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A vigorous simple most extreme force point tracker for pv battery charger

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Abstract

Background: This paper proposes the dynamic way of utilizing the maximum power from solar for battery charger by means of maximum power point tracker with the new controlling parameter for improving the stability in power system network. The most efficient controller for PV related voltage converters is designed by the most efficient way of calculating the controlling parameter for MPPT of a PV battery charger which works in a full range condition with consistent changing environment. Other than this, another strong controller parameter is presented.

Results: Ideal MPPT calculations give PV current or voltage reference esteem as output controller parameter, in which frequent change in atmosphere may bring framework precariousness. Here, another variable is characterized to kill the issue and enhance the soundness of the framework. So as to contrast the introduced circuit and a traditional framework, Perturb and Observe (P&O) MPPT calculation which is surely understood in PV frameworks is actualized on the same framework.

Conclusions: Re-enactment results (Conventional P&O calculation and proposed structure) are displayed and thought about which show execution and adequacy of the proposed simple MPPT circuit.

Keywords: Solar energy, Battery, Maximum power point tracking, Battery charger, DC/DC converter

Background

In view of renewable energy source the photovoltaic system is considered for power generation as it pertains to different points of interest like, cleanness, accessibility, less maintenance and no disorder. Hence it is known to be prominent amongst the most typical sorts of environmentally friendly power vitality possessions (Doris and Gelman 2011). In the use of rechargeable batteries, the Solar PV frameworks use PV battery charger (Fig. 1) is considered as the best decision among compact charging gadgets on account of straight forwardness and sunlight based vitality accessibility. The framework as a rule contains four primary parts, PV module as force source, Battery as energy stockpiling, DC/DC buck boost converter, streaming energy from source to battery, Control framework, for controlling the stream of energy to work proficiently.

As PV module contributes vast part of the framework cost (Enslin et al. 1997) ideal usage is attractive, subsequently discovering ideal working point which is the point, of maximum power separated from PVs is a customary objective in planning the control framework (Sundareswaran et al. 2014; Sera et al. 2013; Weidong et al. 2013). There are two significant methodologies for power extraction; sun following the maximum power point (MPP) (Ts et al. 2002). Solar amplifies the power, as illumination point influences the PV voltage–current (V–I) trademark significant to Kelly-cosine connection, yet it is not in the extent of this paper.

As showed in (Fig. 2) MPP is a novel point at any moment, that progressions with respect to irradiance conditions is presented to the panel, along these lines MPP tracker (MPPT), is an unavoidable part of the control framework.

A few calculations are produced for MPPT for entire system by considering the atmospheric conditions, mainly including power (Applebaum 1987; Braunstein and Zinger 1981), curve (Kislovski and Redl 1994; Wolf and Enslin 1993), slope Perturb & Observe (P&O) strategy. The impacts of supplying DC–DC converter from most maximum power source of PV array. Gow and

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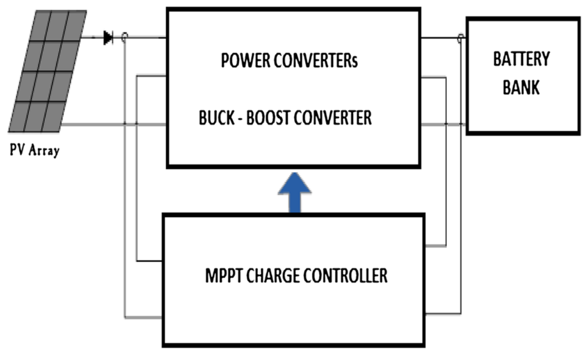

Fig. 1 Block representation of solar PV charger with battery bank

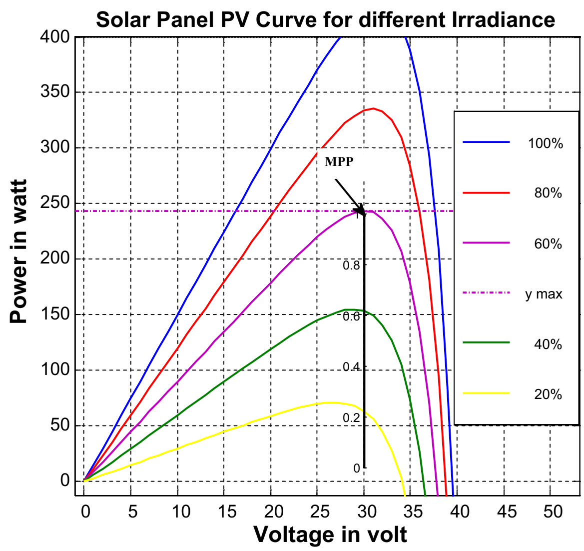

Fig. 2 Solar Panel PV characteristics for different irradiance condition

Manning (2000) P &O MPPT procedure for accomplishing versatile following, no relentless state motions around the MPP and provides a nonspecific outline core (Abdelsalam et al. 2011) is integrated MPPT Converter as a part of the PV board. It is a practical and exceptionally proficient (Enslin et al. 1997) incremental conductance method PV Array, Power Conditioning, Control, DC Load, these four subsystem are tentatively conveys out (Nafeh et al. 1999).

