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Battery States Controlling via PV-Wind Hybrid System

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ABSTRACT

With increasing demand of energy and shortage of conventional sources renewable energy sources are used for environmental concerns. In this paper an integrated system of a wind-PV generating system connected to a battery and load is proposed. Being complimentary in nature, continuous power ability can be obtained from PV and wind system. Main issue in distributed generation is power quality and harmonics etc. In the proposed system PV-wind system draw is the load and battery charging, while the supply from PV-wind system is low, battery draw is the load. The system is modeled and analyzed in MATLAB / SIMULINK. The wind turbine draws wind generator and a bridge rectifier is used for DC conversion. The PV variable DC output is fed to boost converter and maximum power point is tracked by MPPT. PV-wind systems are combined to operate in parallel and total energy is collected and used to draw DC load and to charge battery partly. In the proposed system a useful wind PV model is offered for performance analysis of such a system.

***Index Terms*—Distributed generation, PV-wind system, MPPT, battery.**

I. INTRODUCTION

With increasing demand of energy worldwide, eco-friendly renewable energy sources are more demanded. With some of the projections it is found that global energy demand will be tripled by 2050 [1]. Currently renewable energy sources are fulfilling the 15% -20% of the total energy demand.

In this paper two forms of renewable energy are considered wind and solar. PV-wind system have large potential for fulfilling world's energy needs. In few past years PV and wind energy systems are the fastest growing sources worldwide. In Photovoltaic (PV) generation photo diodes convert solar energy into electrical energy and maximum power point is tracked by MPPT. In wind system the wind generator is drawn by wind turbine.

PV-wind energy is commonly used renewable energy sources because of its various advantages as easy installation, pollution free, low maintenance cost etc. However, the disadvantage of PV-wind system is intermittent, depending upon weather conditions. Thus a battery bank is used to get stable and reliable power from PV-wind system for drawing the load. Hence steady and dynamic behaviors of PV-wind system are improved. Because of its developed technology, low cost and high efficiency battery system are commonly used in distributed generation system. Battery is integrated to PVwind system in hybrid and distributed system for more reliability and stability. This integrated system is composed of PV system, MPPT, Boost Converter, Wind turbine, load, power electronic converters, controllers etc.

II. MODEL OF THE SYSTEM COMPONENTS

PV-wind generation system consists of photovoltaic array with MPPT for maximum power point tracking, wind generator integrated with wind turbine, battery system, boost converter, rectifier, controller and other devices. Schematic diagram of basic system is shown in fig-1. PV and wind system work together to draw the load [2]. When PV-wind system is generating excessive power after drawing the load, will be supplied to feed the battery until it is in its SOC (State of Charge). Opposite to it, when the PV-wind system is generating lesser power, the battery will draw the load partly to assist the PV-wind system to draw the load until it is in its SOD (State of Discharge).

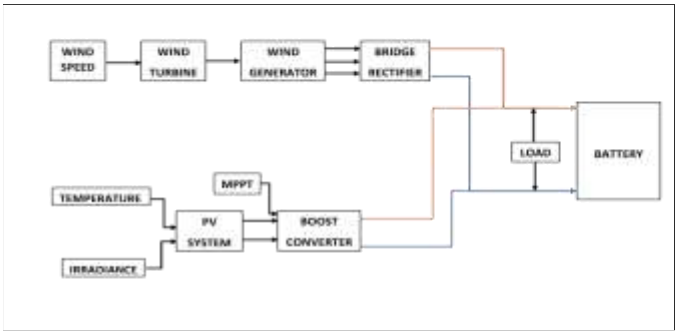

Fig. 1. Model of the system components

To determine the overall system performance, individual PV and wind systems need to be modeled first and then their overall system performance can be evaluated to draw the load smoothly.

III. SOLAR SYSTEM

Solar System is one of the most popular non-conventional energy system. PV panels convert solar energy into electrical energy with non-linear internal characteristics. The voltagepower characteristics depends upon variation of insolation and temperature. With high initial installation cost, it is always necessary to operate PV at its maximum power point. For this proposed dc-dc interfacing PV-wind and battery system is required [3]. Commonly used single diode 100 KW PV array is used in this work. The power flow from PV panel is controlled via boost converter and MPPT is used to find out the peak power of the PV panel.

