Journal of Energy Research and Environmental Technology (JERET)
p-ISSN: 2394-1561; e-ISSN: 2394-157X; Volume 3, Issue 1; January-March, 2016; pp. 6-11

http://www.krishisanskriti.org/Publication.html

Grid Connected PV System based Fault Analysis

Saurabh Kumar Singh[1], Ashish Kumar[2], Puja Bharti[3] and M.A. Ansari[4]

[1,2,3,4]*Gautam Buddha University*
E-mail: [1]singhsaurabh5193@gmail.com, [2]ashishelectrical025@gmail.com,
[3]pujabharti025@gmail.com

Abstract—*In the Modern time, Renewable source of energy is use as vast as compare to non-renewable source of energy. Solar energy is the renewable energy which is use to convert sun to electrical energy by the PV (Photo-Voltaic) array. PV array are used to generate the electricity which connected with grid system. MPPT is used to track the maximum power. DC-DC converter is used to increase the voltage whose name is boost converter. The grid connected PV system is not assured the system is safe for faults and their effect. Grid system directly connected with three phase inverter. In this paper, Analysis of fault condition in grid connected PV system in which Perturb- and Observe (P&O) algorithm is used. In the Power System, ten type of fault are their namely- Single line to Ground Fault (r-g, b-g, y-g), Double Line to ground Fault (r-b-g, b-y-g, y-r-g), Line to line fault (r-b, b-y, y-r) and three phase fault (r-b-y or r-y-b-g).*

1. INTRODUCTION

The renewable energy resources demand is increased in past few years. The non-renewable energy sources harmful effect on environment. Renewable energy most reliable form is solar energy. Solar energy is the fastest growing energy sources. Photo-Voltaic (PV) panel is used to generating electrical power from solar energy. Photovoltaic is used to conversion of sun rays into direct electricity. Photovoltaic panel advantage is pollution free and less maintenance required no noise produce because here is not moving part. Solar energy is presented freely in nature. Its installation cost is low and can be installed on the roof of the building. Solar energy is presented only during day time. Here photovoltaic used to grid connected system. Stand-alone PV system is mostly used in rural area. The output power of PV system is effected due to the irradiation and temperature.

The output power of PV array is depend upon irradiance and temperature. The output power of solar cell is low then we need to obtain maximum power output from a solar cell which required MPPT (Maximum Power Point Tracking). MPPT is a power electronics system to get better the PV system efficiency [1]. MPPT is used in DC-DC converter to control the duty cycle. MPPT algorithm implemented on DC-DC converter to reach maximum power of PV array. Here we use perturb and observe MPPT algorithm. The PV array output power is dc then we use DC-DC Boost converter. The DC-DC Boost converter is stepping-up or regulating the PV system output voltage before DC-AC inverter. The power electronics devices is required to convert DC power into AC power. Here we used three phase inverter which convert DC to AC power. The PV array is connected with the grid system. The AC power is transmit in the grid by use of DC-AC converter. AC power throughout the inverter sent to the grid using the transformer in between them [2]. A grid system is an interrelated network in the electrical grid system. Through a high–voltage transmission lines the power transmitted to substations from far sources that link the power to the consumers via distribution lines. The PV array produce output characteristics such as power-voltage (P-V) and current-voltage (I-V) curve are depending upon usually two variables one is solar irradiance and other one is temperature. To produce electricity the grid connected-PV system is one of the best way [3]. As long as there always be a fault produce. The fault produce in the system accidently no matter system is perfectly built. In a grid connected PV system the fault occur anywhere in the system. The fault occur any part of system is effected whole system.

In this paper analyze the fault in grid-connected PV system. Ten types of fault occur in grid system which under in single line to ground fault, double line to ground fault, line to line fault, three phase fault and observe the ac power, ac current, ac voltage waveforms at the grid side with and without fault [4,5]. To conduct this simulation was performed using MATLAB®/Simulink system. The whole system efficiency which depends up on the type of converter which is used. For grid connected PV system, we used boost converter because of its simplicity.

The output power of solar PV array change due to varies of solar irradiation and change in weather. Therefore, the maximum power point tracking (MPPT) algorithm implemented in converter to ensure that PV array operates at maximum power point. Here we used two transformer in PV Grid connected system.

