Design and Simulation of Improved Particle Swarm Optimization based Maximum Power Point Tracking System for Solar Photovoltaic System Under Variable Irradiance Condition

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Article Info
Volume 83
Page Number: 368 - 374
Publication Issue:
July - August 2020

Abstract

The Indian government has set an ambitious goal that by 2030, 40% of the energy comes from renewable energy, the purpose is to meet the country ’s rapidly growing demand, which is currently mainly met by coal and oil. New Delhi is working hard to use renewable energy to generate 175 GW (GW) by 2022, with solar energy predominant, with a target of 100GW, followed by wind power. India has 450,000 KW of hydropower, has an installed wind power capacity of 230,000 KW, but has almost no great level for renewable power. Solar energy represents a large proportion of the government's expansion strategy. Photovoltaic energy must be converted from DC to AC to supply the grid or AC load. When using an IGBT inverter, the applied DC voltage on the DC link is converted to a single-phase AC voltage.. In this research, a diode based circuit model of solar photovoltaic system has been developed under MATLAB. Intelligent model for duty cycle optimization has been developed using particle swarm optimization. The optimization model of particle swarm optimization has been improved using optimization of acceleration coefficient as well as velocity factors. It provides efficient tracking of global peak power point swiftly and avoids early convergence. Comprehensive study on grid-connected solar system is developed and forecasting model for analytical analysis of the system is done. The result have shown least transient response and stable steady state response of proposed system as compared to contemporary soft computing techniques and conventional methods of power point tracking.

Keywords:-Photovoltaic (PV), Matrix laboratory (MATLAB), orthogonal frequency-division multiplexing (OFDM), Particle Swarm Optimization (PSO), Mega Watt Peak (MWp), Soft Computing Techniques, Maximum Power Point Tracker (MPPT), Global Maximum Power Point (GMPP).

Article History
Article Received*: 06 June 2020*
Revised*: 29 June 2020*
Accepted*: 14 July 2020*
Publication*: 25 July 2020*

I. INTRODUCTION

Photovoltaic energy conversion in solar cells has two basic advances. Initial one is the assimilation of light which creates an electron-hole pair. The electron and hole are isolated by the structure of the gadget. The electrons go to the negative terminal and the holes go to the positive terminal. The electric potential is produced dependent on the partition of the holes and the electrons.Solar photovoltaic exhibits are arranged either in equal, arrangement or the blend of arrangement and corresponding to set the ideal terminal voltage and current. On account of arrangement string setup, a higher voltage level can be accomplished however the current evaluations are restricted by the individual rating of photovoltaic cell.

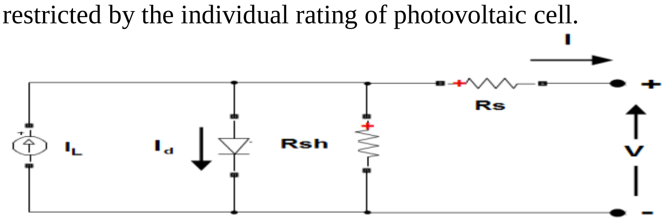

Fig. 1.1: Diode Modelling of Solar Cell

Figure 1.1 talk about the diode modeling of solar cell. The diode model of solar cell is used to ascertain the I-V and P-V attributes of solar cell. The administering conditions for the diode model is given by thinking about the impact of Rs and Rp, the overseeing condition is examined as:

$$I = I_{sc} - I_{01}\left[e^{q\left(\frac{V+I.R_s}{kT}\right)} - 1\right] - I_{02}\left[e^{q\left(\frac{V+I.R_s}{kT}\right)} - 1\right] - \left(\frac{V+IR_s}{R_p}\right) \quad (1.1)$$

$$I = I_{sc} - I_0\left[e^{q\left(\frac{V+I.R_s}{nkT}\right)} - 1\right] - \left(\frac{V+IR_s}{R_p}\right)$$

(1.2)where: n is known as the "ideality factor" and by and large the estimation of ideality factor relies upon assembling innovation of solar cell.

