iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** XI **Month of publication:** November 2019

DOI: http://doi.org/10.22214/ijraset.2019.11034

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue XI, Nov 2019- Available at www.ijraset.com

Fault Analysis of Grid Connected Solar Photovoltaic System

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Abstract: A new method of present control strategy for the photovoltaic (PV) system connected to the grid is presented in this paper. The connection of the photovoltaic system with the grid is a difficult task because the solar radiation is a nonlinear quantity. The purpose of this work is to create a photovoltaic system is to develop a model in which maximum power point tracking (MPPT) system is implemented by implementing new control technology. The considered system includes a PV system, MPPT (incremental conductance) controller, boost converter, voltage source inverter (VSI), three phase filter, a control system, a distribution network, load and grid. Initially, the model of photovoltaic array was developed and then designed from an MPPT controller and a DC-DC boost converter. To connect the PV system to the grid, a power electronics converter is required which can convert the DC voltage to AC voltage in three steps. After that there is a simulation of the last model using MATLAB / SIMULINK and different output waves are analysed for different conditions. Finally, the fault analysis system is found to inspect the behaviour.
Keywords: Photovoltaic, MPPT, Incremental Conductance, VSI, DC-DC Boost Converter.

I. INTRODUCTION

Most of the energy in the world is obtained from the burning of coal primarily from fossil fuels. But this traditional method of generating electricity is a challenging issue because it contributes to greenhouse gas emissions. Apart from this, fossil fuels and all non-renewable resources are also being reduced over time and the population is generating electricity increasing.

On the other hand, renewable energy resources promise alternative solutions for these problems because they are considered permanent and clean sources. Therefore, these issues are being handled in the present Renewable resources that include solar photovoltaic, wind; tidal, wave and biomass are alternative sources for generating electricity [1].

For the last few decades, solar photovoltaic energy has turned into one of the important sources of renewable energy because it requires less maintenance and is noisy and pollution-free. Solar PV panels are used to power efficiently with power converters. This forms a photovoltaic system. There are various configurations of PV system. These standalone and grid-connected systems are the most important in configuration [1]. There are more advantages over the grid connected solar system electricity can be taken as standalone PV system or can be sent to electric grid on load demand. This reduces the cost of the bill because the net power consumption can be reduced by sending additional power to the grid. They can also be installed without battery backup.

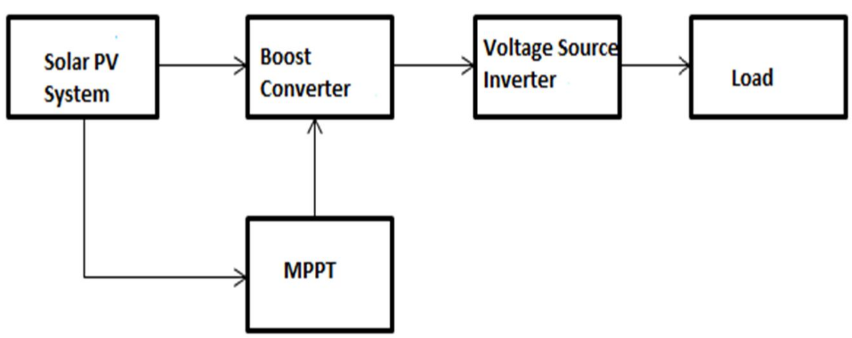

Fig. 1. Block Diagram of Solar PV System

A photovoltaic Installed without battery backup, the system produces more power because there is no storage loss in the system [2]. The grid-connected PV systems have been prepared using MATLAB / Simulink. The system presented is made of solar PV array, maximum power point tracker, to extract maximum power from PV array, in order to control PV arrays and increase the DC-DC boost converter, DC power into AC power; Inverter Output is an LC filter for filtering current harmonics from the present.

II. METHODOLOGY

A. PV Array

A solar cell is the basic unit of a photovoltaic (PV) system. The combination of solar cells in the series creates a PV panel or PV Module. These modules are connected in series and PV in parallel form Arrays. PV cell modelling [1] has been done by looking at single diode of PV cell. The basic diagrams and equations used for solar cell modelling have been considered. Based on the number of these equations have been modified total numbers of solar cells and series in these PV panels and these panels connected in parallel. Circuit diagram of single non-ideal solar cell is shown in Figure 2.

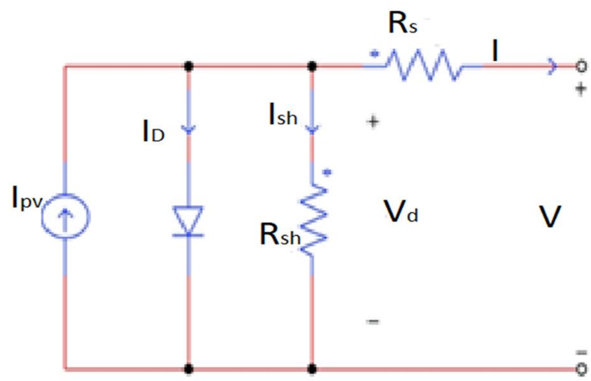

Fig 2. Single Diode Model of PV Cell

From the Figure 1 current equation can be written as

$$I = I_{pv} - I_D - I_{sh} \quad (1)$$

Where, I is the current generated by a solar cell, I_{pv} is the photon current, I_D is the diode current and Ish is the current flow through shunt resistor R_{sh}.

For solar cell [1]:

$$I_D = I_0 \left[\exp^{\left(\frac{V+IR_s}{aV_{th}}\right)} - 1\right] \quad (2)$$

$$I_{sh} = \frac{V + IR_s}{R_{sh}} \quad (3)$$

Equation (1) can be written now,

$$I = I_{pv} - I_0 \left[\exp^{\left(\frac{V+I\,R_s}{aV_{th}}\right)} - 1\right] - \frac{V + IR_s}{R_{sh}} \quad (4)$$

Where, I_0 is the reverse saturation current, R_s and R_{sh} are the series and shunt resistance of a PV cell respectively, a is diode ideality factor, V_{th} is the thermal voltage. It is given here.

$$V_{th} = \frac{KT}{q} \quad (5)$$

Where, K is Boltzmann constant = 1.23 x 10^{-23} J/K, T is the cell temperature, q is the charge of an electron = 1.6 x 10^{-19}C

Know the total number of solar-linked series N which is by solar panel / module and numbers Series Ns and parallel NP connected solar panels, current equation for PV array is given by:

$$I = N_p I_{pv} - N_p I_0 \left[\exp\left(\frac{\frac{V+IR_s}{N_s}}{aNV_{th}}\right) - 1\right] - \frac{V+IR_s}{R_{sh}} \quad (6)$$

