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Real Time Implementation of Hybrid Maximum Power Point Tracking (MPPT) for Solar PV System

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Abstract: Solar radiation from the sun is the richest source of renewable energy in nature, MPPT is a major concern in PV power system. The most common methods considered are the Perturb and Observe (P&O), Hill Climbing and Incremental Conductance (INC). The scope of these techniques also encloses their disparities and characterized by their forms. This work deals with real time implementation of hybrid MPPT under partial shading condition. MATLAB™/Dspace™ platform have been utilized for real time simulation of buck converter controlled PV system. . The performance of these MPPT methods has undergone a process of different comparisons. These investigational results of different MPPT methods for tracking the MPP under quickly changing solar irradiation have been presented.

Keywords: Perturb and Observe, MPPT, Incremental Conductance, Particle swarm optimization, PV tracker

I. INTRODUCTION

Solar power vitality is the most promptly accessible wellspring of vitality. It doesn't have a place with anyone and is, in this manner, free. A photovoltaic framework changes over the sun's radiation into usable power. A few solar cells are associated together in either arrangement or parallel design to expand yield voltage or current individually. Distinct photovoltaic modules are associated in cluster called sun based PV exhibit to further improve the yield. The significant segments of sun powered PV framework are appeared.

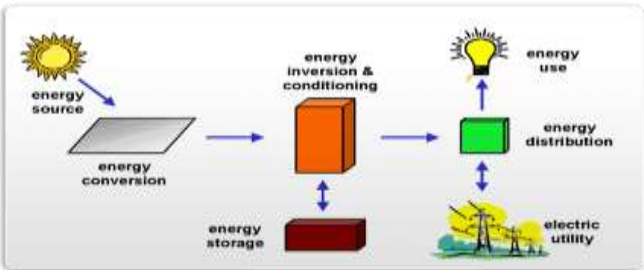

Figure 1: Various Constituents of solar PV system

P-V and I-V curves of a solar based cell with steady module temperature and solar radiation have been appeared in figure 2. At the crossing point of Imp and Vmp, exhibit creates greatest electrical power [1].

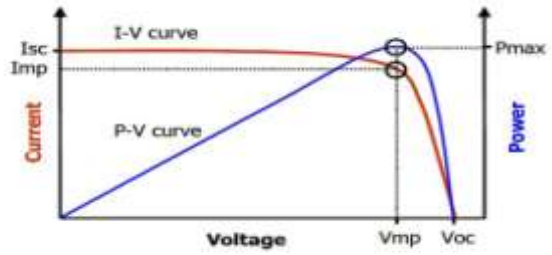

Figure 2: P-V and V- I characteristics of a solar cell

As per most extreme power transfer hypothesis, the circuit supplies greatest power to the load when source impedance coordinates the load impedance. In this paper constant reproduction and near investigation of three generally favored following plans viz. annoy and watch, incremental conductance, cross breed PSO based MPPT procedures have been exhibited.

II. DIFFERENT MPPT TECHNIQUE

A. *P & O Method*

In P and O strategy, photovoltaic current and photovoltaic voltage are calculated utilizing current and voltage sensors, and coming about power P_1 is figured. At that point presenting little annoyance of voltage, ΔV or bother of obligation cycle of dc-dc converter, Δd in one heading, comparing power P2 is figured. Control P2 is then contrasted and power P1.

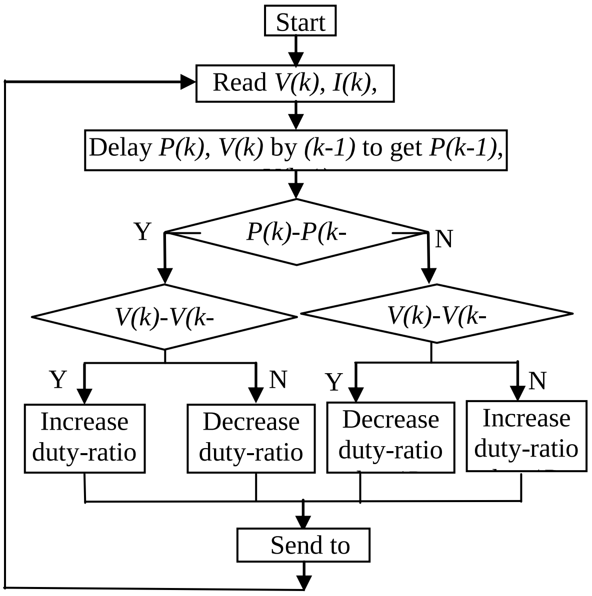

Figure 3: Perturb and Observe MPPT Method Flowchart

In the event that is more than P1, then the irritation is in right heading, generally bearing of the annoyance should be turned around [3]. With this methodology, the most extreme power point is come to. Figure 3 shows the stream graph of P&O strategy.