II. MAXIMUM POWER POINT TRACKING

The arrangement layout of the photovoltaic energy creation system for the most extraordinary power point following control is as showed up in Figure 2.1 It is made of the PV module to change over solar energy into the electrical energy and the lift converter for step-up voltage the PV voltage. In the PV module, a voltage and current are assessed and the power is resolved and the MPPT control is performed about the solar radiation change. By using reference voltage yielded from the MPPT control, the lift converter is controlled through PWM. With respect to the control procedure for MPPT, there is the straightforward methodology and propelled method like bother and watch and steady conductance control technique, etc delicate computng strategies are likewise used for the following of maximum power point system. The MPPT control procedure is yielded in voltage motivator to follow MPP of the solar photovoltaic system going under the effect in the distinction in the solar radiation and surface temperature. MPP is in light of the fact that the power delivered in the identical solar radiation changes consenting to the yield voltage, if there ought to emerge an event of doesn't make the MPPT control, the efficiency of the solar cell is decreased and loss is made. Thusly, according to the distinction in the solar radiation condition and load condition, the MPPT control following the perfect working voltage is required.

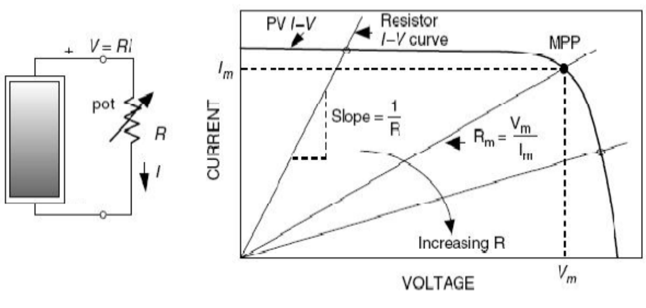

Fig 1.2 PV Model with Resistive Load

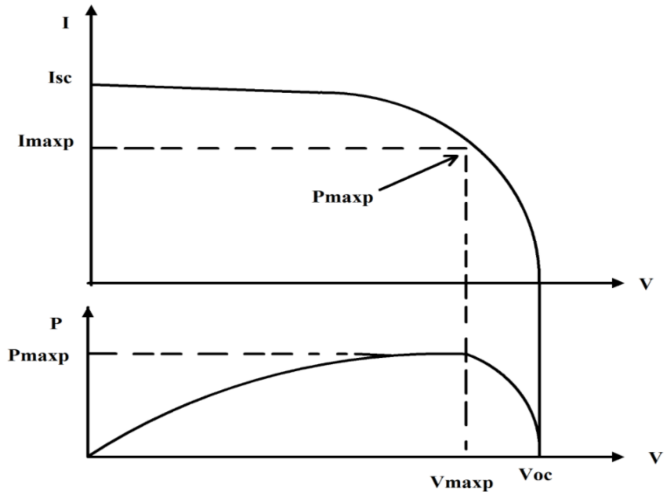

Figure 2.2 Characteristics of a PV Module

Figure 2.2 discuss the I- V and P-V characteristics of photovoltaic module.It shows that the left derivative is greater than zero and less than zero and the peak point to the right.

∂P / ∂V = 0 V = MP (2.1)

∂P / ∂V> 0 if V <V MP (2.2)

∂P / ∂V <0, V> V MP (2.3)

Figure 2.3 denotes the variation in P-V and O-V characteristics of the photovoltaic module with repsect to urradiation and temerature. It is evident that there is rapid decrease in short cicuit current due to change in itradiation and there is rapod change in voltage due to change in temperature, The change of irradiation and change of temperure can not be avoided and it is related to dynamic behaviour of characteristics of solar photovltaic system.

