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Battery Management System for Microgrids

Abstract— *A novel approach of project is to model and control of a battery management system used in microgrid. The system composed of photovoltaic array and battery. The photovoltaic array normally uses a maximum power point tracking (MPPT) technique to continuously deliver the highest power to the load, when there are irradiation and temperature. The disadvantage of photovoltaic energy is that photovoltaic output power depends upon weather condition and cell temperature making it an uncontrollable source. To make the system controllable, the battery is considered. This battery compensate the load variations when solar power is damping in nature.*

System has two operation modes, the unit-power control (UPC) mode and the feeder-flow control (FFC) mode, applied to hybrid system. When load is light, the UPC mode is selected. In UPC mode variation in load demands are compensated by the main grid because the hybrid source output is regulated to reference power. In FFC mode feeder flow is regulated to a constant power, the extra load demand is picked up by hybrid sources and hence feeder reference power must be known. The system can maximize the generated power when load is heavy and minimizes the load shedding area.

The proposed operating strategies with flexible operation mode change always operates the photovoltaic array at maximum output power and battery in its high efficiency performance band, thus improving the performance of system operation, enhance system stability, decreasing the number of operating mode changes in the MATLAB Simulink environment.

***Index Terms*— Battery, Feeder Flow Control, Photovoltaic, Unit Power Control.**

I. INTRODUCTION

With the world economic development and growing need for energy, the conventional energy sources are unable to meet the world demand for the energy. Thus, it is important to explore more and better means of alternative energy sources like sunlight, wind and biomass [5]. Photovoltaic energy is a promising alternate source of energy [4]. It is renewable, inexhaustible and non-polluting. It is more and more intensively used as energy resource in various applications. In regard to endless importance of solar energy, it is worth saying that solar energy is a unique perspective solution for energy crisis. Meanwhile, despite all these advantages of solar energy, they do not present desirable efficiency. The other renewable resources are biomass, geothermal, hydro and wind. PV power systems have the advantage that their installation is static (i.e. no moving parts), simple and quick compared to other renewable sources. They have a longer life span, (typically more than 20 years). Moreover, due to their low operational cost and maintenance, they provide a significant solution for powering remote areas. The photovoltaic (PV) used to harness the solar energy tends to become an uncontrollable source because of the use of maximum power point tracking (MPPT) technique to continuously deliver the highest power to the load when variations in irradiation and temperature occur. The disadvantage of PV energy is that the PV output power depends on weather conditions and cell temperature, making it an uncontrollable source. Furthermore, it is not available during the night. In order to overcome these inherent drawbacks, alternative source, such as BATTERY, is installed along with PV system [9]. By changing the battery output power, the hybrid system becomes controllable. However, battery, in its turn, works only at a high efficiency within a specific power range. By combining with battery sources, the systems power efficiency & reliability can be improved significantly.

The hybrid system can either be connected to the main grid or work autonomously [1], [3]. In the grid-connected mode, the hybrid source is connected to the main grid at the point of common coupling (PCC) to deliver power to the load. When load demand changes, the power supplied by the main grid and hybrid system must be properly changed. The power delivered from the main grid and PV array as well as battery must be coordinated to meet load demand.

The hybrid source has two control modes: 1) unit-power control (UPC) mode and feeder-flow control (FFC) mode. In the UPC mode, variations of load demand are compensated by the main grid because the hybrid source output is regulated to reference power. Therefore, the reference value of the hybrid source output must be determined. In the FFC mode, the feeder flow is regulated to a constant, the extra load demand is picked up by the hybrid source, and, hence, the feeder reference power must be known [2].

The proposed operating strategy is to coordinate the two control modes and determine the reference values of the UPC mode and FFC mode so that all constraints are satisfied. This operating strategy will minimize the number of operating mode changes, improve performance of the system operation, and enhance system stability.

II. SYSTEM DESCRIPTION

A. Structure of Grid-Connected Hybrid Power System

The system consists of PV- Battery hybrid system with the main grid and loads. The main system and hybrid system is connected to the load at the PCC as shown in Fig. 2. The Photovoltaic [4], [5] and battery [8] are model as nonlinear Voltage sources. These sources are connected to DC-DC converter which are coupled at the DC Side of DC-DAC Inverter. The DC-DC connected to PV Array works as an MPPT Controller. Many MPPT algorithms have been proposed in the literature, such as incremental conductance (INC), constant voltage (CV), and perturbation and observation (P & O) [6]. The P&O method has been widely used because of its simple feedback structure and fewer measured. The P &O algorithm with power feedback control is shown in Fig. 2. At the maximum power point, the derivative (dP/dV) is equal to zero. The maximum power point can be achieved by changing the reference voltage by the amount of ΔV_{ref}

B. PV Array Model

Output current of PV Panel is modelled by following equations [13]

$$I = I_{ph} - I_{sat}\{exp\ [q/AKT\ (V + IR_s)] - 1\} \quad (1)$$

Equation (1) shows that the output characteristics of a solar cell and it vitally affected by solar radiation, temperature, and load condition.

