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Energy Storage Management in Grid Connected Solar Photovoltaic System

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Abstract
The penetration of renewable sources in the power system network in the power system has been increasing in the recent years. One of the solutions being proposed to improve the reliability and performance of these systems is to integrate energy storage device into the power system network. This paper discusses the modeling of photo voltaic and status of the storage device such as lead acid battery for better energy management in the system. The energy management for the grid connected system was performed by the dynamic switching process.
Keywords: modeling of PV, storage devices and energy management system.

I. INTRODUCTION

The renewable energy sources (RES) are clean with low environmental impact than the conventional energy source. RES such as wind, solar, biomass, hydro and geothermal are available in nature as a non depleting source. The solar Photovoltaic (PV) cell is an electronic device that essentially converts the solar energy of sunlight into electric energy or electricity. Photovoltaic system consists of many cells, panels and array. The large scale PV plants are used for electricity generation that is fed into the grid and load. Such system, typically consist of one or more PV panels a DC/AC power Converter/Inverter. Additionally such system could also include maximum power point (MPP) and storage devices. The electricity generated is either stored, used directly for self-consumption or is fed into large electricity grids. Interconnections of panel or array, predict the output voltage or current or power and it is a variable that depends upon the sunlight. The converters may be used to regulate voltage and current at the load to control the power flow. There are many advantages of using solar Photovoltaic as a source for generating power, such as clean energy, no pollution and maximum power at peak hours. The modeling of solar PV system is to obtain maximum power for load requirements. Therefore energy storage system is very important for balancing the system or energy management of the system [1]. A grid connected/stand alone solar PV system essentially consist of utility, PV array as primary sources, storage device as external leveling agents to sink/sources the primary source power and load. Hence power flow management is required to balance the power flow among these sources which controls the bidirectional converter connected to battery so that the battery can be charged or discharged. The power flow management controller is based on the state of charge of the battery.

II. OVERVIEW OF ENERGY STORAGE MANAGEMENT

The use of energy storage system reduces the cost of electricity and improves the reliability in the power system. The proper sizing and control of energy storage system (zinc-bromine) is provided for wind power system [2]. The grid connected hybrid system uses storage device to manage the optimal power flow in the system with minimizing overall cost at point of common coupling [3]. The optimal placing of new distributed generation into the existing distribution network with the energy storage device is done for better energy storage management. Multi objective functions are optimized simultaneously using evolutionary algorithm [4]. In distribution system, there are many renewable energy sources for generating power, the allocating renewable sources using probabilistic technique and also minimizing the losses in the power system network [5]. The state of charge of battery is controlled by the fuzzy controller. Over charging and over discharging will affect the battery life time. Battery is allowed to charge or discharge with the standard reference value which is mentioned by the manufacture under some standard test conditions. Battery is controlled by using the fuzzy controller [6]. The circuit diagram for the grid connected solar photovoltaic system is shown below. The modeling of solar panel was done in order to get maximum power during the day time. The power output from the solar photovoltaic is variable and it is regulated through the inverter. The solar photovoltaic generation is connected to the power system through the switching device. The energy storage device such as lead acid battery is used for two purpose, charging process take place when there is a maximum power output from the solar photovoltaic generation and discharging process take place when there is a less power output from the solar photovoltaic generation or power demand on the loads. At the instant, rate of charging and discharging is shown on the display. The utility grid with high voltage is reduced to low voltage by the potential transformer and it is connected to the static load through switch and buses. Whenever there is a less or no energy supply from the solar photovoltaic generation and storage device, at that situation utility grid act as a supply for the load. The solar photovoltaic generation, storage device and utility grid consist of separate switches for connect or disconnect from the power system. The dynamic switching process is performed depends upon the power generation from the solar photovoltaic system.

