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Comparision of ASS and INC Method of Maximum Power Point Tracking for Photovoltaic Array

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***Abstract* - An efficient maximum power point tracking (MPPT) technique is need to improve the efficiency of a solar photovoltaic (PV) array. An asymmetrical step size (ASS) method of maximum power point tracking (MPPT) for photovoltaic generation is proposed in this paper in which present and past slope of power (P) with respect to voltage (V) are compared and based on this step size of the voltage is changed. The main advantage of proposed method is fast tracking of maximum power point of PV array. Also it works successfully in dynamic as well as steady state condition and track maximum power point when irradiation level changes. The obtained simulation results are compared with conventional incremental conductance method (INC). The results show that the ASS method is better than the conventional INC method for tracking MPPs of PV array.**

Keywords – Maximum Power Point Tracking, Photovoltaic System, Asymmerical Step Size, Incremental Conductance.

I. INTRODUCTION

Effective renewable energy sources are those sources in which energy supplies that are refilled by natural processes as fast as we use them. All renewable energy comes, ultimately, from the sun. Solar energy comes directly from the sun and is used to produce electricity, heat, and light. However, there are two main disadvantages of photovoltaic (PV) system, the high installation cost and the low conversion efficiency of PV modules which is only in the range of 9-17% [1]. Besides that, PV characteristics are nonlinear and it is very much weather dependent. Fig. 1 and Fig. 2 show the I-V and P-V characteristics of a typical PV module for a series of solar irradiance levels with constant temperature [2]. It can be noticed that PV output voltage greatly governed by temperature while PV output current has approximate linear relationship with solar irradiances. It can be seen from the P-V characteristic curve that there is only one peak operating point which is named as the maximum power point (MPP). Due to the high capital cost of PV array, maximum power point tracking (MPPT) control techniques are essential in order to extract the maximum available power from PV array in order to maximize the efficiency of PV array. Therefore, a DC-DC converter is inserted between PV generator and load or battery storage. MPPT algorithms are used to control the switching of DC-DC converter by applying pulse-width modulation (PWM) technique [2].The basic block diagram of solar system is shown in Fig. 3.

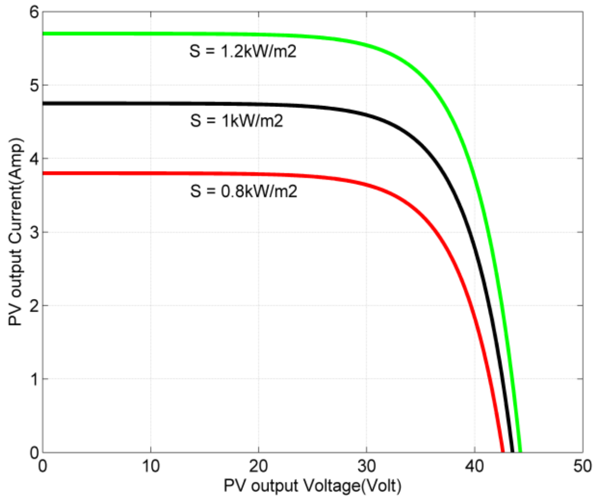


Fig. 1. Current-Voltage characteristic curves of PV array with change in irradiation level at constant temperature

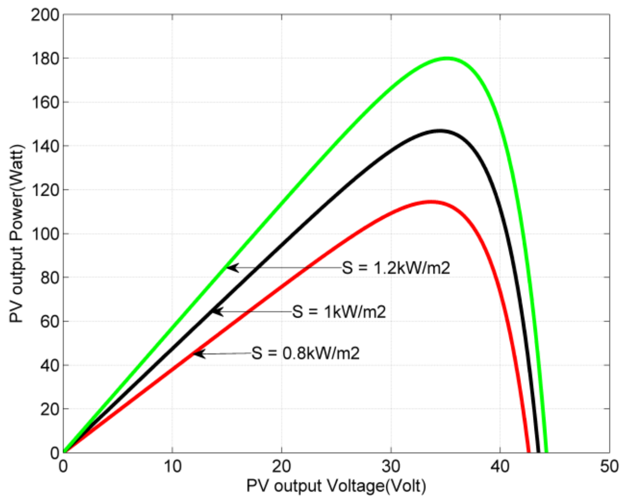


Fig. 2. Power-Voltage characteristic curves of PV array with change in irradiation level at constant temperature