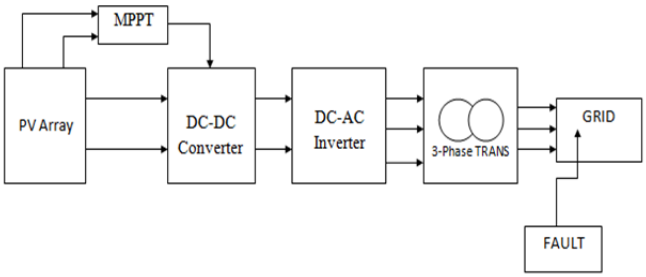

Fig. 1: Block Diagram of system

2. PHOTOVOLTAIC CELL (SOLAR CELL)

Solar cell is used to direct conversion in electrical power of solar energy. A PV system is collected by many strings of solar cells connected in series and in parallel combination, in order to grant desired values of output voltage and current. The model of PV cell two input parameters, i.e. temperature (°C) and solar irradiation (W/m2) [6]. An equivalent electric circuit of a photovoltaic cell is presented in Fig2.

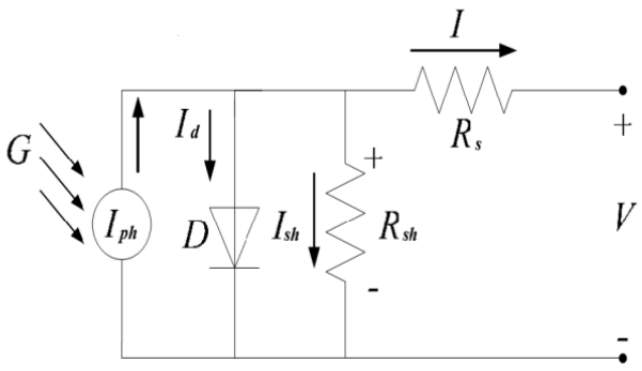

Fig. 2: Equivalent circuit of solar cell

Equivalent circuit of a solar cell that can be treat us a Current source, a diode, a parallel resistor and also a series resistor which helps the flow of current.

The load current is given by,

$$I = I_{ph} N_p - I_d - I_{sh} \quad (1)$$

Where, the photo current is given by,

$$I_{ph} = G_k [I_{sc} + k_I (T_{op} - T_{ref})] \quad (2)$$

The diode current is given by,

$$I_d = [e^{\frac{(V + IR_s)}{(nV_t C N_s)}} - 1] I_s N_p \quad (3)$$

The current flowing through the parallel resistance is given by,

$$I_{sh} = \frac{V + IR_s}{R_p} \quad (4)$$

The saturation current is given by,

$$I_s = I_{rs} (\frac{T_{op}}{T_{ref}})^3 e^{[\frac{qEg}{nk}(\frac{1}{T_{op}} - \frac{1}{T_{ref}})]} \quad (5)$$

The reverse saturation current is given by,

$$I_{rs} = \frac{I_{sc}}{[e^{(\frac{V_{ocq}}{kCT_{op}{}^n})} - 1]} \quad (6)$$

Where,

I is current at terminals of PV cell [A]

I_{ph} is the photoelectric current [A]

I_o is the reverse saturation current [A]

V is the cell voltage [V]

T is cell temperature [K]

q is the electron charge (1.6e-19 coulombs)

K is the Boltzmann constant (1.38e-23 J/K)

n is the diode ideality factor (unit less)

R_s is the series resistance (ohm)

R_p is the parallel resistance (ohm)

G_k is the solar irradiance ratio.

E_g is the Band-gap energy of the cell, 1.12eV.

N_s is the number of cells connected in series.

N_p is the number of cells connected in parallel.

T_{op} is cell operating temperature,

T_{ref} is the Reference temperature at 250 c,

I_s is Module saturation current,

I_{rs} is Diode reversed saturation current at operating temperature

V_{oc} Open Circuit Voltage

V Output Voltage

To increase the output power individual solar cell are interconnected together in series is called module [10]. Here module consists of 36 solar cell. When number of module connected in series and parallel is called PV array [7].

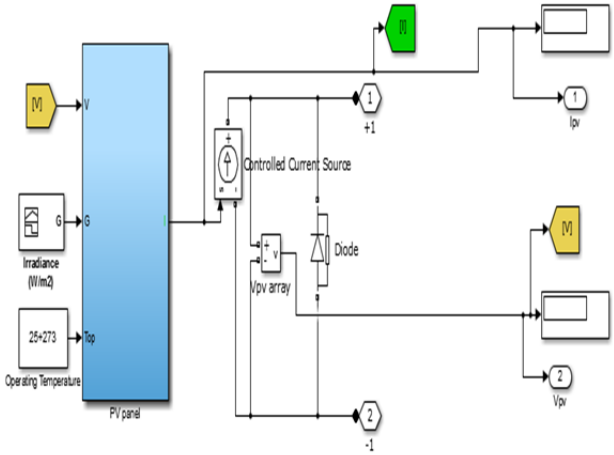

Fig. 3: Simulink Model of PV Module Irradiance for PV module is 1000W/m2 and reference temperature for PV module is 298K (25oC).

