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Simulation of Photovoltaic Cell with Back up Battery Storage System Using Matlab

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Abstract

This project analysis and simulation of a Photovoltaic/battery hybrid system using MATLAB/SIMULINK. The system is designed entirely based on the concept of a parallel hybrid configuration. The software modeling of a Photovoltaic/battery system provides an in-depth understanding of the system operation before building the actual system and also the testing and experiments of system operation under disturbances is not possible on the actual system. Controllers are designed to operate the hybrid system in such a way to reduce the total cost of generation. To measure the stability and performance, the overall system is tested for different disturbances like variation in fuel, irradiation profile and variation in load demand which normally occurs in a Photovoltaic/battery hybrid power system

Keywords- ***Wind, Solar, Fuel Cell, PWM, Hysteresis control***

I .INTRODUCTION

In these years, with the industrial and economic development, the demand forelectric energy becomes increasing, which needs to consume more fossil fuels and causes the deteriorating environment problem. Fortunately, people have been aware of the severity of problem. In order to protect the environment and reserve the limited fossil fuels, it is necessary to develop and use the some clean and natural energy. Photovoltaic (PV) power generation is a good way to utilize renewable natural energy. However, the operation of PV array is unstable because of the fluctuation of insolation and temperature, and so it is necessary to collaboratively operate with controllable power generation unit to improve the stability of the whole system. For this reason, a hybrid distributed power generation system based on direct current (DC) bus has been designed consisting of photovoltaic (PV) power generation unit, microturbine power generation unit, DC-DC converter and inverter unit [2].

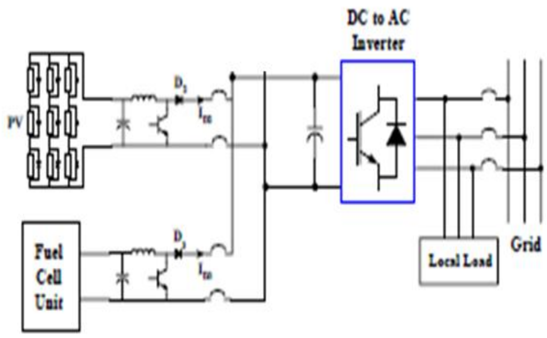

Fig 1 proposed pv with battery model

Photovoltaic (PV) or solar cells as they are often referred to are semiconductor devices that convert sunlight into direct current (DC) electricity. Groups of PV cells are electrically configured into modules and arrays, which can be used to charge batteries, operate motors, and to power any number of electrical loads. With the appropriate power conversion equipment, PV systems can produce alternating current (AC) compatible with any conventional appliances, and operate in parallel with and interconnected to the utility or stand alone system. Photovoltaic systems are the nonlinear variation of output voltage and current with

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solar radiation levels, operating temperature, ageing and load current. Due to variation of voltage and current levels the constant power can not be delivered to the load. To overcome these problems, the variable output of the PV system is fed to DC-DC Converter to maintain constant required voltage [3].

II. PHOTOVOLTAIC CELL

A photovoltaic system is a system which uses one or more solar panels to convert solar energy into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output [6].As conventional sources of energy are rapidly de-pleting and the cost of energy is rising, photovoltaic energy becomes a promising alternative source, since it has some of the advantages i.e. available in bulk, free of cost, pollution free and distributed throughout the earth. The main drawbacks these systems are that the initial installation cost is considerably high and the energy conversion efficiency is relatively low. To overcome these problems, the following two essential ways can be used. 1) Increase the efficiency of conversion for the solar array and 2) Maximize the output power from the solar array. With the development of technology, the cost of the solar arrays is expected to decrease continuously in the future, making them attractive for residential and industrial applications [3].

