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Simulation of Hybrid PV-Battery System with ANFISControl Strategy for Stand-Alone DC Applications

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ABSTRACT: The paper presents a hybrid system comprising of photovoltaic (PV) and battery with fuzzylogic control (FLC) to meet the demands of isolated off grid DC loads. Perturb and Observe (P&O) method is used to achieve the maximum power point tracking (MPPT) by controlling the duty cycle of a dc–dc boost converter. Fuzzy logic controller regulates the power flow of the battery by means of a bidirectional buck-boost converter. The complete energy management system has been validated in MATLAB/SIMUINK with variable solar irradiation profile. The simulation results show that the system with fuzzy logic control prolongs the battery life-span by reducing the battery peak current up to 0.22% and also significantly decreases the settling time and peak overshoot of the DC load voltage up to 16.23% and 14.62% as compared to the system with conventional PID control. And the performance is further more improved by the ANFIS controller where the settling time and peak overshoot of the DC link voltage.

KEYWORDS: Hybrid PV-Battery System, MPPT Control, ANFIS Controller, DC applications

I. INTRODUCTION

Due to the fast depletion of fossil fuel and increasing pollution rate renewable energy sources have become most effective source of energy[1-2]. But the major challenge in integrationof these renewable sources is its intermittent nature and cost. PV is one of the most effective renew-able energy sources, but it is not available at night time. This ensures the requirement of two or more renewable energy sources [3-4]. Therefore, to make this kind of hybrid system more reliable and cost effective, there must be some energy storage devices to store the available energy when available and also feed the load under low PV output situations. Battery and Super Capacitor (SC)are used for storage purposes. The important advantage of battery over SC is its high energy density. They can store at least 3–30 times more charge than SC Whereas, SCs are able to deliverhundred to thousand time more power than a similar sized Battery. So Battery is able to supply long term energy demand compared to SC.

Under all operating conditions, there is a point on the P–V curve at which entire PV systemoperates. This allows the operation to take place producing maximum output power with maximum efficiency. Many MPPT methods have been developed and implemented [5-6]. The methods varyin complexity, sensors required, convergence speed, cost, implementation hardware, range of effectiveness, popularity, and in other respects [7-9]. To incorporate MPPT tracking, an intermediate DC–DC boost converter is proposed which is controlled by Perturb & Observe (P&O) method [10-11]. The MPP tracking is applied to a standalone PV system in order to extract maximum available power at all values of solar irradiation and temperature. The P&O technique [12-13], which is based on iterative algorithms, are widely used since it is easy to implement with rapid tracking capabilities and minimum steady state oscillations. Many researchers have focused their study on control of hybrid system. [14-16], have studied FC-battery-SC based hybrid systemto supply hybrid vehicles type load.

In this paper a Adaptive Neuro-Fuzzy Inference System (ANFIS) controller for maintaining a constant DC link voltage for standalone PV applications is proposed [17-18]. PV isused as the primary energy source but due to the fluctuating nature of the PV power supply, a battery is connected in parallel as a back-up energy storage system. Perturb and Observe control algorithm based MPPT controller gives the required duty cycle to achieve MPP. Bidirectional dc–dc buck-boost converter is used for controlling the power flow from the battery. An ANFIS controller was designed to regulate the duty ratio of the MOSFET switches to maintain power balance in the standalone system under varying solar irradiation conditions. The proposed hybrid system can be implemented in rural households for lightning purpose and running isolated pumps for effective harvesting.

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II. MODELING OF HYBRID SYSTEM

The proposed hybrid energy system considering PV-Battery is shown in Fig. 1. The system is used to sup-ply a standalone DC load at a constant voltage. In this paper, PV is used as the primary source while battery issued as the back-up energy storing element. A boost converter is used to interface the PV arrays with the load. MPPT based on P&O technique is implemented to always extract maximum available solar power. A FLC based control strategy for DC–DC bidirectional buck/boost converter is adopted to keep the DC link voltage constant during changes in solar irradiation [16]. Charging and discharging of the battery is controlled depending on the DC bus voltage.