MPT calculation in view of the way that the MPOP of a PV generator can be followed precisely by looking at the incremental and quick conductance of the PV cluster (Hussein et al. 1995), isolating rectangles calculation maximum power point following methodology for a photovoltaic framework utilizing the partitioning rectangles calculation, and it is equipped for hunting down worldwide greatest (Nguyen and Low 2010). A novel ES calculation uses (Petrone et al. 2011) the normal inverter swell was tried on a mimicked exhibit inverter framework (Brunton et al. 2010) extreme looking for (ES) control and swell connection control (RCC) is actualized. ES control, the examination exhibited there shows generally. RCC soundness and working properties are additionally tended to where the key distinction amongst RCC and prevalent ES control strategies is the bother source (Bazzi and Krein 2011) a food forward MP-point following plan is produced for the coupled-inductor interleaved-support converter-bolstered PV framework utilizing a fluffy controller (Veerachary et al. 2003). The new controller enhances the slope climbing look strategy by fuzzifying the tenets of such methods and wipes out their disadvantages (Alajmi et al. 2011). Comparative tests demonstrate that the proposed strategy can track the progression reaction rapidly and precisely; in the meantime show signs of improvement enhancement result. Zhou et al. (2011) neural system has a very straightforward structure and gives a profoundly precise recognizable proof of the ideal working point furthermore an exceedingly exact estimation of the most extreme force from the PV modules Hiyama et al. (1995) demonstrated that no less than 19 unmistakable techniques have been presented in the writing, with numerous minor departure from usage (Esram and Chapman 2007) assessments among the most normal MPPT systems, doing significant examinations concerning the measure of vitality removed from the photovoltaic board (PV) (tracking factor—TF) in connection to the accessible force, PV voltage swell, dynamic reaction and utilization of sensors (Berito et al. 2013).

These strategies need computerized handling to apply, either in a microcontroller (MCU) or FPGA which expand framework many-sided quality and aggregate cost particularly undesirable in little scale frameworks. Keeping in mind the end goal to evade these, few simple circuits are proposed.

In Chen and Smedley (2004), a simple MPPT in light of one-cycle control (OCC) is proposed, it works well the length of the board temperature variety is little, as this paper concentrates on little compact frameworks used to charge rechargeable batteries, this constraint is basic. A few frameworks utilizing differentiators (Alonso et al. 2006 and Lee et al. 2008) are not appealing, on account of clamor affectability. In Bodur and Ermis (1994), MPPT is determined by clearing PV voltage from 0 V to open circuit voltage (VOC) occasionally. The framework is not powerful in view of requirement for periodical scope.

Another framework utilizing a pilot PV system is proposed in Tariq and Asghar (2005). The pilot PV board, with attributes like that of fundamental PV system, is kept under no-heap condition. A small amount of the pilot PV VOC, which relates to MPP voltage (VMPP), is

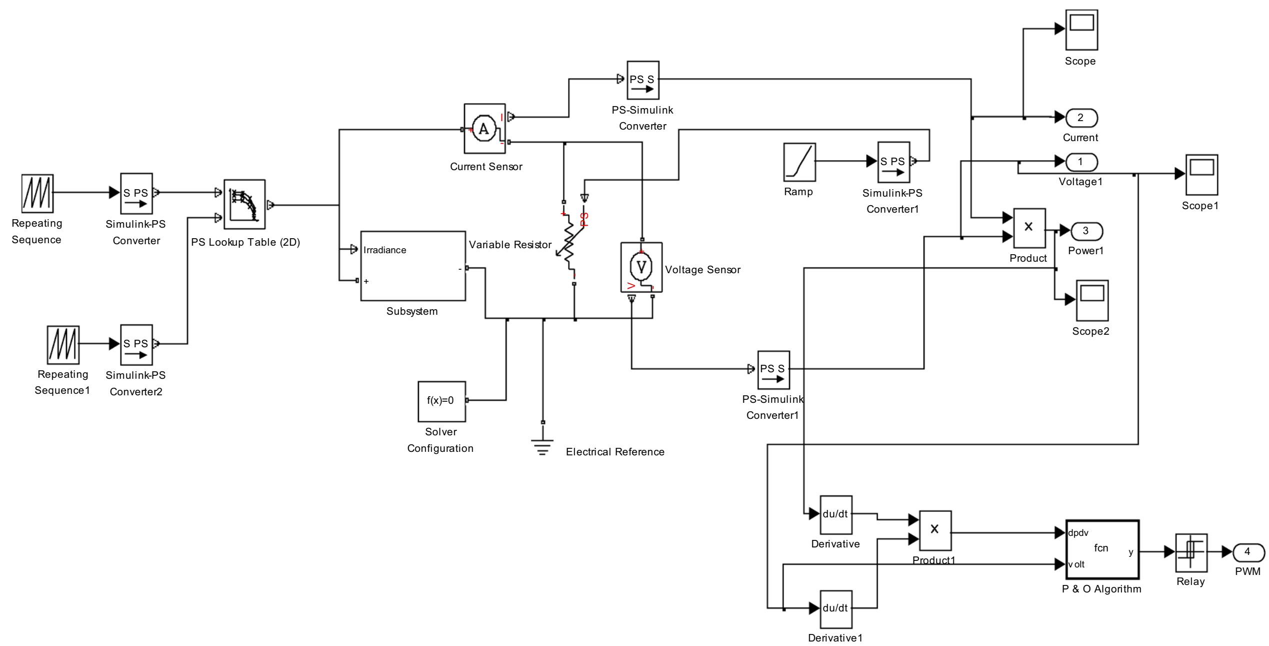

Fig. 3 Simulation circuit for solar PV charge controller with MPPT P&O algorithm

utilized as the reference voltage. This strategy is not productive particularly for little frameworks while initial PV ought to be kept open circuit. The other issue is that the qualities of stacked and emptied boards contrast amid lifetime.

Liang et al. (2010) and Hsieh et al. (2010) proposed a simple circuit to actualize P&O calculation, however it experiences many-sided quality and requiring a circuit to capacity PV voltage and force in any progression.