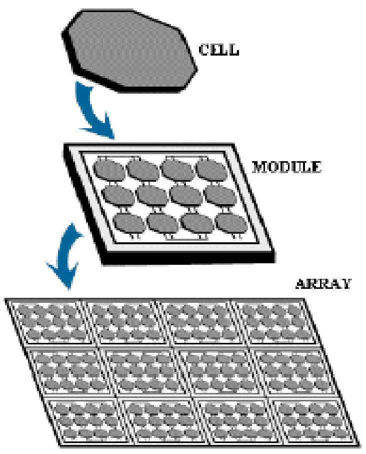

Fig. 2 Photovoltaic Hierarchy

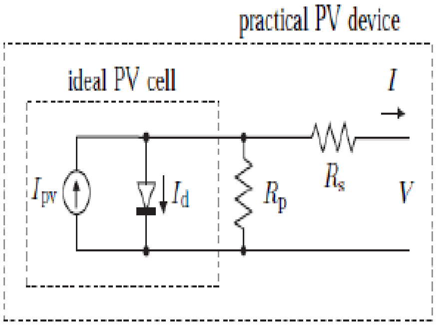

Fig. 3 Ideal photovoltaic cell

The basic equation (2.2) of the elementary photovoltaic cell does not represent the I-V characteristic of a practical photovoltaic array. Practical arrays are composed of several connected photovoltaic cells and the observation of the characteristics at the terminals of the photovoltaic array requires the inclusion of additional parameters to the basic equation:

$$I = Ipv - Io \{exp [(V + I * Rs)/V *a] - 1\} - (V - I * Rs) /Rp \quad (2.4)$$

Where Ipv and Io are the photovoltaic and saturation currents of the array and Vt = NskT/q is the thermal voltage of the array with Ns cells connected in series. Cells connected in parallel increase the current and cells connected in series provide greater output voltages. If the array is composed of Np parallel connections of cells the photovoltaic and saturation currents may be expressed as: Ipv=Ipv,cellNp, I0=I0,cellNp. In (2.3) Rs is the equivalent series resistance of the array and Rp is the equivalent parallel resistance.

III MPPT

Maximum power point tracker (or MPPT) is a high efficiency DC to DC converter that presents an optimal electrical load to a solar panel or array and produces a voltage suitable for the load.

PV cells have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular load resistance, which is equal to V/I as specified by Ohm's Law. A PV cell has an exponential

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relationship between current and voltage, and the maximum power point (MPP) occurs at the knee of the curve, where the resistance is equal to the negative of the differential resistance (V/I = -dV/dI). Maximum power point trackers utilize some type of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell.

Traditional solar inverters perform MPPT for an entire array as a whole. In such systems the same current, dictated by the inverter, flows though all panels in the string. But because different panels have different IV curves, i.e. different MPPs (due to manufacturing tolerance, partial shading, etc.) this architecture means some panels will be performing below their MPP, resulting in the loss of energy.

Some companies (see power optimizer) are now placing peak power point converters into individual panels, allowing each to operate at peak efficiency despite uneven shading, soiling or electrical mismatch.At night, an off-grid PV power system uses batteries to supply its loads. Although the battery pack voltage when fully charged may be close to the PV array's peak power point, this is unlikely to be true at sunrise when the battery is partially discharged. Charging may begin at a voltage considerably below the array peak power point, and a MPPT can resolve this mismatch,

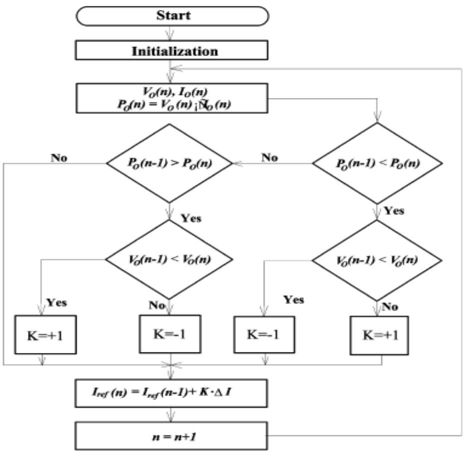

Fig 4 Flow chart of the MPPT algorithm with P&O method.

MPPTs can be designed to drive an electric motor without a storage battery. They provide significant advantages, especially when starting a motor under load. This can require a starting current that is well above the short-circuit rating of the PV panel. A MPPT can step the panel's relatively high voltage and low current down to the low voltage and high current needed to start the motor.