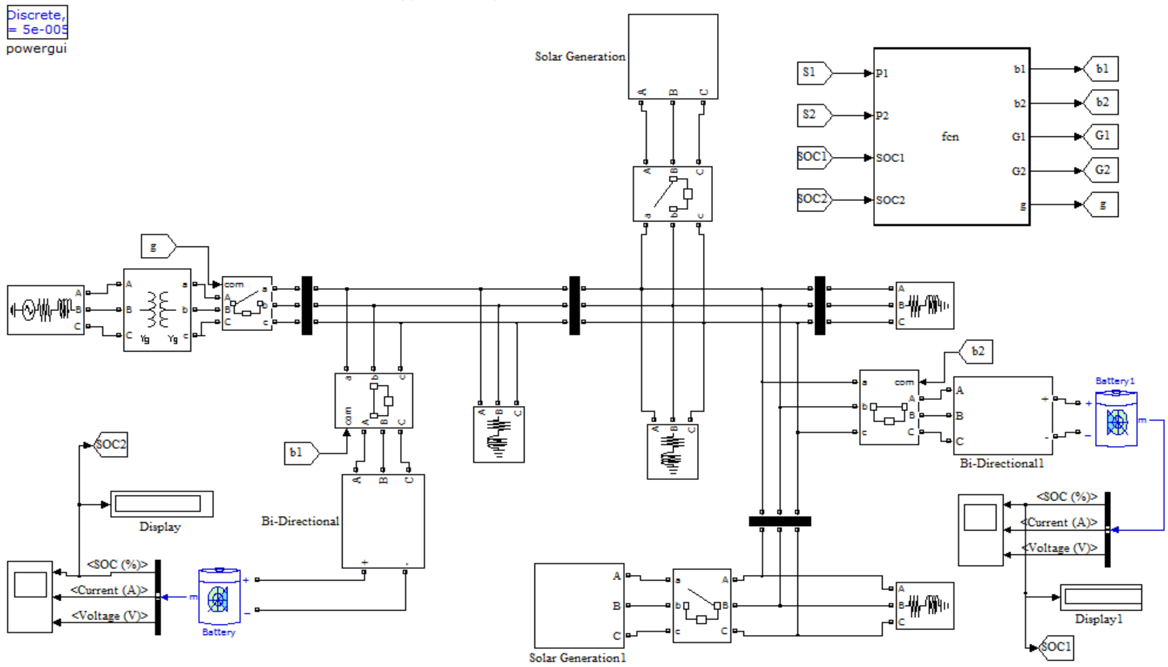

Fig 1. Circuit diagram of grid-connected solar PV system.

III. MODELLING OF SOLAR PV SYSTEM

The basic equation from the theory of semiconductor, the IV characteristic of photovoltaic cell is:

$$I = I_{pv,cell} - I_d \tag{1}$$

Where $I_d = I_{o,cell}\,[\exp(\frac{qV}{akT}) - 1]$

$I_{pv,cell}$ is the current generated by the solar radiations, I_d is the Shockley diode equation, q is the electron charge, I_0, cell is the reverse saturation current, k is the Boltzmann constant. T is the temperature of the p-n junction and 'a' is the diode ideally constant.

The PV array consists of several PV cells and observes the characteristic at the terminal of the photovoltaic array that requires the additional parameters to the basic equation.

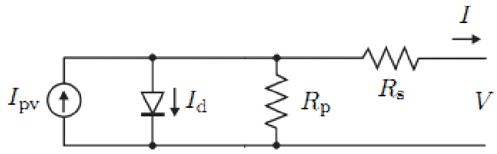

Fig 2: Single-diode model of the photovoltaic cell.

The interconnections of R_s and R_p are shown in the figure 2, at the output terminal of the solar photovoltaic cell, current and voltage are generated. Interconnections of the cells in serious and parallel form the array. Internal resistance, Rs controls current generation and R_p is responsible for voltage generation across the terminals of PV array [7]. The cell connected in parallel increase the current and cell connected in series increase the voltage.

$$I_{pv} = (I_{pv,n} + K_1\Delta_T)\frac{G}{G_n} \tag{2}$$

$$I_0 = \frac{I_{sc,n} + K_I\Delta T}{\exp\left(\frac{V_{oc,n} + K_V\Delta T}{aV_t}\right) - 1} \tag{3}$$

$$V_t = N_s KT/q \tag{4}$$

Where, K_I and K_v is the current and voltage coefficients, ΔT is the change in temperature, G irradiations on the device surface and G_n nominal irradiations. $I_{sc,n}$ and $V_{oc,n}$ is the nominal short circuit current and open circuit voltage. V_t is the terminal voltage of array and N_s is the number of cells in serious connection. Using this equations current on each panel and the terminal voltage are determined.

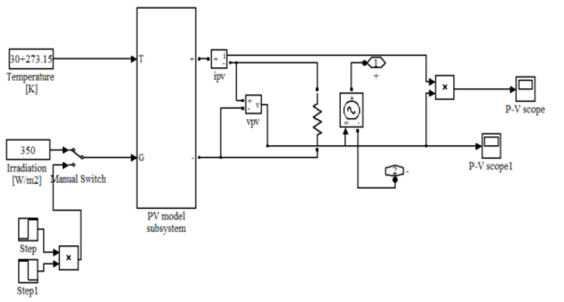

Fig 3. Subsystem of Solar Power generation

The input of the PV cells is temperature and irradiations; the power output of the solar panel depends upon these parameters. If the temperatures of solar panel are increases then the power output will be decreased. If the irradiations of the solar panel are increased then the power output will be increased. The power and voltage measurements are analyzed.