The simple MPPT displayed in (Ji et al. 2010), works by direct control of exchanging order. This prompts variable exchanging recurrence which is not alluring in light of EMC issues and yield current and voltage administrative issues (Villalva et al. 2010).

In this paper a basic simple circuit for MPPT execution of a close planetary system is proposed which is well-working in all meteorological conditions and has an altered recurrence. Another controlling parameter is likewise displayed which enhances the security of the framework.

This paper is sorted out as takes after. The proposed simple circuit and working guideline are portrayed in segment II. Segment III makes a survey on issue of routine controlling variables and presents the new one with a talk on outline criteria. The aftereffects of reproductions for the proposed framework and customary computerized P&O MPPT calculation and the examination are introduced in segment IV. The exploratory set-up and the outcomes are delineated in area V.

Limitations of the existing work

In the existing work for any variation in solar irradiance or any abrupt changes in atmospheric condition the output power on the grid side fluctuates due to solar output power fluctuations. The concept in the existing work is MPPT controller P&O algorithm. The MPPT charge controller ensures that the loads receive maximum current to be used (by quickly charging the battery) and the maximum power point could be understood as an ideal voltage at which the maximum power is delivered to the loads, with minimum losses. The existing MPPT controller with P&O algorithm has the following disadvantages. (i) Real peak solar PV curve cant be identified if there is any shadow on solar clustered array (ii) P&O algorithm is slow to find the maximum peak if the solar voltage is far from MPP.

Tracker implementation

The schematic graph of the PV battery charger control framework with the proposed MPPT circuit is represented in Fig. 3. The solar output power and current are given as input for MPPT algorithm so as to dispense with clamor and high recurrence parts of sign. The algorithm proposed in Fig. 3. Separates the sign by utilizing the comparator analogy. The comparator analogy in MPPT, P&O algorithm has two qualities, (i) zero, when the power is diminishing, (ii) high when the power is expanding. The output of MPPT, comparator analogy develops the reference signal which is required to frame the switching states that is required for triggering the converter state.

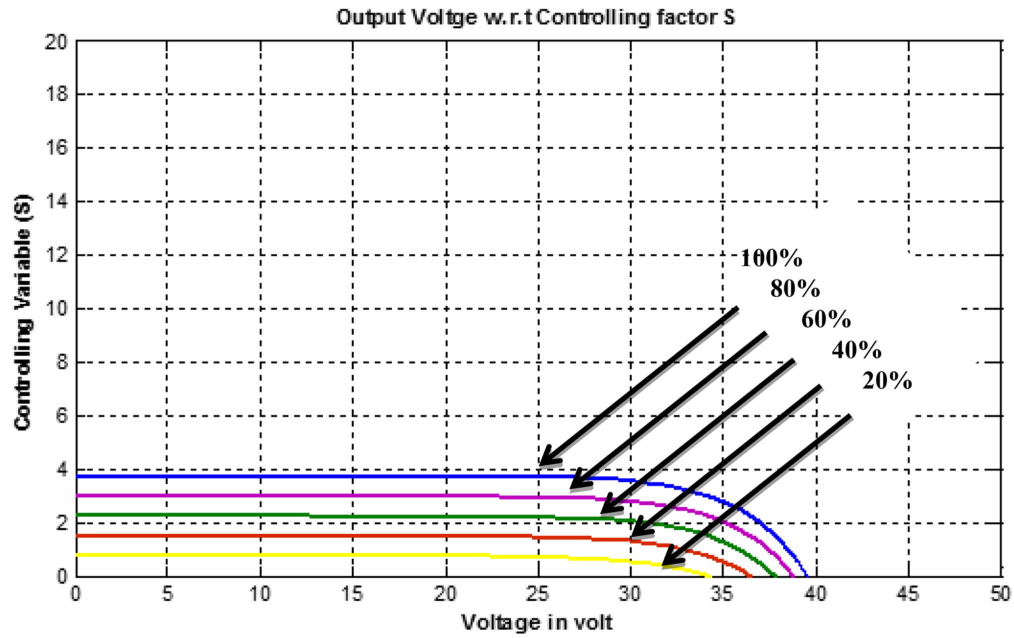

Fig. 4 Solar V–S characteristics for different irradiance factor

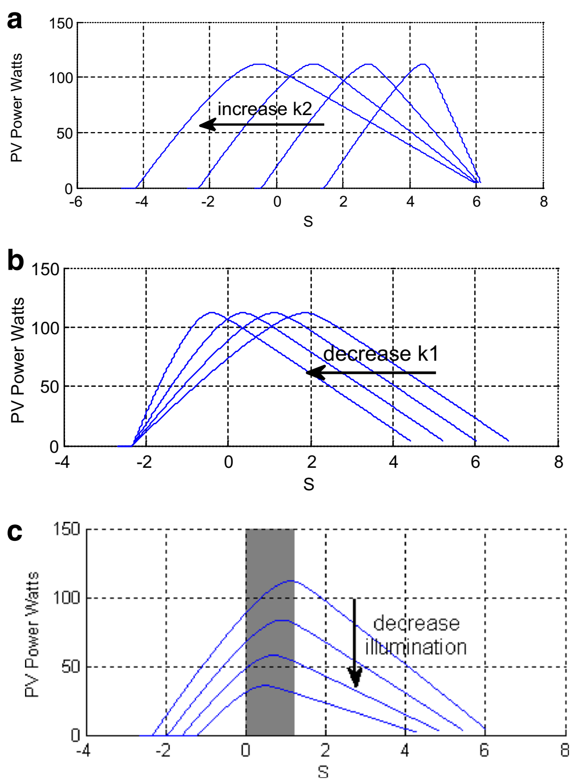

Fig. 5 S–P characteristics of PV panel by variation of **a** k_2, **b** k_1, **c** illumination (range of operation for S is shown by *colored area*)

The reference signal developed at the output of the algorithm is unstable due to frequent change in atmospheric condition. Dur to this variation in the reference signal, the output power fluctuates very badly, causing instability in power system framework. To avoid the cause of instability problem, a new controlling factor 'S' is incorporated in the proposed scheme. The controlling factor has constant K_0, K_1, K_2 constants for controlling the reference controlling parameter S for abrupt input change.