IV BATTERY

Energy Storage:

Electricity is more versatile in use than other types of power, because it is a highly ordered form of energy that can be converted efficiently into other forms. For example, it can be converted into mechanical form with efficiency near 100% or into heat with 100% efficiency. Heat energy, on the other hand, cannot be converted into electricity with such high efficiency, because it is a disordered form of energy in atoms. For this reason, the overall thermal-to-electrical conversion efficiency of a typical fossil thermal power plant is less than 50%.

Disadvantage of electricity is that it cannot be easily stored on a large scale. Almost all electric energy used today is consumed as it is generated. This poses no hardship in conventional power plants, in which fuel consumption is continuously varied with the load requirement. Wind and photovoltaic's (PVs), both being intermittent sources of power, cannot meet the load demand at all times, 24 h a day, 365 d a year.

The primary goal of the battery converter is to regulate the common dc-bus voltage. The battery load current rapidly changes according to changes in weather conditions and power command for grid inverter in dispatching or averaging mode of operation. Common dc-bus voltage must be regulated to stay within a stable region regardless of the battery-current variation. To do this, a modified hysteresis-control strategy is applied. The concept of this strategy is to regulate the common dc voltage within a specific band, for example, a hysteresis band. Therefore, the battery charger/discharger is controlled in such a way that the

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dc-bus voltage should not violate the specified upper and lower limits, *Vdc*_up and *Vdc*_lw, as shown in the figure. A decision criterion for charging/discharging becomes the level of the common dc-bus voltage, and the battery buck–booster operates according to the scheme as below:

$$\text{If } V_{dc} > V_{dc_{up}}, \quad \text{then charging} \rightarrow V^*_{dc} = V_{dc_{up}}$$

$$\text{If } V_{dc} < V_{dc_{up}}, \quad \text{then discharging} \rightarrow V^*_{dc} = V_{dc_{lw}}$$

$$\text{If } V_{dc\_lw} \le V_{dc} \le V_{dc\_up} \quad \text{then no control (rest)}$$

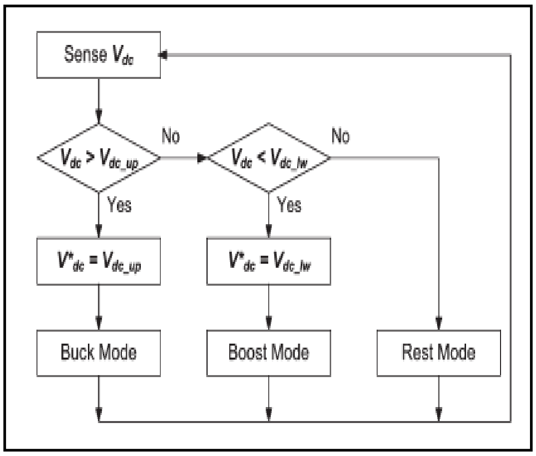

Fig. 5 Battery-mode control block (modified hysteresis).

When the common dc voltage V_{dc} becomes larger than the upper limit, charging mode begins with the voltage command V_{dc} equal to the upper limit and continues until the dc voltage reaches the limit. If V_{dc} goes below the lower limit, then the voltage target is bound at the lower limit and the converter starts operating in boost mode.

V SIMULATION CIRCUITS

Simulink is an environment for multidomain simulation and Model-Based Design for dynamic and embedded systems. It provides an interactive graphical environment and a customizable set of block libraries that let us design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing.

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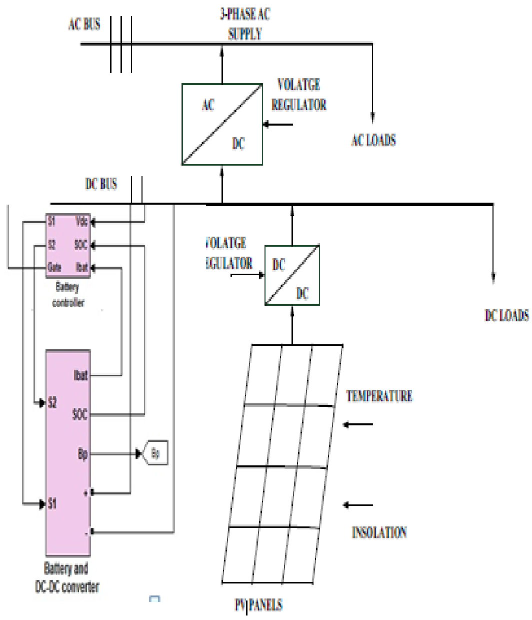