Table 1: PV module parameters

Parameter	Value
Open Circuit Voltage (Voc) of a PV module	21.1V
Short circuit current (Isc) of a PV module	3.8A
Series resistance (Rs) of a PV module	0.18ohm
Parallel resistance (Rp) of a PV module	360.002ohm
No. of cell in Module	36
Operating temperature of a PV module	25oC
Solar irradiance	1000W/m2

PV module characteristics:

The characteristics of PV module is depends upon irradiance and temperature. The PV and IV characteristics of PV module when solar irradiance is 1000W/m2, 800W/m2 and 600W/m2 and temperature is 25oC shown in Fig.

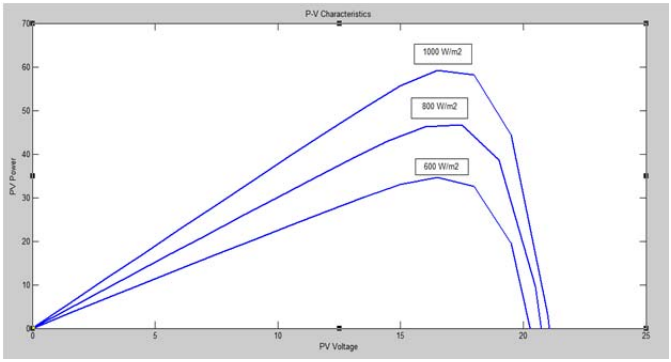

Fig. 4: Characteristics of PV module (P-V)

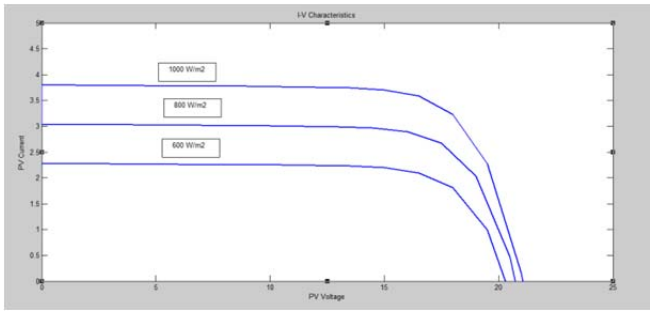

Fig. 5: Characteristics of PV module (I-V)

3. MPPT TECHNIQUE

MPPT technique is use to find the current and voltage at which PV array occurs maximum power point. MPPT technique used with solar panel. Advantages of it's primary investment is smaller because smaller panel power is required. The amount of maximum power that can be extracted from a solar panel which depend upon

Solar irradiance and temperature. With the use of the DC-DC converter the maximum power can be execute by controlling the DC-DC converter duty cycle. The tracking of the most favorable terminal voltage can be performed by various algorithms. There are different techniques used to track the maximum power point. Here we use Perturb and Observe algorithm for tracking the maximum power point.

Perturb and Observe (P&O) Algorithm.

Perturb & Observe (P&O) is the simple method that is Usually used. PWM signal generate by the duty cycle which introduced in power electronics DC-DC boost converter.