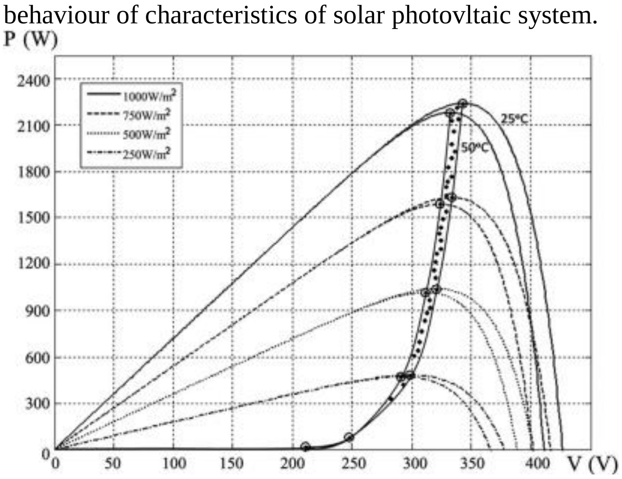

Figure 2.2 Effect of Irradiation and Temperature on Characteristics of a PV Module

The point related to maximum power in the characteristic curve is known as maximum power point it is denoted as maximum power point (MPP). V_m and I_m are voltage and current associated with this point is known as the value at the MPP. The situation related to dynamc behaviour of solar photovoltaic system relates to the the complexity to find the optimum operating point of the photovoltaic system.

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III. PARTIAL SHADING CONDITION

In In this condition, various research explains that the MPPT methods are fail to analyse the exact tracking of global MPP point. To implement MPPT technique in shading condition, the algorithm, cost and failure problem are arise. From the past many years, various tracking methods are explained in each research to decrease the complexity of the system.

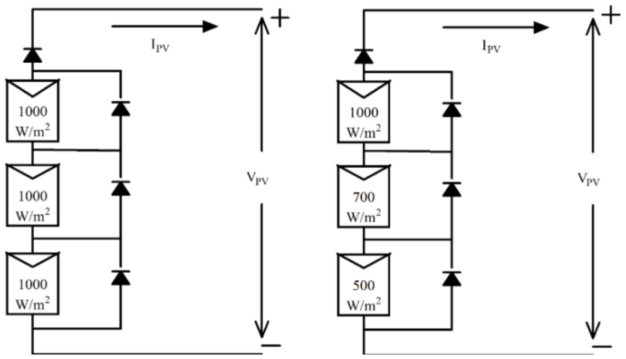

Fig 3.1Comparative Irradiance Representation of Normal System and Partial Shaded System

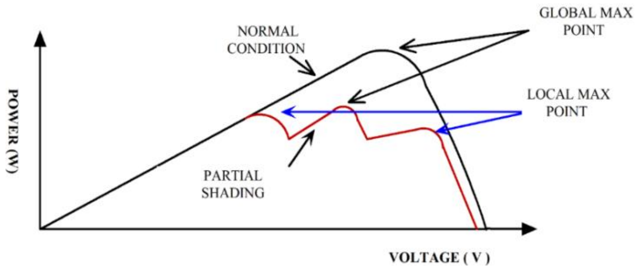

Fig 3.2Characteristics of PV Module under partial shading condition

In partial Shading, multiple points are occur in system. To track the maximum point we use various MPPT methods. PSO (Particle Swarm Optimization) method is one of the best algorithm use to manage the optimal voltage by which maximum power will achieve. In this algorithm various parameters are previously decide before start the process. These parameters are helpful to complete this optimization. Next section discuss the implementation of improved particle swarm optimization for the given operating scenario of partial shaded system.