Fig 6 Composite Model of Proposed Hybrid System

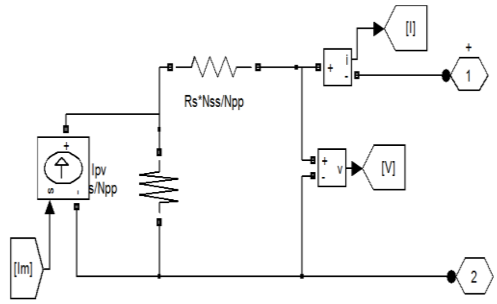

Fig 7 Simulation of Parallel Connection Of Solar Cell

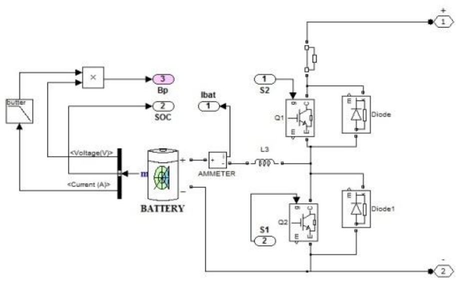

Fig 8 Battery design simulation

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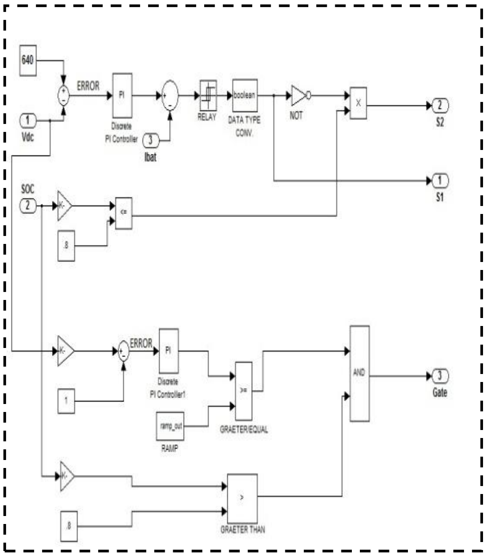

Fig 9 Battery Control

Simulation results

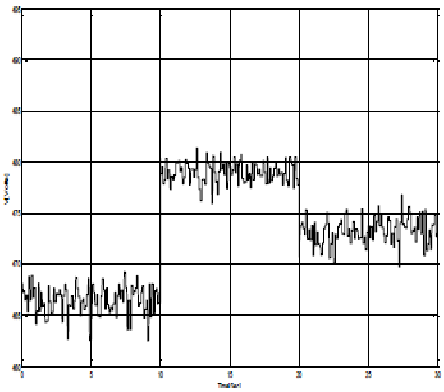

Fig 10 Voltage of the PV system produced at different dc loads.

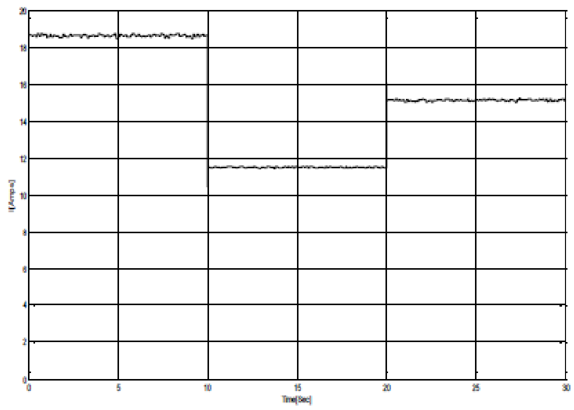

Fig 11 Current of the PV system produced at different dc loads

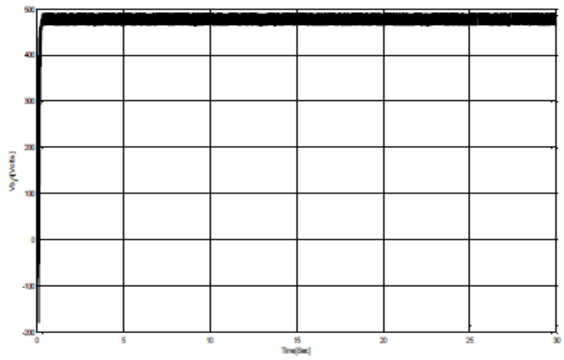

Fig 12 Boost converter input Voltage of the PV system.