B. Maximum Power Point Tracking (MPPT)

There is a non-linear behaviour in the solar PV array and due to the change in the weather conditions, its production often changes. MPP Tracker helps PV array give maximum power over its output and thus enhances system efficiency. This insulated-gate bipolar transistor (IGBT) sets a suitable duty cycle value at the gate of the switch which is used in the boost converter so that maximum power can be removed. Incremental conductance technique with internal regulator has been used to model MPPT. At maximum power point:

$$\frac{dP}{dV} = 0 \tag{7}$$

Now,

$$\frac{d(V \times I)}{dV} = \frac{dV}{dV} \times I + \frac{dI}{dV} \times V = I + \frac{dI}{dV} = 0 \tag{8}$$

Hence,

$$\frac{dI}{dV} + \frac{I}{V} = 0 \tag{9}$$

MPPT tests for $\frac{dI}{dV}$ and $\frac{I}{V}$ to be zero. If the sum is not zero, PI controller/regulator treats the sum as error and minimizes this error. The value received in the output of the PI controller is the change in the duty cycle value. It is added to the initial value of duty cycle (D). The initial D value is determined based on the requirement in the output of DC-DC boost converter. Modelling of MPPT is shown in Figure 3.

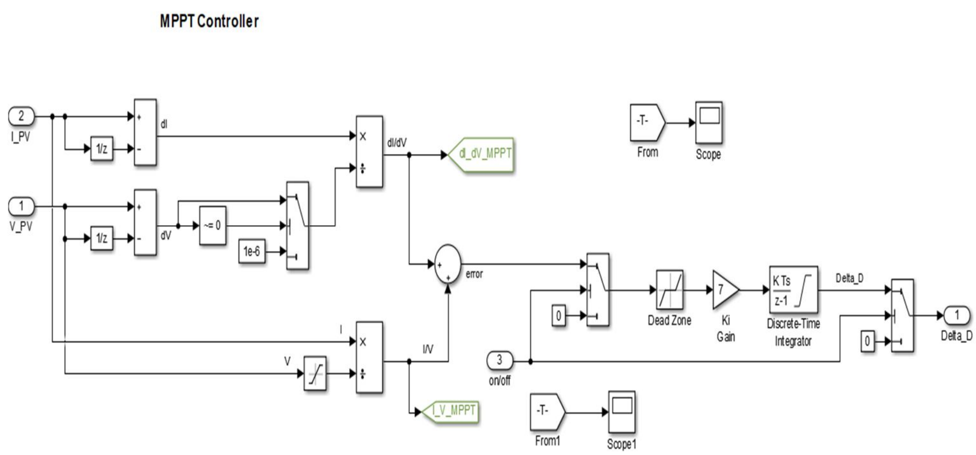

Fig 3. Maximum Power Point Tracking using Incremental Conduction

C. Boost Converter

Used to promote and regulate a DC-DC boost converter to apply the output voltage and maximum of PV array Power Point Tracking. The modelled boost converter circuit is shown in the Fig. 4. The converter output is given by:

$$V_0 = \frac{V_{in}}{1 - D} \tag{10}$$

In the circuit was selected using the inductor and capacitor the following equation

$$L > \frac{V_{in} x D}{f x \Delta t} \tag{11}$$

$$C_1 = C_2 = \frac{V_{out} D}{2f \Delta V_{out} R_{load}} \tag{12}$$

Where in these equations, V_0 is the output voltage V_{in} is the input voltage, D is the duty cycle value, f is the converter frequency, ΔI is current wave, $C_1$and C_2 capacitor capacitance, ΔV_{out} output voltage ripple and R_{load} is the load resistance given V_{out}/I_{out} .

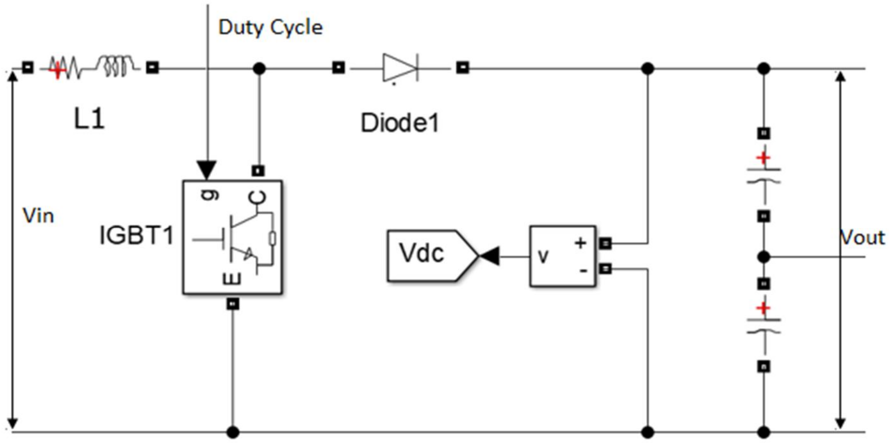

Fig 4. DC to DC Boost Converter Modelling

Table 1. Photovoltaic System Array (SPR-305-WHT)

Specification of the PV Panel (SPR-305-WHT)		
Peak Power (+/-5%)	Pmax	305 W
Rated Voltage	Vmp	54.7 V
Rated Current	Imp	5.58 A
Open Circuit Voltage	Voc	64.2 V
Short Circuit Current	Isc	5.96 A

D. DC to AC Converter

Three-phase three level voltage source converter has been used to convert DC power into AC. Simulink block used for this purpose is shown in Figure 5. Capacitors provide neutral on output of booster converter point N for Inverter. The gate signal on the inverter, the IGBT switch controls the on and off period. These signals are generated by the inverter control loop. Designed inverter control loop consists of

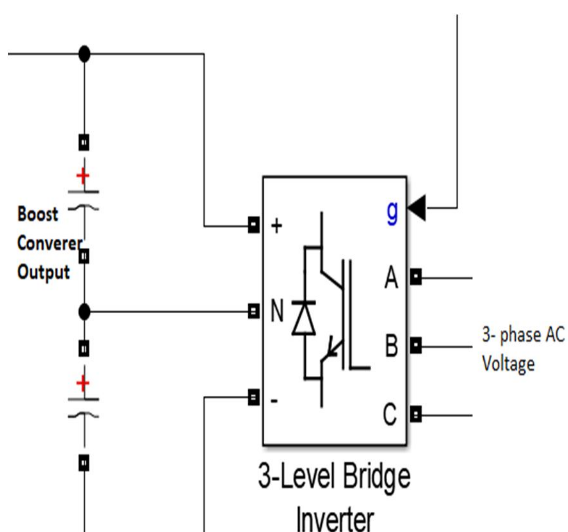

Fig 5. Simulink Three Phase Voltage Source Inverter Bridge Block

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III. SIMULATION RESULTS AND FAULT ANALYSIS

Simulation studies are performed on grid connected PV implemented with proposed MPPT techniques in MATLAB/Simulink. The results obtained from the simulations are taken with some specific values of the parameters.