B. Incremental Conductance MPPT Technique

The INC flowchart shown in figure 4 depends on the slant of P-V curve is zero at most extreme MPP (dP/dV=0). As indicated by this condition, the MPP can be found regarding addition of PV array conductance [4].

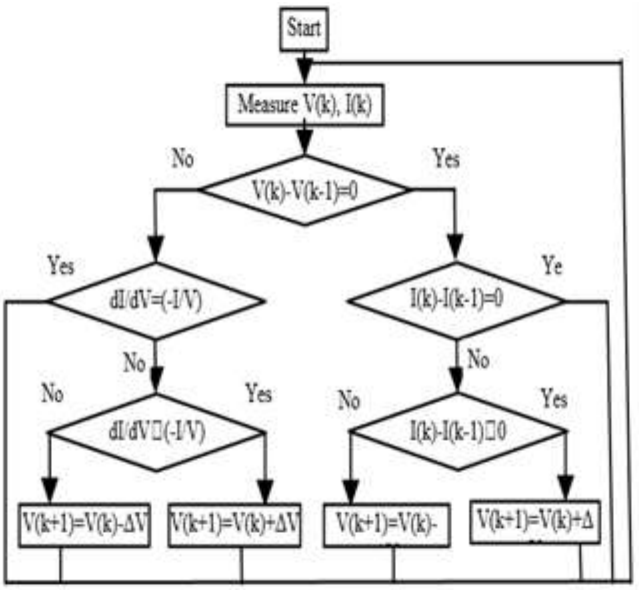

Figure 4: Flowchart of INC MPPT method

C. Hybrid MPPT Method

Hybrid MPPT controller is a combination of PSO and P&O MPPT algorithm. The PSO technique is a metaheuristic approach which can be connected to advance a capacity that is difficult or difficult to express logically. The PSO calculation can be communicated scientifically by two conditions which indicates the speed and position redesign of a particle (i)

$$u_i^{k+1} = wu_i^k + c_1 r_1 (pbest_i - x_i^k) + c_2 r_2 (gbest - x_i^k) \quad (1)$$

$$x_i^{k+1} = x_i^{k+1} + u_i^{k+1} \quad (2)$$

where $ui\ k$ is the velocity of particle i at iteration k, ω is an inertia weight parameter, C_1 and C_2 are acceleration coefficients, r_1 and r2 are random numbers (0 and 1), xik is the position of individual i at iteration k, pbest i is the best position of distinct i at iteration k, and gbest is the best position of the group up to iteration k. The purpose behind the MPPT block is to discover Vref. Consequently, the position (x) factors in (1) and (2) are really the voltage references (Vref), though the speed (u) factors can be viewed as the adjustment terms for the voltage references.

