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Power Management with Solar PV in Grid-connected and Stand-alone Modes

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***Abstract*— As, the use of energy increasing, the power quality requirements are also increasing. Photovoltaic panels are generally used to compensate the energy demand. Due to the characteristics of PV panels and solar irradiation, output power is fluctuated. So that battery storage system is generally used to eliminate power fluctuation problem. The battery bank is communicated with DC bus by a bidirectional DC/DC boost converter. Upper limit and lower limit of the battery storage are considered in power management algorithm to increase the life cycle of battery bank. The paper proposed power management schemes to regulate both AC and DC bus voltages. The proposed power management system is capable to regulate power for grid connected mode and islanded mode. This paper mention power management algorithm and simulation, for both grid connected mode and islanded mode. The paper mention experimental results for both condition main grid connected mode and islanded mode.**

I. Introduction

Renewable energy has great significance for the world's future, given the environmental issues related to energy generation and energy's importance in our society [1]. The energy generation due to natural resources is known as renewable energy generation. It can be done by using solar energy, wind energy and biomass etc. System which deals with this kind of energy, they can be used with two different modes which can be classified as grid connected and stand alone mode as known as island mode [2]. In standalone mode the solar power panel are connected to batteries which stores the energy produced by the Solar Panel then load in the house consumes that energy. In grid connected mode a utility grid is there in which the excess power is fed into and when there is need of extra power more than power produced by solar panel extra power is taken from the utility grid. In recent days grid connected systems are used due to the reliability and they are cheaper in compared to standalone mode [6].

In learning it is found that this system is facing many problems like uncertainty, continuity, reliability etc [3]. Whenever fault occur circuit breaker breaks the circuit of system from grid then system will be depended on standalone mode. Therefore, it has been preferred that a combined system which can be work as both types of mode with more reliability and continuity with highest power of output whenever it is possible [4]. It has been also represented that by using maximum power tracking method which the method to generate maximum output for given parameters or instant condition [7].

II. The Proposed Power Management System

Fig.1 describe the configuration of whole system, contain with PV system. This PV battery system proposed with control and power management system. The battery bank is also connected in this configuration to store external power supply which is produced by PV array. The PV array is communicated with DC bus by DC/DC boost converter [8]. The battery bank is communicated with DC bus by a bidirectional DC/DC boost converter. The battery bank used a bidirectional DC/DC converter to control charging and discharging process [9]. Inverter is used to control a power flow DC bus to AC bus. DC bus providing a power to DC load like DC shunt or series motor etc. AC bus is providing power to AC load like induction motor, buildings, offices etc.

The control and power management system is detecting a real time parameter from the whole system. According to the value of a real time parameter, control and power management system decides the proper control signal to be applied to the converter for reliable power supply to the loads which are connected to PV array system. The control and power management system is design for both islanded mode and grid connected mode.

III. Power Management Algorithm

Fig. 2 and fig. 3 described power management schemes for standalone mode and grid connected mode respectively. As described in the flow chart, PV array and battery bank are connected to the gird by a circuit breaker. This system can operate either islanded mode and grid connected mode,

depending on the condition of both the micro grid and main grid. First analyze the state of circuit breaker and determine various voltage and power control schemes. In grid connected mode, DC bus voltage and reactive power that is exchange with AC side are control by an inverter control. The output power of the PV array is control by PV converters. Charging and discharging state of the battery is control by battery converters.

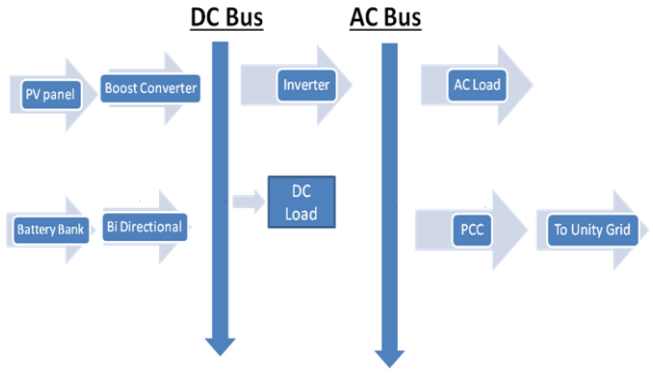

Fig. 1. Flow chart of proposed control system.