Deriving energy conversion

Approximating charger loss (P_{loss}) to zero, and assuming battery voltage (V_{Bat}.) constant (valued while voltage changes dynamically very slow) and considering power balance for charger input and output power,

$$P_{in} = P_{out} + P_{loss} \overset{P_{loss}\approx 0}{\rightarrow} I_{out} = \frac{1}{V_{Bat}} P_{in} \overset{Const V_{bat}}{\rightarrow} I_{out} = kP_{in} \quad (1)$$

where, I_{out} is the charger output current. demonstrates that I_{out} is a well representative for P_{in}, which can be used as input of MPPT algorithm. Therefore multiplying V_{PV} and I_{PV} is omitted from circuit in.

Novel supervisory variable

Predictably controller affords *V*or I_{ref} as the output and uses PV sway as th$_{ref}$ e contribution parameter for implementation of MPPT algorithm. In the proposed systems, rapid weather change, or a to a degree of sudden shadow on PV module which cause a sudden change in V–I characteristic of PV module may result in system instability while following the set value, and thus the PI controller saturates and hence any further step change in the reference value of V_{ref}/I_{ref} causes the output to be ineffective, therefore PV output power remains constant and the defined MPPT algorithm fails to find MPP, when V_{ref}/I_{ref} remnants superior than new short circuit PV current (I_{sc}) or newfangled open circuit PV voltage (V_{oc}). Alternatively unsteadiness occurs when V_{ref}/I_{ref} falls out of range of variations V_{PV}/I_{PV}. This instability is a major problem in PV modules with piercing V–I physical characteristics.

To avoid the instability problem the new controlling variable S is defined as below.

$$S = K_0 + K_1 I_{PV} - K_2 V_{pv} \tag{2}$$

where I_{PV}, and V_{PV} are instantaneous PV current and voltage respectively, and k_0, k_1, k_2 are constants. Selecting appropriate value of k_0, k_1, k_2 cause S_{ref} to endure in variety of operation either for abrupt input change, and hence it improve the stability of the system. With reference to the V–I characteristic, of PV module for different irradiance factor the voltage and current varies in opposite direction, and hence least possible and maximum value of S are calculated as

$$K_0 - K_2 V_{oc} \leq S \leq K_0 + K_1 I_{sc}. \tag{3}$$

Figure 4 shows the solar V–S characteristics for different value of irradiance. Dash lines denote for MPP.

In order to guarantee MPPT working for different conditions, it is necessary to calculate the controlling factor S_{ref}. This relies between the minimum and maximum instantaneous values of S according to the worst condition.

The controlling reference value is incorporated in the proposed algorithm, by considering the entire atmospheric circumstances. With reference to Eq. (3). the maximum worst condition is determined when V_{oc} is minimum. The extreme worst condition ($K_0 - K_2V_{oc}$) is obtained with minimum insolation and maximum PV temperature. ($K_0 + K_1I_{sc}$) is the minimum condition obtained with $I_{sc} = 0$. Based on the above Implementation the Eq. (4) is obtained.

$$K_0 - K_2 V_{oc(max)} \leq S_{ref} \leq K_0 \tag{4}$$

Figure 5 depicts the reference controlling factor for increase in K_2 and decrease in the factor K_1 with decreasing illumination. When the illumination decreases, the output power is decreased in which the V_{oc} is minimum with I_{sc} maintained constant. Therefore S_{ref} which is the main factor in controlling the instability is primarily zero and then increases to S_{ref} (MPP). Therefore for fleeting stability the assortment of difference for S should satisfies the following conditions.

$$\begin{cases} S_{min} \leq 0 \\ S_{max} \geq S_{ref(max)} \end{cases} \tag{5}$$

Using (4) and (5),

$$\begin{cases} K_0 \geq S_{ref(max)} \\ K_0 - K_2 V_{oc}(\max) \geq 0 \end{cases} \tag{6}$$

S_{MPP} should be larger than zero to be able to be shadow by PI controller which means the extreme on S–P curve should be greater than zero. This criterion is used to determine k_1.

$$0 < S_{Mpp(min)} - K_2 V_{MPP(max)} \tag{7}$$

$$K_1 > \frac{K_2 V_{MPP(max)} - K_0}{I_{MPP(min)}} \tag{8}$$

A remarkable firm positive site of utilizing the new controlling variable S cause the system to maintain its stability in abrupt atmospheric change. The circuit contains only a voltage subtractor, promotion two voltage dividers. Using node equation for circuit in is derived.

$$\begin{aligned} S = {} & \frac{R_2 R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3} V_{CNST} \\ & - \frac{R_2 R_3 g_1}{R_1 R_2 + R_1 R_3 + R_2 R_3} V_{PV} \\ & + \frac{R_1 R_3 g_1}{R_1 R_2 + R_1 R_3 + R_2 R_3} \end{aligned} \tag{9}$$

From (3) the constants k_1, k_2, and k_3 are obtained.

$$\begin{cases} K_0 = \frac{R_2 R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3} V_{CNST} \\ K_1 = \frac{R_2 R_3 g_1}{R_1 R_2 + R_1 R_3 + R_2 R_3} V_{PV} \\ K_2 = \frac{R_1 R_3 g_1}{R_1 R_2 + R_1 R_3 + R_2 R_3} \end{cases} \tag{10}$$

Circuit design and stability analysis

In order to analyze the stability of the system, small signal model of the charger using a buck–boost converter as dc/dc converter is derived.