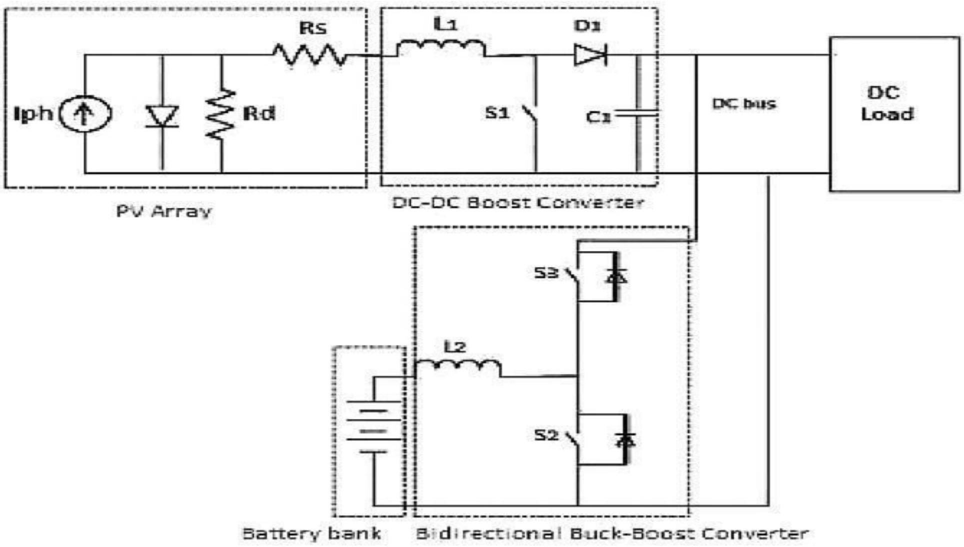

Fig 1. Structure of PV-battery hybrid system

2.1 Modeling of PV module

A PV cell generates around 0.5 V–0.8 V depending upon the semiconductor material and the technology used. Due to the small value of the voltage it cannot be used as a single PV cell. Therefore, the PV cells are connected in series to increase the voltage (i.e. from 36 to 72 cells) to form a PV module. The set of PV cells are also connected in parallel to achieve higher value of output current. This paper carried out a MATLAB/Simulink model of 200 W, 12 V PV modules for which four parallel sets of 36 cells are used. The developed model allows the prediction of theoutput which can be PV current, voltage or power. The weather data such as irradiance and temperature are considered as input variables. The model is based on mathematical equations and any change in the input variables causes an immediate change in the output parameter. The equivalent circuit of a PV cell is shown in the below fig2

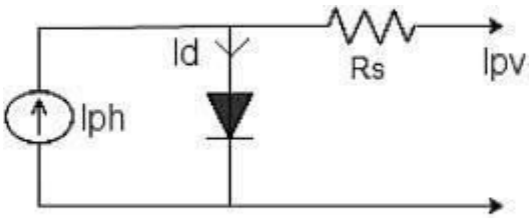

Fig 2. The equivalent circuit of a PV cell

The I–V characteristic of a PV cell is not linear and depends on multiple parameters. While modeling a PV cell, series resistance Rs and shunt resistance Rp of the cell are considered for precise and accurate results. The shunt resistance being very large, some authors neglects the incorporation of shunt resistance in the modeling of a PV cell. The focus of the paper is to design a simplified solar cell model to show the effectiveness of the solar charge controller under different

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situations. Therefore, an ideal PV cell is modeled using a current source in parallel with a diode and a series resistance Rs. Using Kirchhoff law, the current to the load Ipv can be written as:

$I_{pv} = I_{ph} - I_d$
(1)

In Eq. (1), Iph is the photocurrent produced from the PV cell. The PV cell photocurrent depends on the solar radiation and the temperature according to Eq. (2).