In standalone mode, the circuit breaker is open and aim of power management system is to ensure reliable power supply to the loads. DC and AC voltage regulation and AC frequency are maintained to avoid damaging the loads during transitions. In fault condition, grid connected mode is transfer to the islanded mode the AC bus voltage and frequency is maintain by the inverter switches and DC bus voltage is maintain by the battery converter. Power management system works according to the state of charge of a battery bank and value of state of charge is always detected by the power management system. To avoid damaging of the battery bank, upper and lower limit of battery bank must decided by its life cycle and also ensure that the battery bank is not over-charged or discharged. According to the state of charge of battery bank, output power of PV array, grid demand and AC DC load, power management system decide the operation mode of battery(either in charging mode or discharging mode) and PV array(either in MPPT mode or reference mode). So that system gives reliable power supply in any condition. Power management condition is describe in equation (1) and equation (2), for both grid connected mode and standalone mode respectively [10].

Grid -connected mode: $P_{pv} + P_{bat} = P_{dc} + P_{ac} + P_{grid}$ (1)
Standalone mode: $P_{pv} + P_{bat} = P_{dc} + P_{ac}$ (2)

Where, Ppv is supplied power by PV arrays, Pbat is supply power by battery bank, Pac and Pdc are power demand by AC and DC buses respectively, Pgrid is power demand by main grid. The reactive power is provided to grid by PV battery system. For maximum output from the PV array, MPPT (maximum power point tracking) algorithm is used. This algorithm gives maximum power point for which PV array generate maximum output power in various condition of solar irradiation. Where Ppv is the output of the PV array, Pbat is the power flow in the battery converter, Pac and Pdc is the power requirements by AC and DC bus respectively, Pgrid is the power requirement by main grid.

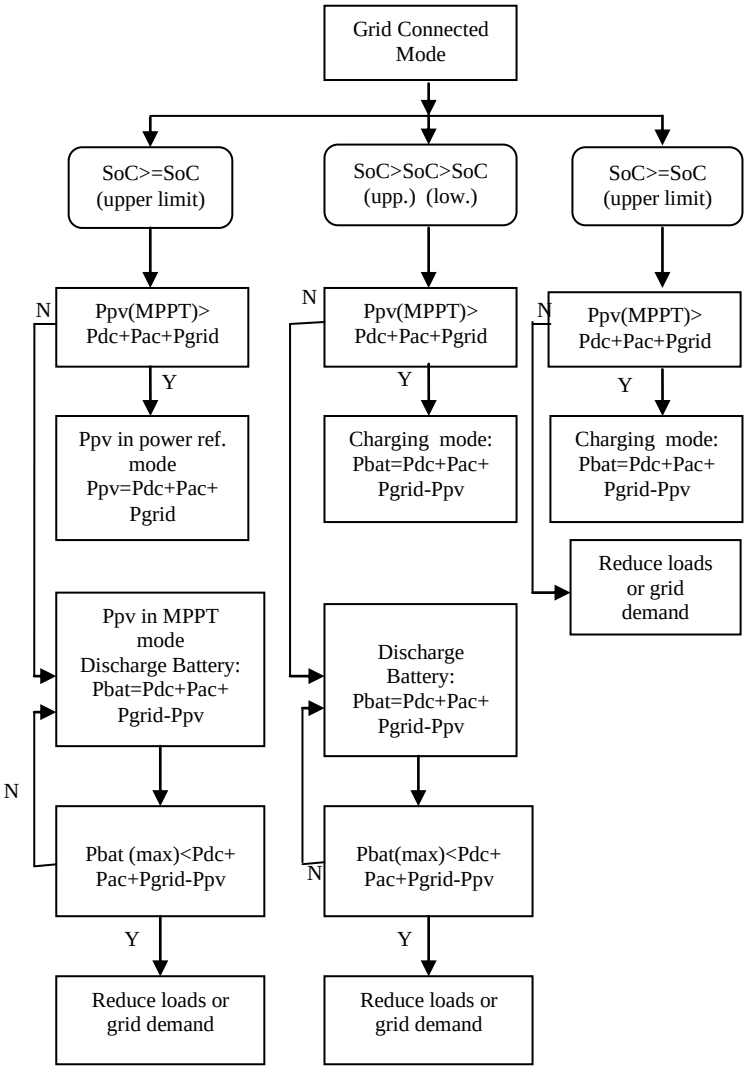

Fig. 2. Power management system algorithm for grid connected mode.