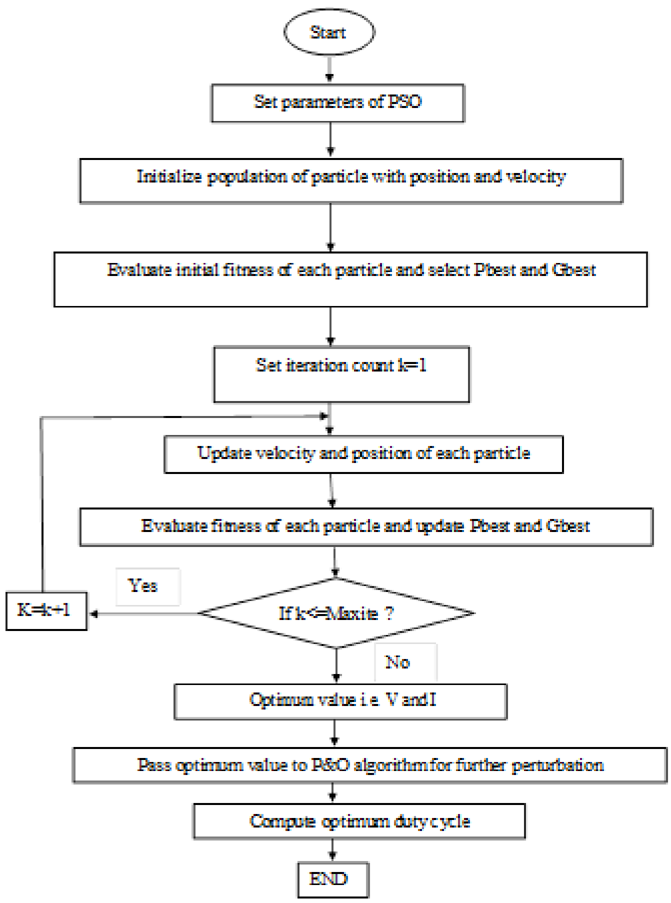

Figure 5: Flowchart for the Proposed Method

III. PV SYSTEM MODELING

Normally a sun powered cell can be displayed by a current source with an altered diode associated in corresponding to it as appeared in figure 3.

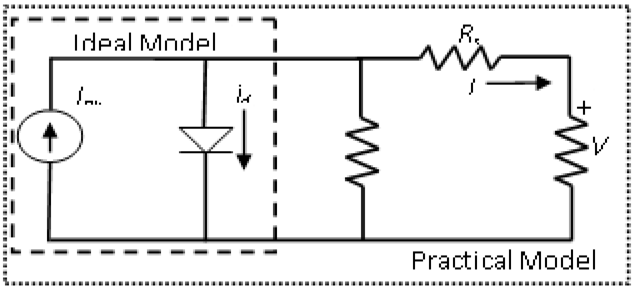

Figure 6: Single Diode Model of a PV Cell

PV module output current can be expressed mathematical as:

$$I = n_p I_{pv,cell} - n_p I_{o,cell}\left[\exp\left(\frac{qV}{kTan_s}\right) - 1\right] \quad (3)$$

Where, I = current, V = voltage of the photo-voltaic module, $I_{0,cell}$ = reverse saturation current

$I_{pv,cell}$ = photo-current

n_s = number of cells (series in connected)

n_p = number of cells (in parallel connected)

q = charge of an electron ($1.6*10^{-19}$C), k is Boltzmann's constant ($1.38*10^{-23}$J/K),

T= PV module temperature

a = p-n junction ideality factor, ($1 < a < 1.5$, $a = 1$ being the ideal value),

T= PV module temperature

. Expression for the practical PV module can be given by:

$$I = n_p I_{pv,cell} - n_p I_{o,cell}\left[\exp\left(\frac{V + R_s I}{V_t a}\right) - 1\right] - \frac{V + R_s I}{R_s} \quad (4)$$

Where, $V_t = N_s kT/q$ (thermal voltage of the module) with N_s. The light generated current of the PV cell depends linearly on the solar radiation and is also influenced by the temperature as expressed in equation 5.

$$I_{pv} = (I_{pv,n} + K_I(\mathrm{T} - \mathrm{T}_n))\frac{G}{G_n} \quad (5)$$

Where, $I_{pv,n}$ = PV current in Amps, (at solar radiation intensity=800 W/m^2, array temperature=20 ^{0}C,

G and G_n = actual and nominal radiation (W/m^2)

T and T_n =the actual and nominal temperatures in Kelvin,

K_I = short-circuit current/temperature coefficient.

The open-circuit voltage at any given condition can be expressed by:

$$V_{oc} = \frac{V_{oc,n}}{1 + \beta \ln(G_n / G)}\left(\frac{T_n}{T}\right)^{\gamma} \quad (7)$$

The short-circuit current then can be resolute by:

$$I_{sc} = I_{sc,n}\left(\frac{G}{G_n}\right)^{\alpha} \quad (6)$$

where, V_{oc} and $V_{oc,n}$ = open-circuit voltage under the radiation value G and the nominal radiation value G_n

β = PV module technology specific coefficient

γ = exponent considering all the non-linear effects.

