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Control and Power Management Scheme for PV – Battery Based Hybrid Microgrid Using Hybrid MPPT

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***Abstract*— The proposed paper incorporate the use of hybrid MPPT to ensure peak energy harvesting under all weather condition. It is the combines the Incremental Conductance and Constant Reference Voltage method used to extract the maximum power from photovoltaic system. Control schemes for PV –Battery systems must be able to stabilize the bus voltage as well as to control the power flow. Battery storage is used to mitigate power fluctuation in PV system due to the change in irradiation characteristics. In micro-grid both grid connected and islanded mode operations are tested using MATLAB/SIMULINK environment and results are verified using simulation results.**

***Keywords*—Photovoltaic system (PV), Battery, Micro-grid, Incremental Conductance (Inc), Constant Reference Voltage (CRV), Maximum Power Point Tracking (MPPT).**

I. INTRODUCTION

In the present scenario many problems such as global warming and environmental pollution, solar PV system emerges as a pollution free, clean and green alternative to conventional non- renewable source. Solar power has extraordinary potential as a renewable energy generating source instantaneous power output of a PV system depends largely on its operating environment, such as solar irradiance and surrounding temperature, resulting in constant fluctuations in the output power [1], [2]. A PV system generates DC electricity when sun rays fall on a PV array. The PV power generation is based on the principle of the photovoltaic effect with the advent of silicon p-n junction the photoelectric current is able to produce power due to inherent voltage drop across the junction. However, such power generation Photovoltaic energy generating systems convert the sun's energy directly into electricity using state-of-the-art semiconductor materials.

Solar PV energy conversion systems can be classified into: standalone and grid interfaced power generation system [3]. This means, they are the source of power to a home, water pump and other load. Stand-alone systems can be designed to run with battery backup or without battery backup. In contrast, stand-alone home power systems often store energy generated during the day in a battery bank for use at night. In order to maintain an uninterruptible power supply to stand-alone loads use of battery energy storage system (BESS) is essential for stand-alone applications [4], A PV system along with battery backup becomes a reliable source that can maintain continuous supply to the load [5]. Stand-alone systems are cost-effective when compared to alternatives, such as utility line extensions. Other PV systems are called "grid-connected systems" [6].When the amount of energy generated by a grid connected PV system exceeds the customer's loads that are excess energy is to the utility turning back the customer's electric meter. Alternatively, the consumer can draw the power needed from the utility. When, under this plan, electricity from the PV system is insufficient to fuel the loads of the house, the monthly electric utility bill for the consumer represents only the net amount of energy generated from the electric utility.

Grid – interfaced solar energy conversion system do not require any other additional devices. The incorporation of any renewable energy source into the electric grid must meet minimum criteria for power quality. There are several issues concerning power management, enhancing the conversion efficiency of a PV array, optimizing PV power output. PV array has to be operated at MPP in order to extract maximum power output the use of MPPT enhances the efficiency up to 11% [7]. The maximum power of PV array changes with shading and climatic conditions. The PV current and voltage change with temperature of the PV array. Thus, an important challenge in a PV system is to ensure that maximum energy is generated from the PV with a dynamic weather condition is achieved by using hybrid MPPT [8]. Fig. 1 shows a typical block diagram of proposed system.

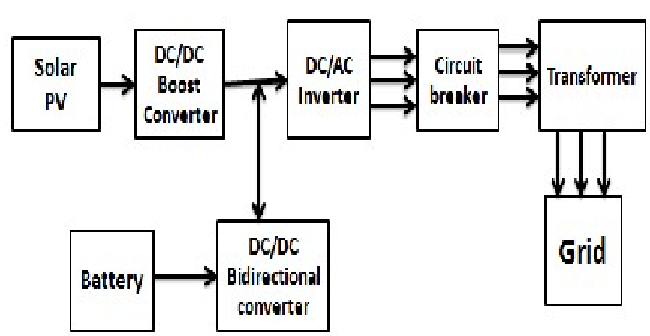

Figure 1: Simplified block diagram of proposed PV-Battery based hybrid micro-grid.

The forward power path from solar PV source to the load typically consists of two stages, as shown. The battery back-up is interfaced with the DC link through a bi-directional dc-dc converter.

