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Review

A system and novel methodology to track maximum power from photo voltaic system: A comparative and experimental analysis

K. Srikumar [*], Ch. Saibabu

JNTUK, Kakinada, Andhra Pradesh, India

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ABSTRACT

This paper gives a new control technique that allows the system to operate at maximum power based on power perturbs and Duty cycle variations along with the Experimental validation using five different methodologies. Though, it is experiencing quite a few drawbacks due to fixed perturb values, the steady state oscillations (SSO) are relative to the perturb value. Larger perturb values cause more oscillations. Unluckily, smaller perturb values result in slower response. This problem can be overcome by adding an appropriate irradiance loop to the basic fixed step size algorithm. This technique is intended for quicker response to irradiance and temperature changes with varying perturbations. However, the problems in which incremental and decremented step of voltage perturbs and the current change threshold remain unclear. This drawback can be minimised by choosing Adaptive fixed Duty Cycle Algorithm (AFDCA) with a fixed duty cycle perturb of photovoltaic system. The tracking capability of new proposed technique has been validated through simulation and experimental set-up with a 100 W solar panel with variation of irradiance under STC, For incremental/step change in irradiance, variations with the load, voltage perturb changes with fine tuning steps, variation of Duty Cycle parameters along with settling times of Power to steady state.

Contents

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[*] Corresponding author.
E-mail address: kotni.77@gmail.com (K. Srikumar).

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1. Introduction

The PV system is important phenomena in the global development towards the alternative energy sources from the ever depleting day to day natural conventional sources of energy, so an effort is made to explore the potential of using PV systems in the domestic and industrial applications (Ahmed and Salam, 2015; Dileep and Singh, 2015; Esram and Chapman, 2007; Jiang et al., 2013; Kok Soon and Saad, 2014a,b). The characteristics of the PV system depend on the natural conditions such as irradiance and temperature but the overall system efficiency is less. In order to overcome this drawback, maximum power should be extracted from the PV systems. Maximum power point tracking is a concurrent control scheme applied to the PV systems, to extract the maximum power. The power delivered from the source to the load can be maximized when the input resistance matches with the source resistance where in using the maximum power transfer technique Therefore, to transfer maximum power from the PV system to the load the internal resistance of the system has to match the resistance of the load. To ensure the maximum efficiency several algorithms were proposed to mitigate several conditions under fast changing input conditions (Kok Soon and Saad, 2014a,b; Pandey et al., 2008; Po-Cheng et al., 2015; Rajdai et al., 2014, 2015). For a fixed (constant) load, the equivalent (total) resistance of the panel can be adjusted by handling the power converter duty cycle, physical input specifications like temperature and irradiance. Some of the works are based on the experimental based using Fuzzy logic control, d-SPACE and Artificial intelligence based have been developed (Satish Kumar and Mahesh Kumar, 2014; Seyedmamoudian et al., 2016; Steven et al., 2010; Young-Hyok et al., 2011; Yuncong, et al., 2013). For further improvement of tracking efficiency, the Incremental voltage step size (IVSS) maximum power point algorithm and Adaptive fixed duty cycle (AFDCA) maximum power point algorithms are proposed and explained in this paper. These both MPPT methods are capable of attaining maximum power equal to the maximum load power. So the tracking efficiency is improved. The comparisons of practical implementation realization with the simulated results are done. The Section 2 of this has dealt with the system and converter specifications (Tables 1–5).

2. System configuration

The tracking efficiency can be further improved by employing IVSSA MPPT technique AFDCA control algorithm. These are simple control algorithms that do not require any previous knowledge of the PV system characteristics or the measurement of solar irradiance and system temperature, and it is also easy to implement with analogue and digital circuits. In addition, this method operates by periodically changing the duty ratio of the boost converter and evaluating the corresponding output power. When the maximum of the product, I * V is found, the Maximum Power Point (MPP) has been located.

Table 1
PV system specifications at standard test condition.

Description	Symbol	Rating
Maximum power	P_{MP}	100 W
Maximum power voltage	V_{MP}	17.1 V
Maximum power current	I_{MP}	5.85 A
Open circuit voltage	V_{OC}	21.75 V
Short circuit current	I_{SC}	6.43

Table 2
DC-DC boost converter specifications.

Description	Rating
Input voltage	25 V
Output voltage	100 V
Output power	100 W
Boost inductor	2.3 mH
Boost capacitor	1200 μF
Switching frequency	20 kHz

Load Resistance: (5–200) Ω.

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

where

$$P(k) = V(k) \bullet .I(k) \tag{2}$$

By investigating the performance of basic system configuration in Fig. 1, the maximum power operating point can always be tracked by keeping derivative of power and voltage (dP/dV) equal to zero with changing solar irradiance and system temperature. The power slope dP/dV can be calculated digitally by sampling the PV array voltage and current at successive time intervals (k – 1) and (k) as shown in Eqs. (1) and (2).

3. Model of proposed MPPT algorithm

3.1. Incremental voltage step size algorithm (IVSSA)

The restriction of the existing MPPT algorithm of tracking under rapidly changing irradiance is attained. The proposed Incremental Voltage step size based MPPT algorithm retains the benefit of the existing MPPT algorithm having fast response to track the maximum power point quickly.

With reference to the change of output power due to atmospheric conditions, changing power (dP) is used. From, the value of dP it can be determined when the irradiation is stable. The expression of IVSSA MPPT tuning method is as it is given in Eq. (5).

The original expressions of perturb and observe MPPT is

$$dP(k) = P(k) - P(k-1) \tag{3}$$

$$dP(k) = dP_1(k) - dP_2(k) \tag{4}$$

where

$$dP_1(k) = P_c(k) - P(k)$$

and

$$dP_2(k) = P(k-1) - P_c(k)$$

Therefore

$$\begin{aligned} dP(k) &= P_c(k) - P(k) - P(k-1) + P_c(k) \\ dP(k) &= 2P_c(k) - P(k) - P(k-1) \end{aligned} \tag{5}$$

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Table 3
Comparison of PV output voltage, current and power at different irradiances and at constant temperature condition.

Irradiance (W/m^2)	Temperature (°C)	IVSSA			AFDCA		
		V_{MP} (V)	I_{MP} (A)	P_{MP} (W)	V_{MP} (V)	I_{MP} (A)	P_{MP} (W)
1000	25	16.40	5.076	83.25	18.97	4.548	86.29
800		15.70	4.233	66.45	17.70	4.120	72.92
600		15.01	3.413	51.23	15.18	3.524	53.49
400		14.60	2.062	30.10	11.87	2.580	30.62
200		13.10	0.947	12.40	9.985	1.293	12.91

Table 4
Comparison of PV output voltage, current and power at different load resistance.

Variations in load (Ω)	IVSSA			AFDCA		
	V_{MP} (V)	I_{MP} (A)	P_{MP} (W)	V_{MP} (V)	I_{MP} (A)	P_{MP} (W)
5	17.99	4.106	73.88	18.32	4.21	77.2
9	18.3	4.512	83.25	18.97	4.548	86.29
12	19.16	3.586	68.70	18.16	4.21	76.49
15	19.54	2.945	57.66	19.81	3.23	66.24
20	19.86	2.256	44.81	19.88	2.66	52.93
50	20.32	0.95	19.30	20.10	1.149	23.10
75	20.4	0.65	13.30	20.24	0.85	17.23
150	20.49	0.35	7.22	20.51	0.342	7.03
200	20.51	0.25	5.10	20.59	0.273	5.64

Table 5
Analytical evaluation of maximum power (or) tracking efficiency (%) vs δV using ivssa.

