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Power Management Strategy in Solar PV System with Battery Protection Scheme in DC Microgrid

T Vijay Muni, S V N L Lalitha

Abstract. Renewable Energy Sources (RES) have been increasing interest in research and industry due to the numerous advantages in comparison of AC. This paper proposes the control algorithm, optimal power management system with battery protection for standalone photovoltaic (PV) system microgrid to decreases its operating & maintenance cost. The microgrid includes PV system and battery. The proposed control strategy consists of three stages: power management system, battery protection and supervisory control. Power or energy management system is responsible for load scheduling power flow between the battery, microgrid sources and loads on economic analysis. Battery protection scheme is responsible for protection of battery from overcharging and over discharging. Supervisory control is responsible for compensate the mismatching power between the schedule power and microgrid power . The proposed control system is demonstrated via case studies, simulation results with matlab and laboratory experimental setup.

Index Words: battery protection, power management system, solar photovoltaic converter, supervisory control.

I. INTRODUCTION

Microgrids are novel structure of electrical distribution systems, which belong to the wider notion of smart grids. The microgrid system can be consider as a small-scale electrical energy grid at the distribution system voltage level, which can characteristic both in grid-connected or islanded mode. It consists of Distributed Generation (DG) units, such as renewable electricity mills and blended warmth and power units, alongside with storage gadgets and controllable hundreds (e.g. air conditioners) [1]. Their special attribute is that they can be islanded, specially throughout fault incidents to increase the furnish reliability. Currently, the most frequent application of DC MGs is the electric powered energy furnish of remoted structures like vehicles, area crafts, statistics centers, telecom systems, whilst they have been proposed for rural areas and islands [2]-[4]. Nowadays, due to the increase of the usage of DC loads, DC MGs have been created due to their advantages in terms of low cost and efficiency [5]–[7]. However, to decrease the quantity of a couple of conversion degrees and to connect the AC and DC sources and loads in a efficient/economic way, AC/DC MGs have grow to be an best desire to connect the MGs [8].

There are many challenges that face microgrids operation. The first challenge is to limit the operational value of the MG. Secondly, the intermittency of RESs such as photovoltaic (PV) and wind turbine (WT) due to the fact of the climate version which may additionally reason energy imbalance and power-quality problems. Therefore, the decision makers are focusing on finding a solution to make the MG operate in a stable and financial way. The power management system plays a key role in controlling the power generation and/or drift of power in microgrids and thus minimizes the working cost. Power Management system controls the power flow in the MG based totally on choicest fee and affords the scheduled, reference values to the nearby controller of the MG. The power scheduling problem to provide reference values to the nearby controllers has been studied earlier than [9]–[11].The proposed system consists of three stages: power management system, battery protection and supervisory control. Power management system is responsible for scheduling power flow between the microgrid sources, battery and loads on economic analysis. Battery protection scheme is responsible for protection of battery from overcharging and over discharging. Supervisory control is responsible for compensating the mismatch power between the schedule power and microgrid power.This paper is organized as follows: Section 2 explains DC microgrid, section 3 explains power management system, section 4 deals with battery protection control scheme, section 5 deals with simulated performance. Finally section 6 conclusions are reported.

II. DC MICROGRID

The structure of standard DC microgrid machine is proven in determine 1. It ought to be cited that the DC MG topology may additionally fluctuate from the radial single feeder configuration to two-pole or ring configuration. In these topologies both unipolar or bipolar configurations can be implemented. Bipolar configurations can provide greater voltage degree selections in assessment with unipolar connections. With respect to the voltage levels, they can fluctuate in accordance with the running requirements of every system .