The Fig. 6 shows the Simulink diagram of the proposed system. In this paper, a 33kV grid integrated PV system is simulated. At 1000 W/m2 solar irradiance the PV array delivers a maximum power of 100 kW at 1000 W/m2 solar irradiance, the PV array generates voltage of about 300V. The Voc, Isc, Vmp

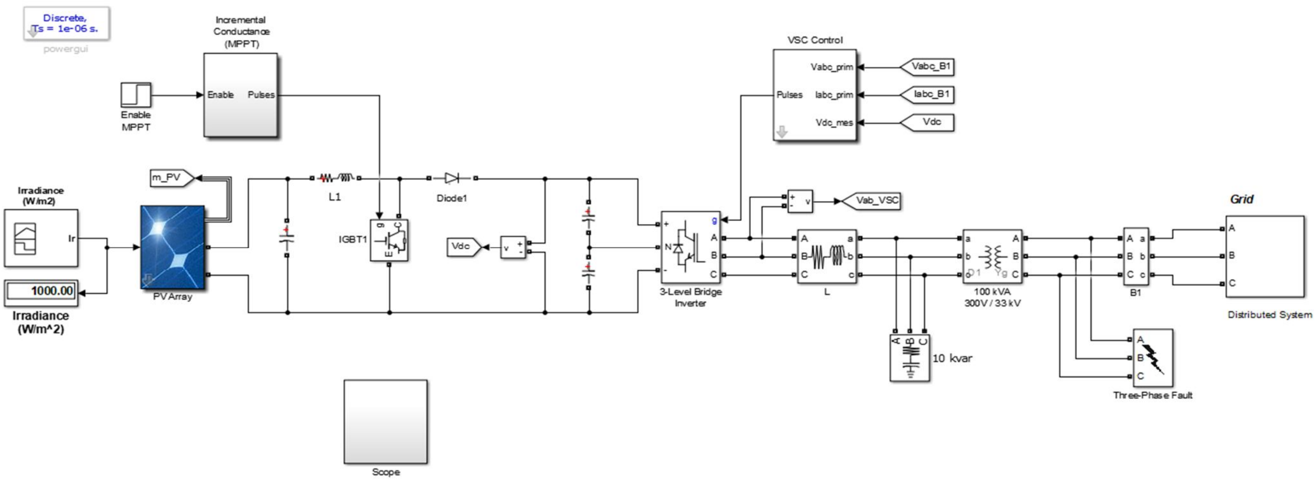

Fig6. Grid connected Solar PV System and Imp of one module of PV array are 64.2V, 5.96A, 54.7V and 5.58A, respectively. A three-phase Pi section line of 15 km length is chosen as a distribution network.

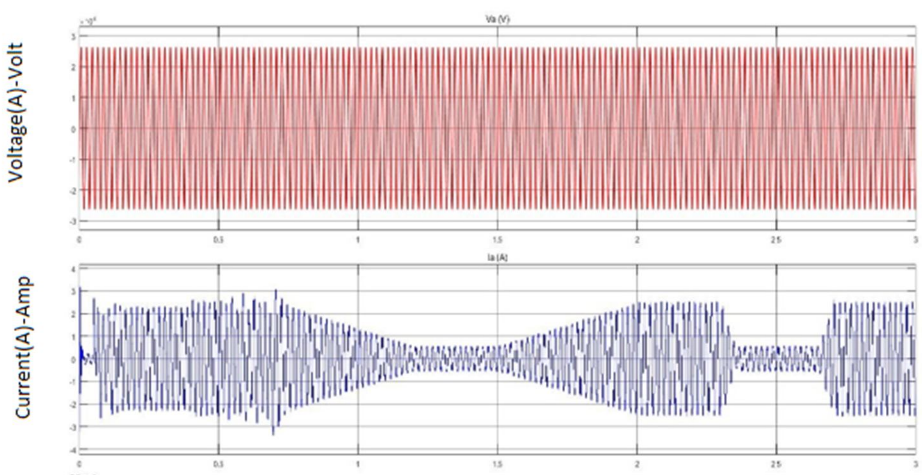

Fig 7. Three Phase AC Grid without Fault

A 10VAR load is connected to the distribution networks. Initially all the parameters are analysed at grid without a fault in the distribution network, The three- phase voltage and current generated at the grid. Fig. 8 depicts that at 1000 W/m2 solar irradiance, the PV array generates voltage of about 272V. The boost converter is increasing voltage from PV natural voltage to 300V DC voltage. Fig. 8 shows the curve of output.

Here, Fig.7 shows that three phase ac supply provide continuous signal at the grid. In first figure, single line shows without fluctuation voltage and second, single phase current shows due to change in radiation. Current is high at 0.7 S and 0.7 S to 1.2 S reduced the current and constant between 1.2 to 1.5 S, 1.5 to 2 S increase the current, 2 to 2.3 the value of system should be maximum. And instantly drop between 2.3 to 2.35 and go to the minimum voltage, 2.35 to 2.65 should be minimum power provide, and so on working shows and 2.7 to 3 S should be maximum as shows in fig 7.