Perturb voltage ΔV (%)	V_{MP} (V)	I_{MP} (A)	P_{MP} (W)	V_{Ref} (V)
1	16.40	5.076	83.25	16.56
2	16.42	5.0	82.11	16.75
3	16.49	4.97	81.92	16.98
4	16.62	4.83	80.18	17.28
5	16.66	4.80	80.0	17.49

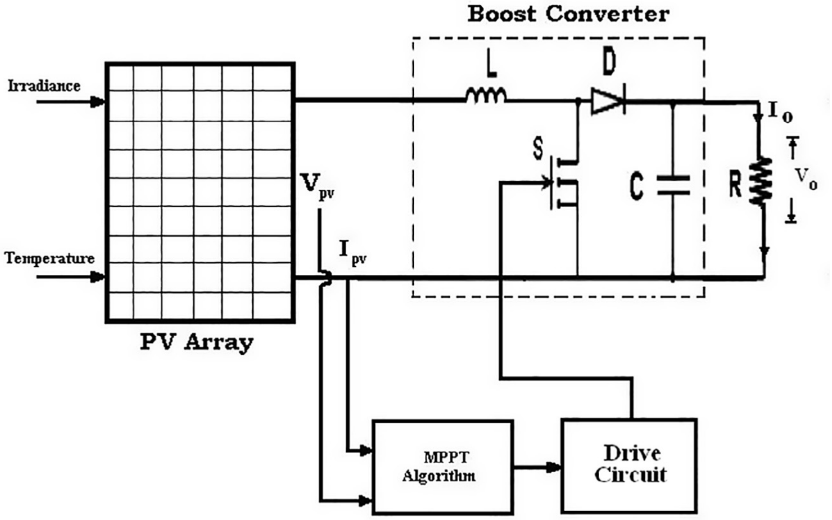

Fig. 1. Photovoltaic system configuration.

It is obvious from the information in the prior section, i.e. by precisely determining the value dP allows tracking to go in the exact direction during the change of irradiance. Even though, in order to track very fast changes of irradiance, the voltage perturbation (in step) need to be increased. Consequently it also leads to oscillations around the maximum power point under steady-state conditions, where in degrading the overall performance of the system. To solve this problem, the value of dP2 can be determined at sudden incremental change of irradiance. To analyze the proposed MPPT algorithm, the P-V curve is shown in Fig. 2.

Fig. 3 shows the flowchart of IVSS MPPT algorithm. A further irradiance control loop has been proposed in this improved version (Tables 6–11).

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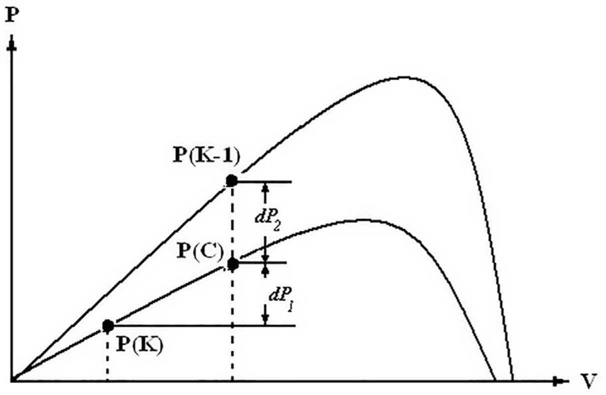

Fig. 2. Control action of incremental voltage step size algorithm (IVSSA).

3.2. Adaptive fixed duty cycle algorithm (AFDCA)

In this proposed method, the duty cycle is varied accordingly to perturbation voltage and operating point oscillates around the MPPs. By changing duty ratio, it can match the characteristic impedance of the PV system to the load impedance. Therefore, it quickly transfers the maximum power to the load.

Fig. 4 shows the association of 'P' and 'D' curve in the photovoltaic system with boost converter as power conditioner. Where, 'P' represents the photovoltaic output power and 'D' represents the duty cycle of the DC-DC boost converter. The modelling of proposed AFDC algorithm can be expressed in Eq. (6).

$$d(k) = d(k-1) \pm \frac{dP/dD}{P/D} \tag{6}$$

If dP/dD > 0 be able to access maximum power point, then the Eq. (6) is modified as

$$d(k) = d(k-1) + \frac{dP/dD}{P/D} \tag{7}$$

Similarly, for dP/dD < 0, then the expression is

$$d(k) = d(k-1) - \frac{dP/dD}{P/D} \tag{8}$$

The operation of P-D curve start with left area, if dP/dD > 0 and the operating point is in the right-hand area, if dP/dD < 0 to reach maximum power delivery. When the tracking system of dP/dD = 0, then, the power reaches maximum point.

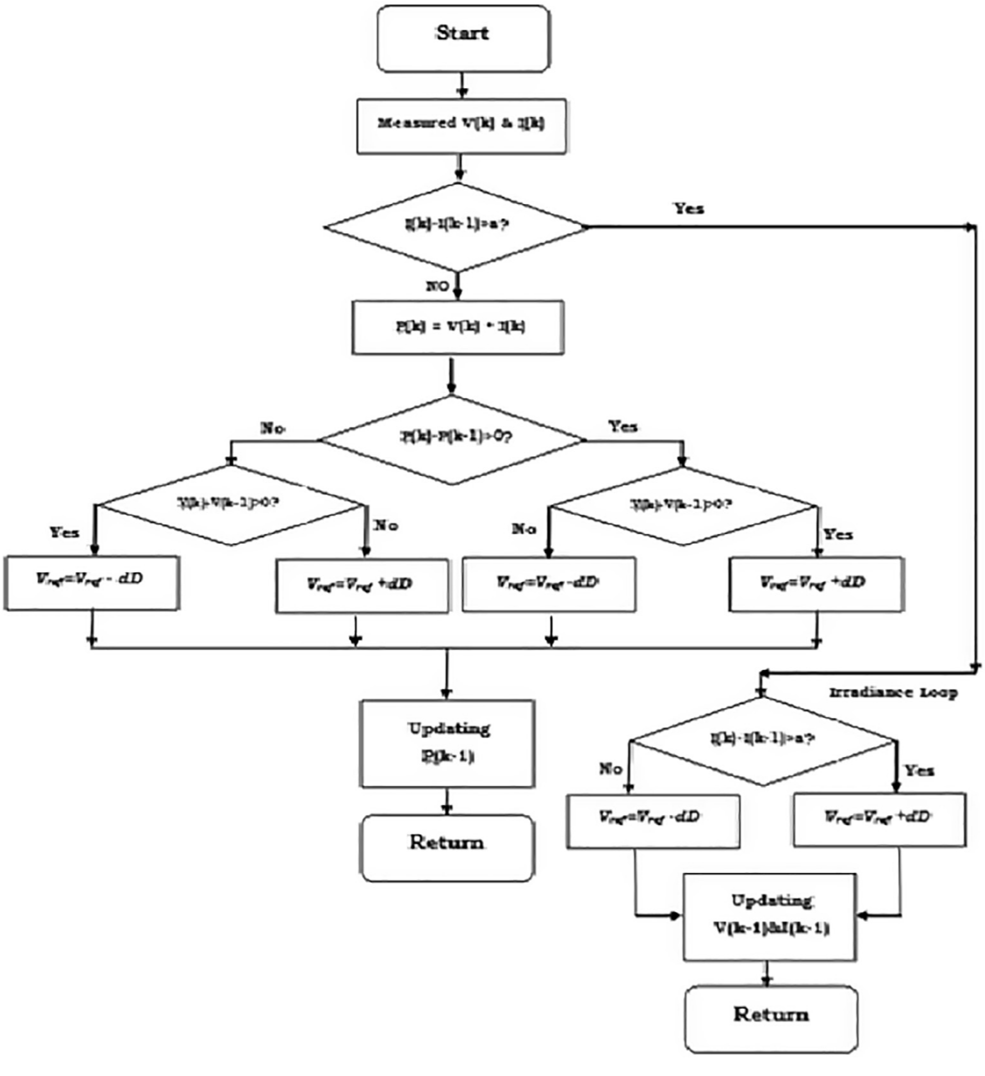

Fig. 3. Flowchart of incremental voltage step size algorithm (IVSSA).

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Table 6
Comparison of PV output voltage, current and power with different duty cycle of AFDCA method.

Duty cycle (%)	Proposed AFDCA		
	V_{PV} (V)	I_{PV} (A)	P_{PV} (W)
40	19.96	2.13	42.51
50	19.57	3.51	68.72
60	18.97	4.548	86.72
70	14.01	4.74	66.53
80	12.35	5.02	62.01

The flowchart of the control algorithm is shown in Fig. 5. "Slope" is a variable with values of '1' or '0', representing the direction that should follow on the P-D curve to increase the output power. While 'c' indicates the incremental step of duty ratio, which is a constant between '0' and '1'. The present power is compared to its value obtained in previous iteration and according to the result of the evaluation; the sign of "Slope" is moreover changed or remains unchanged. Based on this routine operation, the duty cycle changes consequently until operation point oscillate around the MPP.

Table 11
Settling time response comparison.