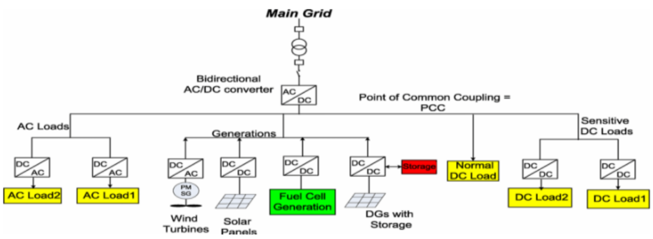

Figure 1. Structure of a typical DC microgrid

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Microgrid control need to insure that: (i) new distributed generation and storage systems can be brought or removed from the microgrid seamlessly, (ii) equal and stable contemporary sharing between parallel strength converters (i.e. sources) is enabled, (iii) output voltage fluctuations can be corrected, and (iv) favored strength glide from/to the microgrid together with technically and economically workable operation is enabled. For protected and dependable operation of DC MG, a well-functioning safety gadget is instrumental in any topology. Its essential goal is to limit the propagation of disturbances by detecting and separating faults within the minimum time frame [12], [13]. Protection of DC systems is in conventional a challenging project due to difficulties in extinguishing arc, which on the contrary takes place naturally in ac systems. Accurate short-circuit modern calculation and fault detection are the most vital conditions for the excellent graph of protection gadget [14] - [19].

III. POWER MANAGEMENT SYSTEM

The proposed diagram is shown in figure 2. From this diagram it can be referred to that no devoted converter is employed for making sure the MPP operation of the PV array, which leads to the multiplied utilization of the converters involved. Furthermore, solely one converter stage is existing in the route between the PV array and the battery, thereby enhancing the charging effectivity of the battery. The inductor present day iL is designed to be continuous. The switches S1 and S2 are operated in complementary fashion. All semiconductor units and passive elements are assumed to be best in the following analysis.

The controller of a stand-alone machine is required to function the following tasks: 1) extraction of most electricity from the PV array; 2) manipulate the battery utilization barring violating the limits of overcharge and overdischarge; and 3) dc–ac conversion whilst retaining the load voltage at the prescribed level. In order to achieve the desired functionalities, proposed system is required to operate in one of the following modes.

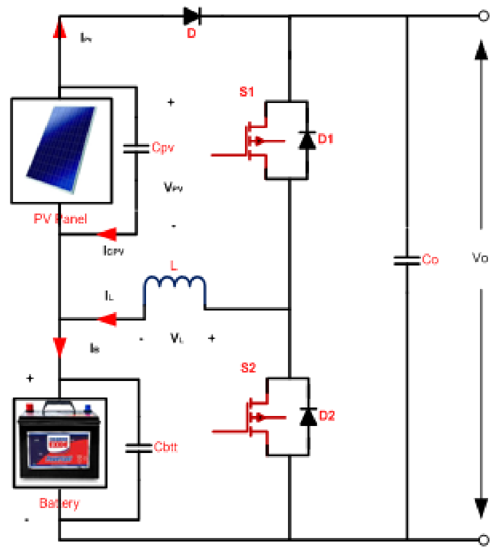

Figure 2. Proposed circuit diagram

Mode 1: MPPT Mode: Maximum power is extracted from the PV array when the system is operating in this mode. However, in order to operate in this mode, one of the following conditions have to be satisfied: 1) Available most PV energy P_{mpp} is greater than the load demand Pl, and the surplus power can be fed on by way of the battery barring being overcharged; and 2) $P_{mpp} < P_l$ and the battery have the functionality to furnish $P_l - P_{mpp}$ barring being overdischarged. The PV electricity in MPPT mode is given by means of $Ppv = P_{mpp} = (P_b + P_l)$, where Pb is the battery strength which is defined as wonderful in the course of charging and bad while discharging.

Mode 2: Non MPPT Mode: Based on the country of cost (SOC) level of the battery, its charging cutting-edge is required to be restricted to a maximum permissible restrict Ibmax to stop the battery from getting broken due to overcharge. The maximum charging current limit I_{bmax} restricts the maximum power that can be absorbed by the battery to $P_{bmax} = I_{bmax} * V_b$. When $P_{mpp} > P_l$ and the surplus power is more than P_{bmax}, the system cannot be operated in MPPT mode as it would overcharge the battery. During this condition, power extraction from PV is reduced to a value given by $P_{pv} = (P_{bmax} + P_l)$. This mode of operation is known as non-MPPT mode.