The proposed control and power management scheme for PV-battery based micro-grid used the hybrid MPPT technique has varies advantages that are

- To extract the maximum power from PV under all weather condition by using INC- CRV method.
- Battery reduces the power fluctuation due the solar PV behavior under varies weather conditions.
- Used Constant Reference Voltage control MPPT method is effective than P&O and Inc.
- Incremental Conductance method is suitable for rapidly changing atmosphere with low radiation level application.
- Provide continuous power supply to the load.
- Deep cycle is possible in Lead-acid battery.
- Lead-acid battery has a relatively long life and lower Depth of Discharge than other battery types.

II. Proposed MPPT Methods

A. Incremental Conductance (INC)method

The disadvantage of the P&O method to track the peak power under fast varying atmospheric condition is overcome by Incremental conductance method. The INC can determine that the MPPT has reaches the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed and can calculated using the relationship between $\frac{dI}{dV}$ and $\frac{-I}{V}$. This relationship is derive from $\frac{dP}{dV}$ is negative when the MPPT is to the right of MPP and positive when it is to left of the MPP.

$$\frac{dI}{dV} = -\frac{I}{V} \quad at\ MPP$$

$$\frac{dI}{dV} > -\frac{I}{V} \quad left\ of\ MPP$$

$$\frac{dI}{dV} < -\frac{I}{V} \quad right\ of\ MPP$$

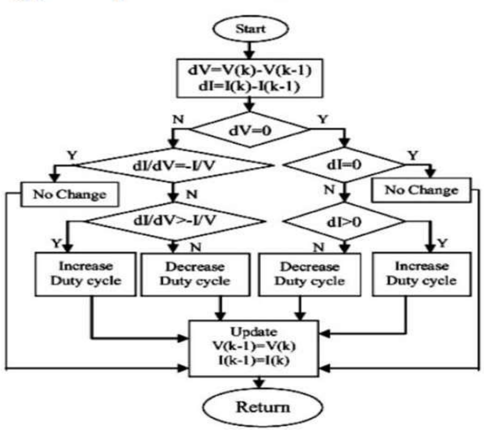

Figure 2: Incremental conductance MPPT flowchart

B. Constant Reference Voltage MPPT(CRV) Method

One form of MPPT algorithm is the constant voltage method. This method makes use of the fact that the ratio of maximum power point voltage and the open circuit voltage is 0.76. it is the simplest MPPT control method. The operating point of the PV array is maintained near the MPP by regulating and adjusting the voltage of the array to a given reference voltage Vref. The CV method does not require any input. It is important to observe that when the PV panel is in now isolation conditions, the CV technique is more effective than either the P&O method or the IC method.

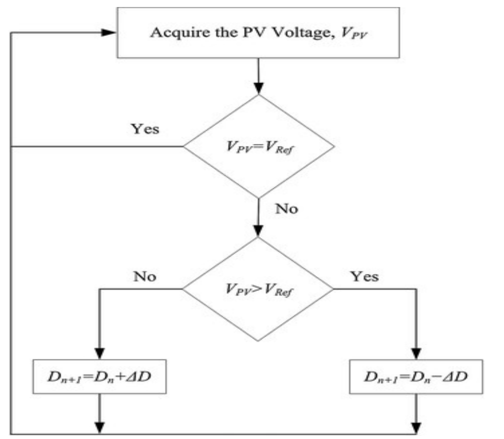

Figure 3: Constant reference voltage MPPT flowchart

C. Proposed Hybrid MPPT

This method used to get the maximum power from a varying source under a variable temperature and irradiance conditions. The main operation of MPPT is to sample the output of solar cells and apply the proper load to obtain the maximum power for any given location, time, season and environmental conditions. Below figure shows the hybrid MPPT control the DC-DC converter duty cycle block diagram. The duty cycle is generated by PV array voltage and current value.