Response	Irradiance W/m^2	MPPT control methods	
		VSSPV	AFDC
Settling time (s)	1000 (High)	0.15	0.01
	200 (Low)	0.25	0.006

4. Simulation results and analysis

For extracting the Maximum Power from the PV System different methodologies with different fine tuning parameters were carried out with 5 different methodologies:

A. Variation of Irradiance under Standard Test Condition (STC)
B. For Step/Incremental change in irradiance
C. For variations in load side
D. Voltage perturb changes with fine tuning steps
E. Variation of Duty Cycle parameter in Boost Converter.

Table 7
For different irradiance and temperature of simulation and hardware analysis.

Proposed MMPT control technique	Type of analysis	Improvement of % tracking efficiency	
		Irrad = 1080 W/m^2 & Temp = 37 °C	Irrad = 912 W/m^2 & Temp = 34 °C
AFDC	Simulation investigation	59	63.2
	Hardware investigation	55	58.6

Table 8
Simulation and hardware analysis for step change of irradiance.

Proposed MPPT control technique	Type of analysis	Irradiance at 842 W/m^2 and 37 °C		Irradiance at 1080 W/m^2 and 37 °C	
		V_{PV} (V)	I_{PV} (A)	V_{PV} (V)	I_{PV} (A)
AFDCA	Simulation investigation	11.99	2.78	16.44	3.79
	Hardware investigation	9.82	2.32	15.2	3.61

Table 9
For different load of simulation and hardware analysis.

Proposed MMPT control technique	Type of analysis	Improvement of % tracking Efficiency at Irrad = 1080 W/m^2 & Temp = 37 °C	
		Load resistance 75 Ω	Load resistance 35 Ω
AFDC	Simulation investigation	17.30	63.64
	Hardware investigation	16.42	61.20

Table 10
For different duty cycle of simulation and hardware analysis.

Proposed MMPT control technique	Type of analysis	Improvement of% tracking Efficiency at Irrad = 1080 W/m^2 & Temp = 37 °C	
		Duty cycle 60%	Duty cycle 40%
AFDC	Simulation investigation	59	42.02
	Hardware investigation	55	38.72

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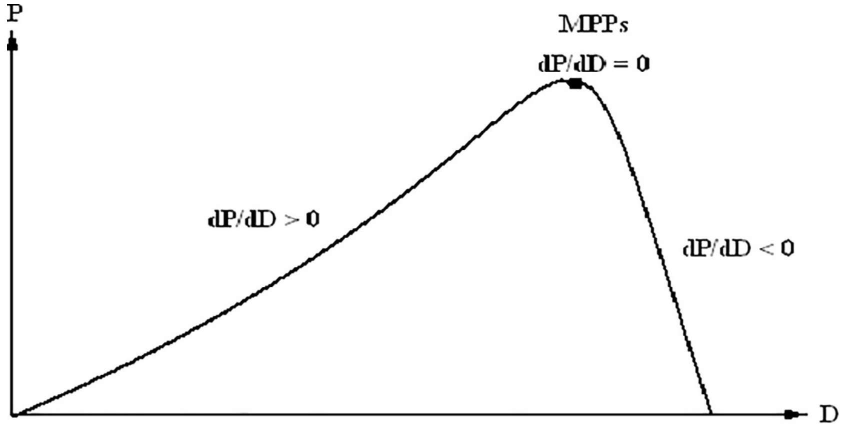

Fig. 4. Variation of P with respect to D.

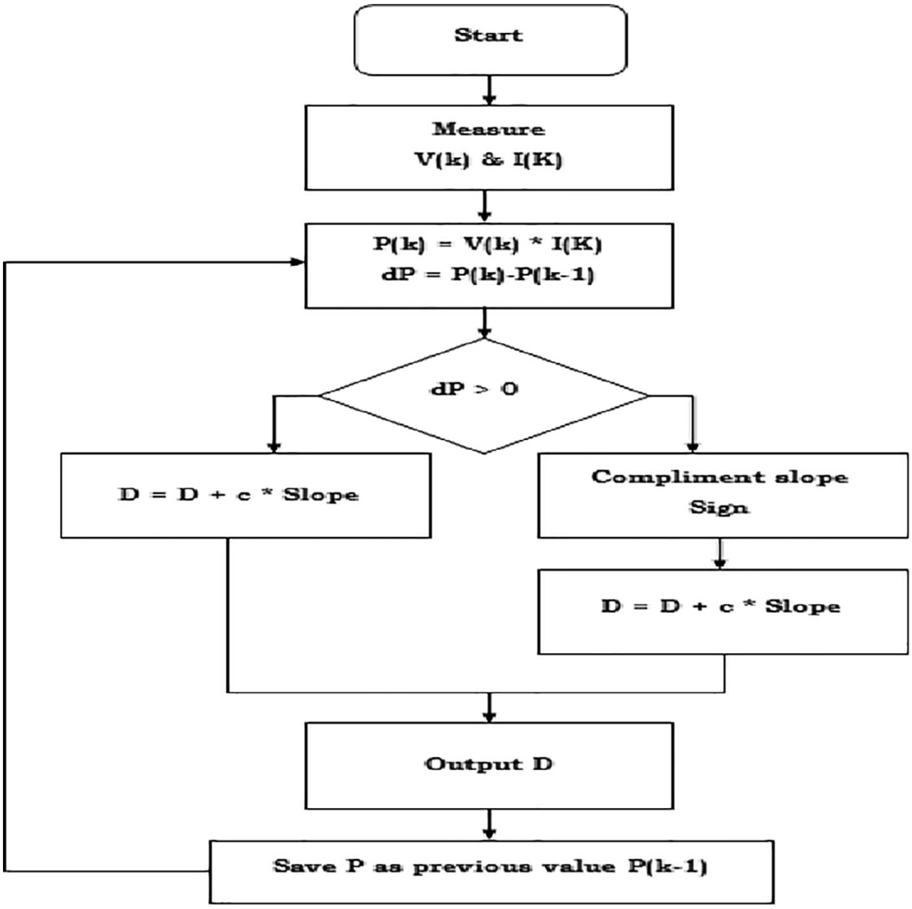

Fig. 5. Flowchart of proposed adaptive fixed duty cycle MPPT algorithm.

4.1. Variation of irradiance

The simulation results that are yielded under standard test condition i.e. at 1000 W/m^2 and 25 °C for the IVSSA method and AFDCA method are shown in Fig. 6. The PV Voltage 16.40 V at 0.17 s and 18.97 V at 0.01 s can be seen for the IVSSA method and AFDCA method respectively. Similarly the PV system ouput current and Power are 5.076 A & 83.25 W and 4.548 A & 86.92 W respectively. The performance analysis for extracting more power is better in the AFDCA method than the former one in all three parameters of Voltage, Current and Power.

4.2. For step change in irradiance

The simulation results were observed for the Incremental step change in the irradiances i.e. 400 W/m^2–800 W/m^2–1000 W/m^2 for both the methods and the proposed AFDCA method has given the better output results under step changes made