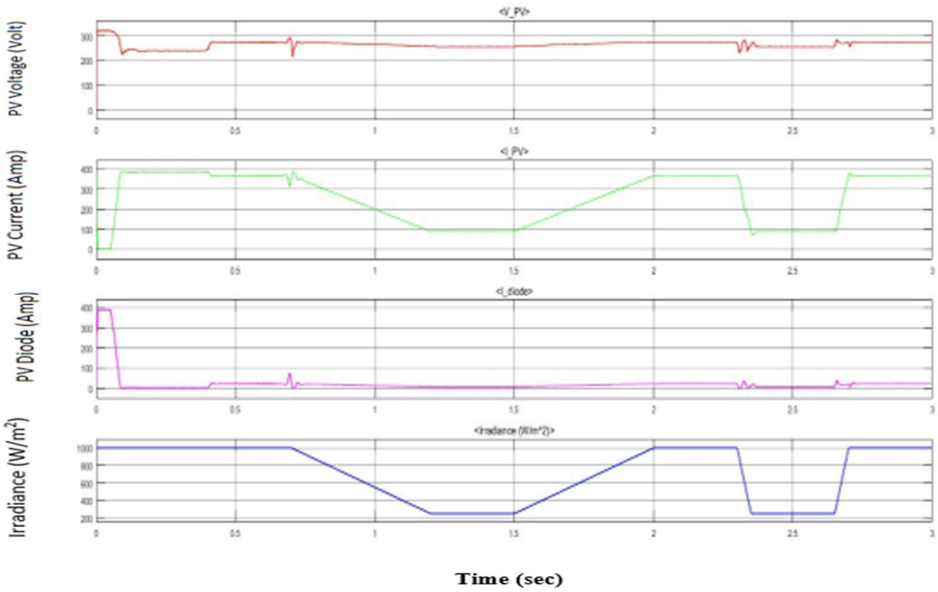

Fig 8. Photovoltaic System Voltage, Current and Radiance

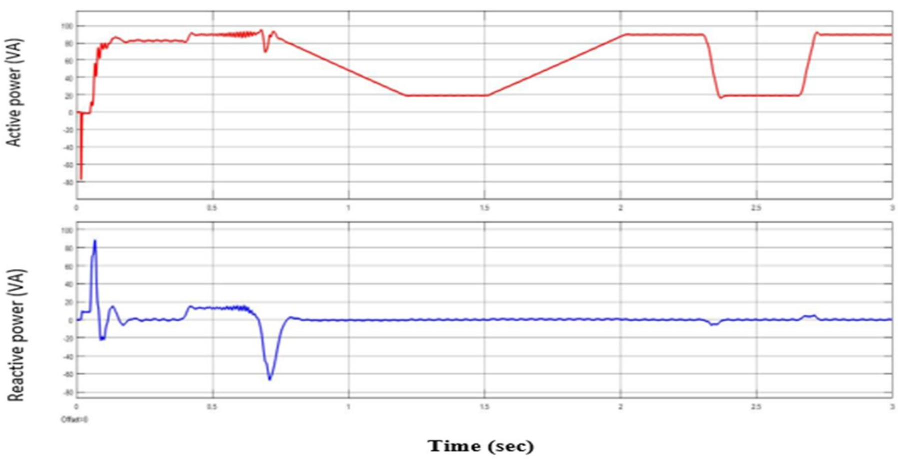

Fig 9. Active and Reactive Power of Three Phase AC Grid without Fault

A. Faults Analysis

Although there are many ways to check transient status and the stability of the system, only a few factors are taken into account. The next part shows about the dynamic performance of the plant. Here the system is tested under the worst fault conditions i.e. symmetric fault in AC side. Fault analysis is done on grid connected PV systems in MATLAB / Simulink to analyse the dynamic behaviour of the system. The behaviour of the PV system is also checked during the event of a mistake. Three-phase line to ground fault, single phase line to ground fault and line-to-line fault are a common fault in industrial environment. which is actually very dangerous for power electronics-based converters. Due to the rapid reaction of semiconductor devices, the voltage dip and current flow have to be controlled to avoid any damage to the equipment.

1) Case 1: Three Phase AC Grid with LG Fault

Initially all the parameters are analysed at grid without a
fault in the distribution network. The DC voltage delivered given the voltage delivered by PV inverter after filtering. Fig.10 show the three- phase voltage and current

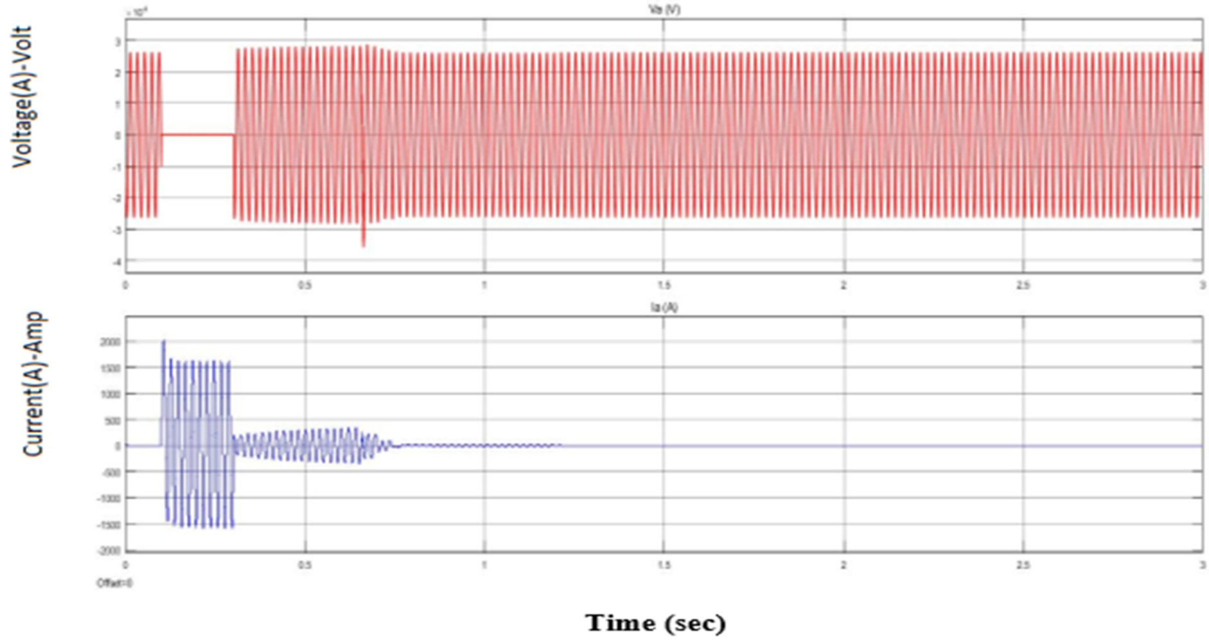

Fig 10. Three Phase AC Grid with LG Fault generated at the grid. Fig.10 give the idea about active and reactive power injected to the grid. Fig. 11 depicts that at 1000 W/m2 solar irradiance, the PV array generates voltage of about 272 V. The boost converter is increasing voltage from PV natural voltage to 300 V DC voltage.

The behaviour of the three-phase current during the LL mistake is shown in Figure 11, which indicates that before the initiation and with injection, the fault in 0.4 seconds increases to the current 2000A. Usually the current return duration at 1-5A after its normal value The result shows that at present there is a sudden increase in the initial time before the reduction of the stabilized phase at 2000 to about 0.7 seconds during the time period.