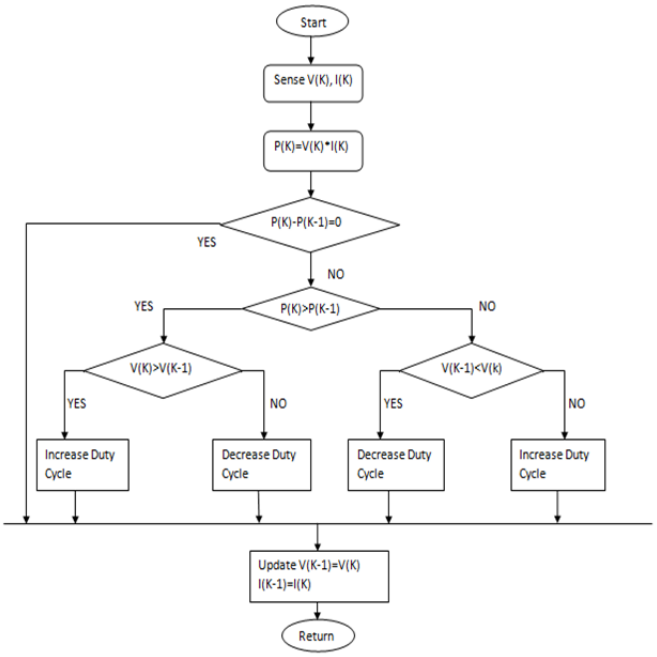

Fig. 6: Flow chart of P&O algorithm

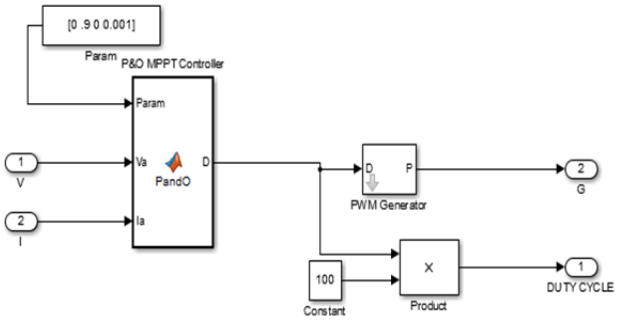

Fig. 7: MATLAB/SIMULINK model of P&O algorithm

4. BOOST CONVERTER

PV array output current increases when increase the solar irradiance and PV array output voltage decreases when increases the module temperature. So output power of PV array depends upon solar irradiance and module temperature parameters. Due to the presence of shadow, cloud, rain etc these two parameter change at any time.

Hence, a boost DC-DC converter is used to regulate the system and convert low DC voltage to high DC voltage.

A boost converter consist an inductor, a capacitor, a diode and an IGBT which act as a switch. The inductor begins to charge from input voltage when the switch is ON. The flow of current from the source to the load is restricting by the diode. The output voltage is provided by the capacitor [9]. When the switch turns OFF, The magnetic field of inductor begins to breakdown. The field generates current and the reverses polarity of the inductor's voltage. This voltage combines with input voltage, hence input voltage produce a high voltage. For this the diode is forward–biased, allows the current to flow for the capacitor to recharge it.

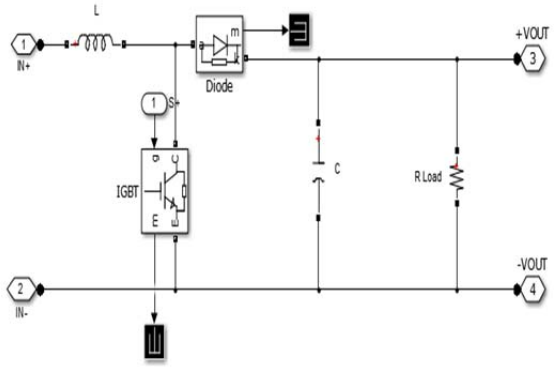

Fig. 8: Boost Converter equivalent circuit

Table 2. Parameter

Irradiance (W/m2)	PV Module Output Power(W)	Boost Converter Output Power(W)	Load (ohm)
1000	929.3	1498	5
1000	722.1	1465	10
1000	595	1253	15
1000	516.6	1048	20
1000	468.5	881.4	25

All the value on 25oC temperature. In grid connected PV system the Inverter is connected after boost DC-DC converter. Inverter is used to convert DC to AC in 3-Phase power. Two transformer are connected first transformer is used to convert 260 volt to 25 kilovolt. And second transformer which convert 25 kv to 120 kv.

Table 3: Parameters of the system

Quantity	Value
Gridvoltage	260V
Frequency	50Hz
Switching frequency	5kHz
Boost converter inductance	1mH
Boost converter capacitor	1000mF
Grid voltage	25kV
Inverter voltage	260V
Transformer1	260V/25kV
Transformer2	25kV/120kV