Small signal model while using S as control parameter

The small signal model of the buck–boost converter using voltage and current control are designed by utilizing the model Voltage and current to duty cycle transfer functions of the entire system and are given by (11) and (12).

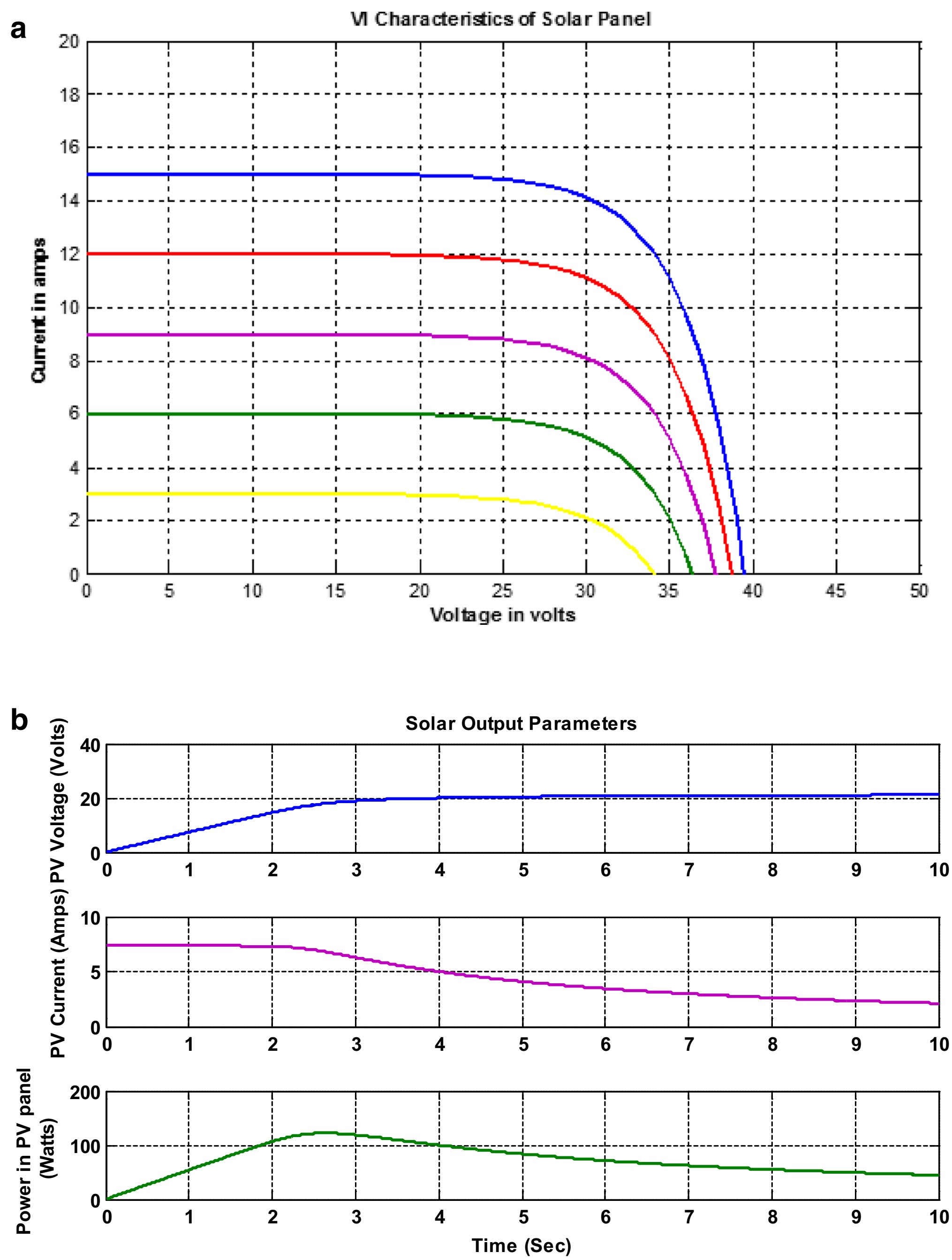

Fig. 6 **a** Solar PV array VI characteristics with MPPT P&O Algorithm, **b** solar PV voltage, current, power w.r.t time

$$G_{VD}(s) = \widehat{V_{PV}}/\widehat{d'(s)} = \frac{(1+sCR_c)[I_L + VD(1-sCR_C)/(R_L+sL)]}{sC + \left(1+R_c/R_{equ}\right)\left[\left(1/R_{equ}\right)+\left(D^2/R_L+sL\right)\right]} \tag{11}$$

$$G_{id}(s) = \widehat{i_L(s)}/\widehat{d'}(s) = \frac{\left(V - \frac{I_L D}{sC(1+R_c/R_{equ})) + (1/R_{equ})}\right)(1+sR_c)}{R_L + sL + \frac{D^2(1+sR_c)}{sC(1+R_c/R_{equ})) + (1/R_{equ})}} \tag{12}$$

