International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 5, July-August 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Modelling of Solar PV with Enhanced Boost Converter and PWM Based Inverter

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ABSTRACT

This work represents analysis of a solar PV array and connection up to the grid with various components in details in different conditions. In this work PV array is connected with a boost converter and after that an inverter is required for the conversion to a well and smooth waveform of ac output voltage. Due to so many nonlinear characteristics of solar radiation the frequency and amplitude variation is the most common problem so a PWM based inverter is used in this model. A fault analysis also been done on this model. The output voltage & current as well as active and reactive power has been explored and analyzed. The simulation has been done on a Matlab software and simulation results obtained and analyzed.

KEYWORDS: *Pulse Width Modulation (PWM), Insulated gate bipolar transistor (IGBT), THD (Total harmonic distortion), STATCOM (static synchronous compensator), PV (Photovoltaic), THD (Total harmonic distortion) SVC (Static VAR compensator)*

How to cite this paper: Devendra Kumar Dhankar | Uma Shankar Patel "Modelling of Solar PV with Enhanced Boost Converter and PWM Based Inverter" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-5, August 2022, pp.231-236, URL: www.ijtsrd.com/papers/ijtsrd50432.pdf

IJTSRD50432

INTRODUCTION

With the modern lifestyles and the fast growth in industries the energy supply and demand chain has been subjected to remarkable strain. In addition, the issues of climate change and the need to diminish carbon footprints have added to the strong thrust for companies and nations to invest in alternate energy sources, particularly the renewable energy (RE) resources. Among the available RE resources, SPV source has emerged as one of the finest green energy resource and seen as a better replacement for conventional energy. The contribution of the energy harvested through the SPV systems had been significant in the past decade in meeting the national as well as international energy demands. In addition, the enhanced scale and eco-friendly nature of solar energy have attracted many researchers to propose scholarly research in this area. [1].

The world constraint of fossil fuels reserves and additionally the ever growing environmental pollutants have driven powerfully throughout ultimate many years the occasion of renewable strength sources (RES). The necessity of getting obtainable property power systems for substitution bit through bit trendy ones demands the improvement of systems of power provide based on smooth and renewable resources. At present, solar electric photovoltaic (PV) era is ahead redoubled significance as a RES application because of distinctive blessings like simplicity of allocation, high responsibility, absence of gasoline value, low preservation and absence of noise and wear thanks to the absence of moving factors or practical's. Moreover, the alternative energy characterizes a clean, pollutants-loose and inexhaustible power supply. Additionally to those elements are the declining value and expenses of solar PV modules, associate degree increasing efficiency of sun cells, producing generation enhancements and economies of scale [2].

The warming of global surfaces increasing day by day. The warming caused due to release of toxic gases. Main reason of these gases in the environment is due to air pollution caused by generation plants that all uses fossil fuels like coal, fuels, gas etc. This causes acid rain, depletion of ozone layer and radioactive emission these effects can be minimized by searching some effective solution. Solution must include energy conservation with improved energy efficiency.

Renewable sources of energy can be used for the power generation. The main challenge is the installation cost which is having a high capital as compared to the fuel plant comparison on the basis of output. Many government financial incentives schemes running to promote solar and wind energy for the power generation.

Major aim is to reduce carbon footprints and now a days solar PV also installing in the commercial as well as residential buildings.