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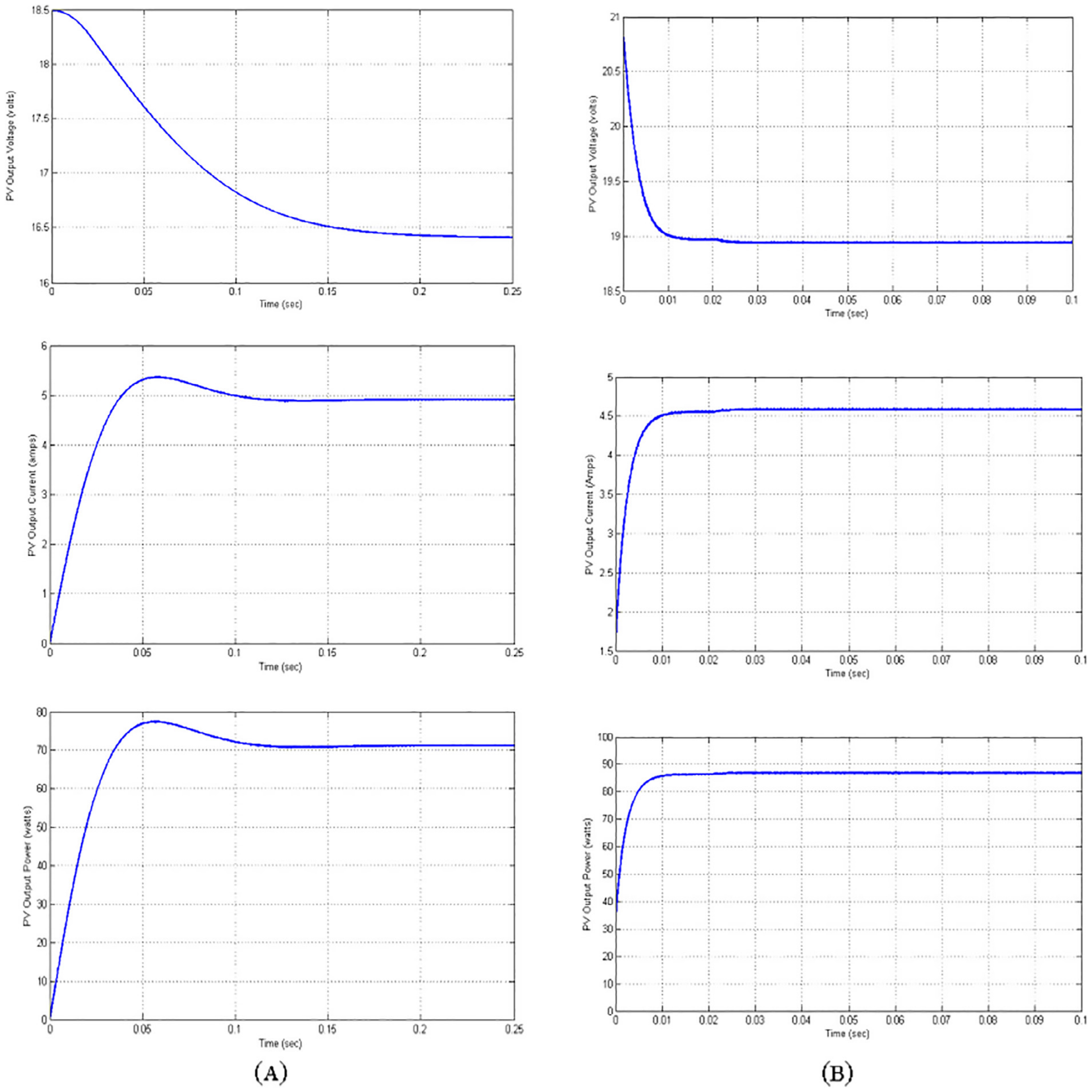

Fig. 6. Response of pv output voltage, current and power for ivssa (B) afdca under standard test condition.

with irradiance. The tracking of maximum output power has yielded from 30.10 W to 30.62 W at 400 W/m^2, 66.45 W to 72.92 W at 800 W/m^2 and 83.29 W to 86.29 W at 1000 W/m^2. The results obtained from AFDCA method signifies a good variation of outputs even for the sudden/step change in irradiance which is a normal phenomena in atmospheric conditions from time to time.

4.3. Load variations

The load is connected to the system with variations done from minimum to maximum. The load connected can be chosen in a way that the maximum tracking power can be transferred to load from the PV system to have an effective utilization of power transfer from source to load by utilizing the maximum power transfer theorem.

4.4. Variations of perturb voltage

The efficiency of tracking the maximum power can be achieved by a fine tuning parametric changes in voltage called as perturb voltage where in tracking is confined with in the small area. By varying the change in voltage by 1% to 5% in steps the maximum power can be tracked effectively at a faster rate with 83.25 W of 1% of perturb voltage i.e. for smaller perturb

4.5. Variation of duty cycle

The variation of Duty cycle of the dc – dc boost converter gives a better tracking efficiency of power. The maximum power of 86.72 W is achieved ay 60% of the Duty cycle rather than of 42.51 W at 40% and 62.01 W at 80% (Figs. 7–10).

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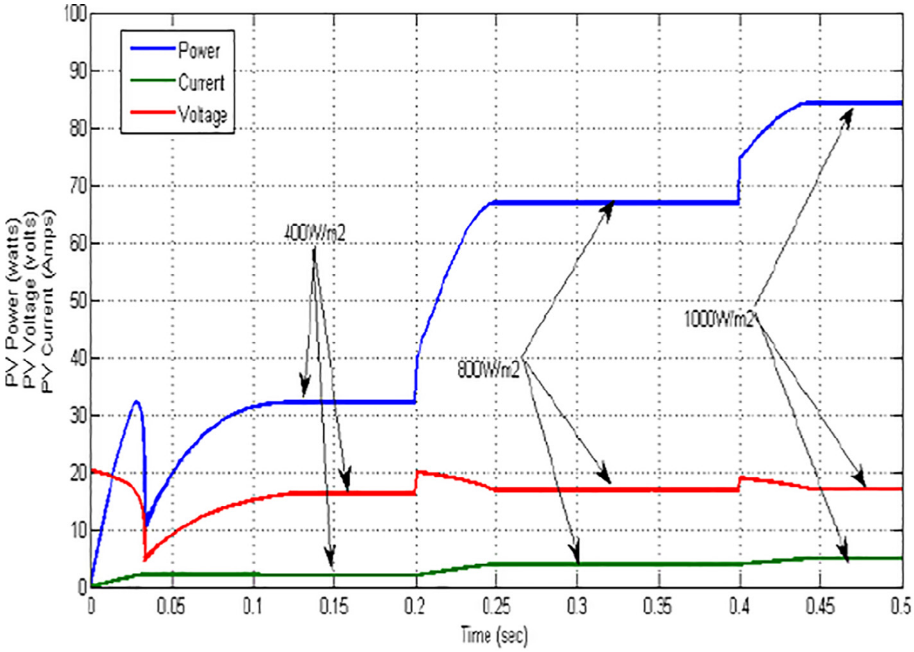

Fig. 7a. (A) Simulated results of pv output voltage, current and power with step changes of irradiance: ivssa.

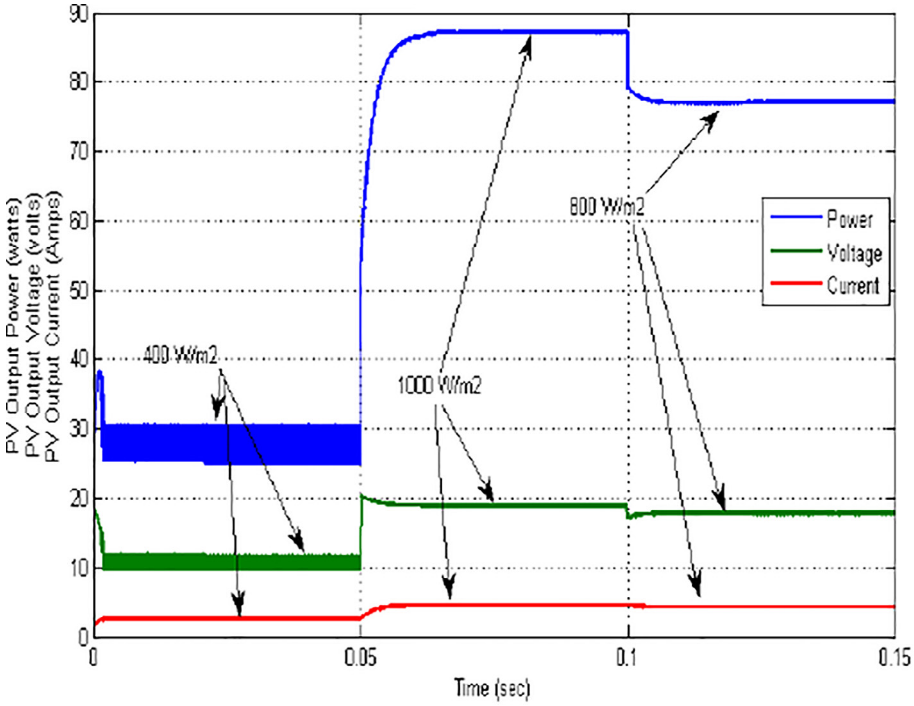

Fig. 7b. (B) Simulated results of pv output voltage, current and power with step changes of irradiance: AFDCA.

5. Experimental results

Fig. 11 shows the experimental arrangement of the testing system. In this application, 100 W PV panel is used as power source, which delivers power to the load and supplies control to circuits unit. The DSP (TMS320F2407) is performed as a digital controller for the total photovoltaic system, in which proposed control algorithm is implemented. The DC-DC boost converter, power board is the executive unit for MPPT by way of power conversion. Voltage and current sensors are also located in the experimental setup (Figs. 12–17).