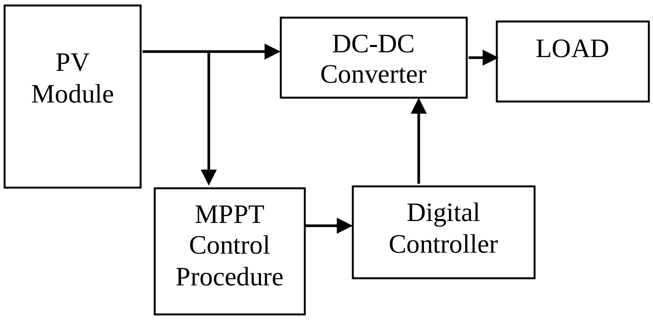


Fig. 3. Basic Block Diagram of photovoltaic system

II. MODEL OF PV ARRAY

The PV cell is the key unit of PV power system, mainly made up of silicon and compound semiconductor material, which has non-linear characteristic between power and voltage. A PV array is made up of series or parallel-connected combinations of solar cells. The output current and voltage generated by a PV array depend on solar irradiation level, array temperature and load resistance. The model of a PV array is usually described by its current-voltage (I-V) characteristic and by the equivalent circuit as shown in Fig. 4.

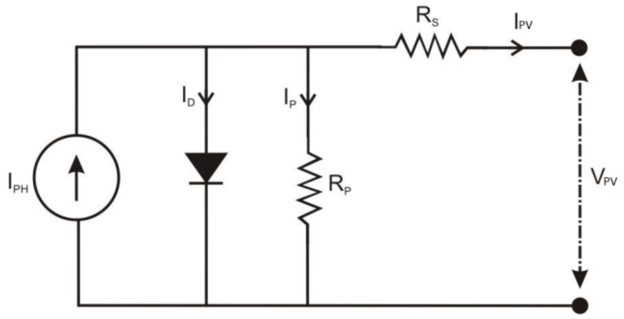


Fig. 4. Equivalent circuit of solar cell

Where I_{PV} is the PV array output current, V_{PV} is the PV array output voltage, I_{PH} is the generated photo current under a given solar irradiation, I_D is the P-N junction dark current of the cell unit, q is the charge of an electron (1.6×10^{-19} C), n is the P-N junction curve constant, when PV cell output high voltage, n=1, otherwise n=2, K is the Boltzmann's constant (1.38×10^{-23} J/K), T is the cell absolute temperature (K), R_S and R_P are the intrinsic resistances associated with the silicon PV array, R_S is the equivalent series resistance of the PV array, and R_P is the equivalent shunt resistance of the PV array. The value of R_P is thousands of ohms.

According to Fig. 4, when shunt resistance is neglected in the equivalent circuit, the relation of the output current of PV array can be expressed as the following equations [3]:

$$I_{PV} = I_{PH} - I_D \tag{1}$$

$$I_D = I_{os}\left\{\exp\left[\frac{q(V_{PV}+I_{PV}*R_S)}{nKT} - 1\right]\right\} \tag{2}$$

$$I_{PH} = S\,[I_{scr} + \beta\,(T - T_r)] \tag{3}$$

$$I_{PV} = I_{PH} - I_{os}\left\{\exp\left[\frac{q(V_{PV}+I_{PV}*R_S)}{nKT} - 1\right]\right\} \tag{4}$$

$$I_{os} = I_{or}\left(\frac{T}{T_r}\right)^3\left\{exp\left[\frac{qE_g}{nK}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right]\right\} \tag{5}$$

Where I_{os} is the diode reverse saturation current which depends on temperature, not solar radiation. I_{or} is the diode reverse saturation current at reference temperature T_r (298K), I_{scr} is the normal short circuit current of the cell under the temperature of 298K and the irradiation (S) of 1kW/m^2, E_g is the band gap energy of the cell semiconductor.

III. MPPT METHOD

The conventional incremental conductance method is reviewed in the part A of this section followed by an asymmetrical step size method.

A. Conventional Incremental Conductance(INC) Method

The IC MPPT method has a simple structure and its implementation is easy. The IC MPPT method uses P-V characteristics curve. Fig. 3 shows the IC MPPT method. The maximum power point in IC method is when a slope of P-V is zero. A left side of MPP has the positive slope and right side has the negative slope.