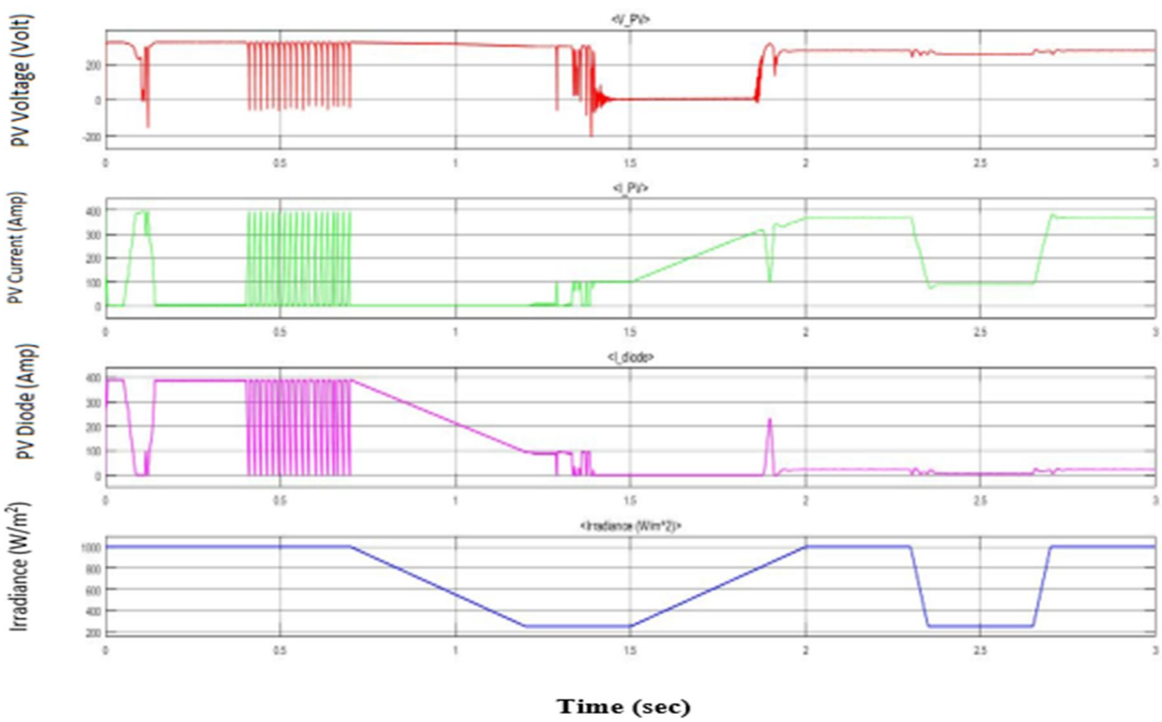

Fig 11. LG Fault Effect on PV Panel Parameters

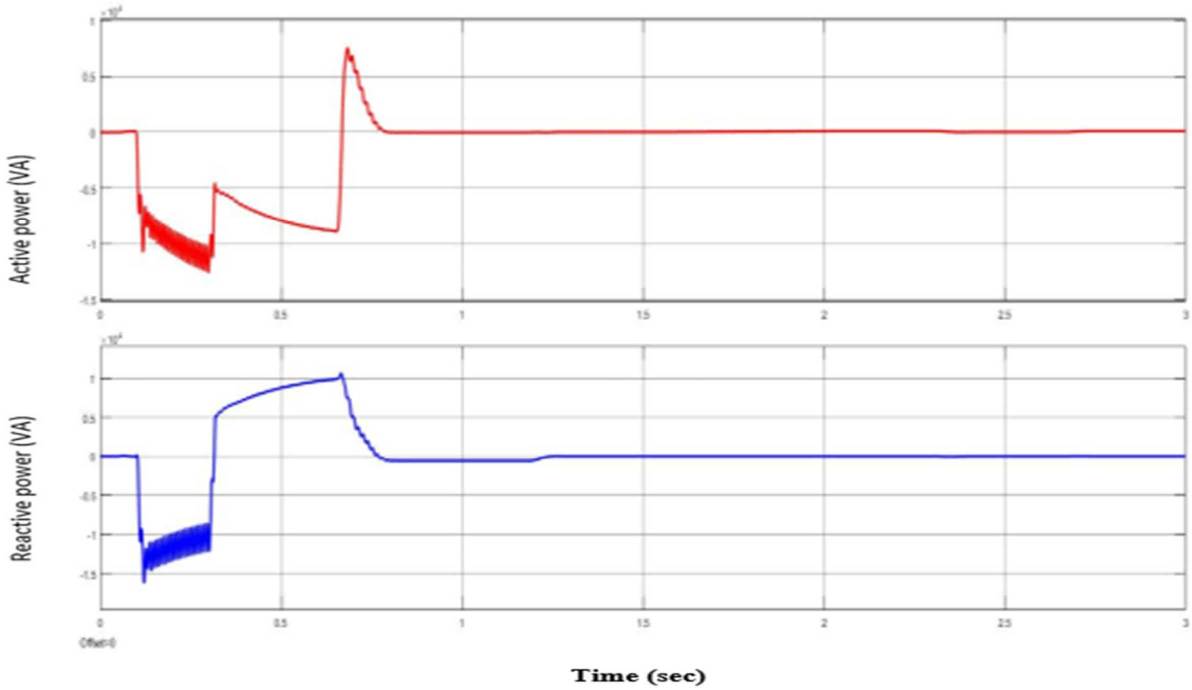

Fig 12. Active and Reactive Power of Three Phase AC Grid with LG Fault

2) *Case 2:* Three Phase AC Grid with LL Fault

The behaviour of the three-phase current during the LL mistake is shown in Figure 14, which indicates that before the initiation and with injection, the fault in 0.4 seconds increases to the current 2000A. Usually the current return