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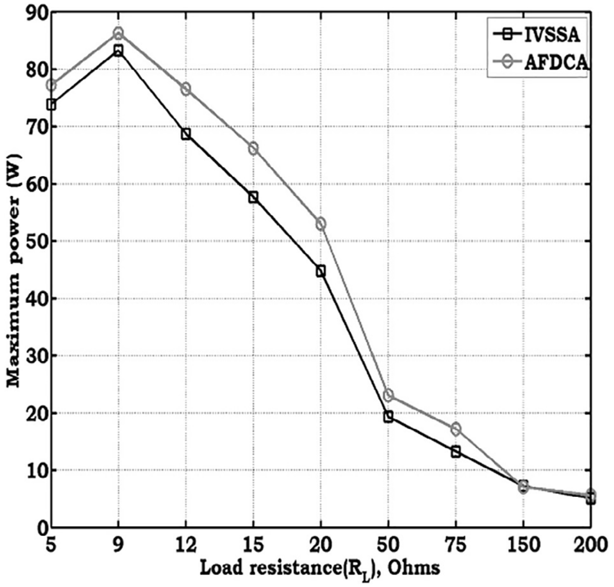

Fig. 8. Plot for poptimal vs rl for different values of irradiances and temperatures using the ivssa and afdca (two) algorithms.

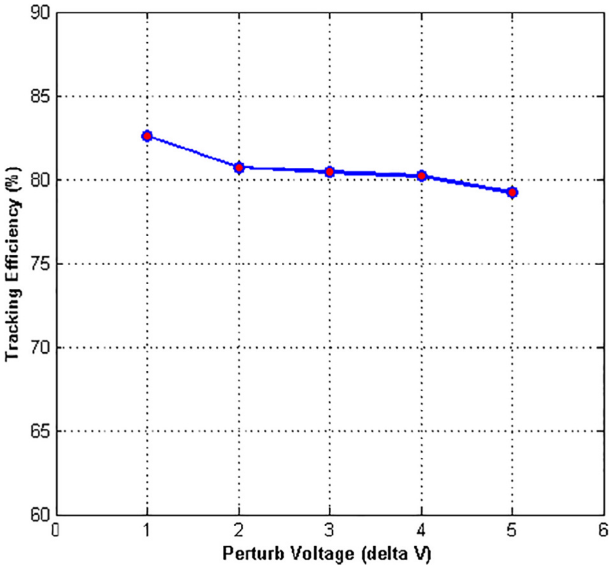

Fig. 9. Analytical evaluation of tracking efficiency (%) vs δv using IVSSA.

5.1. Variation of solar irradiances

By AFDCA the tracking efficiency is about 59% through simulation where as 55% has been achieved through Experimental setup for irradiance of 1080 W/m^2 and at a temperature of 37 °C.

5.2. For step change of irradiance

Here by AFDCA method the Output voltage and Output current of a PV System with simulation and Hardware results are 16.44 V/15.2 V and 3.79 A/3.61 A for the irradiance of 1080 W/m^2 and for a temperature of 37 °C.

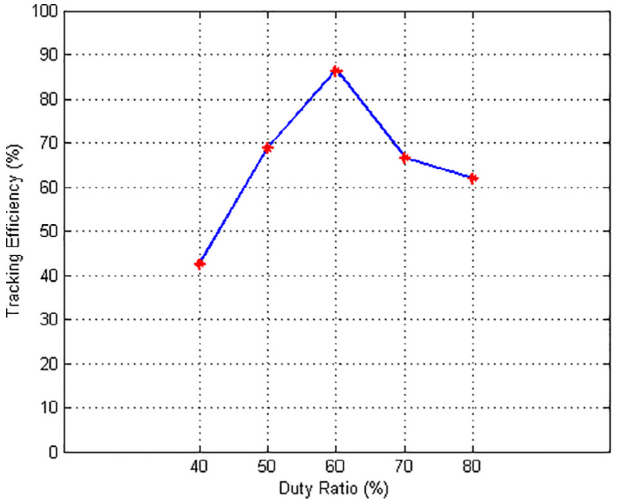

Fig. 10. Simulated relationship of tracking efficiency vs duty cycle of afdca method.

5.3. Variation of load resistance

The tracking efficiency through FDCA method has yielded a 63.64% and 61.20% for simulation and Hardware analysis for the load resistance of 35 Ω.

5.4. Variation of duty cycle

The tracking efficiency of output power for the PV system is 59% and 55% for the simulation and hardware analysis for the irradiance at 1080 W/m^2 and at a temperature of 37 °C.

The steady state power has reached the settling time faster by AFDC method (0.01/0.006 s) to VSSPV method (0.15/0.25 s) for the highest irradiance of 1000 W/m^2 and lowest irradiance of 200 W/m^2.

6. Conclusions

The proposed IVSSA and AFDCA MPPT algorithms are validated with a simulation model using 5 different methodologies such as variation of irradiance under standard test condition (STC) i.e. at 100 W/m^2 irradiance and temperature of 25 °C, then for a sequential step change of irradiance i.e. 400 W/m^2–800 W/m^2–1000 W/m^2 at a temperature of 25 °C, load variations (from 5 to 200 Ω in variable steps), voltage perturbations (i.e. from 1% to 5% in incremental equal steps), duty cycle variations (from 40% to 80% in incremental equal steps). These two algorithms are compared for their better yielding values in tracking efficiency/ maximum power extraction for input changes, converter parameter variation and output load changes. The results are tabulated for the better understanding for all the above variations. Then an experimental setup is done for the proposed AFDCA method and results were tabulated for all the above discussed cases but for the temperature and irradiance which we could capture to the best of our effort due fastly varying conditions from time to time. The proposed FDCA method has yielded the best results in terms of tracking efficiency, maximum tracking power and settling time response over the already existing methods.

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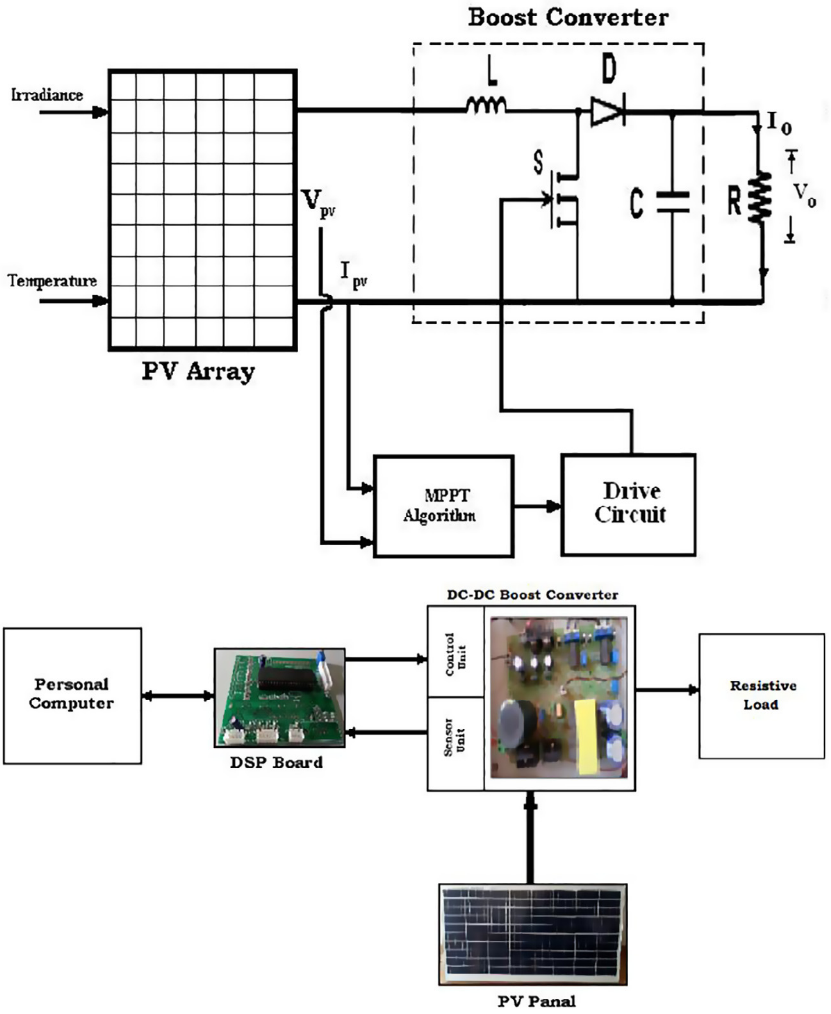

Fig. 11. Experimental setup of the total system.