IV. Simulation Results

A. Simulation Verification: Grid connected mode

In grid connected mode, three power flow conditions are covered in experiment. In standalone mode, two power flow conditions are covered in experiment. MATLAB/SIMULINK is used for simulation verification.

1) Case 1: In first case, state of charge of battery bank is in between upper limit and lower limit. So that battery bank is available for power exchange to balance the whole system. The PV array is in MPPT mode. Power management system always detects the data of power generation, demand of a main grid, demand of AC bus and DC bus.

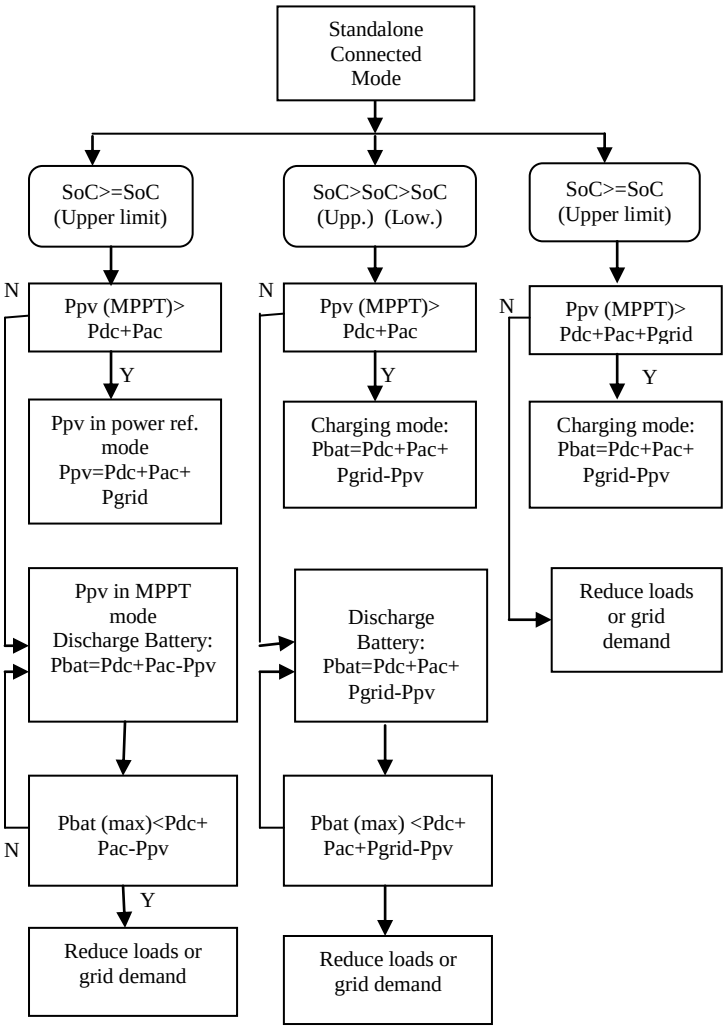

Fig. 3. Power management system algorithm for islanded mode.

2) Case 2: In second case, state of charge of battery bank is above upper limit. When SoC of battery bank is beyond upper limit, surplus power is flow to the main grid. Whenever grid demand is increase, extra power is provided by a battery bank. Battery bank is available to fulfill the grid demand. As the grid demand is increasing after 1 sec., power of the battery storage system is decreasing. Simulation result is presented in fig. 4.

3) Case 3: In third case, state of charge of battery bank is above upper limit. Total power provided by PV array is greater than main grid demand and loads. So that power of the battery bank is not use for reliable power supply. If main grid can't absorb a surplus power, the PV array mode is transfer to the power-reference mode to balance whole PV battery system. The operation mode of PV array is changed from MPPT to power-reference mode by power management system. As the grid demand increasing after 1 sec., reference level of PV arrays is changing. Simulation result is presented in fig. 5.