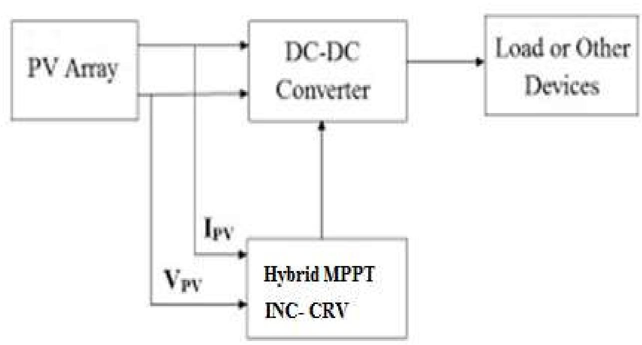

Figure 4: Solar array with hybrid MPPT controller

It designed for good performance, fast response, and less fluctuations. Since the efficiency of the PV is affected by the panel irradiance and temperature which are dynamic and unpredictable. For this reason, it is implemented to connect the load directly to the PV to obtain the maximum power, so it is necessary to balance the system. The main advantage of the converter is managing the power delivered to the load. The boost converter is designed to transfer maximum power from the Solar PV module to the load.. This converter acts as an interface the duty cycle and matched at Point of peak power with source for maximum power transfer. There are several MPPT methods are used to extract the maximum power among all the MPPT methods in this paper used the INC and CONSTANT REFERENCE VOLTAGE method as a combinational form and to overcome the drawback of other methods. The below figure 6 shows the proposed hybrid MPPT algorithm.

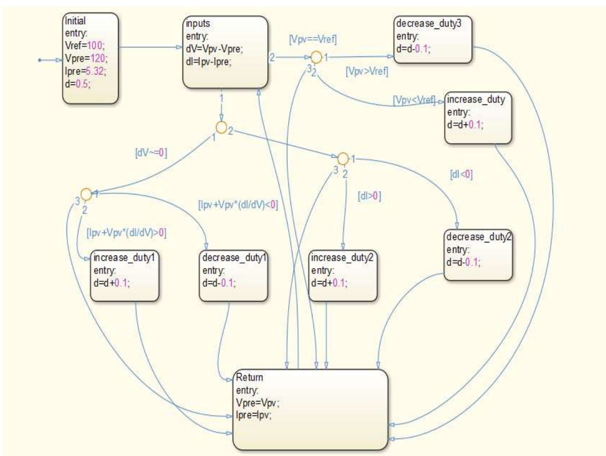

Figure 6: Proposed Hybrid MPPT method state flow

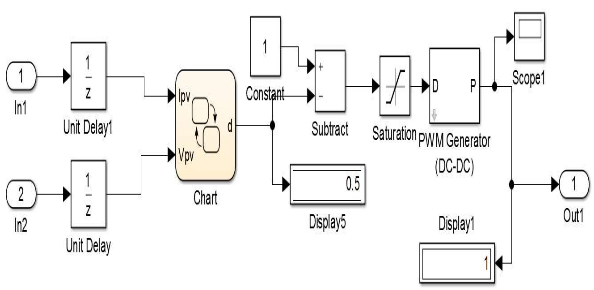

Figure 7: Boost converter switching control

III. PV PANEL AND BOOST CONVERTER

A. Solar panel design

The PV panel is designed based upon the Vpv using function block arrangement in MATLAB/ SIMIULINK

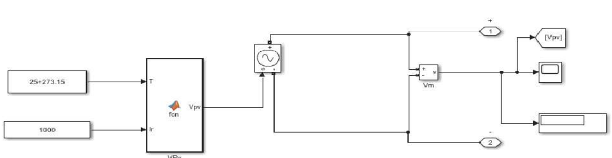

Figure 7: Simulink model of solar panel

Table 1: Specification of solar PV panel

Parameter	Value
Maximum power (Pmax)	715W
Voltage at MPP (Vmpp)	106V
Current at MPP (Impp)	6.72A
Open circuit voltage (Voc)	32.9V
Short circuit current (Isc)	8.21A
Number of parallel cell (Np)	1
Number of series cell (Ns)	72
Irradiations(W/m2)	800,1000

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B. Boost converter

The DC-DC boost converter used to supply a regulated DC output with the given DC input. These are widely used as an interface between the photovoltaic panel and the load in PV generating system. The charge has to be balanced to suit the solar panel's current and voltage to provide maximum power. DC-DC boost converter described as power electronic switching circuits it is used to convert one form of voltage in to another. It using a power MOSFET, the circuit diagram operation can be divided into two modes:

1.On-state 2.Off-state

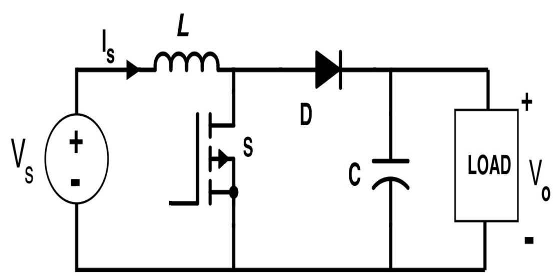


Figure 8: Boost converter

C. Equations for boost converter design

The DC-DC boost converter circuit consists of inductor, capacitor, diode, load resistor, and control switch. These components are connected with the input voltage source (Vin) so as to step up the voltage. The duty cycle of the control switch controls the output voltage of the boost converter. Hence by varying the ON time of switch, the output voltage can be varied. So the average output voltage can be determined for the duty cycle "D"

Vo/Vs = 1/(1-D) (1)

The inductor value of the converter is calculated by

L = Vs/Fs*ΔIL (2) $\frac{Vs}{Fs\Delta Il}$

The capacitor value can be obtained by

$$C = Io/Fs*\Delta Vo*D \quad (3)$$

D. Bidirectional converter with battery controller

In Bi-directional converter power can flow at both directions it means can feed power to the load and the load can also feed the power back to the source. Battery bank is required for power balancing in PV systems. This system's battery bank is connected to the DC bus and operated with a bidirectional Ac / DC converter. It has the arrangement of capacitor, inductor, switching element with a battery input for this project. The operation of this converter based upon the switching signal generated by the control circuit based upon the value of solar input and battery voltage rating.