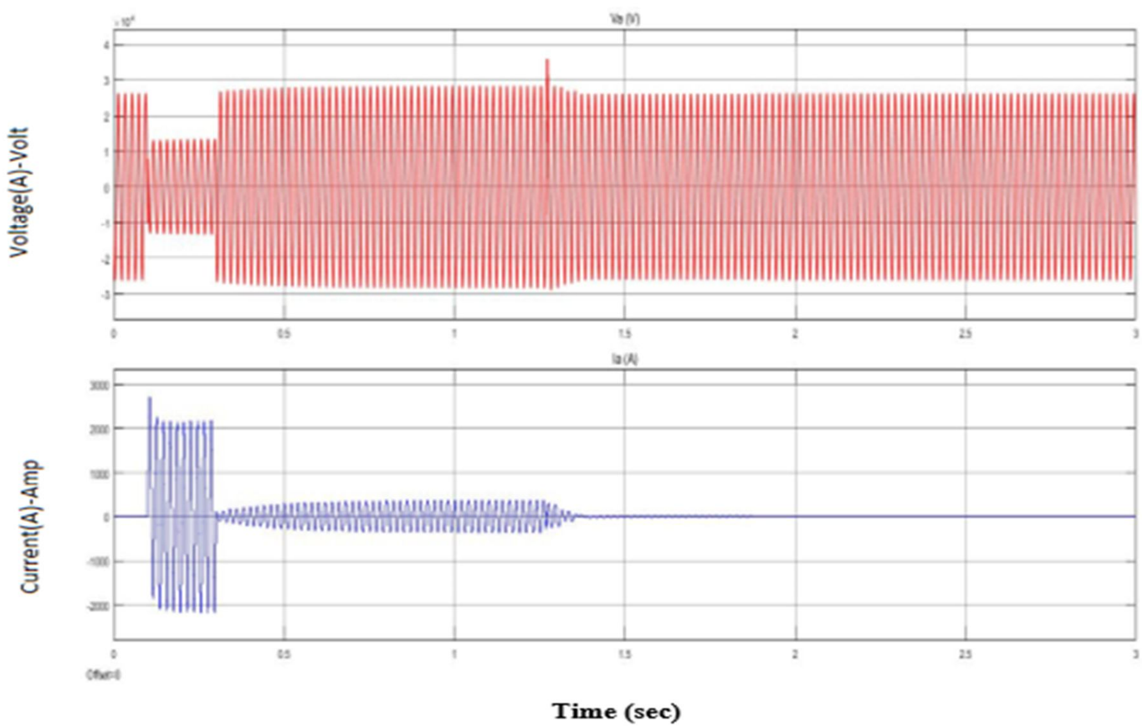

Fig 13. Three Phase AC Grid with LL Fault

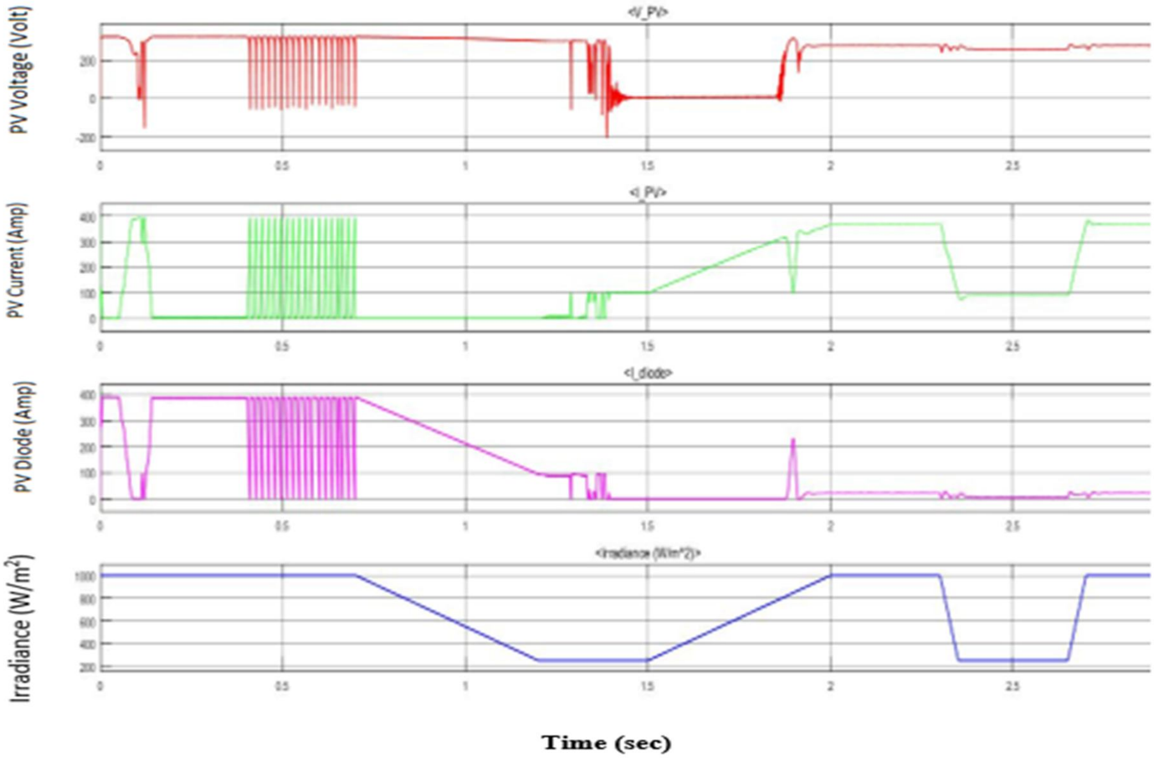

Fig 14. Photovoltaic System Voltage, Current and Radiance with LLLG Fault

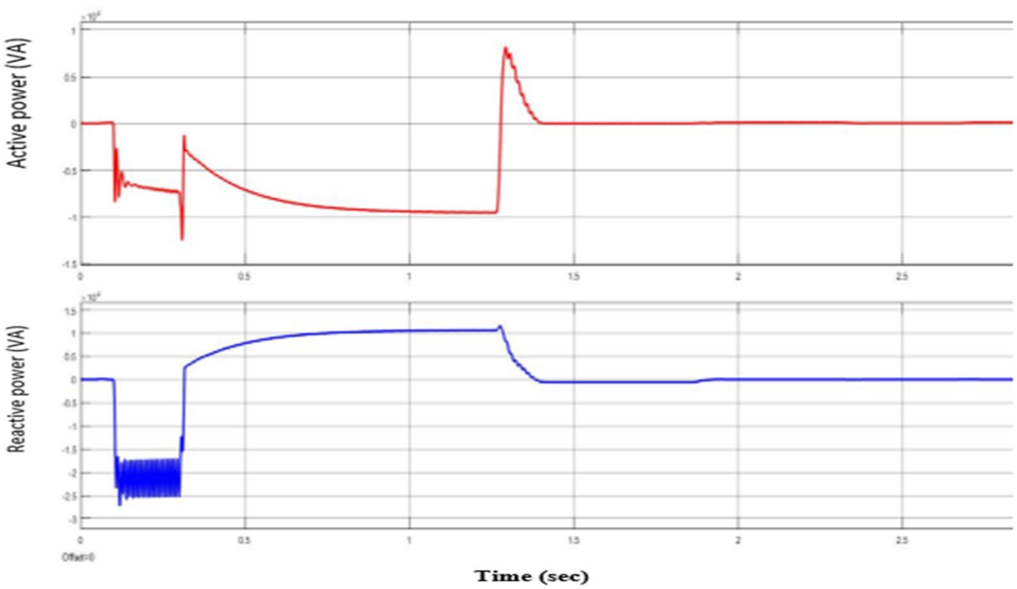

Fig 15. Active and Reactive Power of Three Phase AC Grid with LL Fault

3) Case 3: Three Phase AC Grid with LLLG Fault

The behaviour of the three-phase current during the LLLG mistake is shown in Figure 17, which indicates that before the initiation and with injection, the fault in 0.4 seconds increases to the current 2500A. Usually the current return duration at 1-5A after its normal value The result shows that at present there is a sudden increase in the initial time before the reduction of the stabilized phase at 2500 to about 0.7 seconds during the time period.