IV. PROPOSED METHODOLOGY

This technique is amassed by fish and fowls and other organic training exercises invigorated support social line is. PSO gives populace based inquiry program, of which the individual is alluded to as a halfway change their situation after some time. In the PSO - based system, the particles flying in multi-dimensional hunt space. Every molecule during its flight modifies its situation as indicated by its own understanding and experience nearby particles, utilizing the best situation of itself and its neighbors experience it . In multi locate the best solution dimensional space to move every molecule in the set point by including speed ideal position. Molecule speed is influenced by three variables, idleness, comprehension, and society. The inertial segment reenacts the inertial conduct of feathered creatures flying the past way. The psychological part impersonates the flying creature's best area and social memory, which copies the memory of winged creatures, which is the best area for certain cats. Particles multidimensional inquiry space to move around the room until you locate the best solution. The speed of every change can utilize the current speed and figure the separation of the specialist to Pbest and Gbest as follows .

$$V_i^{k+1} = W \times V_i^k + C_1 \times r_1 \times \left(Pbest_i^k - X_i^k\right) + C_2 \times r_2 \times \left(Gbest^k - X_i^k\right) \quad (4.1)$$

Where, V_i^kThe speed of individual i when iterating k, X_i^k Individual i is in the position of iteration k, W inertial weight C1 , C2 acceleration factor, $Pbest_i^k$The best position of individual i in iteration k, $Gbest^k$ Group's best position until iteration k r1 , r2 Random number between 0 and 1. Accelerate during this speed update the coefficients C1, C2 and the inertia weight W are Predefined and r1, r2 are randomly generated uniformly The number is in the range [0, 1].

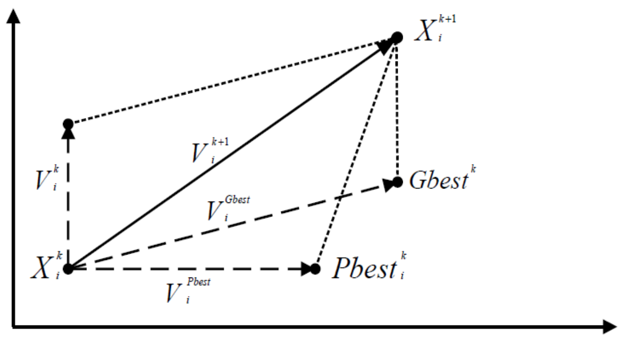

Figure 4.1 PSO Optimization system

The modified velocity equation (6) is given by:

$$V_i^{K+1} = K.\left(W.V_i^k + C_1 G_d()\left(Pbest_i^k - X_i^k\right) + C_2 C_d()\left(Gbest^k - X_i^k\right)\right)$$

$$K = \frac{2}{\left|2 - \varphi - \sqrt{\varphi^2 - 4\varphi}\right|}$$

Where $\varphi = C_1 + C_2, \varphi > 4$

The combination normal for the system can be controlled byφ. Compression factor strategy (CFA) φ must be more prominent than 4.0 to ensure solidness. Nevertheless, as φ Increase Factor K is diminished, enhancement is decreased, Produces a more slow response. Normally when Using shrinkage factors, φSet to 4.1 (ie C1, C2 = Therefore, the consistent multiplier K is 0.729.QPSO, proposed and created by Sun et al., is the extension of PSO in the field of quantum figuring. The idea of qubits and spinning entryways is here to present the improvement of segment qualities Diversity. Qubit and edge Represents the condition of the molecule instead of the

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position and the molecule speed finished in the essential PSO. In this manner, QPSO has powerful hunt abilities and powerful inquiry capacities Fast combination highlight. The fundamental distinction between a qubit and a traditional piece is the last can remain simultaneously Superposition of two diverse quantum states,