The fill factor (FF) is the measure of quality of the solar cell/ module.as:

$$FF = \frac{V_{mp} \times I_{mp}}{V_{oc} \times I_{sc}} \quad (8)$$

At the short circuit current (I_{sc}) and open circuit voltage (V_{oc}) points, the power will be minimum and the maximum value will occur in between these two points. The maximum power output P_{max} produced by PV module can be given by:

$$P_{\max} = FF \times V_{oc} \times I_{sc} \quad (9)$$

$$P_{\max} = \frac{v_{oc} - \ln(v_{oc} + 0.72)}{1 + v_{oc}}\left(1 - \frac{R_s}{V_{oc}/I_{sc}}\right)\frac{V_{oc,n}}{1 + \beta\ln(G_n/G)}\left(\frac{T_n}{T}\right)^{\gamma} I_{sc,n}\left(\frac{G}{G_n}\right)^{\alpha} \quad (10)$$

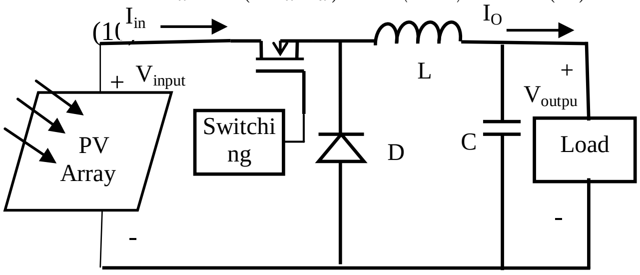

Figure 7: Buck Converter Configuration

IV. MPPT ALGORITHMS IMPLEMENTATION

A. Hardware details

A poly-crystalline photovoltaic panel with a converter of buck configuration has been utilized for investigational exploration of different MPPT techniques. MATLAB™/SIMULINK™ platform have been utilized for real time simulation of buck converter controlled PV system.

TABLE 1: PV Module Parameters (Vikram Solar ELV37)

Sr. No.	Parameter	Value
01	Maximum power P_{max}	37W
02	Voltage at the maximum power point V_{MPP}	17.5 V
03	Current at the maximum power point I_{MPP}	2.24 A

04	Open circuit voltage V_{oc}	21.7 V
05	Short circuit current I_{sc}	2.41 A
06	Number of cells in series N_s	36
07	Temperature coefficient of V_{oc}	-0.32%/ºC
08	Temperature coefficient of I_{sc}	0.04% /ºC

TABLE 2: Parameters of Buck Converter

Sr. No.	Parameter	Value
01	Inductor (L)	7 µH
02	Inductor series resistance (R_L)	30 m Ohm
03	Output capacitor (C_o)	2200 µF
04	Output capacitor ESR (R_{co})	18 m Ohm
05	Input capacitor (C_i)	470 µF
06	Input capacitor ESR (R_{ci})	18 m Ohm
07	Switching frequency (f_s),	100KHz
08	Input voltage	20 V
09	Duty-ratio (D)	0.8
10	Load resistance	7.55 Ohm

Block diagram of experimental setup interfacing of photovoltaic arrangement is presented in figure 10 and the hardware setup is given in figure 8.

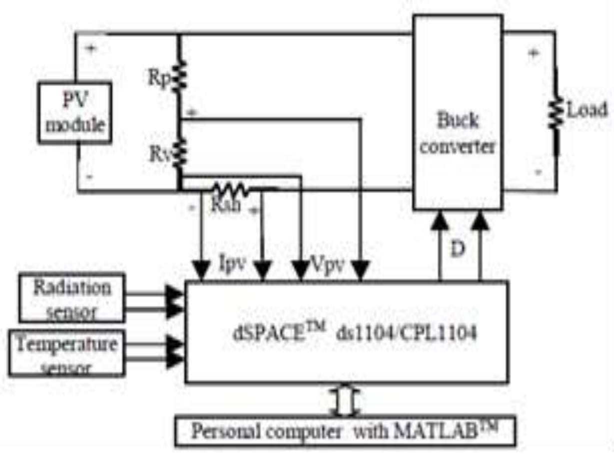

Figure 8: Block Diagram of Prototype Model

Radiation Sensor is required for determining hypothetical maximum power (Pmax, theoretical) while current and voltage measuring device are required for working of MPP tracking controllers. Voltage divider resistive network is used for designing the voltage sensor. Current calibration has been done using low value (0.01 Ohm) shunt resistor (Rsh) that will output a voltage proportionate to the current flowing through it.

The objective of Dspace™ module is to sample and convert the output of sensor to digital signals while processing them in MATLAB™ and consequently provide PWM output signal to drive the buck converter circuit via PWM output channel.