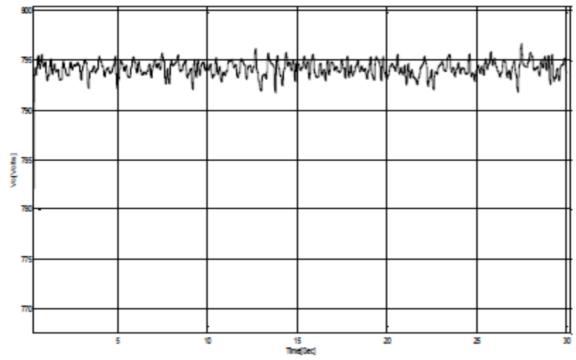

Fig 13 Boost converter output Voltage.

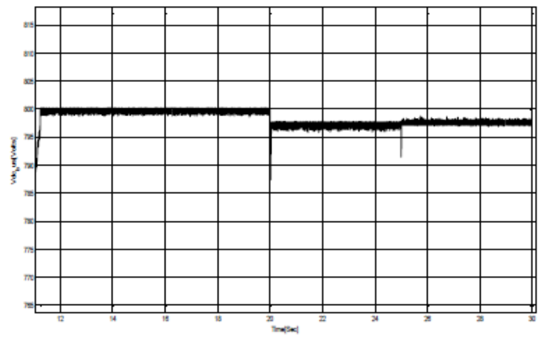

Fig 14 DC bus voltage

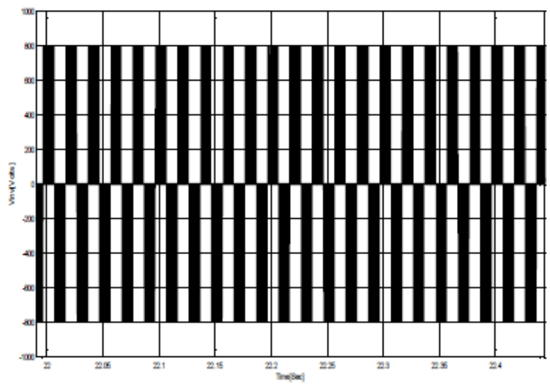

Fig 15 Part of Inverter output voltage

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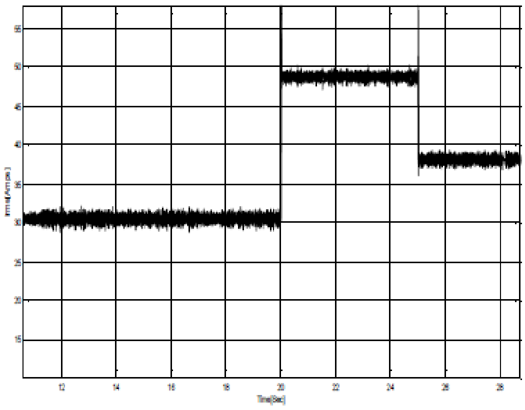

Fig 16 RMS current at different load

V. CONCLUSION

The available power from the renewable energy sources is highly dependent on environmental condition such as radiation, and ambient temperature. To overcome this deficiency of the solar cell we integrated them with the battery system. The output voltage fluctuations of the solar cell varying with both environmental temperature and sun irradiation are reduced by using a battery system. Therefore, the system can tolerate the rapid changes in the load and environmental conditions, and suppress the effects of these fluctuations on the equipment side voltage. This hybrid topology exhibits good performance under variable radiation, ambient temperature and load power requirements. This system can be used for off-grid power generation in non interconnected areas or remote isolated communities.

These two systems (PV and battery system) were integrated through a power electronic interface, feeding an AC load, and simulated in MATLAB/Simulink/simpower system. Also, simulations results show that the power electronics interfacing maintained the output voltage and frequency of the 3-phase inverter at the prescribed values during the entire period of operation

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