Photocurrent Iph is directly proportional to solar radiation Ga

$$I_{ph}\ (G_a) = I_{sc}\ (G_a/G_{as}) \quad (2)$$

Short-circuit current of solar cell I_{sc} depends linearly on cell temperature.

$$I_{sc}\ (T) = I_{scs}\ [1 + \Delta I_{sc}(T - T_s)] \quad (3)$$

Photocurrent I_{ph} and I_{sat} is depend on solar radiation and cell temperature.

$$I_{ph}\ (G_a, T) = I_{scs}\ G_a/G_{as}\ [1 + \Delta I_{sc}(T - T_s)] \quad (4)$$

$$I_{sat}(G_a, T) = I_{ph}\ (G_a, T)/\ e^{(Voc(T)/Vt(T))}-1 \quad (5)$$

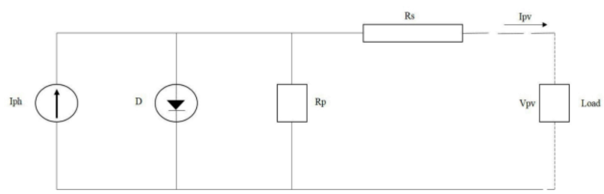

Fig. 1. Equivalent Circuit of Solar Cell

III. PV-BATTERY HYBRID SYSTEM

The proposed system consists of PV- Battery hybrid system with the main grid and loads. The main system and hybrid system is connected to the load at the PCC as shown in Fig. 1. The Photovoltaic and battery are model as nonlinear Voltage sources. Solar and battery sources are connected to DC to DC converter which are coupled at the DC Side of DC to AC Inverter. PV Array works as an MPPT Controller for DC-DC converter.

The proposed system has solar PV and battery as the sources in the microgrid for providing supply to the load in islanded mode of operation [1], [2], [3].

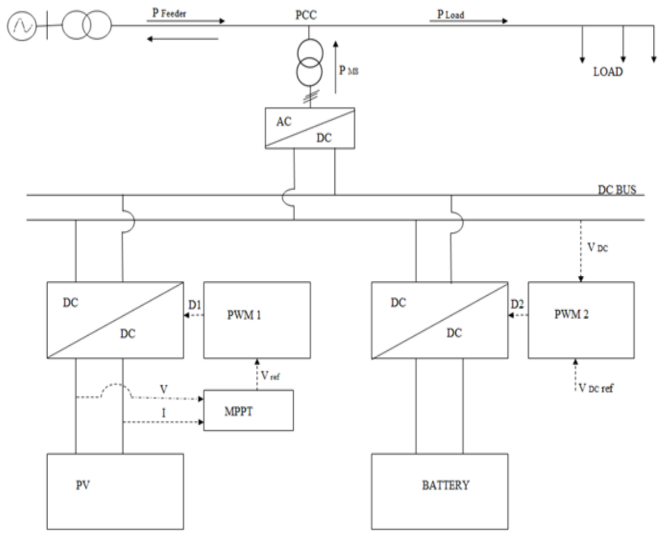

Fig. 2. PV-Battery Hybrid system.

A. MPPT Control

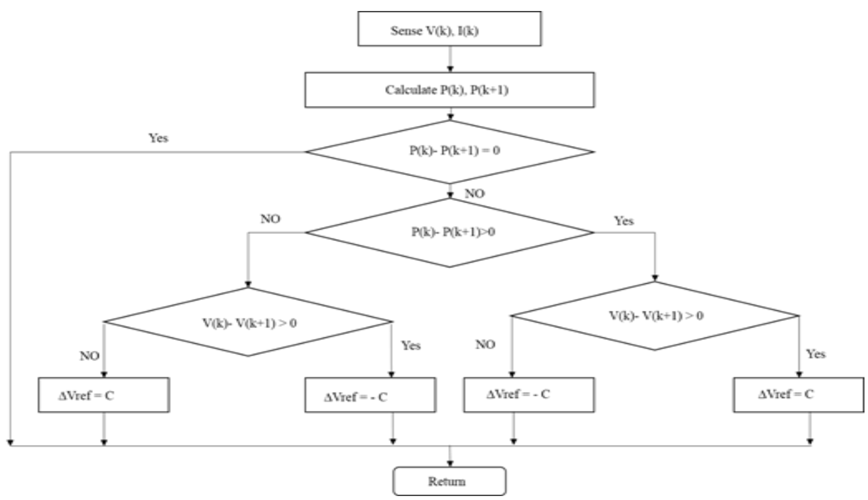

Fig. 3. Flow chart of MPPT

Perturb and Observe compared with incremental conductance and constant voltage method for MPPT tracking. The incremental conductance provides much better performance than P & O as well as constant voltage method. Due to the complexity of algorithm and expensive hardware P &O algorithm is used for tracking MPP of PV panel in this project.