$$I_{ph} = [I_{scr} + K_i (T - T_r)] (\frac{S}{1000}) \quad (2)$$

Where S: Solar radiation (W/m2),

T_r: Cell temperature under standard test condition (STC) = 273 + 25 = 298 K,T: Actual cell temperature (Kelvin),

K_i: Temperature coefficient of the cell's short circuit current (0.0023 A/K),

I_S : Reference photo current under standard test conditions (0.0023 A)

The diode current I_d is proportional to the reverse saturation current I_{ph} as given by the Eq. (3).

$$I_d = I_{rs} \ [exp (\frac{▯▯}{A N_S V_T}) - 1] \quad (3)$$

Where V is the voltage across the diode, A is the ideality factor of the diode,
Ns is the number of PV cells in series (Ns= 36) and
V_T is called the thermal voltage which is a function of temperature.

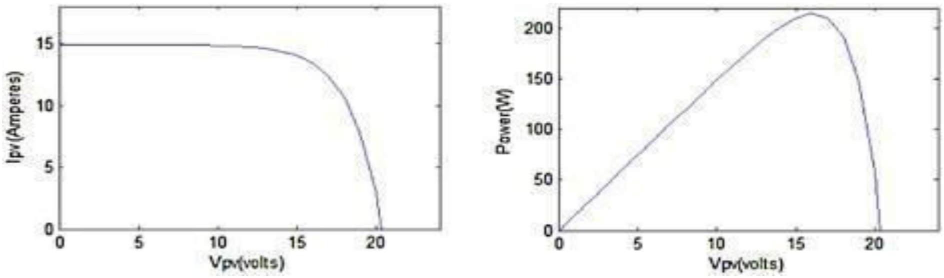

Fig 3. (a) I–V curve of the PV model. (b) P–V curve of the PV model

$$V_T = \frac{k.T}{q} \quad (4)$$

where k is the Boltzmann's constant (1.381 × 10^{-23}) and q is electron charge (1.602 × 10^{-19}C).Recombining the above two Eqs. (3) and (4) we arrive to Eq. (5).

$$I_d = I \ [exp (qV) - 1] \quad (5)$$

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The diode reverse saturation current is (6)

$$I_{rs} = I_{rr}\left(\frac{T}{T_r}\right)^3 exp\left[\left(\frac{qE_g}{A.k}\right)\left(\frac{1}{T_r}-\frac{1}{T}\right)\right]$$

The diode reverse saturation current varies as a cubic function of the temperature. E_g is the band gap energy of the semiconductor (1.166 eV) and I_{rr} is the reference value of the reverse saturation current under STC (0.000021 A).Finally, the PV array output current (I_{pv}) is obtained using the mathematical Eqs. (5) and (7). Np is the number of PV cells is parallel (Np= 4).

$$I_{pv} = N_p.I_{ph} - N_p.I_d \quad (7)$$

In this PV model, four parallel sets of 36 PV cells in series are interconnected to form one PV module of 200 W,12 V rating. The I–V and P–V simulation of the designed PV module in Fig. 3(a) and (b) show that the open circuit voltage is nearly 21.5 V and the short circuit current is 11.3A for a solar radiation of 1000 W/m2and temperature of 298 K

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$$Ipv = Np.Iph - Np.Id \quad (7)$$

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III. CONCLUSION

A Perturb and Observe (P&O) MPPT controller is designed for receiving the maximum power from the PV array under all weather conditions. The resultant system is capable of tracking MPPs accurately and rapidly without steadystate oscillations. The comparison of fuzzy controller significantly smoothens the battery current that improves the battery lifespan and also reduces settling time and peak overshoot of the DC link voltage by 16.23% and 14.62% respectively as compared to the system with PID controller. And the performance is further more improved by theANFIS controller where the settling time and peak overshoot of the DC link voltage is reduced much more which increases battery lifespan.