PV array consists of N_{par} strings of modules connected in parallel, each string consisting of N_{ser} modules connected in series.
Number of series connected modules per string (N_{ser}) = 5;
Number of parallel strings (N_{par}) =66

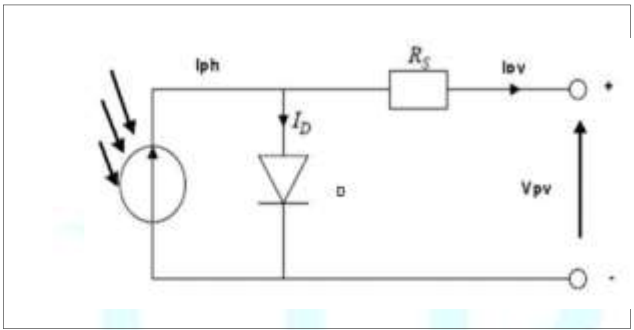

Fig. 2. PV cell equivalent circuit (Lorenzo, 1994)

PV cell can be represented by the simple equivalent circuit shown in Fig.2. The output current is the function of solar radiation, temperature and coefficients that are particular to the cell technology.

IV. PV CELL CHARACTERISTICS:

A PV cell can be represented by a current source connected in parallel with a diode, since it generates current when it is illuminated and acts as a diode when it is not. The equivalent circuit model also includes a shunt and series internal resistance. Rs is the intrinsic series resistance whose value is very small. Rp is the equivalent shunt resistance which has a very high value.

The basic equation from the theory of semiconductors that mathematically describes the I-V characteristic of the ideal photovoltaic cell is:

$$I_{pv} = I_{Ph} - I_D \;\dots\dots\dots (1)$$

Where;

I_{Ph}= Current generated by the incident light (it is directly proportional to the Sun irradiation)

I_D= Shockley Diode Equation

$$I_D = I_{sat}\left[e^{\left(V_D/V_T\right)} - 1\right] \;\dots\dots\dots (2)$$

Where;

I_{Sat}=Diode Saturation Current or Leakage Current of the diode

V_D =Diode Voltage (Volts)

V_T= Temperature-Voltage

$$V_D = \left(V_{pv} + I_{pv}R_S\right) \;\dots\dots\dots (3)$$

$$V_T = {kT}/{qQ_d N_{cell} N_{ser}} \;\dots\dots\dots (4)$$

Where;

V_{pv}= PV cell Voltage

I_{pv}=PV cell Current

R_S=Intrinsic Series Resistance

T=Cell Temperature (K)

k=Boltzmann Constant (1.3806503×10^{-23} J/K)

q=Electron Charge (1.60217646×10^{-19} C)

Q_d =Diode Quality Factor

N_{cell} =No. of Series Connected Cells per module

N_{ser} = No. of Series Connected modules per string

V. MAXIMUM POWER POINT TRACKING (MPPT):

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different.

The proposed MPPT controller tracks the peak power of the PV module based on the incremental conductance method.

Maximum Power Point is obtained when:

$$\frac{dP}{dV} = 0 \quad \dots\dots\dots(5)$$

Where:

$$P = V \times I \quad \dots\dots\dots(6)$$

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

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

$$\frac{dI}{dV} = -\left(\frac{I}{V}\right) \quad \dots\dots\dots(7)$$

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 regular minimizes the error $(dI/dV + I/V)$

Regulator Output = Duty Cycle Correction

The MPPT gives the pulsating signal which is fed to IGBT in Boost Converter for Step up of PV Panel Output.

VI. BOOST CONVERTER:

The boost converter is a high efficiency step-up DC/DC switching converter. The converter uses a transistor switch, in proposed system IGBT is used, to pulse width modulate the voltage into an inductor. Rectangular pulses of voltage into an inductor result in a triangular current waveform.

VII. BATTERY:

Battery systems are used because of its features as wide operating temperature range, low self-discharge, long service life and maintenance free. Installation cost of battery is low but lifetime cost is high compared to PV or wind system because of its limited service time.