B. Buck-Boost Converter

The boost topology is non-isolating like the buck topology. The boost steps up the voltage rather than stepping it down unlike the buck topology. The stepping up or stepping down the voltage is the **buck-**boost topology which is quite beneficial in applications involving powered where the variable input is available. The buck boost converter is a type of DC-TO-DC converter. Its output voltage magnitude is either greater than or less than the input voltage magnitude. It is equivalent to a fly back converter using a single inductor instead of a transformer.

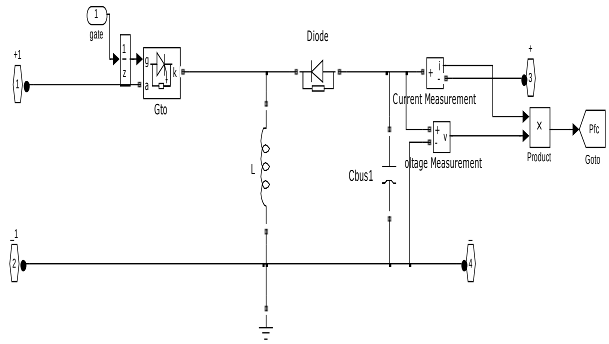

Fig. 4. Modelling of Buck-Boost Converter.

C. Battery Management system

In proposed system battery has the main role [7], [10]. In battery management system, system has convertor, pulse width modulation generator block.

In battery management system, battery operate with high efficiency in a limited range. It regulate voltage magnitude in both operating mode.

1) Unit Power Control Mode:

In the UPC mode, power will be transmitted to the main grid power if hybrid source output power is greater than load power. The hybrid source varies as per variation in the load. The system works more stably as battery compensated with the change in load and PV output power.

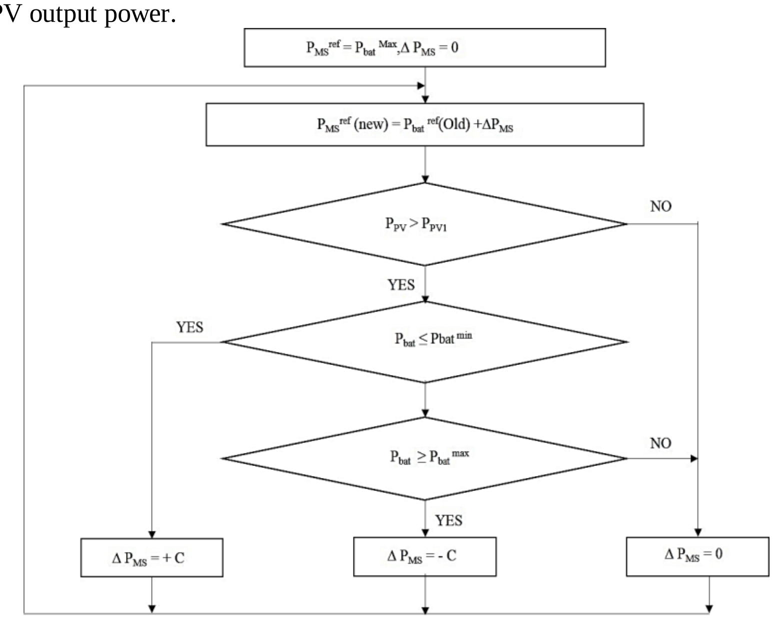

Fig. 5. Control algorithm diagram in the UPC mode

2) Feeder Flow Control Mode:

In excessive load conditions, the control mode changes to Feeder flow control mode. In the FFC mode, to fulfil the load demand power will draw from the main grid. Feeder flow will increase as load increases. Its maximum value always greater than feeder flow value. As per the current load demand operating mode will change, the PV output and constraints of battery and feeder power. The system can maximize the generated power when load is heavy and minimizes the load shedding area.