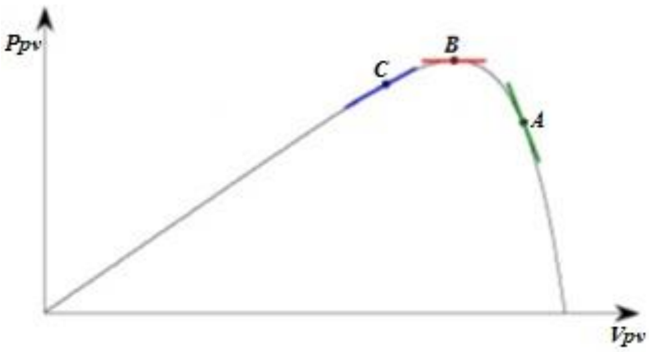


Fig. 5. Control theory of INC MPPT

The slope $\frac{dP_{PV}}{dV_{PV}}$ of P-V curve can be expressed as follow.

$$\frac{dP_{PV}}{dV_{PV}} = \frac{d(V_{PV}I_{PV})}{dV_{PV}} = I_{PV} + V_{PV}\frac{dI_{PV}}{dV_{PV}} \tag{6}$$

The A, B, C point in fig. 5 is as follows.

$$\frac{dP_{PV}}{dV_{PV}} = I_{PV} + V_{PV}\frac{dI_{PV}}{dV_{PV}} < 0\ (at\ point\ A) \tag{7}$$

$$\frac{dP_{PV}}{dV_{PV}} = I_{PV} + V_{PV}\frac{dI_{PV}}{dV_{PV}} = 0\ (at\ point\ B) \tag{8}$$

$$\frac{dP_{PV}}{dV_{PV}} = I_{PV} + V_{PV}\frac{dI_{PV}}{dV_{PV}} > 0\ (at\ point\ C) \tag{9}$$

Fig.6 shows flow chart of conventional INC method in which fixed step size is uses to change the PV output voltage to track the maximum power point according to slope of power with respect to voltage.

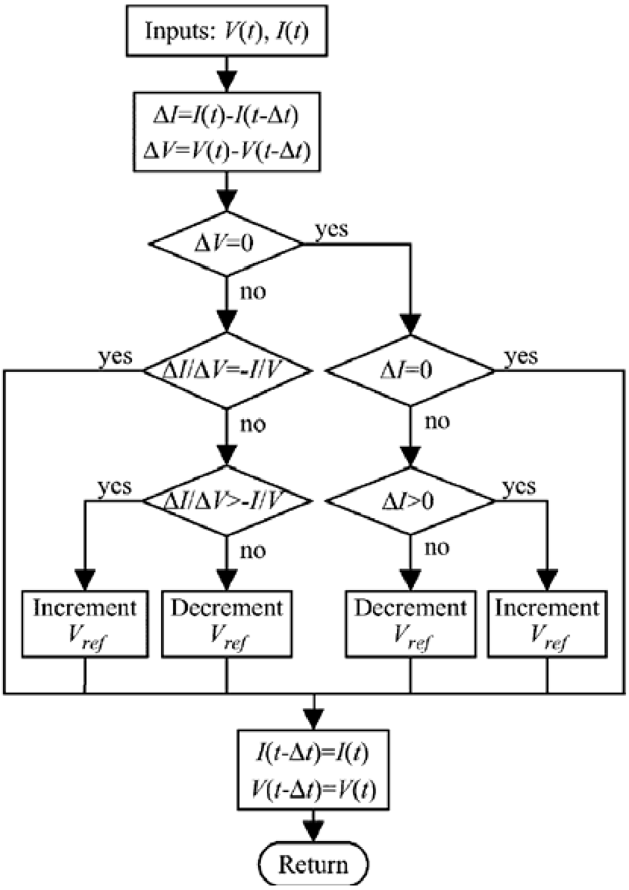


Fig. 6. Flow chart of INC MPPT method

B. *Assymetrical Step Size(ASS) Method*

The MPPT performance of a conventional MPPT method is depend on the step size of voltage. The large step size is improved the tracking speed, but the accuracy of tracking is decreased. The small step size is improved the tracking accuracy, but the tracking speed is slowed [4]. Fig. 7 shows the P-V characteristic curves (P_1 & P_2) and $|\frac{dP}{dV}|$-V characteristic curves with change in irradiation condition.