Battery life time is reduced if there is low PV-wind energy availability for longer period i.e. improper charging and discharging. So battery charging requires control of achieving SOC (State of Charge) and longer battery life.

Hence proper controller for battery charging is required. The main function of battery charging is PV-wind System is to fully charge without permitting overcharging while preventing reverse current flow and deep discharge under low conditions.

A simple equivalent circuit model structure for Ni-MH (Nickel-Metal-Hybrid) battery is used to facilitate the battery model part of the system model.

The proposed discharge model is similar to the Shepherd model but can represent accurately the voltage dynamics when the current varies and takes into account the open circuit voltage (OCV) as a function of SOC. A term concerning the polarization voltages added to better represent the OCV behaviour and the term concerning the polarization resistance is slightly modified. The battery voltage obtained is given by:

$$V_{batt} = E_0 - K\frac{Q}{Q-it}.it - R.i + Ae^{(-B.it)} - K\frac{Q}{Q-it}.i* \quad \dots.(8)$$

Where;

V_{batt}= Battery Voltage

E_0= Battery Constant Voltage

K= Polarization Constant (V/Ah) or Polarization Resistance (Ω)

Q= Battery Capacity (Ah)

it= $\int idt$= Actual Battery Charge (Ah)

A= exponential zone amplitude (V)

B= exponential zone time constant inverse $(Ah)^{-1}$

R= internal resistance (Ω)

i= Battery current (A)

$i*$= Filtered current (A)

The particularity of this model is the use of a filtered current $(i*)$ flowing through the polarization resistance. In fact, experimental results show a voltage slow dynamic behaviour for a current step response.

This filtered current solve also the algebraic loop problem due to the simulation of electrical systems in Simulink. Finally, the OCV varies non-linearly with the SOC. This phenomenon is modelled by the polarization voltage term.

The exponential zone of above is valid for the Li-Ion battery. For the other batteries (Lead-Acid, NiMH and NiCD), there is a hysteresis phenomenon between the charge and the discharge, no matter the SOC of the battery.

$$e^{(t)} = B.|i(t)|.\left(-e^{(t)} + A.u(t)\right) \quad \dots\dots\dots(9)$$

Where;

$e^{(t)}$ = exponential zone voltage (V)

$i(t)$ = battery current (A)

$u(t)$ = charge or discharge mode

The exponential voltage depends on its initial value $e^{(t_0)}$ and the charge ($u(t)$=1) or discharge ($u(t)=0$) mode.

VIII. THE CHARGE MODEL:

The charge behaviour, particularly the state of the charge (SOC) characteristic, is different and depends on the battery type. The Ni-MH batteries have a particular behaviour at SOC. Indeed, after the battery has reached the full charge voltage, the voltage decreases slowly, depending on the current amplitude. This phenomenon is very important to model because a battery charger monitors the ΔV value to stop the charge. This behaviour is represented by modifying the charge polarization resistance. When the battery is fully charged (it = 0), the voltage starts to drop. The charger continues to overcharge the battery (it0) and the voltage decreases. This phenomenon can be represented by decreasing the polarization resistance when it

$$Pol.Resistance = K\frac{Q}{|it| - 0.1Q} \quad \dots\dots\dots(10)$$

the battery is overcharged by using the absolute value of the charge ( ):

Similar to the discharge model, the exponential voltage for these batteries is given by:

$$e^{(t)} = B.|i(t)|.\left(-e^{(t)} + A.u(t)\right) \dots\dots\dots(11)$$

Charge Model Overview:

$$E_{batt} = E_0 - K\frac{Q}{|it| - 0.1Q}.i * -K\frac{Q}{Q - it}.it + e^{(t)} \dots\dots\dots(12)$$

IX. WIND TURBINE SYSTEM

Wind turbine is an important element in a wind power system to generate electricity. It is categorize into different sizes according to the amount of power generated. A large wind turbine is able to generate up to megawatts (MW) of electricity. A small wind turbine is producing electricity less than 100kW, which is suitable to be used as backup source. A very small wind turbine is generating around 20 to 500 watts of electricity, and is normally used for batteries charging purpose.