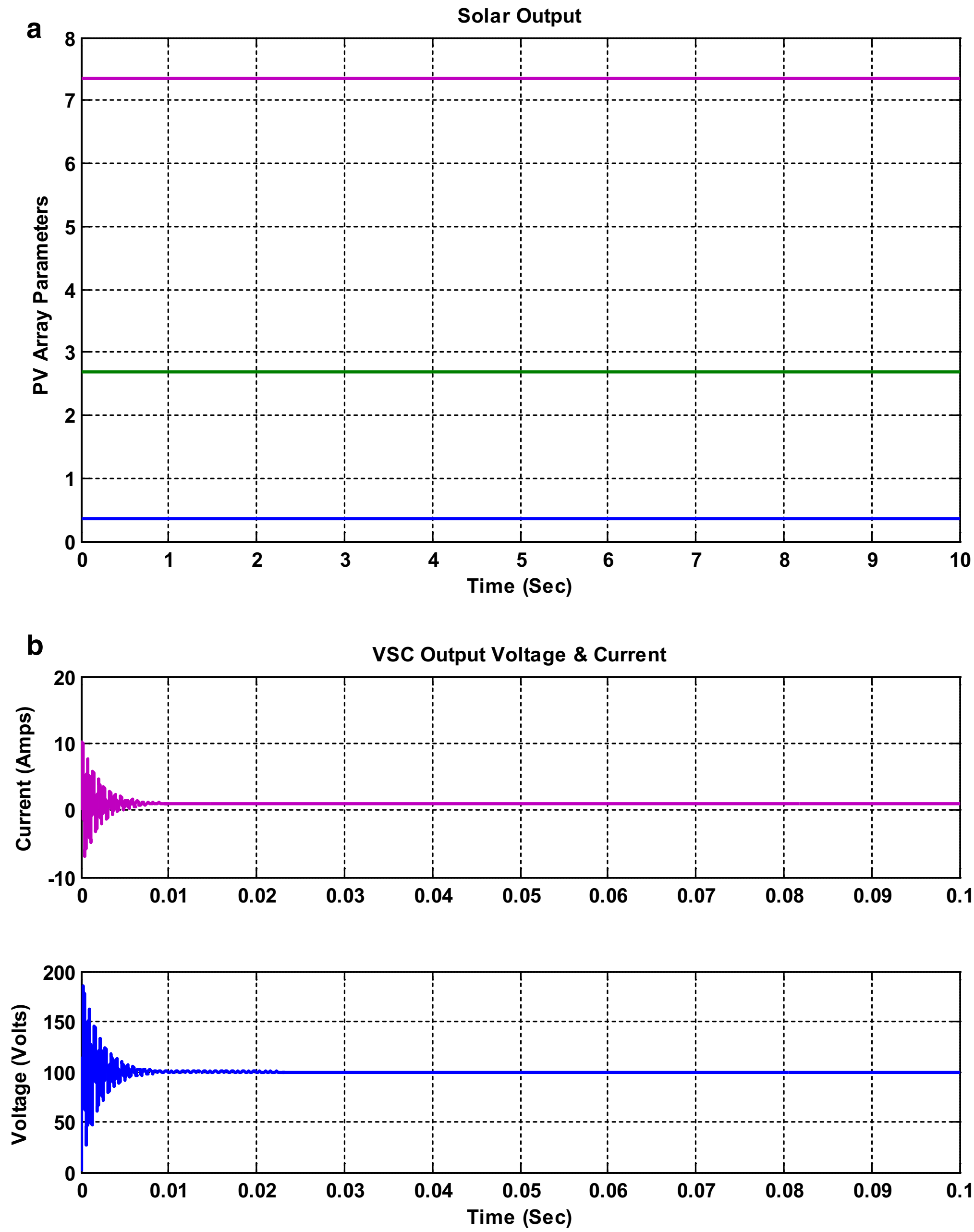

Fig. 7 Simulation results of the charger controller using digital MPPT P&O algorithm. **a** Solar Output with controlling S factor. **b** VSC converter output without filter

where, *Req* is the input resistance of the converter.

The small signal variables used in (11) and (12), are defined in the following.

$$\overline{V_C} = V_C + \widehat{V_C}$$
$$i_c = I_L + \widehat{i_L} \quad (13)$$
$$d = D - \widehat{d}$$

Using (2), (11) and (12) $G_{sd}(s)$ can be calculated,

$$G_{sd}(s) = K_1 G_{id}(s) - K_2 G_{Vd}(s) \quad (14)$$

Simulation and experimental results

Dualistic virtual reality is performed using conventional digital Perturb &Observe algorithms. The V–I curve of PV panel is shown in Figs. 6, 7, 8. A buck converter model is used as charger with 100 kHz switching occurrence