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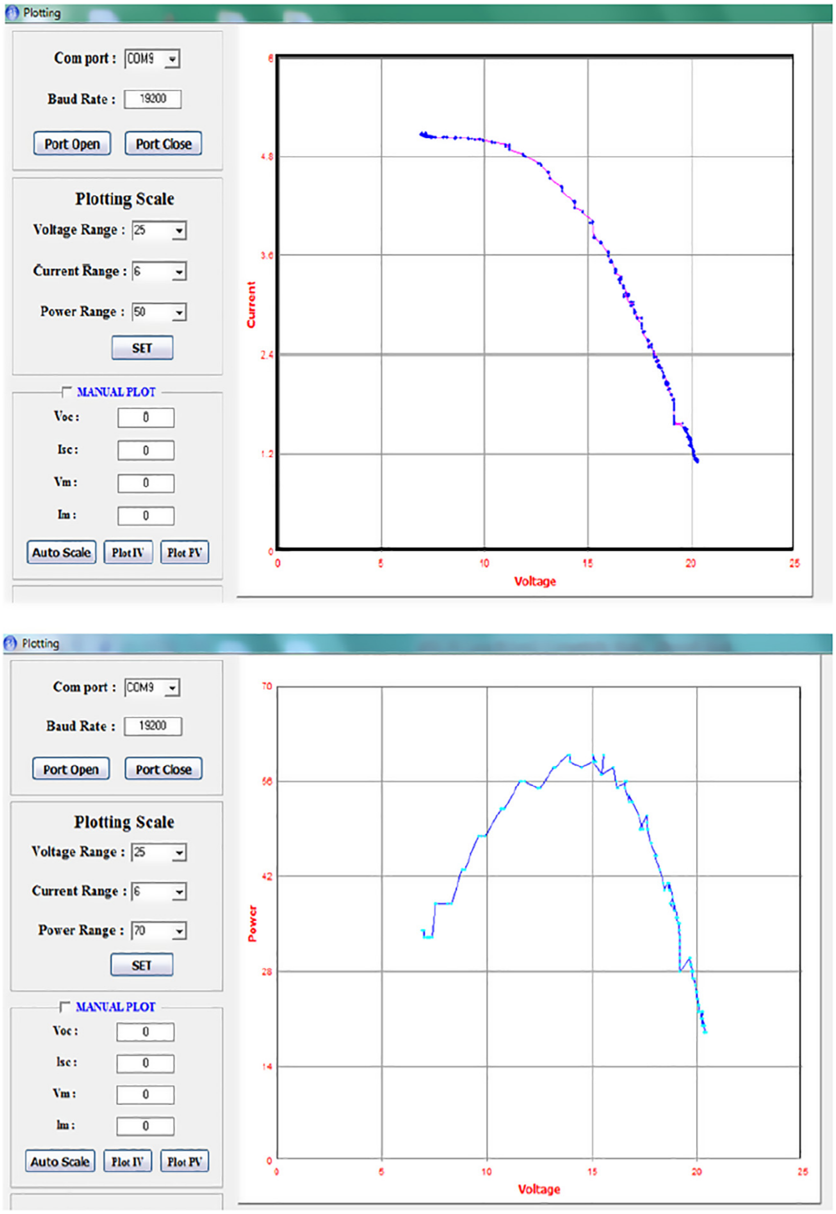

Com port : COM9
Baud Rate : 19200
Voltage Range : 25
Current Range : 6
Power Range : 50
☐ MANUAL PLOT
Voc : 0
Isc : 0
Vm : 0
Im : 0

Com port : COM9
Baud Rate : 19200
Voltage Range : 25
Current Range : 6
Power Range : 70
☐ MANUAL PLOT
Voc : 0
Isc : 0
Vm : 0
Im : 0

Fig. 12. Proposed afdca method: experimental I-V & P-V characteristics of pv system at different duty cycle from (10%–90%).

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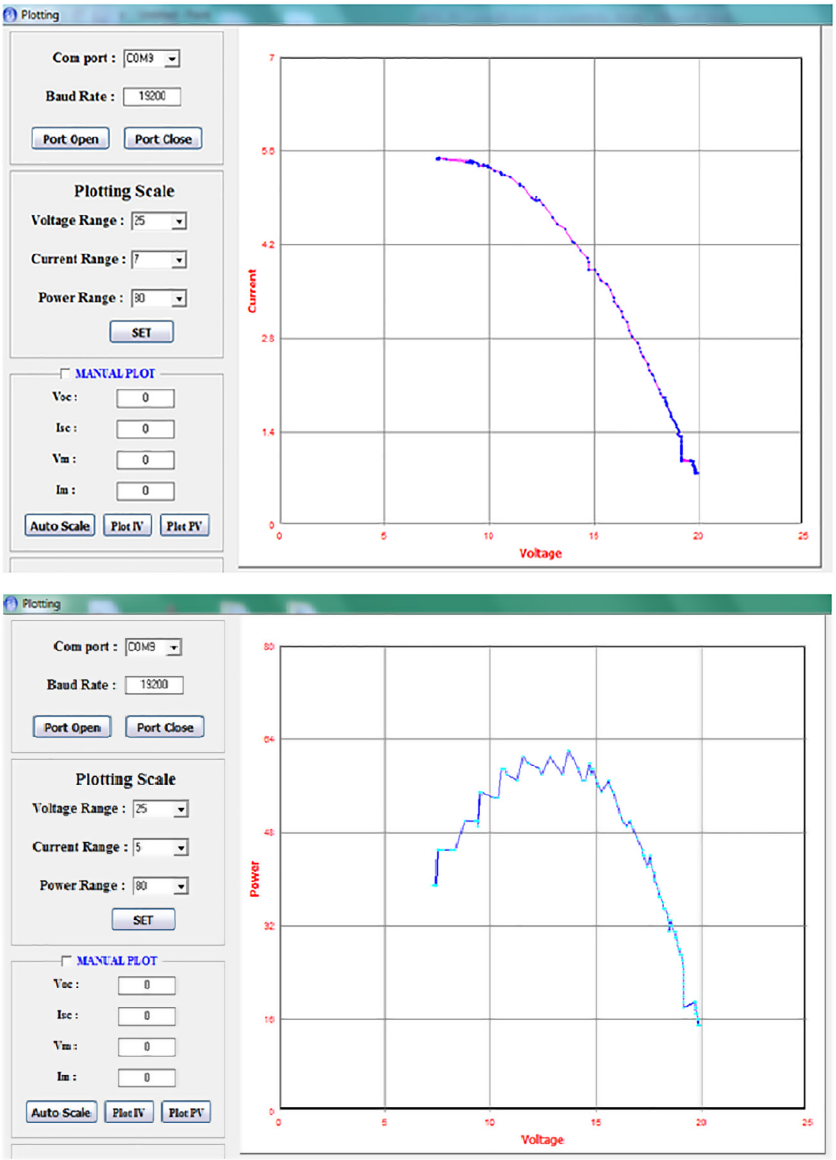

Com port : COM3
Baud Rate : 19200
Voltage Range : 25
Current Range : 7
Power Range : 80
Voc : 0
Isc : 0
Vm : 0
Im : 0

Com port : COM3
Baud Rate : 19200
Voltage Range : 25
Current Range : 5
Power Range : 80
Voc : 0
Isc : 0
Vm : 0
Im : 0

Fig. 13. Proposed afdca method: experimental I-V & P-V characteristics of pv system for different load values (5–200 Ω).