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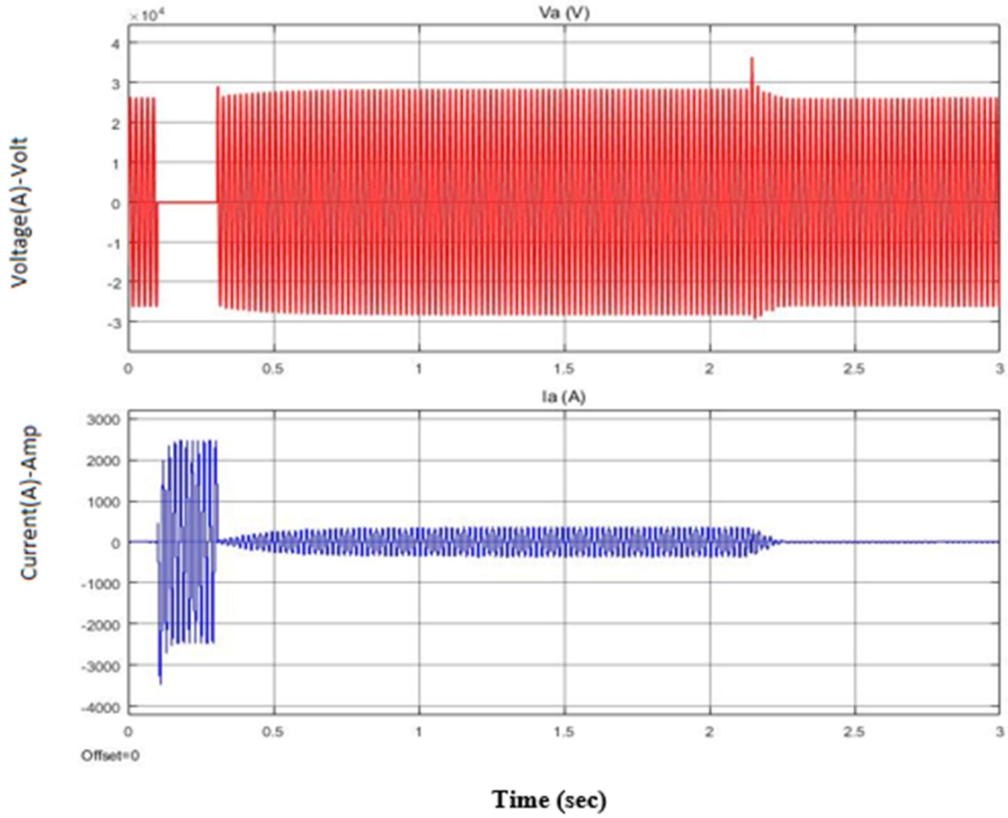