Proposed Model

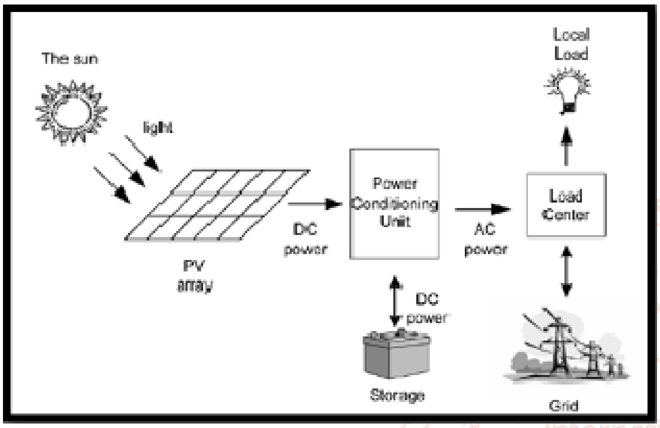


Figure 1 Block diagram of solar PV system connected with grid

In this model a PV array is connected with the boost converter and the output of boost converter goes to the inverter and after that we can store the power or directly connect it to the grid.

MODELLING OF PV ARRAY

Total 30 array system is connected to achieve 30 KW of power with suitable series and parallel combination. In a single module 30 cells are connected in series to get 22 v open circuit voltage. The mathematical model of PV cell is represented by a current source with a diode connected in parallel as shown in figure 2. The intrinsic series resistance whose value is very small. The equivalent shunt resistance whose value is very high, applying Kirchhoff's law to the node where Iph, diode, Rp and Rs meet. [2]

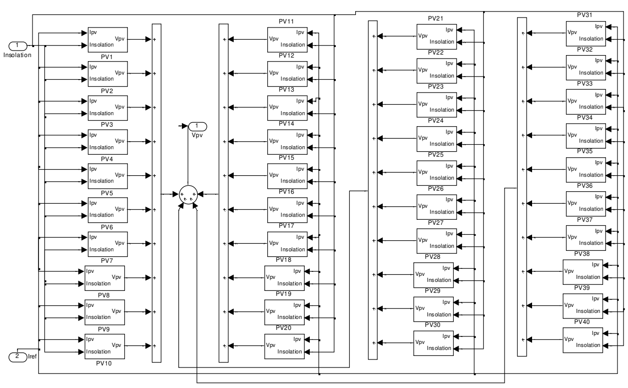


Figure 2 Block diagram of solar PV system

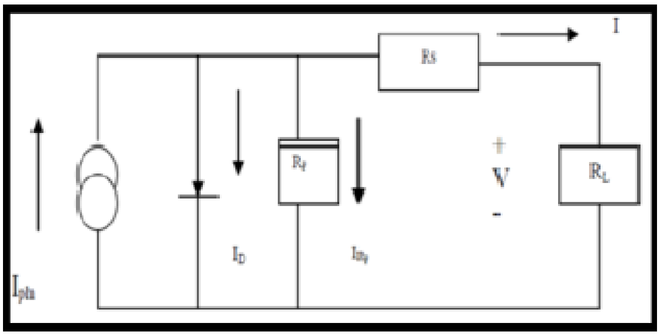


Figure 3 Electrical model of solar PV system

$$I = I_D - I_{RP} - I_{ph} \quad \ldots\ldots (1)$$

$$I = I_{ph} - I_0 - \left[exp\left(\frac{V+IRs}{V_T}\right) - 1\right] - \left[\left(\frac{V+IRs}{R_p}\right)\right] \ldots (2)$$

$$I = n_p I_{ph} - n_p I_{rs} - \left[exp\left(\frac{q}{KTA} * \frac{V}{n_s}\right) - 1\right] \ldots (3)$$

$$I_{rs} = I_{rr}\left[\frac{T}{T_R}\right]^3 exp\left(\frac{qE_G}{KA}\left[\frac{1}{T_r} - \frac{1}{T}\right]\right) \ldots (4)$$

$$E_G = E_G(0)\frac{\alpha T^2}{T+\beta} \ldots (5)$$

$$I_{ph} = [I_{scr} + K_i(T - T_r)]\frac{s}{1000} \ldots (6)$$

Iph is the Insolation current, I is the Cell current, I0 is the Reverse saturation current, V is the Cell voltage, Rs is the Series resistance, Rp is the Parallel resistance, VT is the Thermal voltage (KT/q), K is the Boltzmann constant, T is the Temperature in Kelvin, q is the Charge of an electron.

