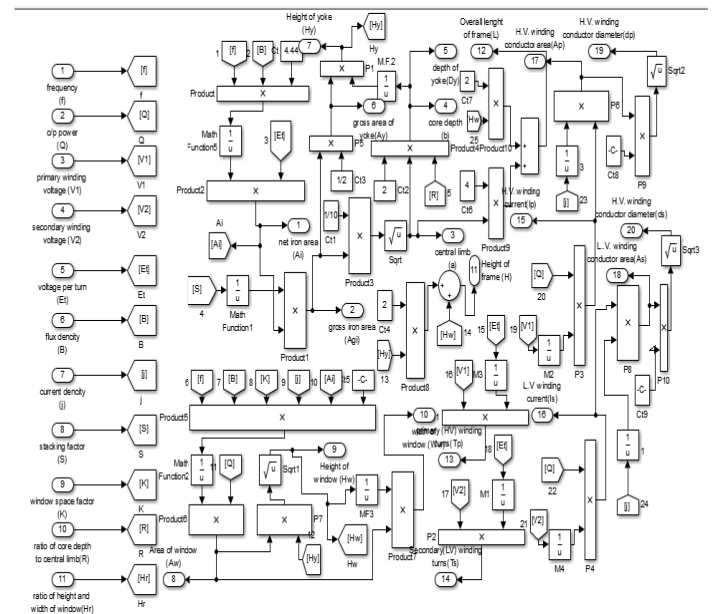


Fig. 10:- Simulation of Transformer

G. Utility Grid

The utility grid is a commercial electric power distribution system. In a utility grid, electric power from different power stations is connected in synchronism. A utility grid of 120KV with 19Km feeder line is used and 2500MVA line with designed solar power system is connected to this utility grid. The simulation of the Utility grid is shown in figure 11. [10]-[11]

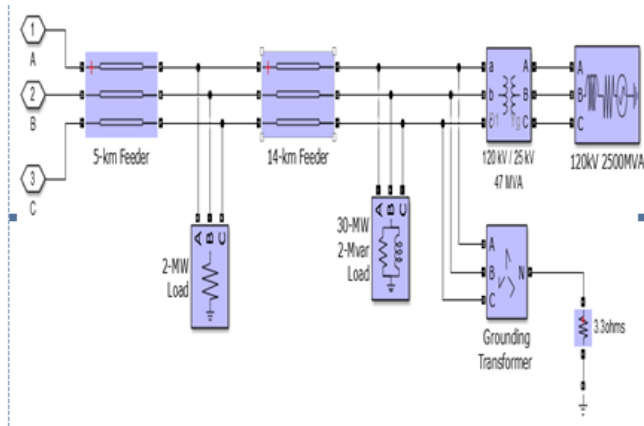


Fig. 11:- Simulation of Feeder Line

V. IMPLEMENTATION OF HARDWARE SYSTEM IN MATLAB

The hardware of the work includes a Bluetooth device for wireless connection and a serial port UART for communication. Using MATLAB commands, serial port data can be fetched on the screen directly. The hardware sends two different types of data sets for temperature and irradiance for a particular area location with a specified time tag. This data is fed to the signal builder for the identification of the change in solar energy by MATLAB simulation. Commands for fetching data from hardware is given in Fig. 12 and the data are tabulated in Table II.

Further, this data sends to the virtually designed PV grid system PV array converts the solar energy in DC voltage
 Mean Power = 92.89 KW
 DC Voltage = 251.54V
 DC voltage is increased by the boost converter.
 Input voltage for boost converter = 251.54V
 Output Voltage of Boost Converter= 499.97V
 Duty cycle = 0.5
 Then, DC voltage is converted into AC voltage by VSC inverter which is given to grid followed by the compensator.
 Output Power supply to grid = 91.28KW
 Line voltage = 20Kv
 Line Current = 3A

The output waveform of the simulation is shown in Fig. 13 and Fig. 14.

```
>> instrhwinfo('Bluetooth','pradumnbt')
>> instrhwinfo('Bluetooth','pradumnbt')
|
>> instrhwinfo('Bluetooth','pradumnbt')

>> bt=Bluetooth('pradumnbt',1);
>> fopen(bt);
>> fgets(bt)
```