B. Simulation Verification: Stand alone mode

1) Case 1: In first case, the battery bank is available for power balancing. In standalone mode, power provide by PV array and battery bank to AC and DC loads. Main grid is disconnecting from the whole system in standalone mode. Power balance equation in standalone mode is given as follows:

$$Ppv + Pbat = Pac + Pdc \quad (3)$$

Simulation result is presented in fig. 6. As power demand by AC and DC buses in increasing after 1 sec., power of the battery bank is decreasing.

2) Case 2: In second case, the battery bank is available for power balance. Power output by PV array is depending on the value of solar irradiation. The amount of solar irradiation is changed.

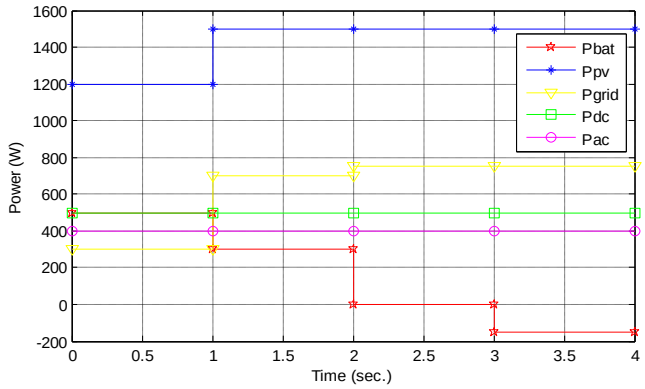

Fig. 4. Grid connected mode Case 1: Power flow of PV battery system with changing load.

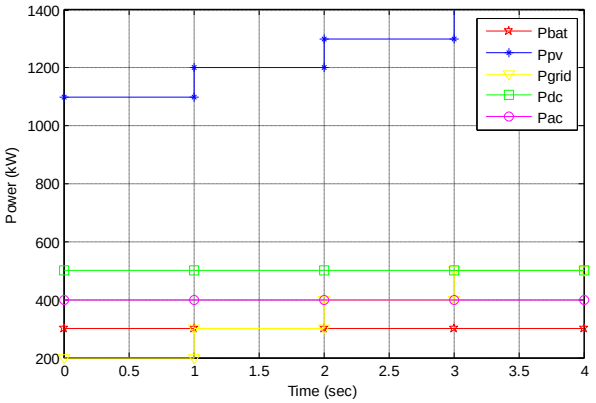

Fig. 5. Grid connected mode Case 3: Power flow of PV battery system with changing in solar irradiation.

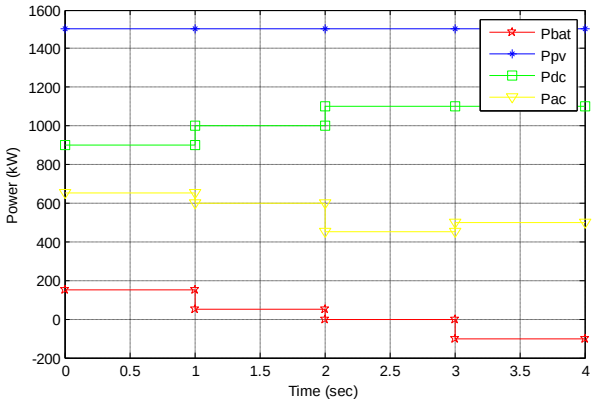

Fig. 6. Islanded mode Case 1: Power flow of PV battery system with changing in loads.

V. Conclusion

This paper proposed a power management system for both AC and DC buses and loads. The PV array is communicated with DC bus by DC/DC boost converter. The power management system is capable to regulate a power flow for both grid connected mode and islanded mode. The proposed power management system is verified by MATALAB/SIMULINK in various conditions. The battery bank used a bidirectional DC/DC converter to control charging and discharging process. Charging and discharging conditions are mentioned in power management algorithm. Power management algorithm also considered upper and lower limit for protection of battery storage. The power management system is able to give reliable power in any condition. Various conditions of power flow are discussed in experimental cases. The system is able to give reliable power supply in both conditions, for grid connected mode and standalone mode.

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