The wind turbine captures the wind's kinetic energy in a rotor which consists of two or more blades mechanically coupled to an electrical generator and it is mounted on tall tower to enhance the energy capture. Currently two types of configuration for wind turbine exist, which is the vertical-axis configuration and the widely used horizontal-axis configuration.

Wind turbine consists of the following basic components.

- Tower structure
- Rotor with three blades attached to the hub
- Shaft with mechanical gear
- Electrical generator
- Yaw mechanism

X. MODELING OF WIND TURBINE

Cultura and Salameh had proposed that wind power available at the shaft depends on both the wind speed and the turbine blades swept area. Vergauwa also presents a commonly used equation to determine the wind turbine generated power output. In addition, Diaz introduced a sensor less control of a permanent magnet synchronous generator (PMSG) for wind turbine, where the main function of a generator is converting the mechanical energy from the wind turbine into electrical energy. Hence, the modeling of wind system is based on mathematical model and also the PMSG generator model.

The total amount of power capture from wind can be expressed as:

$$P_{wb} = \frac{1}{2}\rho C_p(\lambda,\beta)\pi R^2 V_w^{\ 3}[W] \dots\dots\dots(13)$$

Where power coefficient (C_p) depends on tip speed ratio (λ) and blade pitch angle (β) of the wind turbine. The power coefficient value can be calculated using equation:

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i^{\ 2}} - C_3\beta - C_4\right)e^{-C_5/\lambda_i} + C_6\lambda \dots (14)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \dots\dots\dots(15)$$

The wind turbine torque on the shaft can be calculated by using the following equation,

$$T_m = \frac{P_m}{\omega} = \frac{1}{2}\rho C_p \pi R^2 \frac{V_w^{\ 3}}{\omega} \dots\dots\dots(16)$$

P_{wb} is the extracted power from the wind, ρ is the air density (kg/m^3), R is the blade radius (m), V_w is the wind speed (m/s), β is the blade pitch angle (deg), ω is the rotational speed (rad/s) and T_m is the wind turbine output torque (Nm).

XIII. POWER ELECTRONIC CIRCUIT (UNIVERSAL BRIDGE)

Power electronic circuits are used in converting electrical energy. To have a common source in the hybrid system that combined wind and PV model, power converter is needed to convert alternating current (AC) to direct current (DC) or vice versa. The converting is perform by solid-state semiconductor devices that operate with periodically switched on and off at a desired frequency. Therefore, power electronic converter also known as switching converter because the output is controlled by switches.

Here, power converter AC-DC Universal Bridge Rectifier is used to complete the hybrid wind and PV model.