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

In the above condition, α and β are unpredictable numbers that fulfill the condition

$$|\alpha|^2 + |\beta|^2 = 1$$

The pivot state is spoken to by | 0> and the turn state is It is spoken to by | 1>. As can be seen from (1), a qubit is Represents two data states (| 0> and | 1>) all the while. This superposition state can likewise communicated as

$$|\psi\rangle = \sin\theta|0\rangle + \cos\theta\,|1\rangle$$

Where the phase of the qubit is represented by θ. the relation among α,β and θ. The relation among α,β and θ can be defined as the position of the particle in QPSO can be described

asθ = arctan(β/α)

$$x_{id} = p_{id} \pm \frac{L}{2}\ln\left(\frac{1}{u}\right)$$

Where x_{id} is the position of the ith particle and p_{id} is local attractor of particle i is located between pbest and gbest and u is a uniformly distributed random number in the range [0,1]. The value of L can be used following equation

$$L = 2\alpha|x_{id} - p_{id}|$$

Where α is the only parameter of QPSO, which can be calculated using the following equation

$$\alpha = (1 - 0.5).\frac{t_{max} - t}{t_{max}} + 0.5$$

And the local attractor p can be represented as below

$$p = \varphi.pbest + (1 - \varphi).gbest$$

Where φ alludes to a consistently conveyed arbitrary number. The scope of φ is [0, 1]. Figure 1 portrays a stream diagram of the QPSO. In the initial step, Algorithm boundaries, for example, populace size, particles instate the measurement and the maximum number of emphasess. The subsequent advance is to assess the wellness of every molecule and Record pbest and gbest.

Table 1 Parameters use in PSO Algorithm

Parameters	**Values**
Number of Particles	10
Number of Dimensions	1 or 2
Maximum Velocity	2.70
Number of Iterations	80
Position step size	0.15
ω_{max}	0.9
ω_{min}	0.4
r1 r2	[0,1]

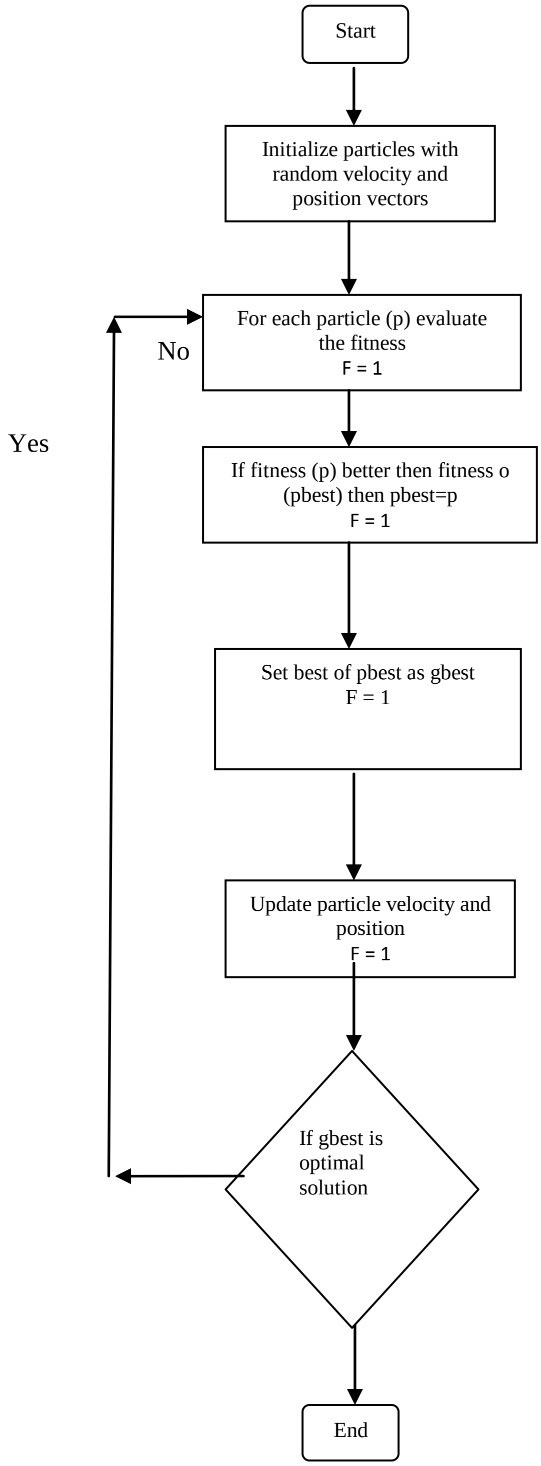

Fig 4.2Flow Chart of Methodology

Now, solar PV array generates voltage through the system consist of boost converter. In this boost converter various parameters are connected that is :