Mode 3: Battery Mode: The system operates in BO mode when there is no PV energy and the battery has the capability to provide the load demand without being overdischarged. *Mode 4: Shutdown Mode:* When Pmpp < Pl and the battery does not have the capability to supply Pl − Pmpp, the machine needs to be shut down to forestall the battery from being overdischarged.Figure 3 shows the control circuit 1 which sets the maximum power point voltage and figure 4 shows control circuit 2 which sets the reference voltage for PV system (V_{pvref}). These two control circuits will decide whether the system will be operate in mode 1 or in mode 3 When $i_{pv} > 0$ it indicates PV power is availability, then it selects mode 1 operation and the output voltage is V_{pvref} When $i_{pv} < 0$, system will selects mode 3 operation and V_{pvref} is taken as V_{dc} which is a desired value of 250-450 voltage.

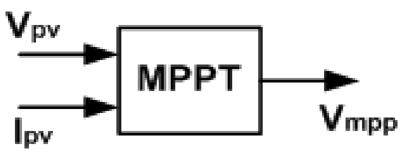

Figure 3. Control circuit 1

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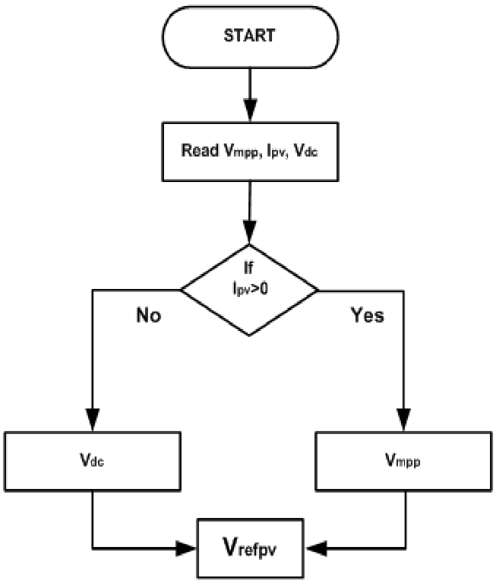


Figure 4. Control circuit 2

If $I_L < I_{PV}$ Battery Should be discharge

There by controlling the I_L and I_{pv} battery charging and discharging can be controlled.

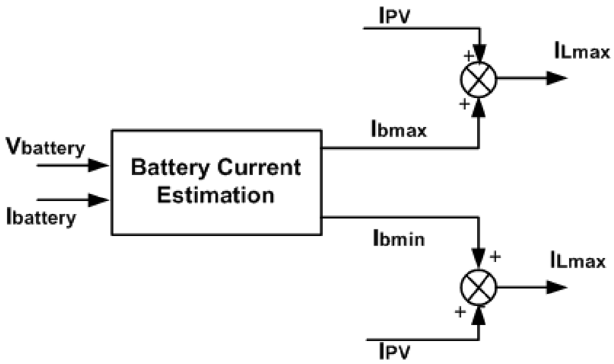


Figure 5. Control circuit 3

IV. Battery Protection Scheme

Battery protection scheme in the proposed system is explained briefly in this section. Depending upon the SOC of the battery and availability of power from the solar array a control strategy is developed for protection of battery from overcharging and over discharging.

From figure 2, when S1 is ON and S2 is OFF. The voltage across the inductor is V_{pv}