Fig. 12:- MATLAB Code for Fetching Data from Hardware

Date/Time	Temperature(deg C)	Irradiance
08-04-19/07:00	24.59	105.02
08-04-19/09:00	30	571
08-04-19/011:00	35	793
08-04-19/13:00	38	885.55
08-04-19/014:00	40	598.97

Table 2:- Temperature & Irrediance Data Of Delhi Ncr

VI. RESULT & DISCUSSION

In this work, the effectiveness of utilization of Non-Conventional Energy is analyzed in the MATLAB/Simulink environment by using solar energy along with the use of MPPT which draws maximum power from PV module which is highly efficient.

The results from the scope which is connected for VSC output and grid connection analysis gives the results listed below. First, the data of irradiance and temperature of the sunlight of an area is collected which strikes on the PV module.

Irradiance = 1000
 Temperature =50 °C

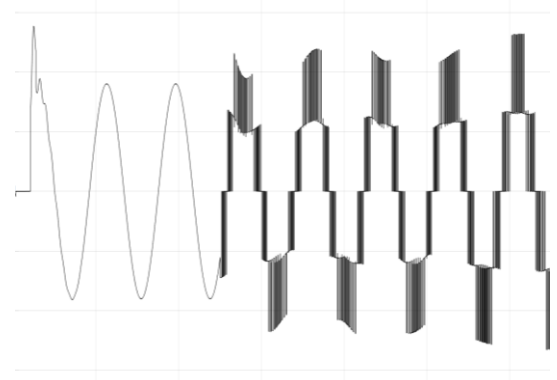


Fig. 13:- Result for VSC Output (Voltage Vs Time)

VII. CONCLUSION

The implementation of this work using designed hardware and MATLAB simulation gives proper analytic data to perform the power system in the real world using PV-array, inverter, converter and other designed equipment. The result of simulation gives approximate data because of the algorithms and calculations used to perform the designing of the virtual power system are efficient enough to give a proper analogy. The hardware part of the project is quite robust and efficient in terms of the economy. Using this simulation and hardware it is easy to define the utilization of solar energy with on grid power system with properly implemented data and designed analysis. This paper also fulfills the requirements to designed economically strong utilization of non-conventional energy resources with synchronized grid connection.

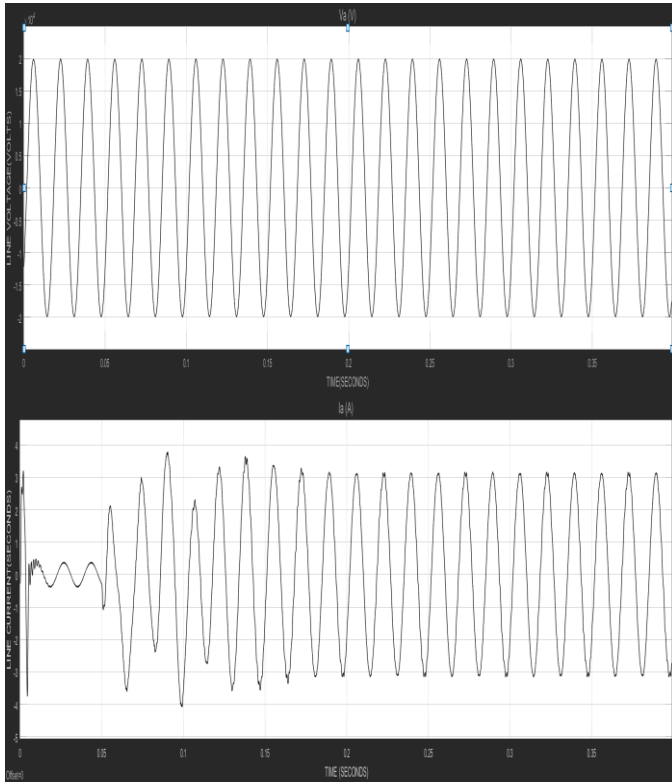


Fig. 14:- Result for Grid connection (Line Voltage Vs Time and Line Current Vs Time)

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