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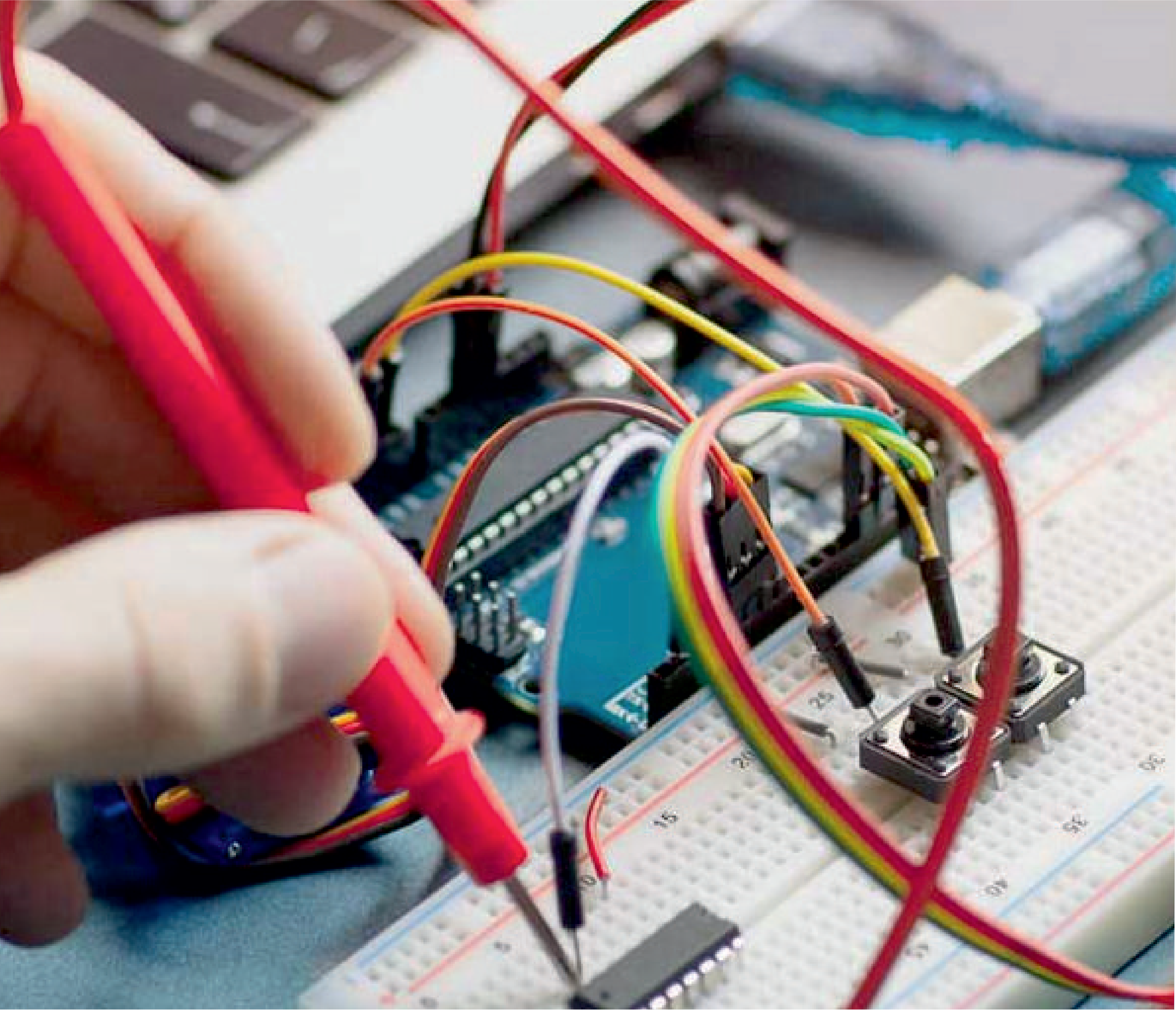

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