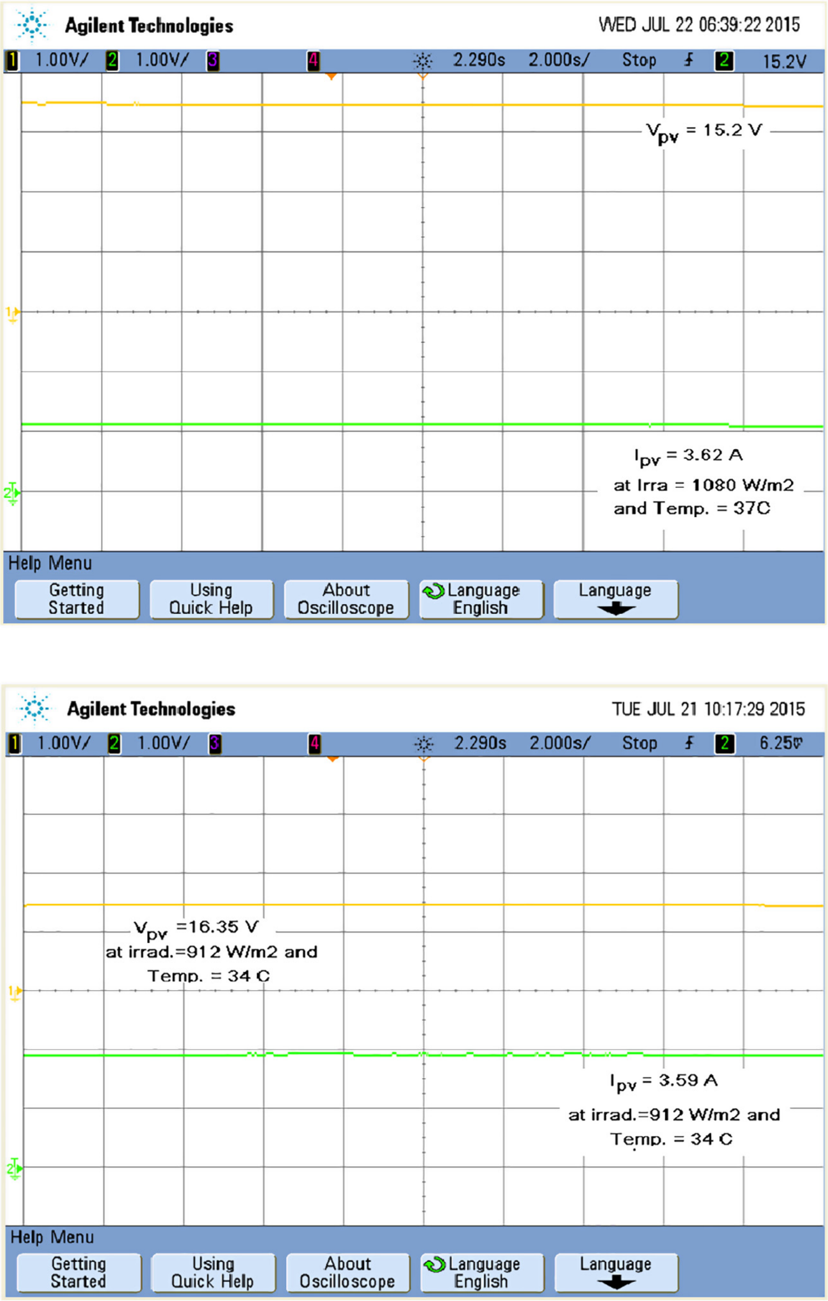

Fig. 14. Experimental pv output voltage and current waveform of AFDC tracking algorithm at irradiance of 1080 w/m^2 at 37 °C and 912 w/m^2 at 34 °C.

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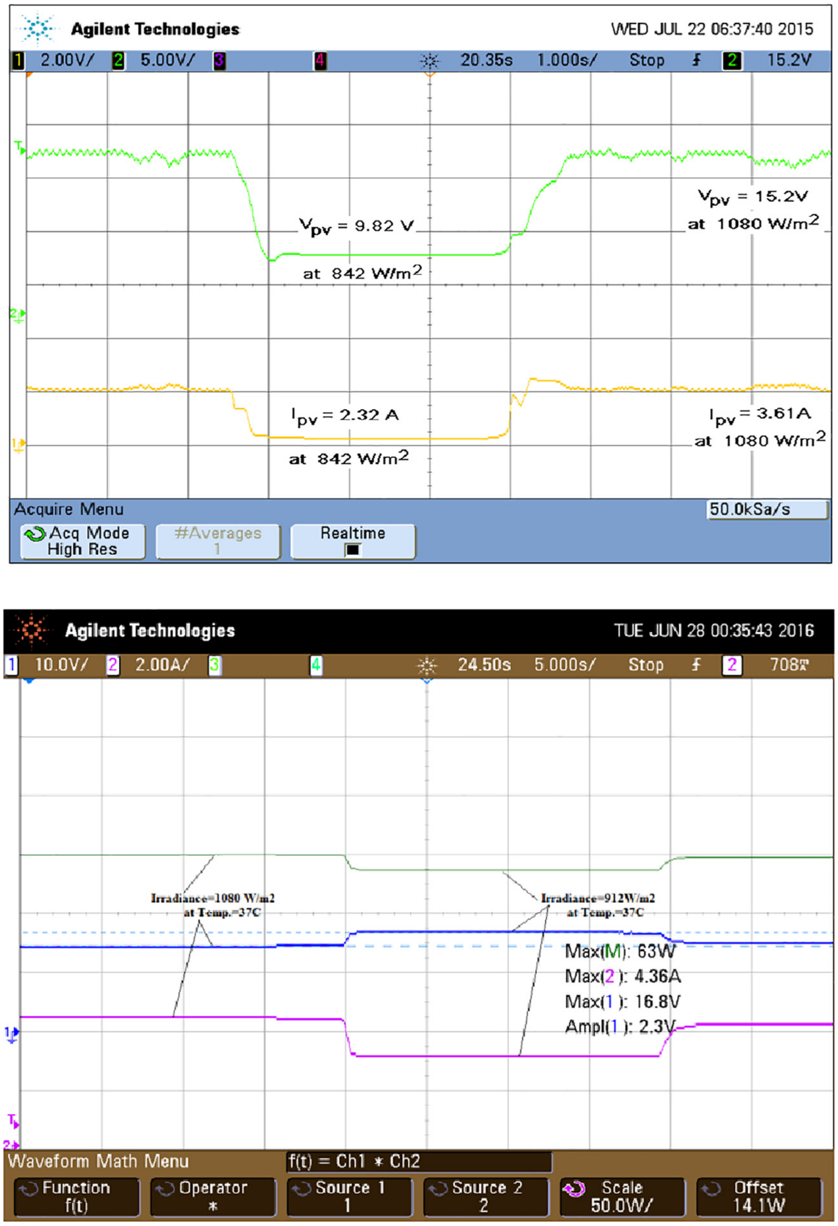
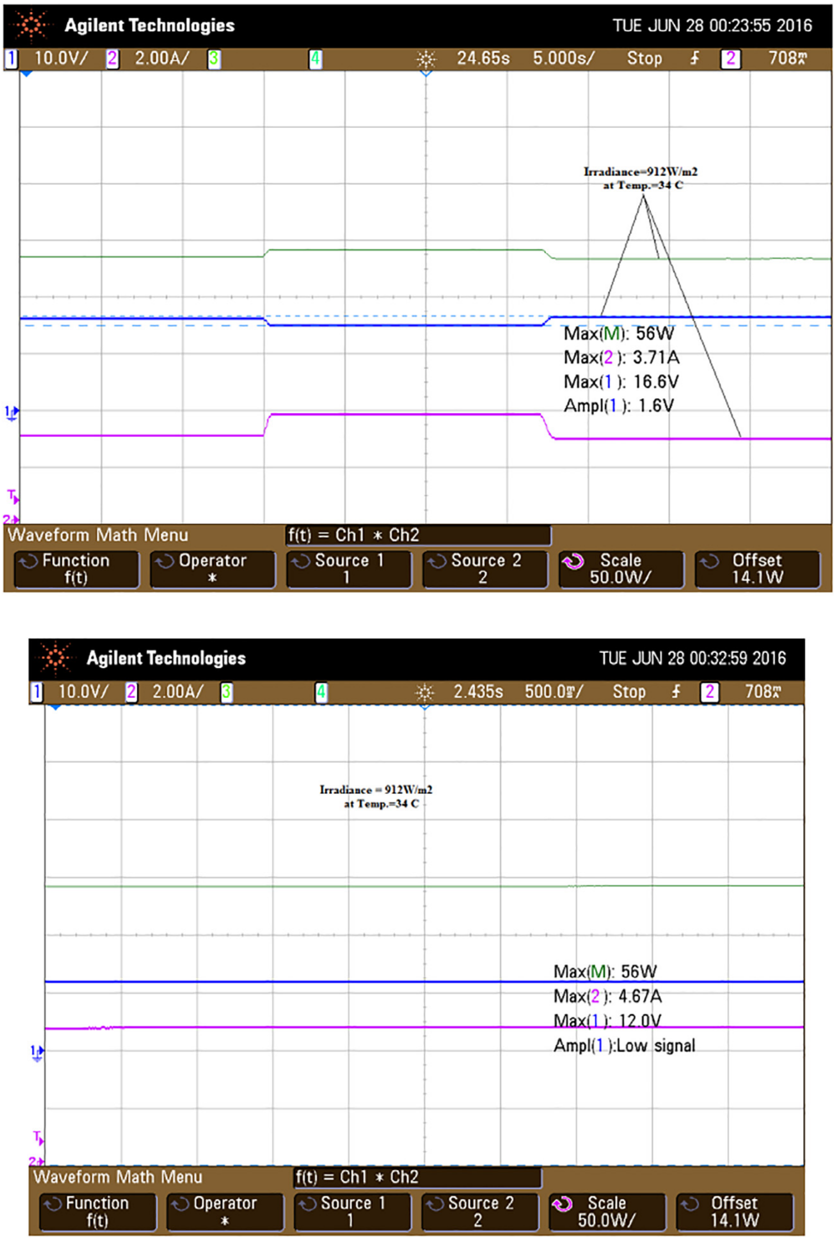