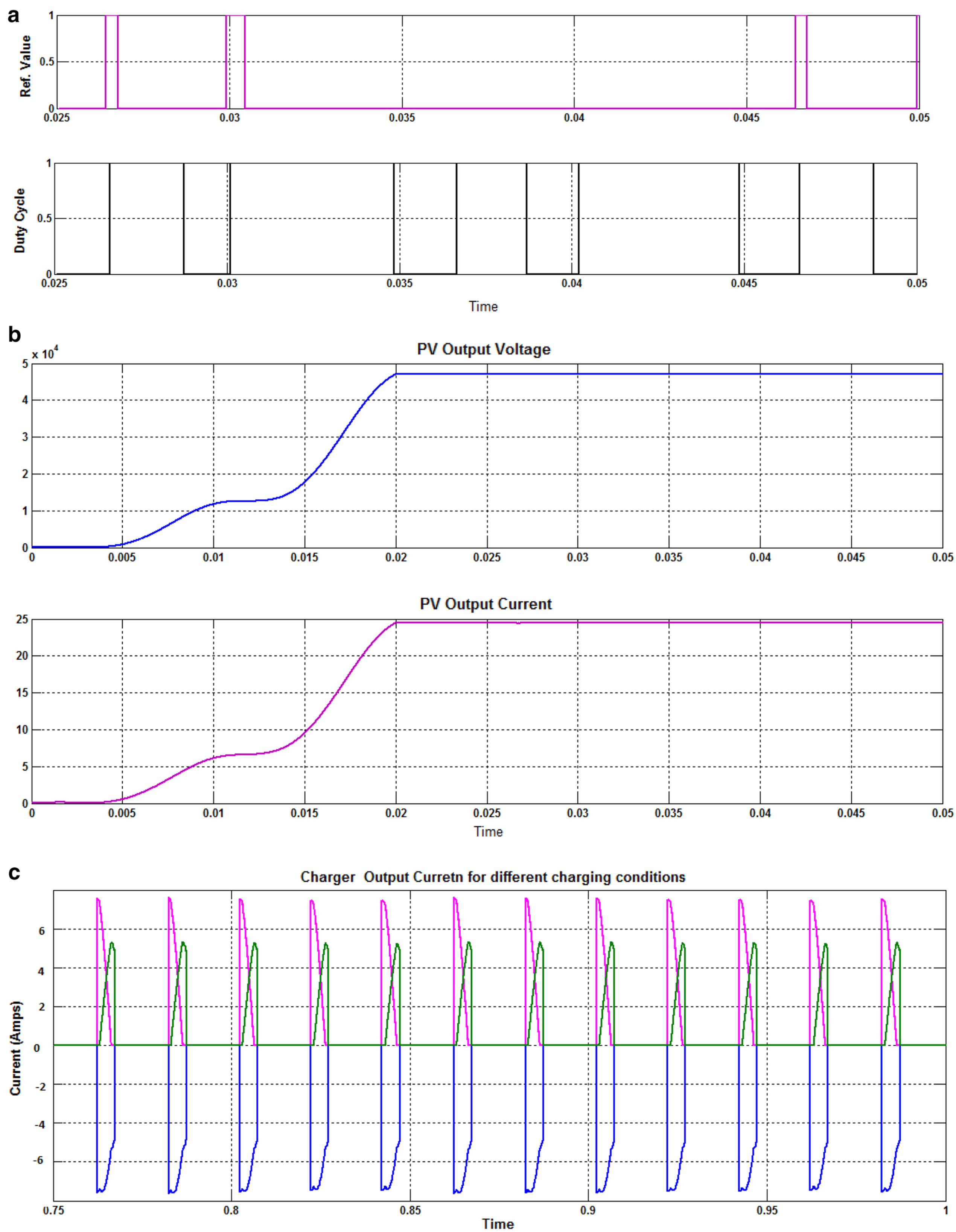

Fig. 8 Simulation results of the charger using proposed analog algorithm. **a** Controlling factor S ref. Value and duty cycle of the converter. **b** Solar PV array output voltage and output current. **c** Charger output current for different charging conditions

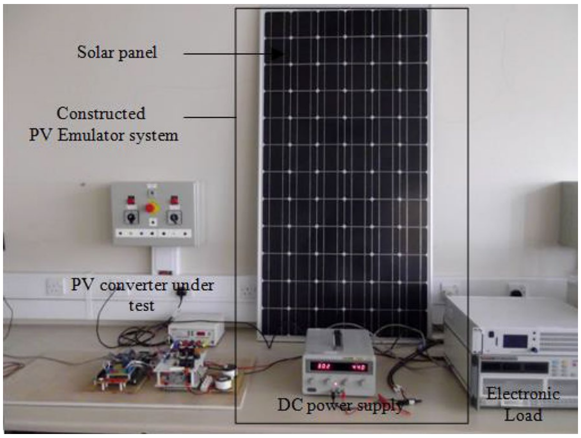

Fig. 9 Experimental set up

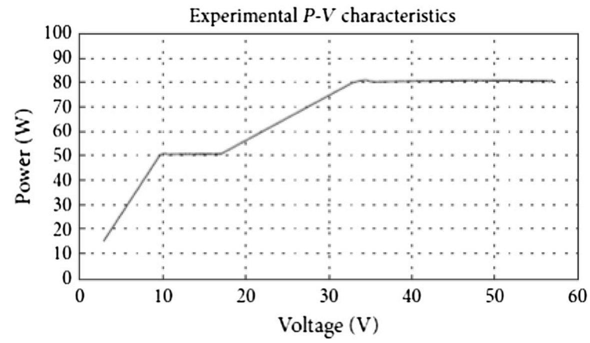

Fig. 11 Experimental result of PV output voltage (5 V/div)

and the nominal voltage of the battery is anticipated to be 12 V. The operating Clock frequency for implemented MPPT algorithm and step frequency for P&O algorithm are same as 100 Hz. The platform for computing and making decision for any change in the duty cycle is done at specific time intervals in case of conventional P&O algorithm. The step frequency represent the time interval for deciding the time interval. For example if change in duty cycle is done every 1 ms. then the step frequency is 100 Hz.

S is used as controlling variable to implement both the algorithms. The scenario of simulating illumination is described in the following.

90% illumination at first 0.1 s time interval then gradually increase to 100% illumination for 0.1 s time interval, and remaining constant till t = 0.3 s. Finally sudden change to 80% illumination at t = 0.3 s.

A prototype model is designed (Fig. 9) to accept the capacity of the solar framework in which the qualities are described. Three solar panel are paralleled so as to support the power output from solar and utilized as the power source in converter. The power output supported by the entire system (solar PV converter) is around 1.5 Kw for the designed prototype model (Fig. 10).