Figure 9: PV System Experimental Setup

B. Real-Time Simulation With of MPPT Algorithms

MATLAB™/SIMULINK™ platform have been utilized for real time simulation of buck converter controlled PV system. Analysis of the existing MPPT controllers on the basis of their reactions for step change in the solar irradiation is performed. For step change in the irradiation two similar halogen lamps were acquaint with using a toggle button. Hybrid PSO based maximum power point tracking system shown in figure 14.

In this, three maximum power point tracking control technique have been programmed with MATLAB™ and implemented using dSPACE™ DS1104 R&D controller board. Three channels of analogue data input and one channel of PWM output have been used to interface three sensors viz. voltage, current, and radiation sensors and one output signal (duty-ratio). As per the specifications of the dSPACE™, the SIMULINK™ output is in the range of -1 V to +1 V for an analogue input in the range -10 V to +10 V. Hence, proper gains for the input signals have to be chosen.

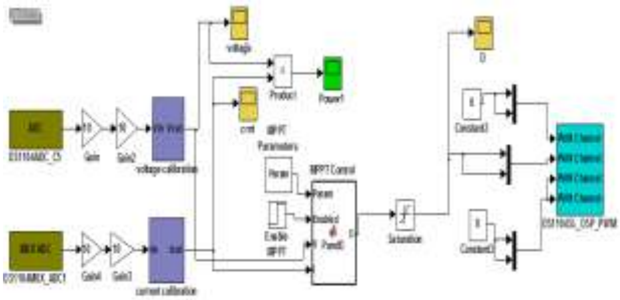

Figure 10: Model of P&O MPPT Controller

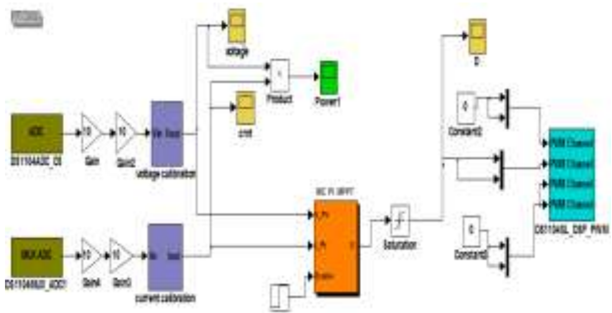

Figure 11: Model of INC MPPT Controller

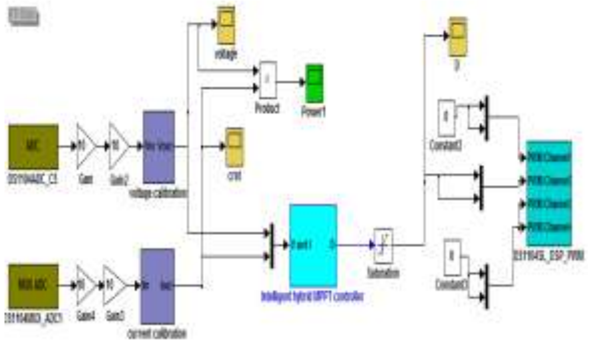

Figure 12: Model of Hybrid PSO Based MPPT Controller

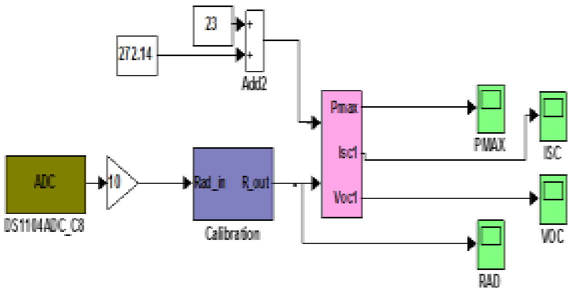

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Figure 13: Model for Determination of $P_{max,\ theoretical}$

Variation in the PV power has been recorded along with the calculated value of the PV power (*Pmax, theoretical*) on the basis of the temperature and radiation data. Several such experiments have been carried out for various MPPT algorithms for 8-10 seconds duration. No variation in the temperature has been observed for step change in radiation during the simulation period. For the experimental study buck converter manufactured by ECOSENSE™ has been used.