$$V_L = V_{PV} \qquad (1)$$

When S1 is OFF and S2 is ON The voltage across the inductor is -V_b

$$V_L = -V_b \qquad (2)$$

Average voltage drop across inductor is

$$V_{Lavg} = DV_{PV} - (1-D)V_b \qquad (3)$$

Assuming average voltage drop across the inductor is zero

$$0 = DV_{PV} - (1-D)V_b \qquad (4)$$

$$V_{PV} = \frac{1-D}{D} V_b \qquad (5)$$

Applying KCL

$$I_L + I_{CPV} = I_b + I_{PV} \qquad (6)$$

If average value of $I_{CPV} = 0$

$$I_b = I_L - I_{PV} \qquad (7)$$

If $I_L > I_{PV}$ Battery Should be charge

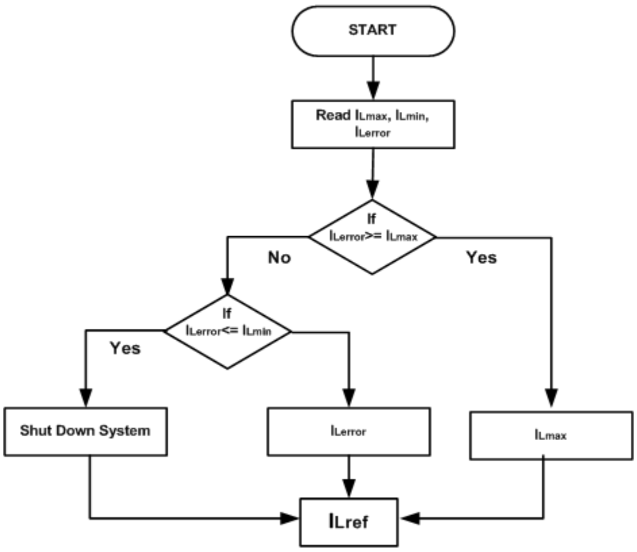


Figure 6. Control circuit 4

Figure 5 shows the battery estimation control circuit which finds the inductor minimum and maximum current. Figure 6 shows the control circuit 4 which estimates the inductor reference current I_{Lref}.

To forestall overcharging and overdischarging of the battery.

Maximum and Minimum current limits of are derived as follows:

$$I_{L\max} = I_{b\max} + I_{pv} \qquad (8)$$

$$I_{L\min} = I_{b\min} + I_{pv} \qquad (9)$$

wherein I_{bmax} and I_{bmin} are the maximum permissible charging and discharging current of the battery, respectively. These two limits are set based totally on the SOC stage and the allowable depth of discharge of the battery.

V. Simulated Performance

The proposed system is simulated on Matlab/Simulink platform, and the simulated responses got beneath distinctive operating stipulations are in this section. The different parameters/elements used in the simulation model are provided in Table I.

Table I

Parameter	Value
MPPT Algorithm	Incremental Conductance
Switching Frequency	15 kHz
Inductor	L=3 mH
Capacitors	Cpv = 2000 μF, Cbtt = 1000 μF

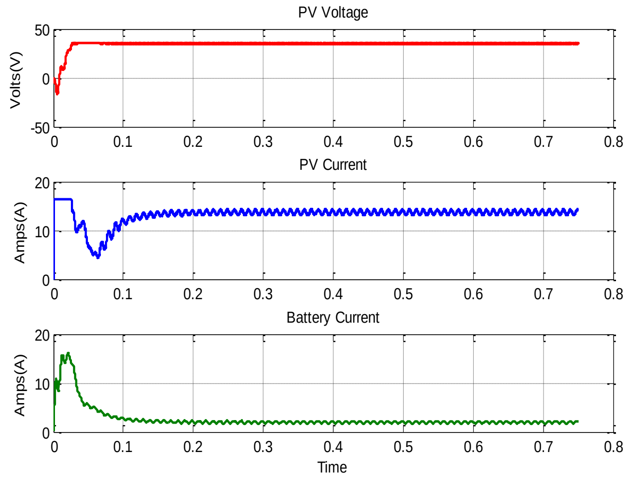


Figure 7. Simulation Response Steady State Operation (a)PV Voltage, (b) PV Current, (c)Battery Current

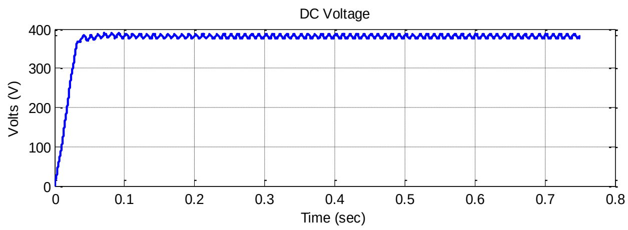


Figure 8. Simulation Response Steady State Operation – DC Link Voltage

The steady-state response of the device while operating in MPPT mode is proven in Fig. 7. The level of insolation is chosen to be 1 kW/m^2 with the corresponding I_{mpp}, V_{mpp}, and *Pmpp* as 14.8 A, 35.4 V, and 525 W, respectively. The load is kept at 450 W which is less than MPP Power, P_{mpp}. It can be attendant from Fig. 7 that V_{pv} and I_{pv} are at their respective MPP values, whereas *ib* is positive, indicating that the battery is charged to consume the surplus power. The load voltage which is being maintained at 230 V and the dc-link voltage profile are shown in Fig. 8.