XIV. SIMULINK MODELLINGS

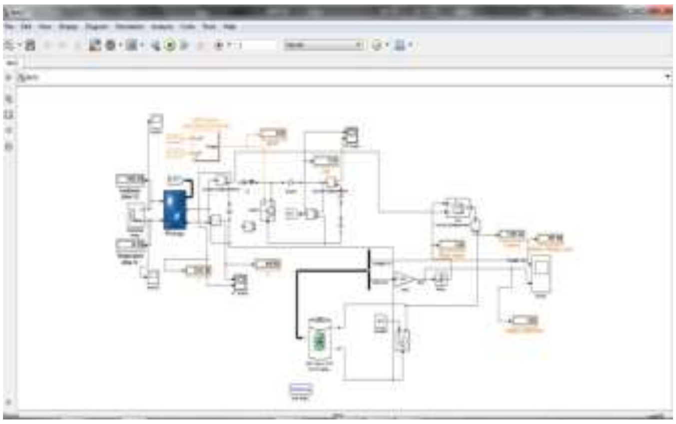

Fig. 3. PV-Battery SIMULINK Model

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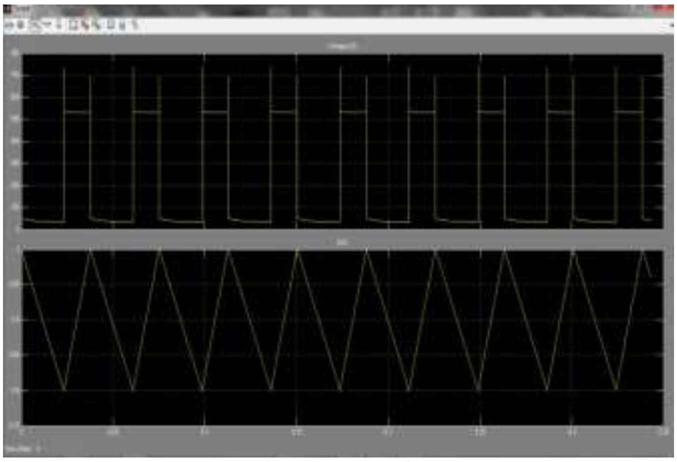

Fig. 4. Controlling of SOD & SOC of Battery via PV

The waveform above obtained explains that the PV array sized at 18 string in series and 218 string at parallel generating a voltage of 850V peak and a constant supply of 500V at STC of the module. The state of charging (SOC) is set at 1 and state of discharging is 0.8 of 200V battery which is obtained successfully by proposed system.

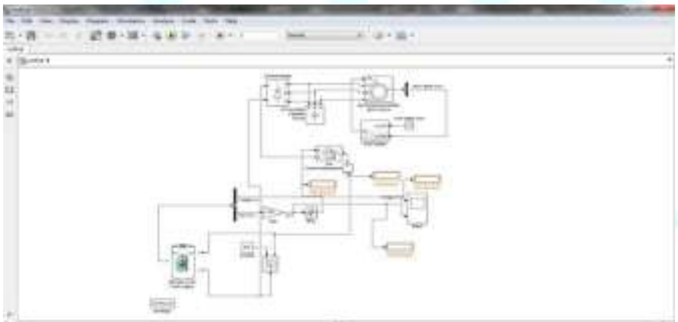

Fig. 5. Wind-Battery SIMULINK Model

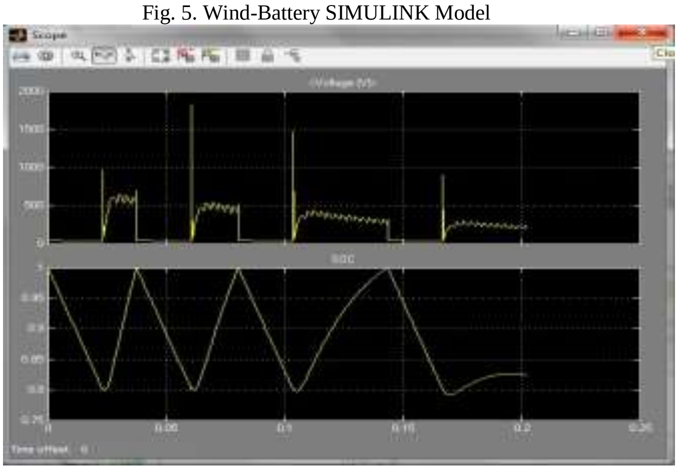

Fig. 6. Controlling of SOD & SOC of Battery via Wind System

The waveform above obtained shows the wind generator obtains a nominal voltage of 500V with the SOD and SOC of Wind-Battery System as SOD=0.8 and SOC=1.