V. RESULTS AND DISCUSSIONS

The performance of P&O tracking scheme has been analyzed with fixed perturbation sizes of ΔD=0.1. But for PV system incorporated with buck converter, entire MPPT effectiveness is restricted to about 88%. Incremental conductance tracking scheme displays very less steady-state oscillations and steady-state error is lesser as compared to that of P&O scheme response to sudden change in irradiation. It can be seen that the dynamic response has also been enhanced as compared to the P&O MPPT. Intelligent hybrid PSO based tracking scheme resulted in almost 95% of efficiency with lower steady-state error as compared to the P&O tracking scheme. As stated in Table 6.1, Intelligence based techniques offered higher efficiency. During steady-state maximum power point tracking, in the case of hybrid PSO based MPPT techniques, Oscillatory response has been observed due to resolution issues. Although the hybrid PSO tracking scheme resulted in higher efficiency, the overshoot and steady-state oscillations presented were much higher.

Table 3: Comparison of MPPT Controllers

Characterastics	P&O	INC	Proposed MPPT
Tracking efficiency(%)	88.39	90.25	95.70
Over-shoot(%)	No	3.35	6.56
Settling- time (sec)	0.98	1.65	1.15
Delay in dynamic response (sec)	0.06	0.001	0
Maximum steady state error (%)	15.14	7.35	5.15

Results of the real-time simulations of three MPPT controller algorithms applied to buck controlled PV system with have been shown in Figure 14 to Figure16.

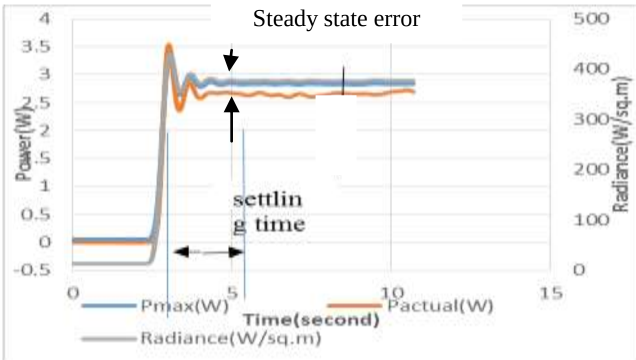

Figure 14: Response of P&O MPPT Controller

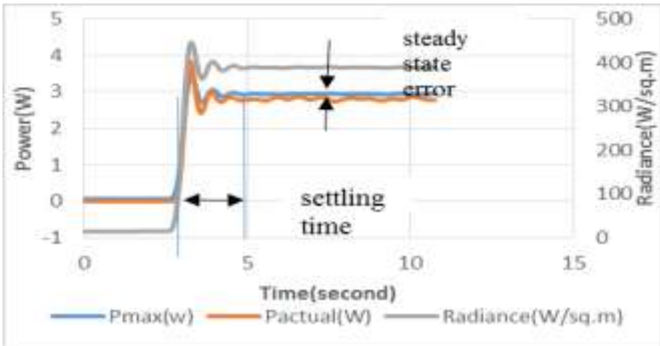

Figure15: Response of INC MPPT Controller

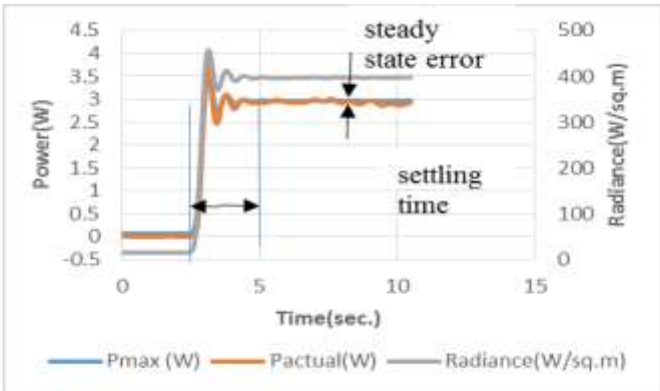

Figure 16: Response of Hybrid PSO Based MPPT Controller

VI. CONCLUSIONS

This paper presents the comparative study of three MPPT techniques. MATLAB™/ SIMULINK™ based prototypes incorporating several maximum power point tracking technique have been established. A solar PV systems prototype controlled by buck converter was utilized for real time simulations. Performance parameters such as tracking efficiency, steady state and dynamic behaviour have been taken into consideration while comparing the maximum power point tracking technique in quick variation in radiation.

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