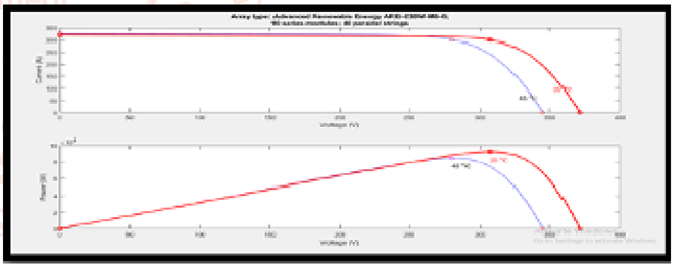


Figure 4 I-V and P-V Characteristics

A system used to transform solar radiation directly into electricity. At the heart of a solar power system, also known as a photovoltaic (PV) system or solar electric system. The solar cell produces only a small amount of current and voltage. So, in order to meet a large load demand, the solar cell array has to be connected into modules and the modules connected into arrays. The output voltage from PV array is changeable with solar radiation and ambient temperature. So in order to connect the electrical grid the output voltage from PV array should be fixed and converted to AC voltage which can be done by an inverter. Here the PV modules are connected with DC to DC converter so as to maintain increased and fix voltage across the converter. The PV converter and inverter have the task to guarantee safe and efficient operation, to track the maximum power of the PV solar cell array and controlling the power which is injected from the inverters to the electrical grid. An important technique for achieving the above is called the maximum power point tracking (MPPT). In principle, this controls the output of a PV system to match with the grid for all atmospheric conditions. Hence, it results in the system operating at the maximum power point at all times. Before converter battery bank is connected which store the solar power when do not used by the load. This helps to maintain reliable and quality of supply across the load. The filter or transformer is connected after the inverter to remove the DC contain from supply. The aim of this paper is to introduce a complete modelling and simulation of whole PV system connected to electrical grid under Matlab/Simulink software. Working

BOOST CONVERTER

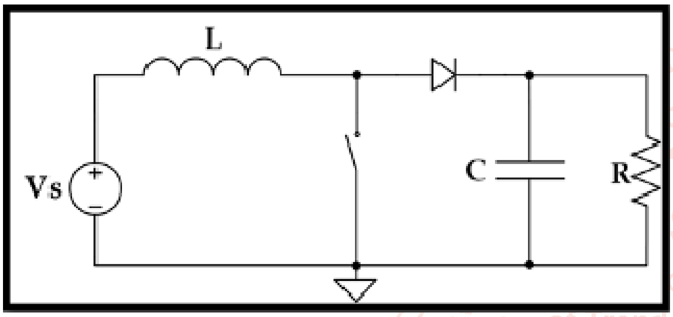


Figure 5 Torque slip characteristic of induction motor

We can use DC-DC converters as switching mode regulators. The unregulated dc voltage can be converted to regulated dc output voltage. The PWM at a fixed frequency is the main key to get regulated supply. Commonly used switching devices are BJT, MOSFET or IGBT. The minimum oscillator frequency should be about 100 times longer than the transistor switching time to maximize efficiency [3].

$$V_{out} = \frac{1}{1-D} V_{in} \quad \text{.................................} \quad (7)$$