Fig. 15. Experimental pv output voltage and currentwaveform of AFDC tracking algorithm at sudden change of irradiance (1080 w/m^2 at 37 °C and 912 w/m^2 at 34 °C.



f(t) = Ch1 * Ch2

Max(M): 56W
Max(2): 3.71A
Max(1): 16.6V
Ampl(1): 1.6V

f(t) = Ch1 * Ch2

Max(M): 56W
Max(2): 4.67A
Max(1): 12.0V
Ampl(1):Low signal

Fig. 15 (*continued*)

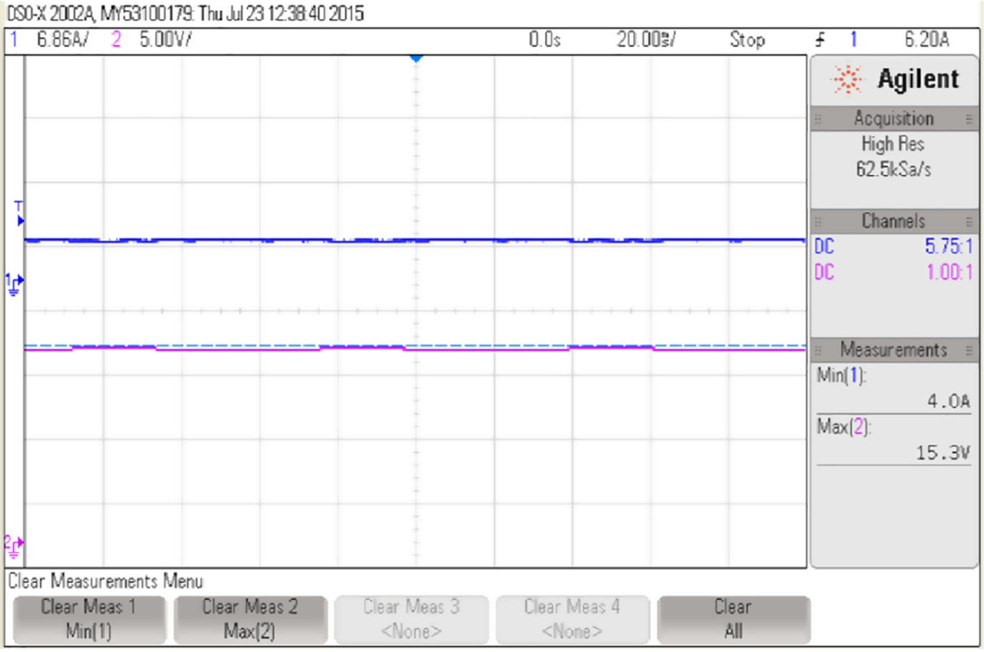


Fig. 16. Experimental PV output voltage and current at load resistance is 35 Ω.

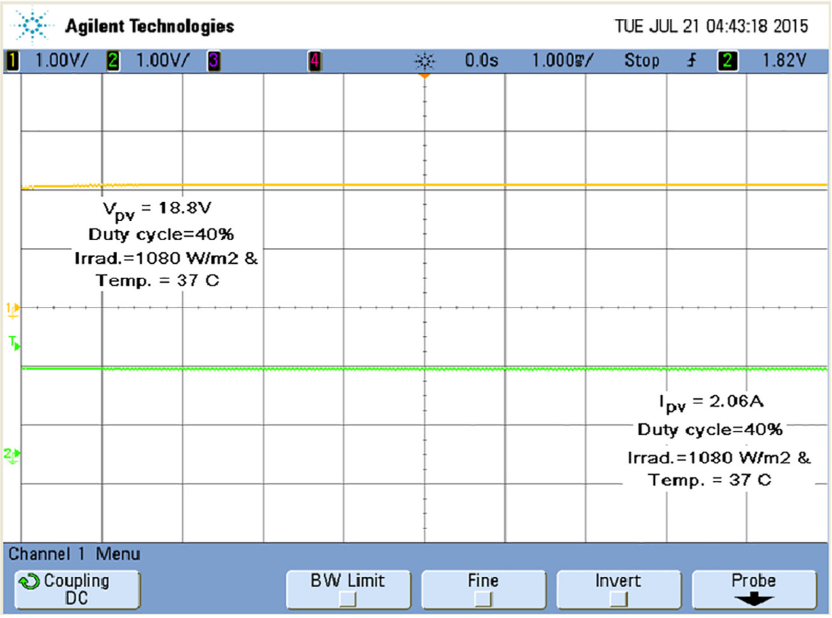


Fig. 17. Experimental PV output voltage and current with duty cycle of 40%.

References

Ahmed, J., Salam, Z., 2015. A critical evaluation on maximum power point tracking methods for partial shading in PV systems. Renew. Sustainable Energy Rev. 47, 933–953.

Dileep, G., Singh, S.N., 2015. Maximum power point tracking of solar photovoltaic system using modified perturbation and observation method. Renew. Sustainable Energy Rev. 50, 109–129.

Esram, T., Chapman, P.L., 2007. Comparison of photovoltaic array maximum power point tracking techniques. IEEE Trans. Energy Convers. 22 (2), 439–449.

Jiang, Y. et al., 2013. Adaptive step size with adaptive perturbation frequency digital MPPT controller for a single sensor photovoltaic solar system. IEEE Trans. Power Electron. 28 (7), 3195–3205.

Kok Soon, T., Saad, M., 2014a. Modified Incremental conductance MPPT algorithm to mitigate inaccurate responses under fast – changing solar irradiation level. Sol. Energy 101, 333–342.

Kok Soon, T., Saad, M., 2014b. Modified incremental conductance algorithm for photovoltaic system under partial shading conditions and load variations. IEEE Trans. Indus. Electron. 61 (10), 5384–5392.

Pandey, A. et al., 2008. High-performance algorithms for drift avoidance and fast tracking in solar MPPT system. IEEE Trans. Energy Convers. 23 (2), 681–689.

Po-Cheng, Ch. et al., 2015. A comparative study on maximum power point tracking techniques for photovoltaic generation systems operating under fast changing environments. Sol. Energy 119, 261–276.

Rajdai, T. et al., 2015. Experimental Verification of P&O MPPT algorithm with direct control based on fuzzy logic control using CUK converter. Int. Trans. Electron. Energy Syst. 25 (12), 3492–3508.

Rajdai, T. et al., 2014. Implementation of a modified incremental conductance MPPT algorithm with direct control based on a fuzzy duty cycle change estimator using dSPACE. Sol. Energy 110, 325–337.

Satish Kumar, K., Mahesh Kumar, M., 2014. A novel adaptive P & O MPPT algorithm considering sudden changes in the irradiance. IEEE Trans. Energy Convers. 29 (3), 602–610.

Please cite this article in press as: Srikumar, K., Saibabu, C. A system and novel methodology to track maximum power from photo voltaic system: A comparative and experimental analysis. Journal of King Saud University – Engineering Sciences (2018), https://doi.org/10.1016/j.jksues.2018.02.006

Seyedmamoudian, M. et al., 2016. State of the art artificial intelligence-based MPPT techniques for mitigating partial shading effects on PV systems – A review. Renew. Sustainable Energy Rev. 64, 436–455.

Steven, L., B., et al., 2010. Maximum power point tracking for photovoltaic optimization using ripple-based extremum seeking control. IEEE Trans. Power Electron. 25 (10), 2531–2540.

Young-Hyok, Ji et al., 2011. A real maximum power point tracking method for mismatching compensation in PV array under partially shaded conditions. IEEE Trans. Power Electron. 26 (4), 1001–1009.

Yuncong, J. et al., 2013. Adaptive step size with adaptive – perturbation – frequency digital MPPT controller for a single – sensor photovoltaic solar system. IEEE Trans. Power Electron. 28 (7), 3195–3205.

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