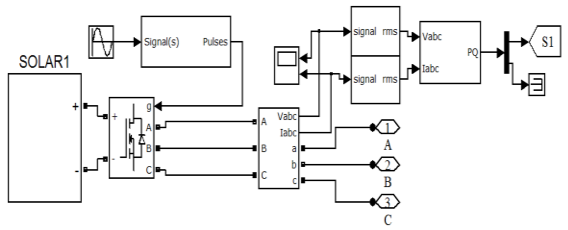

Fig 4. Solar PV generation

From the figure 3. The output of the solar is DC voltage or current, it is inverted to AC using PWM technique. The regulated or inverted output is connected to the power lines [8]. S1 is the operating switch which makes or breaks the contact from the electrical network. AC power output from the inverter is linear. The real power is feed into the system through the switch S1 and the reactive power is terminated, since it creates losses in the system.

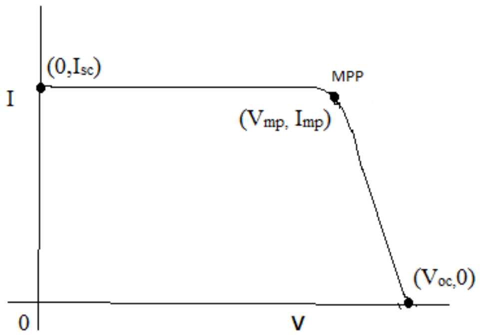

Fig 5. Characteristic of I-V curve.

An efficient maximum power point is necessary to improve the efficiency of a solar Photovoltaic panel. Solar PV cells have a non-linear VI characteristic with a distinct Maximum power point which depends on environmental factors such as temperature and irradiations. The important parameters to be analyzed in solar PV are open circuit voltage, short circuit current and the maximum power where the voltage and current are maximum; the solar cells are manufactured under some standard test conditions will specify the nominal operating conditions, which is shown in table I and II.

TABLE I solar array 1000W/m^2

I_{mp}	7.61 A
V_{mp}	26.3 V
P_{max}	200.143 W
I_{sc}	8.21 A
V_{oc}	32.9 V
K_v	-0.1230 V/K
K_1	0.0032 A/K
N_s	54
R_s	0.221 ohm

TABLE II solar array at nominal operating conditions.

I_{mp}	7.61 A
V_{mp}	26.3 V
P_{max}	200.143 W
I_{sc}	8.21 A
V_{oc}	32.9 V
$I_{o,n}$	9.825 A
I_{pv}	8.214 A
a	1.3
R_p	415.405 ohm
R_s	0.221 ohm

The solar PV system is modeled using the basic semiconductor equation which is already shown. The below equations shows that $I_{pv,n}$ is calculated as internal serious and parallel resistance, short circuit current.

$$I_{pv,n} = \frac{Rp+Rs}{Rp} I_{sc,n} \tag{5}$$

The Photovoltaic subsystem circuits are modeled from the basic semiconductor theory. The parameter of I-V equations by using the following nominal information from the array data sheet: open circuit voltage, short circuit current, maximum output power, voltage and current at maximum power point, current/temperature and voltage/temperature coefficients.

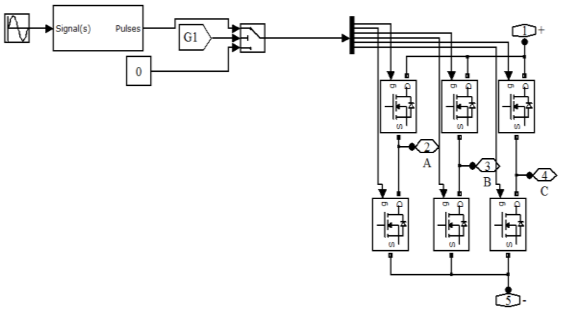

Fig 6. Bidirectional converter.

The reference wave are combined with the carrier wave to generate pulses is used for triggering the gate pulses, to the operation of device such as MOSFET [9]. It is the low power high switching devices, the circuit is connected to G1 the energy is stored in the battery and when it is connected to low signal energy is supplied by the battery to the electrical network. If the switch is connected to the pulse generation, AC-DC conversion takes place to store the energy. If the switch is connected to the G1 then DC-AC conversion take place to act as a supply for the load and the witch is connected to the zero then no action takes place.