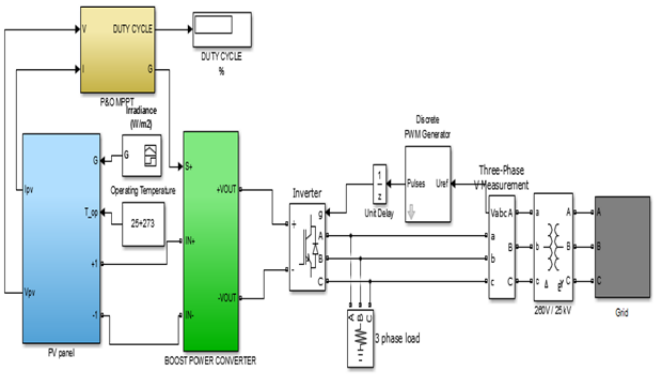

Fig. 9: Block diagram of solar array connected with grid

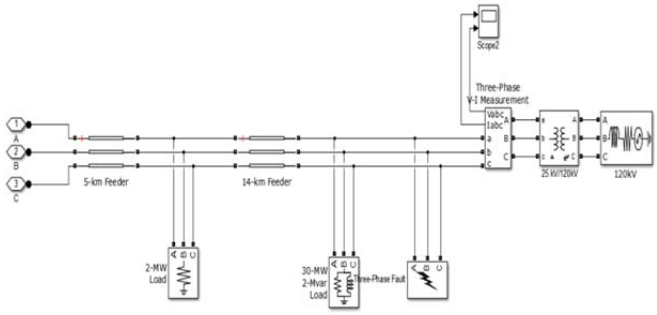

Fig. 10: Grid connection structure

5. FAULT ANALYSIS

In the PV array grid connected system, Create the fault in the grid system for analysis to detect the fault. Fault are generated by the three phase fault block components.

Line Fault are mainly two type symmetrical and unsymmetrical fault. In symmetrical fault, three phase fault are come. Symmetrical fault are also called as balanced fault. Unsymmetrical fault has three type namely- SLG (Single line to ground fault), DLG (Double line to ground fault), LL (Line to line fault).

Mostly SLG fault are occurs in the overhead grid system. Overhead transmission and distribution line occurs 99% in India.