PV yield voltage for ordinary operation of the charger is appeared in Fig. 11 the working point is the MPP (≈17 V). So as to demonstrate the issue of utilizing current (or voltage) as charger control parameter, two tests has been performed while IPV was the charger control parameter (first test), and quick environmental change was mimicked by in part shading the board range. The outcome (PV yield voltage) appeared. The same condition is considered for the charger with S and without S as charger control parameter. Figures 12 and 13 shows

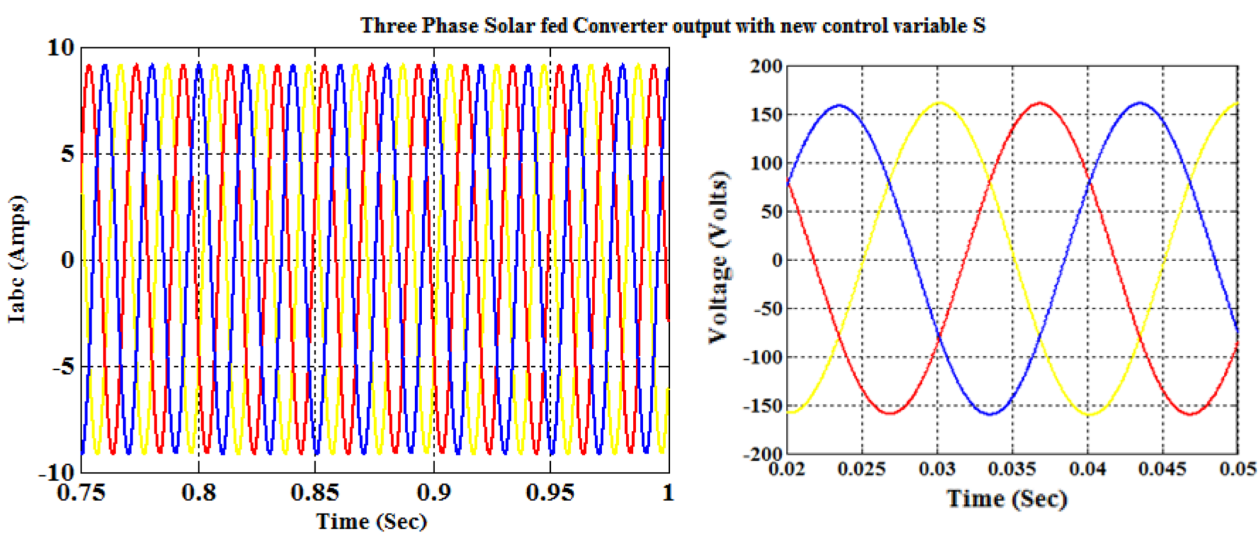

Fig. 10 Current variation in three phase solar PV system for varying irradiance with controlling factor S

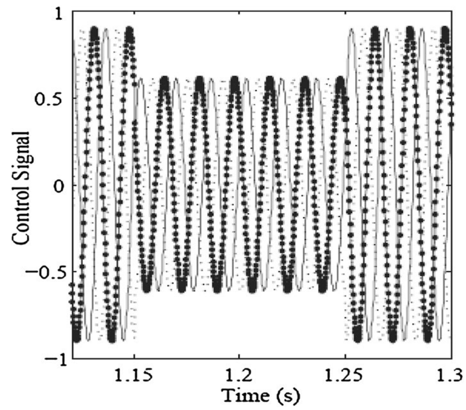

Fig. 12 Control input (*solid line* K_0, *dash line* K_1, *solid with dash* K_2)

the current variation for change in irradiance (new control variable not considered) with respect to time. On

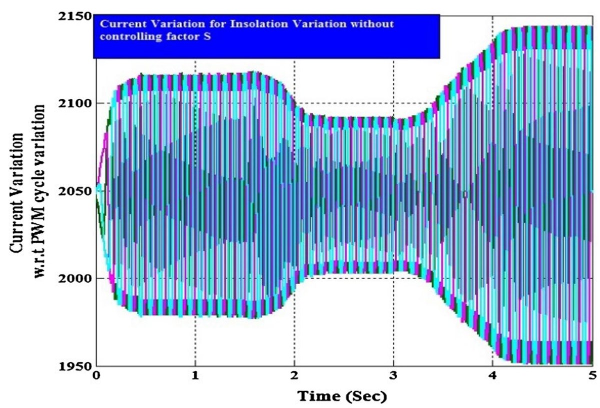

Fig. 13 Current variation in three phase Solar PV System for varying irradiance without controlling factor S

observing the output (Fig. 13) it is noticed switching time of the converter varies as the insolation varies at different instant, which in turn the current fluctuates causing instability in the entire network. This is eliminated in Fig. 10 by implementing MPPT calculation with new control variable 'S' to maintain the stability of the entire system and also the proposed framework in the same condition has a well execution to track the MPP.

Conclusion

In the proposed manuscript dynamic control scheme is presented to analyze the performance of a three-phase grid-connected PV system and to enhance the dynamic stability limit with the change in atmospheric conditions by utilizing the new control factor. The projected controller setup cancels all possible nonlinearities by converting the entire PV system into two decoupled linear subsystems with stable internal dynamics by incorporating the control variable 'S'. The DC link voltage and current from solar PV system controlled by MPPT P&O algorithm with controlling script is injected into grid are controlled to ensure the operation of the PV system at unity power factor and in Stable condition. From the simulation results, it is clear that the controller performs better under varying atmospheric conditions. Future work will deal with the expansion of the projected method by considering the mismatches within the solar PV model and to implement it on a large interrelated structure.

Authors' contributions

TY implemented the MPPT tracer. RK formed the experimental scheme. Both authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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