$$R_{pv} = (1-D)^2 R_{out} \quad \text{...........................} \quad (8)$$

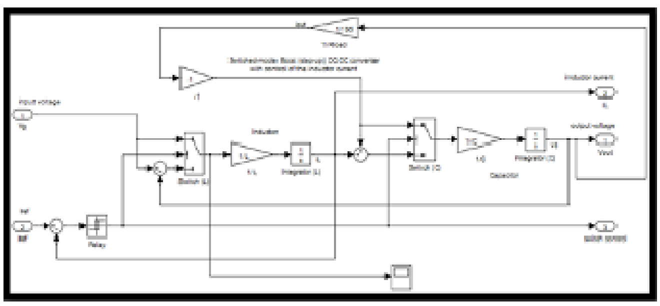


Figure 6 Simulink Model for Subsystem of DC to DC Boost Converter

INVERTER

A device that converts DC power into AC power at desired output voltage and frequency is known as Inverter. Phase controlled converters when operated in the inverter mode are called line commutated inverters. But line commutated inverters require at the output terminals an existing AC supply which is used for their commutation. This means that line commutated inverters can't role as isolated AC voltage sources or as variable frequency generators with DC power at the input. Therefore, voltage level, frequency and waveform on the AC side of the line commutated inverters can't be changed. On the other hand, force commutated inverters provide an independent AC output voltage of adjustable voltage and adjustable frequency and have therefore Much wider application. Inverters can be broadly classified into two types based on their operation:

- ➢ Voltage Source Inverters (VSI)
- ➢ Current Source Inverters (CSI)

Voltage Source Inverters is one in which the DC source has small or negligible impedance. In other words VSI has inflexible DC voltage source at its input terminals. A current source inverter is fed with adjustable current from a DC source of high impedance, i.e.; from an inflexible DC current source. In a CSI fed with stiff current source, output current waves are not affected by the load. [4]

INVERTER CONTROL

To control induction motor drives PWM inverters are very popular. Voltage source inverters mostly used to control both frequency and magnitude of voltage and current applied to motors. PWM fed induction motor drives gives better performance as compared to the fixed frequency induction motor drives.

A number of Pulse width modulation (PWM) schemes are used to obtain variable voltage and frequency from a Inverter to control IM drives But most widely used PWM techniques for three-phase VSI are Sine PWM (SPWM) and space vector PWM (SVPWM). But to reduce harmonic content & increase magnitude of voltage space vector PWM (SVPWM) is better than SPWM. Also space vector PWM technique (SVPWM) instead of sine PWM technique (SPWM) is utilized 15% more DC link voltage. So using SVPWM techniques for 3 phase inverter switches & Output of inverter is fed to speed control of IM drives. Simulation is done in a MATLAB/ SIMULINK.

The circuit model of a typical three-phase voltage source

Bridge inverter is shown in Figure, S1 to S6 are the six power switches that shape the output, which are controlled by the switching variables a, a‟, b, b‟, c and c‟. When an upper switches is switched on, i.e., when a, b or c is 1, the

Corresponding lower switches is switched off, i.e., the

Corresponding a‟, „b or c‟ is 0.Therefore, the on and off states of the upper transistors S1, S3 and S5 can be used to

Determine the output voltage. [5]

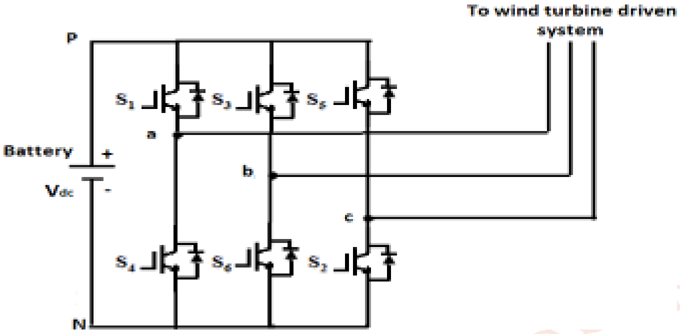


Figure 7 Six switch composition of converter

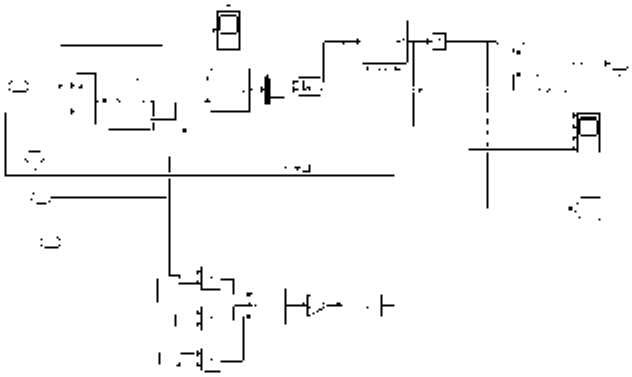


Figure 8 Subsystem Of gate pulse generation

Gate pulse generation has been done with the help of SVM modulator accomplished with synchronous reference frame theory. Fig 8 shows that the generation of input currents of SVM modulator.