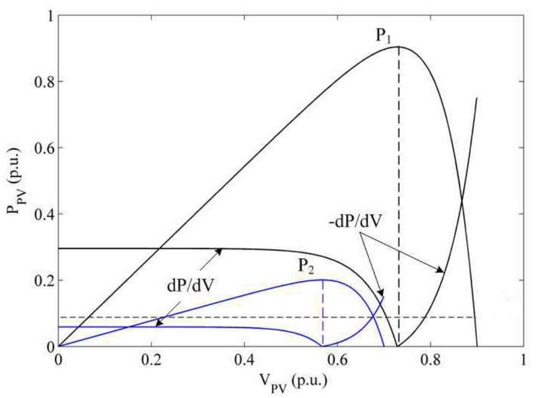


Fig. 7. Slope of power versus voltage under different irradiation conditions

The $|\frac{dP}{dV}|$-V characteristics of P_1 shows that when operating point is in between 0pu and 0.6pu (far from the MPP and in left side of MPP), slope of power with respect to voltage is constant. When operating point is in between 0.6pu and 0.75pu (Near the MPP), slope of power with respect to voltage decreases. When operating point is in the right side of the MPP, the magnitude of slope of power with respect to voltage increases and at the MPP the slope of power with respect to voltage is zero. The ASS MPPT method proposed in this paper uses a maximum step size when operating point of the photovoltaic system is far from the MPP i.e. when present and past slope of power is equal whereas minimum step size is used when an operating point is near to the MPP i.e. present and past slope of power is not equal. MPP is reached when change in present power and past power is zero.

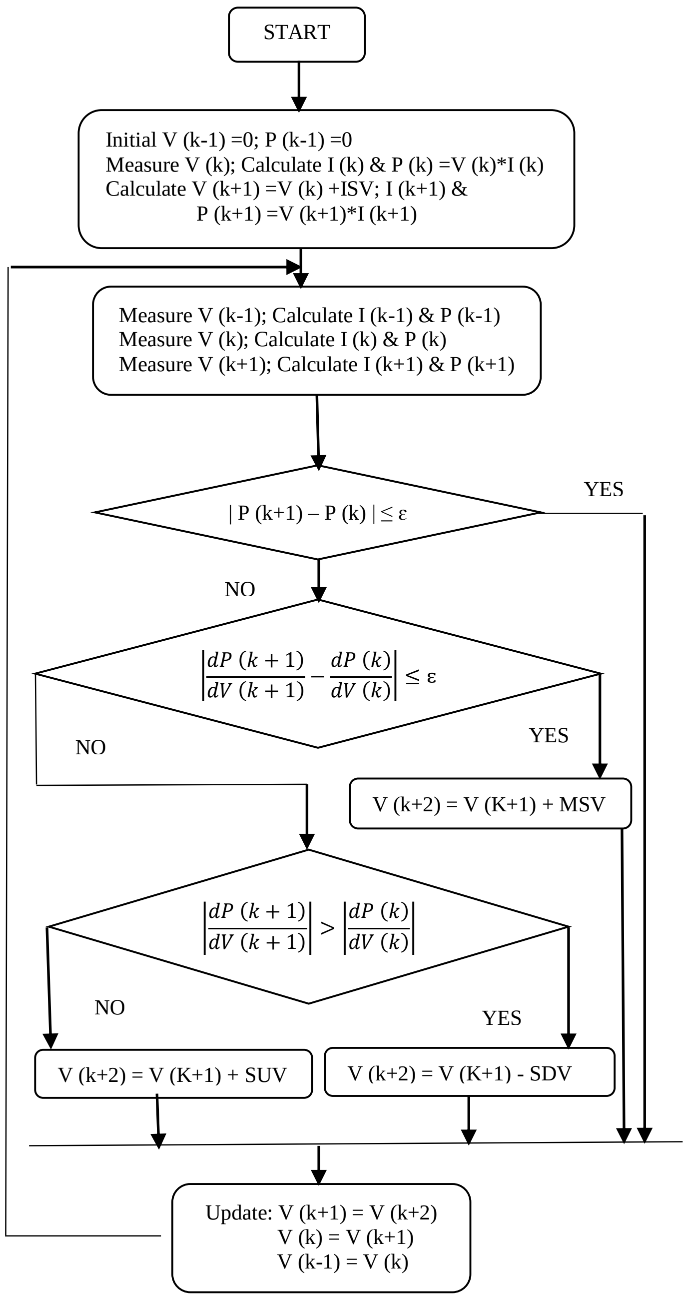


Fig. 8. Flow Chart of ASS MPPT Algorithm

Present slope of power with respect to voltage is defined as:

$$\frac{dP\ (k+1)}{dV\ (k+1)} = \frac{P\ (k+1) - P\ (k)}{V\ (k+1) - V\ (k)}$$

Past slope of power with respect to voltage is defined as:

$$\frac{dP\ (k)}{dV\ (k)} = \frac{P\ (k) - P\ (k-1)}{V\ (k) - V\ (k-1)}$$

Fig. 8 shows flow chart of ASS method proposed in this paper in which ISV, MSV, SUV, SDV & ε represent initial step voltage, maximum step voltage, step up voltage, step down voltage and tolerance of change in power or change in slope of power with respect to voltage respectively.

IV. PERFORMANCE AND RESULTS

The BPSX150[5] PV module of BP Solar Power Company (Madrid, Spain) is chosen for modeling, which is made up of 72 series-connected multicrystalline silicon photovoltaic cells and the electrical characteristics at standard test condition (STC) of irradiance (1kW/m^2) and module temperature (25^{0}C) are shown in Table I.

TABLE I. PARAMETERS OF BPSX150 SOLAR MODULE

Parameter	Value
Maximum Power (P_{max})	150W
Voltage at P_{max} (V_{mp})	34.5V
Current at P_{max} (I_{mp})	4.35A
Warranted minimum (P_{max})	140W
Short circuit current (I_{sc})	4.75A
Open circuit voltage (V_{oc})	43.5V
Maximum system voltage	600V
Temperature coefficient of I_{sc}	(0.065±0.015)%/^{0}C
Temperature coefficient of V_{oc}	-(160±20)mV/^{0}C
Temperature coefficient of power	-(0.5±0.05)%/^{0}C
NOCT	47±2^{0}C

To track MPP the value of step size for ASS method are taken MSV = 4V, ISV = 0.5V, SUV = 0.1V, SDV = 1V and ε = 0.01. Fig. 9 shows P-V characteristic curves with change in irradiation level and tracking of MPP from an operating point voltage (8V) for irradiation (S) of 0.8kW/m^2.When S is changed to 1kW/m^2 and 1.2kW/m^2 the MPP automatically shift from MPP of 0.8kW/m^2 to the MPP of 1kW/m^2 and 1.2kW/m^2 respectively. The value of maximum power obtained and time to track MPP using ASS method and INC method are compared in Table II.

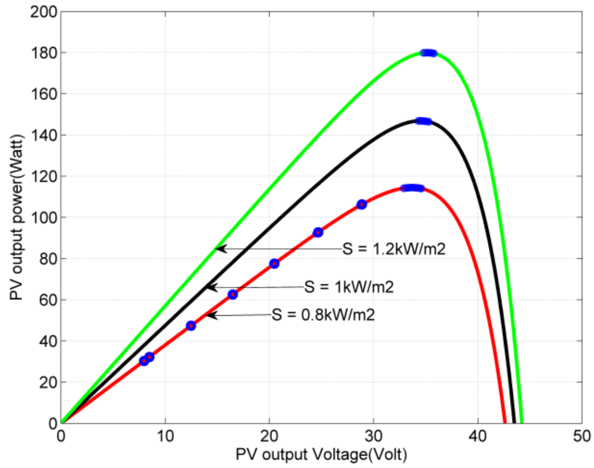


Fig. 9. P-V characterstic curves with tracking of maximum power and change in irradiation level using ASS method

TABLE II. MAXIMUM POWER OBTAINED WITH CHANGE IN IRRADIATION LEVEL

Irradiation level (S)	Maximum Power (P_{max}) obtained with ASS method	Maximum Power (P_{max}) obtained with INC method	Time to track MPP with ASS	Time to track MPP with INC
0.8 kW/m^2	114.451W	113.998W	0.03s	0.34s
1 kW/m^2	146.725W	146.474W	0.02s	0.37s
1.2 kW/m^2	179.658W	179.621W	0.02s	0.37s