IV. ENERGY STORAGE MANAGEMENT IN SOLAR PV SYSTEM

The energy storage will improve the availability and reliability of the power system. There are many energy storage devices are used in the electrical power system such as battery, flywheels, ultra-capacitor and fuel cell. Applications of the storage device power generation and the load requirements, for example battery is used as solar photovoltaic generation, flywheels are used at the shaft of the wind mills and ultra capacitors are used in the transmission line to reduce the line loses in the electrical power system. In this paper the main parameter of managing the energy storage is state of charge in the battery; its operation depends upon the load and the source.

The state of charge is defined as the available capacity expressed as a percentage of its rated capacity. The SOC of battery is so important of elections of various modes of operations such as grid connected electrical network and stand alone or islanding electrical network. Normally the battery charger which is in existence does not incorporate any of the state of charge measurements so as to limit the charging rate of the battery based on SOC to improve the life period of the battery. The operations of charging and discharging of the battery is stated in the embedded MATLAB function. Life lime and the capacity of the battery are improved by the parameter state of charge. The state of charge is determined by the following equations.

$$\mathrm{SOC}(t) = \frac{Q(t)}{\mathrm{Qn}} \quad (6)$$

Where, Q(t) is the current capacity of the storage devices with respect to time.

Q_n is the nominal current capacity which is represented by the manufacture.

SOC(t) is the state of charge with respect to time.

State of charge could be calculated from measured cell parameters, operating conditions and temperature. There are some methods for determination of state of charge; they are voltage at open circuit conditions, current at short circuit conditions and chemical methods.

V. SIMULATION RESULTS AND DISCUSSIONS

The state of charge and state of discharge is shown above was the energy management for grid connected solar PV system. In this system lead acid is used as a storage device for better energy management between the source and the load. The state of charging and discharging occurs when the solar generation not able to supply the power or during the peak time of the demand.

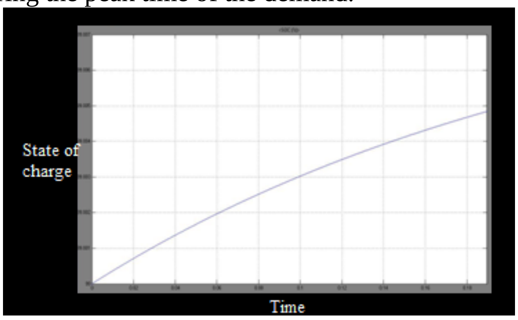

Fig 7. State of Charge

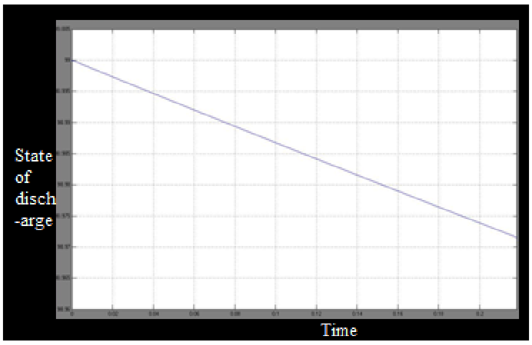

Fig 8. State of Discharge

The modeling of the PV is to get the desired constant output of power and voltage. The converter/inverter is connected to the battery for storing the energy or deliver power to the load. Solar photovoltaic panel 1 and 2 can able to generate power up to 50KW and 500KW is a variable power output, power demand or variable power output is managed by the storage device. In the grid connected system proper switching operations was performed by using the embedded MATLAB function, this leads the system as uninterrupted power supply to the load. The maximum energy from the solar generation and storage device gives supply to the load; the minimum energy is drawn from the grid.

VI. CONCLUSION

The battery storage technology will play a major role in the reliable and economic operations of grid connected solar photovoltaic system. The cost of the electricity was reduced or maintains constant by the usage of energy storage devices and it required less maintenance, life of the battery depends upon the frequent charging and discharging with the specified limit. The modeling of photovoltaic system to regulate the power and voltage, for the grid connected system, in order to reduce the fluctuation in the system. The simulation results tell that the energy is managed by the storage device will balance the power systems. Thus the battery storage system leads the energy management in the grid connected solar photovoltaic system. The dynamic switching process is performed by the EMBEDED/MATLAB function, thus the energy is managed in the grid connected solar photovoltaic system.

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