IV. MANAGEMENT SYSTEM FOR MICROGRIDS

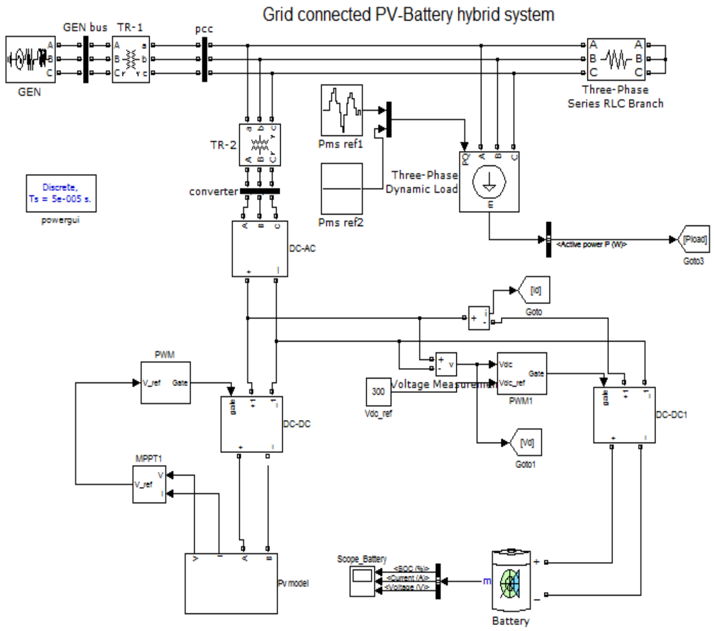

Fig. 6. Simulink model for microgrid system.

The proposed system consists of PV- Battery hybrid system with the main grid and loads. The main system and hybrid system is connected to the load at the PCC as shown in Fig. 6. The Photovoltaic and battery are model as nonlinear Voltage sources. Solar and battery sources are connected to DC to DC converter. This converter are connected at the DC Side of DC to AC Inverter. The DC to DC converter works as an MPPT Controller for PV Array

TABLE 1
BATTERY PARAMETER [13]

Battery type	Lead-acid
Nominal Voltage	300
Rated capacity (Ah)	200
Initial state of charge	100%
Nominal discharge current	40A
P_{bat} Battery output power	Varies according to PV output
P_{bat}^{up}	70Kw
P_{bat}^{low}	10kW
P_{bat}^{Max} Battery output power	70kW

TABLE 2
COLOR PARAMETER FOR PV-BATTERY WITHOUT GRID SYSTEM

Yellow	P_{ms_ref}
Pink	P_{bat}
Red	P_{pv}
Blue	P_{ms}

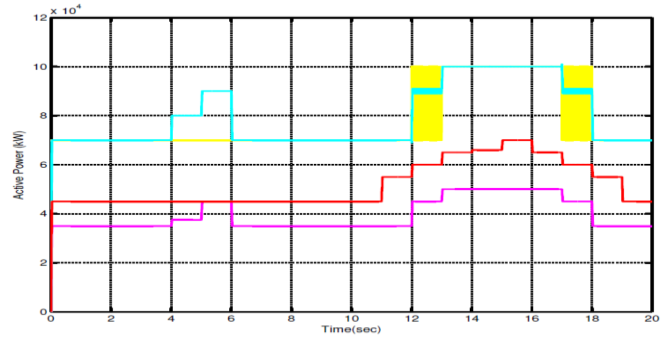

Fig. 7. PV-Battery without Grid System

TABLE 3
COLOR PARAMETER FOR PV-BATTERY WITH GRID SYSTEM

Yellow	Load
Pink	$P_{pv} + P_{bat}$
Red	P_{feeder}^{max}
Blue	P_{feeder}

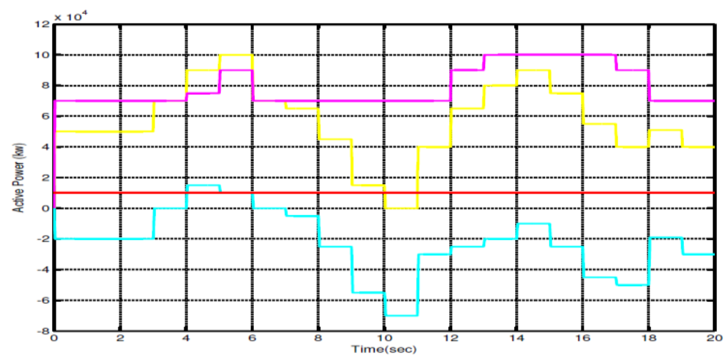

Fig. 8. PV-Battery with Grid System

V. CONCLUSION

The FFC mode and UPC mode are the main operating strategy of the system. In light load condition Unit power control mode is active and in heavy load conditions, the control mode changes to Feeder flow control mode.

In UPC mode, if hybrid source output power is greater than load power then the remaining power will be passed on to the main grid. Hybrid source matches the load variation. Battery power compensates the load changes and PV output power this results in a stable system.

Operating of PV and battery in UPC and FFC mode shows maximum power point operation of PV and high-efficiency performance of the battery. This results show that the overall system performance is improved and system is more stable in operation.

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