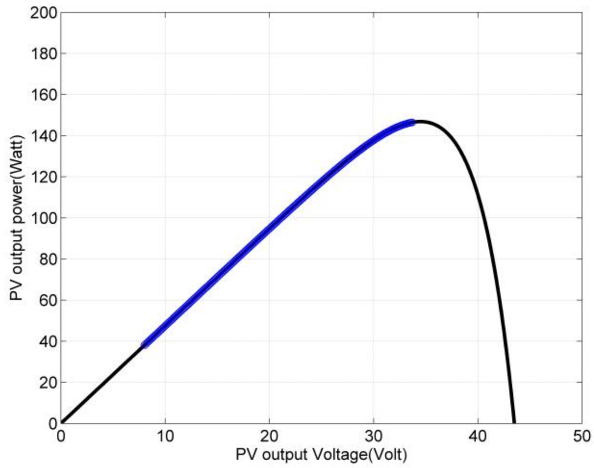
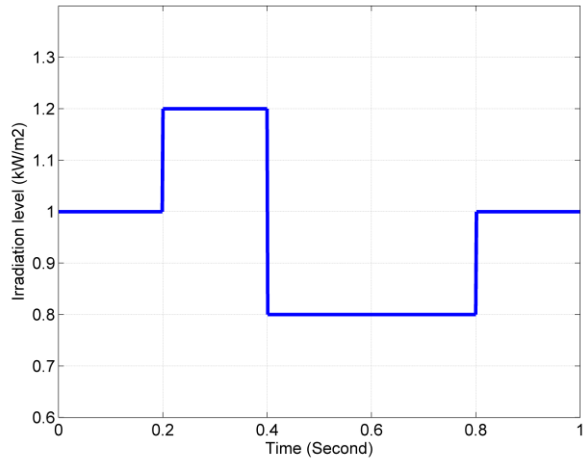
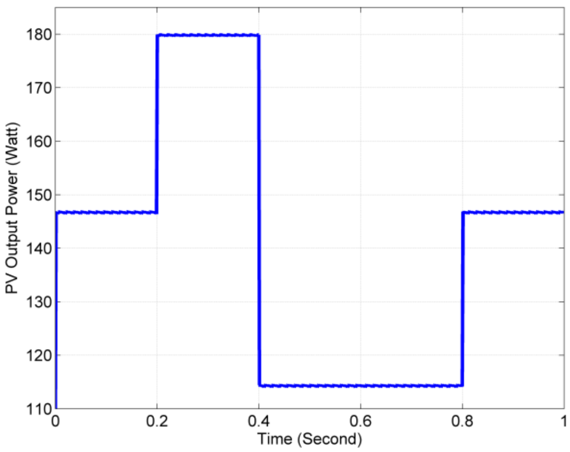


Fig. 10. P-V characterstic curves with tracking of maximum power using INC method at irradiation level of 1kW/m^2

Fig. 11(a) shows that after every 0.2 sec the irradiation level changes randomly and Fig. 11(b) shows that when irradiation level changes, the maximum power tracked corresponding to irradiation condition using ASS method.



(a)



(b)

Fig. 11. Response characterstics of MPPT control with radiation changing using ASS method

V. CONCLUSION

A novel asymmetrical step size algorithm for MPPT of photovoltaic system was developed in this study and it is compared with INC method. The ASS algorithm considers the asymmetrical step size based on the slope of power with respect to voltage curve of a PV array. The characteristics of a BPSX150-type PV module are modeled and analyzed. Its output voltage and current has nonlinear characteristics depending on the atmospheric conditions such as the irradiance and temperature. Because of the nonlinear characteristics, a control circuit must drive the PV module for the maximum power. A solar MPPT controller based on an asymmetrical step size algorithm is designed for a PV energy system. The MPPT controller based on microprocessor, including a DC/DC converter circuit, has a better response under rapid atmospheric conditions, can fast track the maximum power point by using the ASS method. This method can improve the dynamic and steady state performance of the PV system. MATLAB simulation results verify the feasibility and effectiveness of the ASS method over INC method.

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