Fig 16. Three Phase AC Grid with LLLG Fault

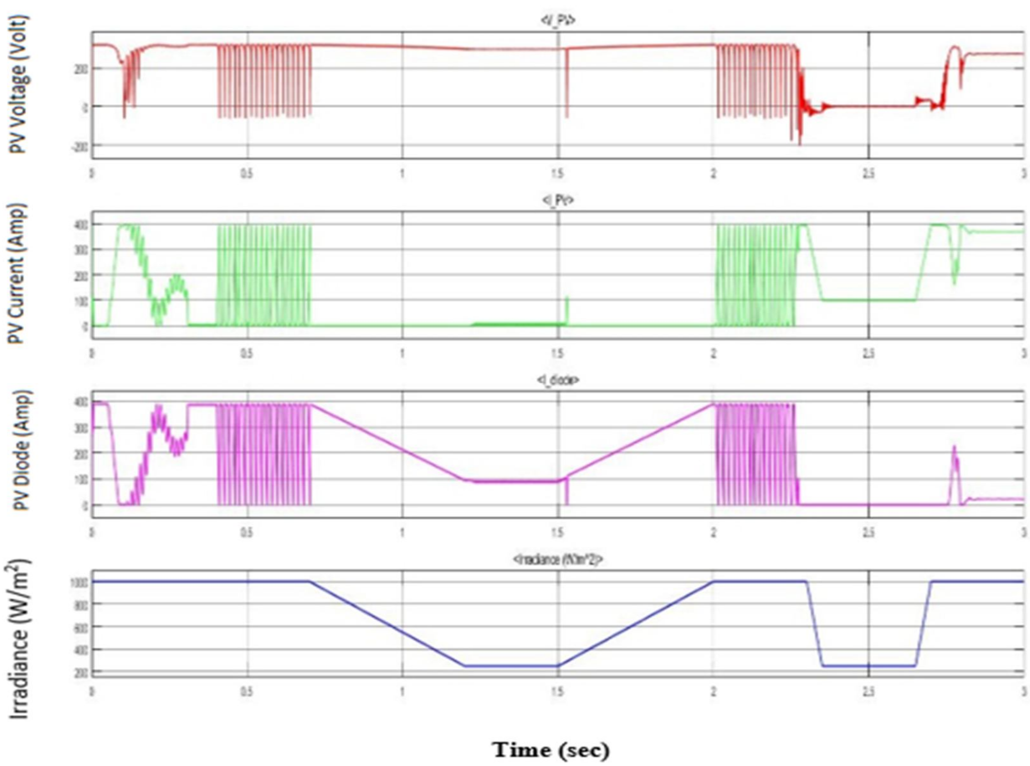

Fig 17. LLLG Fault Effect on PV Panel Parameters

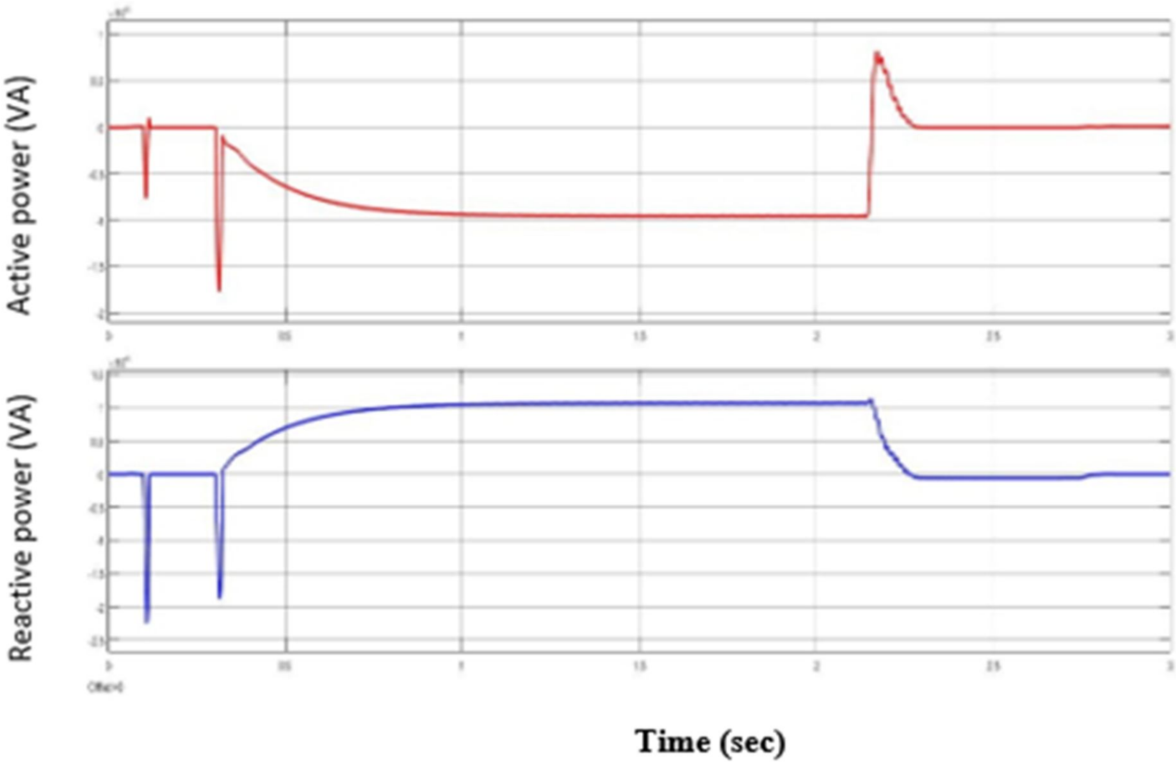

Fig 18. Active and Reactive Power of Three Phase AC Grid with LLLG Fault

IV. CONCLUSION

In this paper, a 33kV grid integrated PV system is simulated on the Matlab/Simulink. the study of the photovoltaic system with maximum power point controller has been developed. From the theory of the photovoltaic, a mathematical model of the PV system has been presented. Then, the photovoltaic systems with DC-DC boost converter, maximum power point controller, voltage source inverter and grid have been designed.

The following conclusions made from this work are as follows:

A. Analyse the graph of the PV Panel of the Single Module and Array Module.
B. Analyse the three different type faults and test voltage and current behaviour.
C. Solar PV system generated 100 KW energy. And under fault condition, this system work very well. And After fault its work without any disturbance and provide good result
D. Solar PV system tested on three type of fault LG fault, LL Fault, LLLG Fault.

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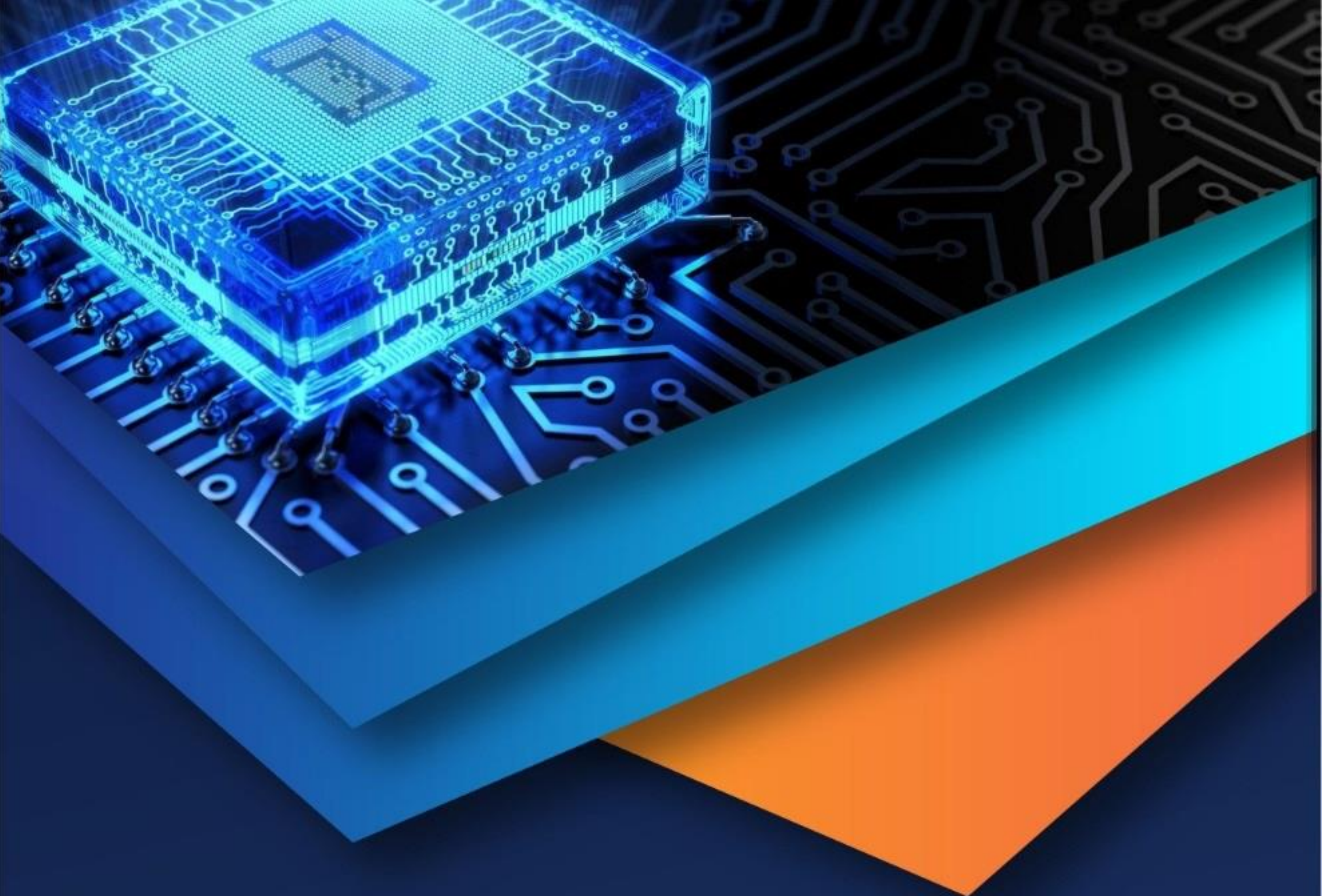

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