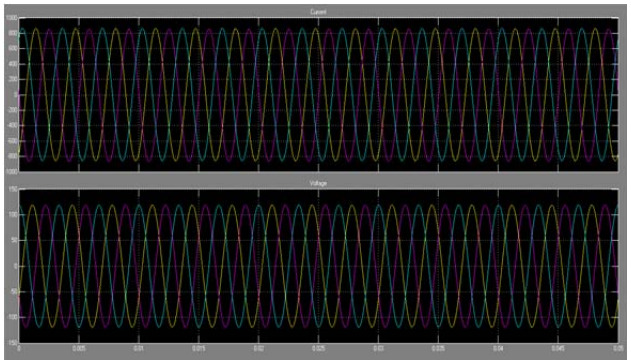

Fig. 11: Without fault of current and voltage waveform

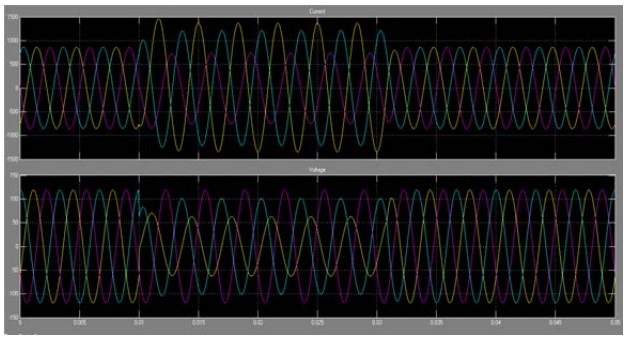

Fig. 12: SLG fault of current and voltage waveform

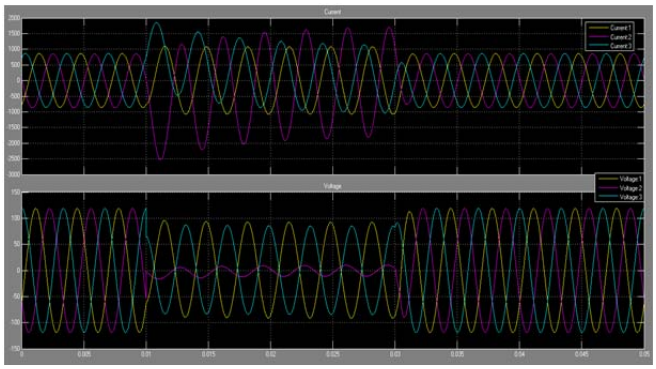

Fig. 13: DLG fault of current and voltage waveform

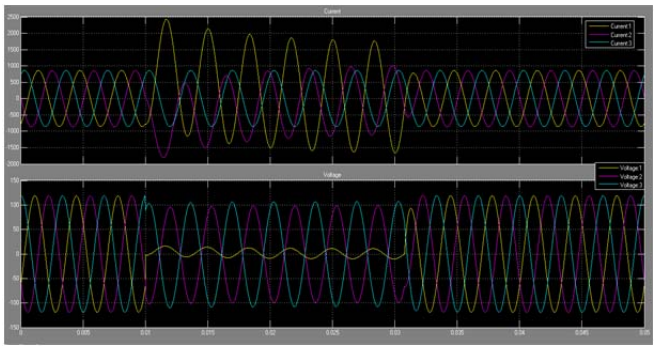

Fig. 14: LL fault of current and voltage waveform

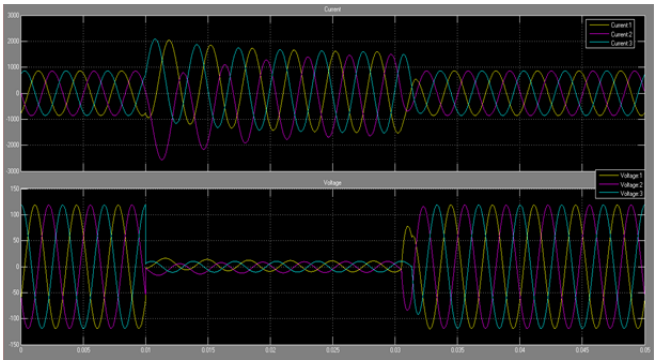

Fig. 15: Three phase fault of current and voltage waveform

All these waveform helps to detect the fault and know about the pattern if any fault are occurs in the system.

6. CONCLUSION

Solar Array is renewable source of energy. From solar array convert sun to electrical energy in dc. This DC source convert into AC. AC source connected to the grid connected system which help to transfer the power from solar to grid connected system. Fault analysis with the help of their waveform. This waveform help to detect the fault in the system. After detection of fault, clear the fault as soon as possible. All the detection are on the current basis because in line fault, current factor are more dominant.

REFERENCES

[1] Almoataz Y. Abdelaziz1, Hadi M. El-Helw2 and Basem Abdelhamed3,"Transient Analysis of Grid-Connected Photovoltaic System Based on Comparative Study of Maximum Power Point Tracking Techniques", *International Journal of Advances in Power Systems (IJAPS)* Vol. 1, No. 3, December 2013.

[2] Sujata. M. Bagi, N. Jayakumar and Thrivonasundari. D, "Performance Analysis of Power Flow Controller for Photovoltaic Generation System using MATLAB/SIMULINK", *International Journal of Engineering Research & Technology (IJERT)*, ISSN: 2278-0181 Vol. 3 Issue 3, March – 2014.

[3] Listhianne Willy Anak Badi and Zuhaina Zakaria, "Unbalanced Faults Analysis in Grid – Connected PV System", *IEEE International Conference Power and Energy*, December 2014.

[4] K.Manohar and P.Sobha Rani, "Mppt and Simulation for a Grid-Connected Photovoltaic System and Fault Analysis", *The International Journal of Engineering And Science (IJES)*, Vol-1, Issue- 2, pp. 158-166, ISSN: 2319 – 1813, ISBN: 2319 – 1805, 2012.

[5] Sibasish Pandaa, Anup Kumar Pandab and H.N Pratiharia, " Fault Analysis on Grid Connected MPPT based Photovoltaic System", *International Journal of Current Engineering and Technology*, ISSN 2277 – 4106, 2013.

[6] W. Chine, A. Mellit, A. Massi Pavan and S.A. Kalogirou, "Fault detection method for grid-connected photovoltaic plants", *ScienceDirect Renewable Energy*, 2014.

[7] Abbas Haijing and Zulkeflee khalidin, "Fault Condition Analysis in a Grid Connected PV Energy System", *International Conference on Circuits, System and Simulation*, IPCSIT, vol-7, IACSIT Press, Singapore, 2011.

[8] Tekeshwar Prasad Sahu and T. v. Dixit, "Modelling and Analysis of Perturb & Observe and Incremental Conductance MPPT Algorithm for PVArray Using Cuk Converter", *IEEE Student's Conference on Electrical, Electronics and Computer Science, 2014*.

[9] Dr.Anil S. Hiwale, MugdhaV.Patil and Hemangi Vinchurkar, "An Efficient MPPT Solar Charge Controller", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 3, Issue 7, July 2014.

[10] Dezso Sera, Laszlo Mathe, TamasKerekes, Sergiu Viorel Spataru, and Remus Teodorescu,"On the Perturb-and-Observe and Incremental Conductance MPPT Methods for PV Systems", *IEEE JOURNAL of photovoltaic*, Vol. 3, No. 3, July 2013.