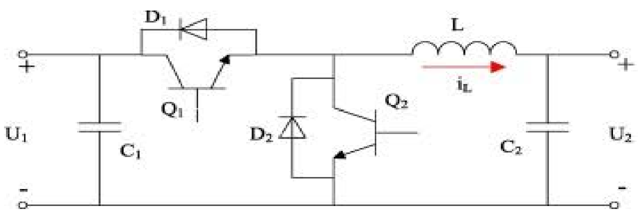


Figure 9: Bidirectional converter

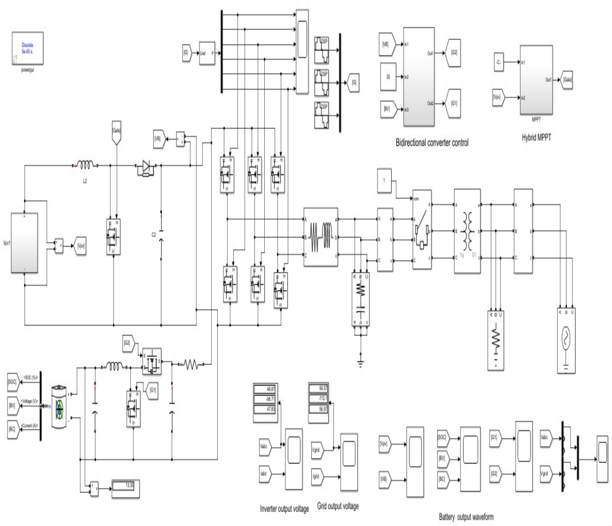


Figure 10: Simulation diagram of proposed system

IV. RESULTS

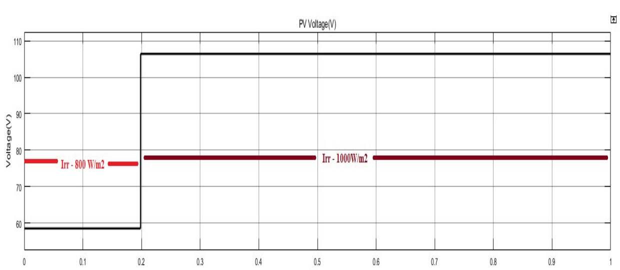


Figure 10: PV voltage

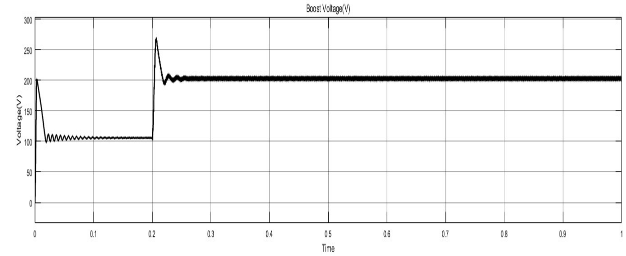


Figure 11: Boost converter output voltage

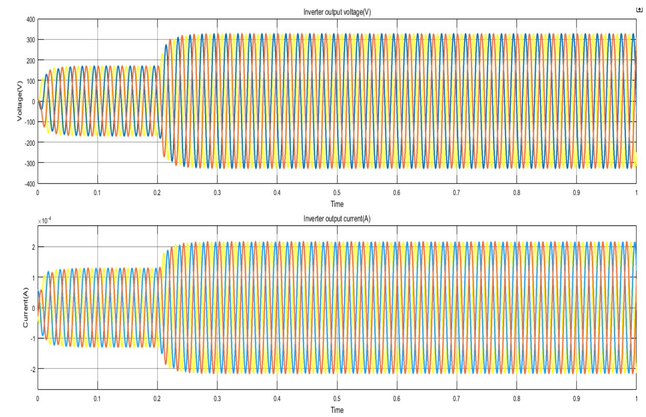


Figure 12: Islanded mode output voltage and current

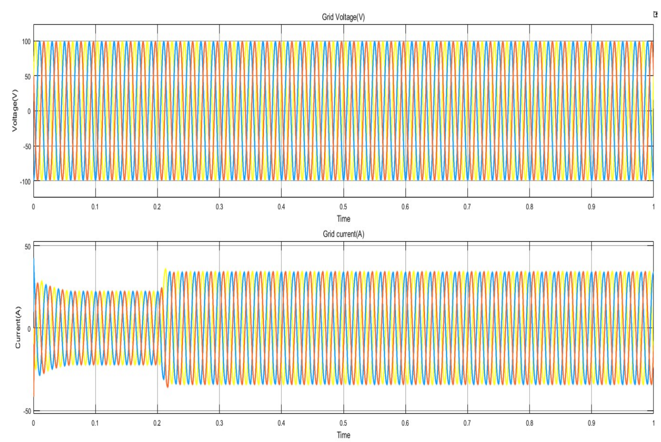
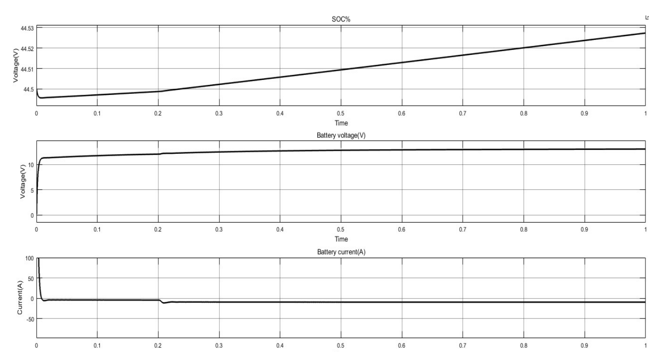
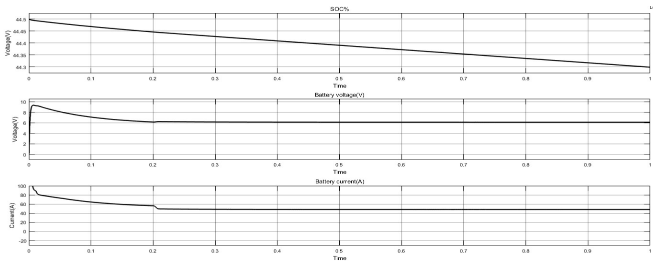


Figure 13: Grid connected mode output voltage and current



(a)



(b)

Figure 14: Battery power changes with PV generation

(a) Charging state and (b) Discharging state

V. CONCLUSION

This paper proposes control and power management scheme for PV-Battery system with both grid connected and islanded mode operation using hybrid MPPT. The presented battery is able to manage the power flow in an inverter and AC load of all units flexibly and effectively. And ultimately realize the power balance between the hybrid micro grid and it ensures a reliable power supply to the system when PV power fluctuation due to unstable irradiance or PV array shutdown due to fault. The boost converter with hybrid MPPT is accomplished with the use of Incremental conductance and constant voltage method. It ensures the confinement of Vpv within a specified limit that makes it possible to use this system over a reasonable load range of load conditions. The prototype was built and experimentally validation by simulation result.

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