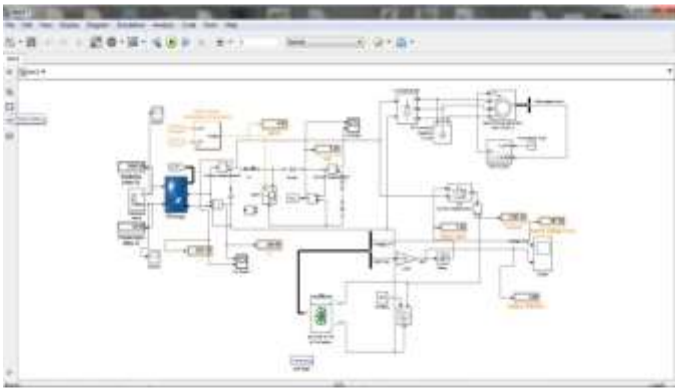

Fig. 7. PV- Wind-Battery Hybrid System SIMULINK Model

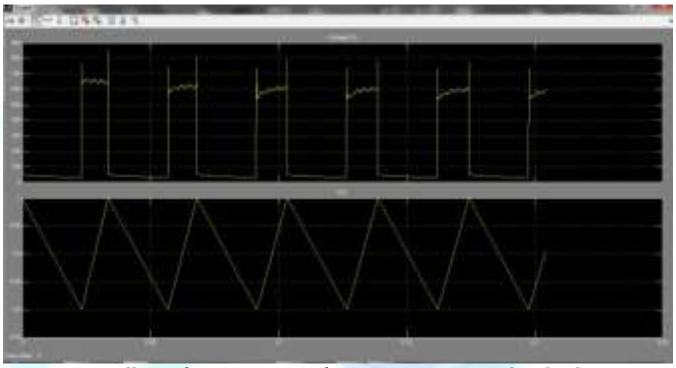

Fig. 6. Controlling of SOD & SOC of Battery via PV-Wind Hybrid System

The above waveform is obtained by connecting the wind generator output and solar output parallel with the 200V battery and SOD and SOC is successfully controlled by the PV-Wind Hybrid Model as the SOD=0.8 and SOC=1.

XV. CONCLUSION:

The study presents a PV array to attain a nominal voltage with proper string sizing of the plant as 18 strings in series and 218 strings in parallel. The wind turbine is provided with the cut in speed of 3m/s and cut out speed at 30m/s getting a DC supply by connecting a universal bridge. The both system are synchronized parallel with battery of 200V 6.5AH as shown in model of system components with SOC and SOD parameters set at 1 and 0.8 thereby providing a good nominal voltage and Charging-Discharging states of the battery is successfully attained.

The hybrid system can be used to satisfy demand of the consumer by connecting the system to the grid or can be feasible as a standalone system at the remote location to light up India future with a renewable power. The Plant load factor of the hybrid system is high due to more power peak condition multiplied when connected as a hybrid system.

REFERENCES

[1] Eftichios Koutroulis, "Methodology for optimal sizing of standalone photovoltaic/wind-generator systems using genetic algorithms," Solar Energy 80. ELSEVIER: 2006, pp. 10721088.

[2] Hongxing Yang, Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm, Solar Energy 82. ELSEVIER: 2008, pp.354-367.

[3] Chiang, S.J. Shieh, H.J. Chen, M.C. —Modeling and Control of PV Charger System with SEPIC Converter‖. Industrial Electronics, IEEE Transactions, Vol.56, no.11, Nov 2009

[4] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[5] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[6] "Power Quality in Grid Connected Renewable Energy System:Role of Custom Power Devices" by S.K.Khadem, M.Basu and M.F.Conlon Electrical Power Research Group,School of Electrical Engineering Systems, Dublin Institute of Technology, Kevin Street, Dublin 8, Ireland, 23-25 March 2011.

[7] "Analysis and Implementation of Grid-Connected Solar PV with Harmonic Compensation" Jianwu Cao, Florida State University, 4 January 2011.

[8] "Modeling and Simulation of Grid-connected Hybrid Photovoltaic/Battery Distributed Generation System" M. Makhlouf , F. Messai, H. Benalla, Department of Electrical Engineering, Faculty of Engineering Sciences, Mentouri University Route d'Ain E Bey, Constantine, Algeria, 1 January 2012

[9] "Fault Condition Analysis in a Grid Connected PV Energy System" Abbas Haijing, Zulkeflee khalidin, Electrical and Electronic Faculty, University Malaysia Pahang, 2011 International Conference on Circuits, System and Simulation IPCSIT vol.7 (2011)© (2011) IACSIT Press, Singapore.

[10] "Modeling and Analysis of Single Phase Grid Connected Photovoltaic System" SWATI BHASME, DR. A.P.
REVANKAR Research Scholar, Govt. Engineering College, [11] "A Grid-Connected Photovoltaic System with Direct Coupled
Aurangabad, India, Principal, Matyodari Engineering college, Power Quality Control" Sung-Hun Ko and Seong-Ryong Lee Jalna, India Hooman Dehbonei and C.V. Nayar, School of Electronic & Information Engineering Department of Electrical.