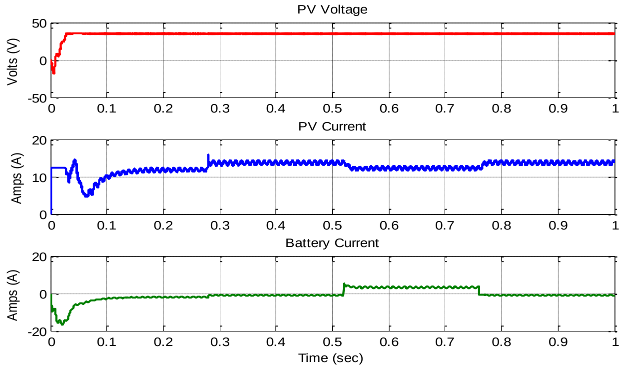
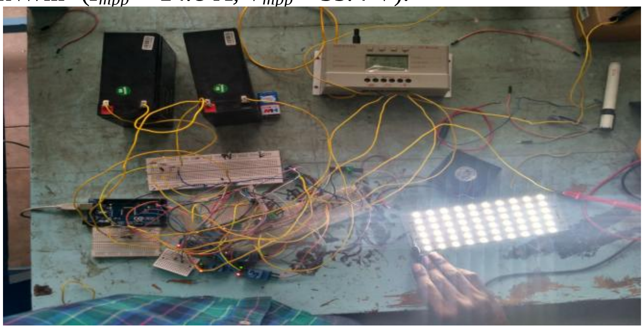
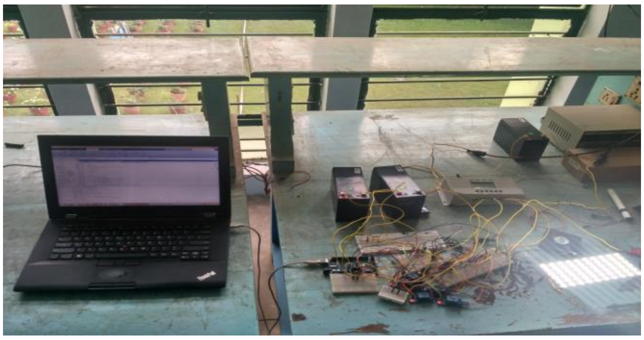


Figure 9. Simulation Response under changes in irradiance and Load (a) PV Voltage, (b) PV Current, (c)Battery Current

The simulation response (results) of the system under the load and insolation level changes while it is operating inMPPT mode (mode 1) is shown in Fig. 9. Initially, the insolation level is set at 0.75 kW/m2 (*Impp* = 11 A, *Vmpp* = 35 V). At 0.28 s, the solar insolation level is changed to 1 kW/m^2 (I_{mpp} = 14.8 A, V_{mpp} = 35.4 V).



(a)



(b)

Figure 10. (a) & (b) Laboratory setup of proposed system

VI. Conclusion

A solar PV-based stand-alone scheme with battery protection scheme in DC microgrid is proposed in this paper The most important features of the proposed control scheme include the following: 1) The MPPT of the PV array, charge control of the battery, and boosting of the dc voltage are accomplished in a single converter 2) enhancement in battery charging efficiency as a single converter is present in the battery charging path; 3) simple and efficient control structure ensuring proper operating mode selection and smooth transition between different possible operating modes.

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The experimental setup is developed at KLEF laboratory same is developed in simulation. The viability of the proposed system is confirmed through detailed simulation and experimental studies.

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