Control system of inverter

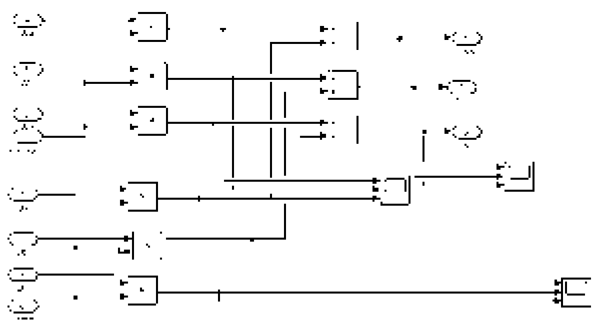


Figure 9 Control system of inverter

This control system of inverter consists of three main subsystems. The first subsystem is voltage measurement block. This block measured three phase voltage of load side as it varies as voltage magnitude varies. This voltage is then converted to terminal voltage, line voltage and rms value of phase voltage. The next is controller. The second block is controller; it is the heart of the inverter scheme employed. The detailed description is shown below. The V*LL rms gives the value of reference voltage line to line which we have to maintain across the grid and load .The V*LL is taken from the grid side which is then multiplied with the RMS value of the Load side phase voltage. The obtained value is again compared with the unit value. The obtained signal is then given to three phase PI controller. The values of proportion gain and integral gain is set to normalise the values of voltage, which is compared with unit input signals so that it will help to maintain the output of the inverter. This PI controller produces unit reference signals whose output is limited between1 to 1.5. The signal obtained from the PI controller is DC value, which doesn't contain the sinusoidal components. In order to make this a perfect sinusoidal values of unit magnitude, a PLL block is taken to match the bus sinusoidal voltage and frequency. The PLL is set to 50 Hz and zero degree so that it can produce unity power factor active power. Therefore we can say that our inverter produces the maximum power in this mode. The output of the controller is given to Discrete PWM generator. The discrete PWM generator compares the unit reference sinusoidal signal with the triangular wave, which then generates the firing pulses as using PWM Modulation technique.The Vt and Vt ref likewise Vdc and Vdc ref passes through controller. The output of this controller then passes through the PWM generator. This PWM generator compares the sinusoidal signal with the triangular wave and then generates the firing pulses by PWM modulation technique.[5]

PROPOSED MODEL

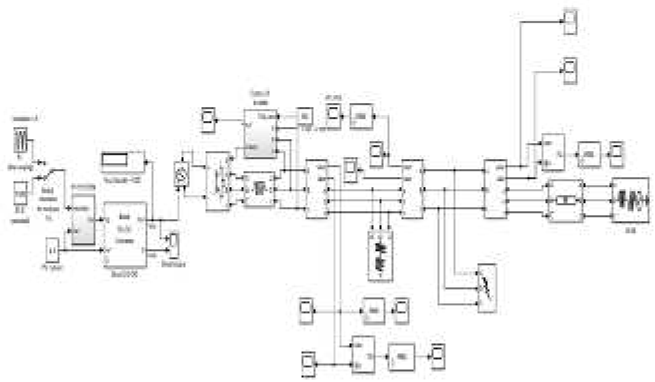


Figure 11 Proposed model

The proposed model describes a 30 Kw and 1000 VARs and 400 V is connected through common bus bar. PV modules are connected to produce approximately 700 V and this voltage is fed to the boost converter which boosts the voltage near about 800 V. The output is then passed through the inverter that converts DC into AC voltage. This inverter is used to control by firing pulses given by IGBT. The inverter is used to control the fundamental voltage magnitude and frequency of ac output voltage.

Various measurement system has been placed with the help of scope at various stages to measure all the parameters for the research and analysis at various stages of the system.

RESULTS

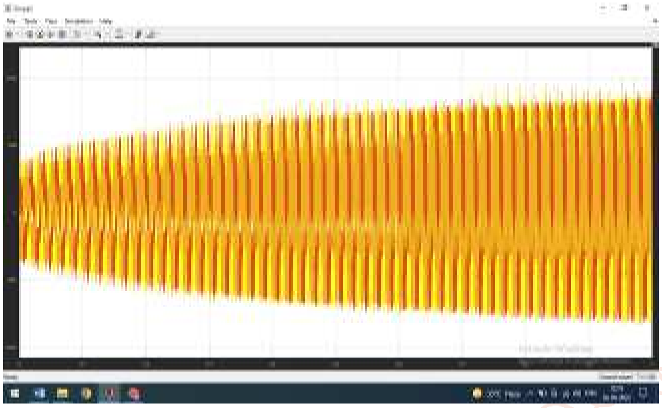


Figure 12 Three Phase Voltage

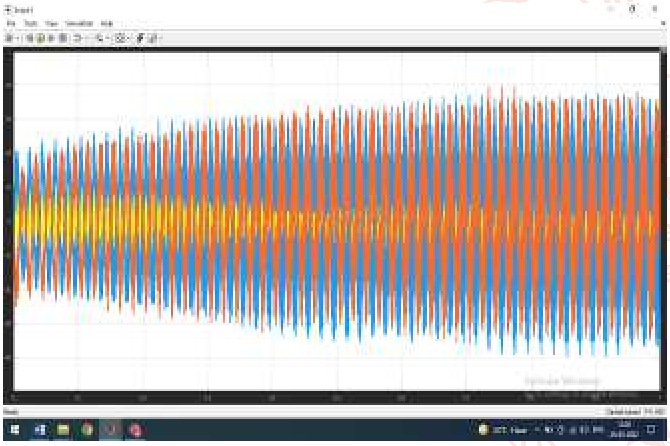


Figure 13 Three Phase Current

Figure 14 Active and reactive power

Figure 15 Vout and duty

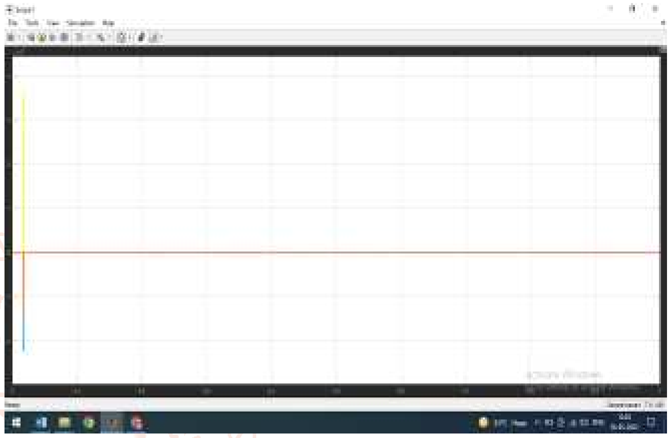


Figure 16 Current after Three phase fault

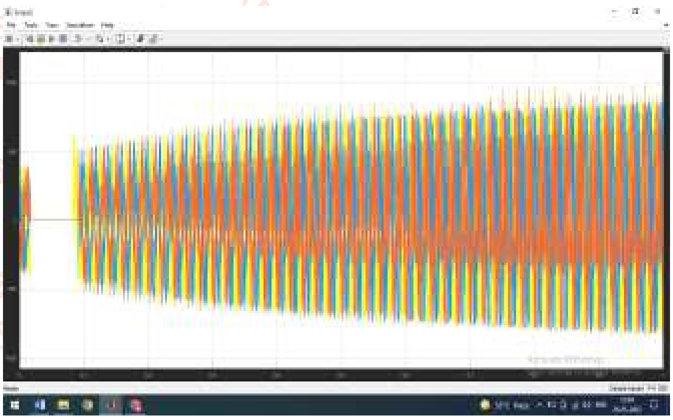
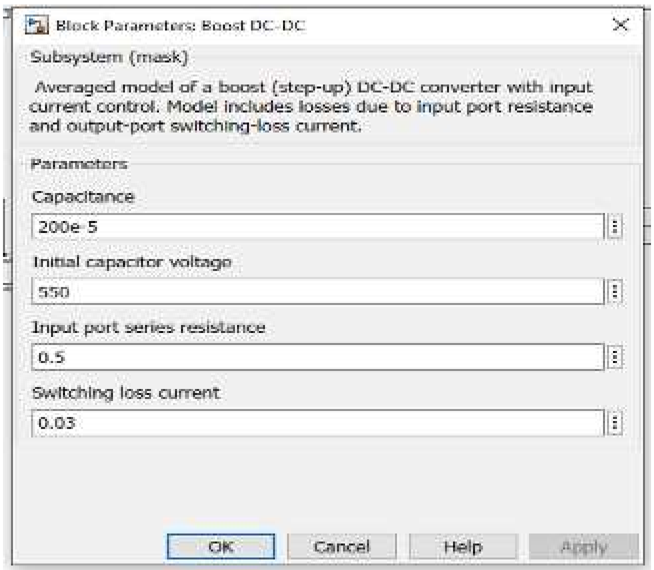
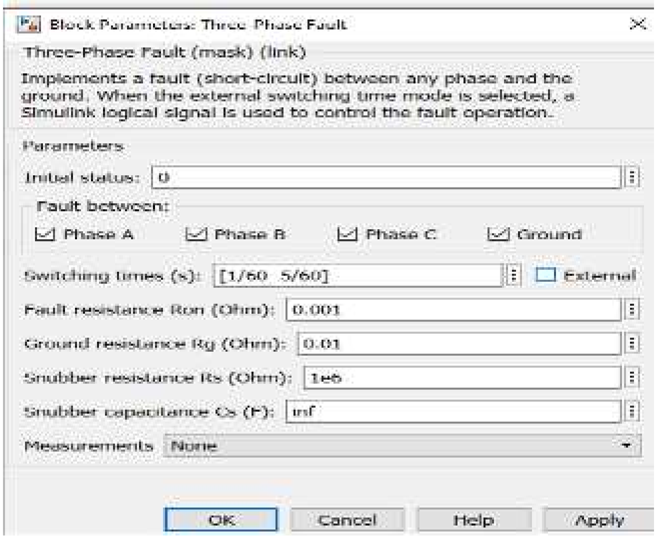


Figure 17 Voltage after Three phase fault

Boost Converter Parameters



Fault Parameters



CONCLUSION

The output voltage from the solar PV array ids near about 700 V and after the boost converter voltage boosted up to 800 volts and then after conversion into AC with the help of inverter we can see that the simulation is done for 60 seconds and the voltage gets increasing at the starting and become near about 1500 V and then gets steady state condition and remains constant. Active power increasing continuously up to 12000W.

After introducing 3 phase to ground fault in the system near grid the output shows that in between 0 to 0.1 seconds voltage seems to be near about zero value and current is extremely high during this period results in large losses.

Active and reactive power both increasing continuously with respect to time and it will also increase the harmonic distortion we can work further to reduce that harmonic distortion in our future work. Without fault the output is near about desired value and can also improve the waveform by better power quality improvement apparatus. THD can be reduced further by using different FACTS devices like SVC and STATCOM.

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