- MOSFET switch
- Inductor (L) of 130mH
- Capacitor (C1) of 20micro farad
- Capacitor (C2) of 700micro farad

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- Load resistance (R) of 350ohms

These parameters are connected across the system to reduce the fluctuation of the system. After applying the input parameters. Output of the system is obtained. In output actual voltage is compare with optimal voltage obtained from PSO (particle Swarm optimization) method system. After that the solar PV system is work on optimal voltage to achieve the maximum power point.Fig.1.5 explains about the modelling of PV system using particle swarm optimization method and table itself shows the comparison of proposed method with the other two methods use in [19] and [11] .

V. RESULTS

Figure 4.2 represents the implementation of particle swarm optimization under partial shading condition.Table 2 indicates partial shading scenario for partial shaded photovoltaic system in this scenario fixed temperature input has been provided to the system whereas radiation in increasing order has been implemented to various modules connected in series with each other.

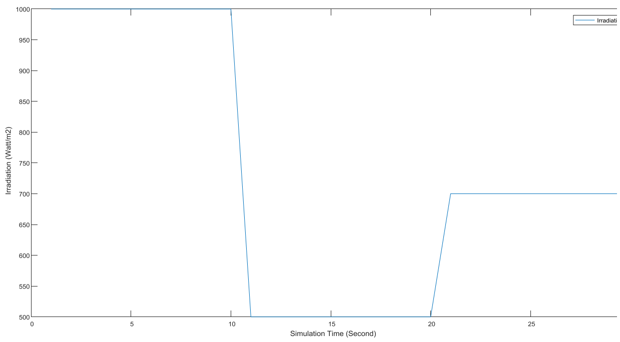

Fig.5.1 Plot of Variable Irradiation With Respect to time

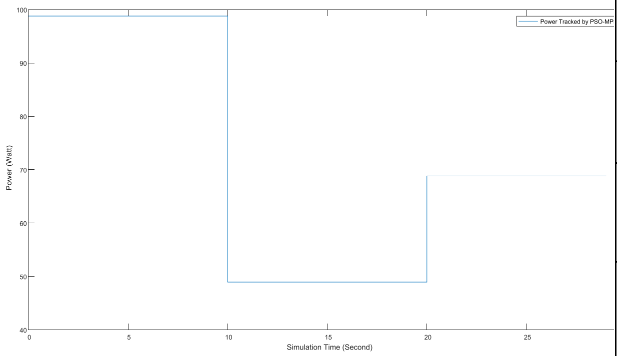

Fig.5.2Plot of Maximum Power Tracked by the Proposed System Under Given Condition

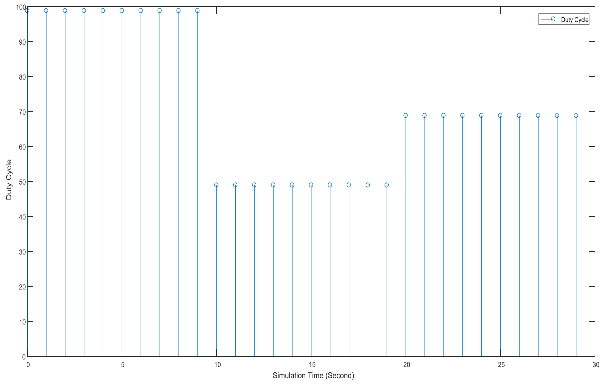

Fig.5.3Variation of Duty Cycle with Respect to Proposed Working Condition

The application of particle swarm opimization is utilied here to design and effective and efficient power point tracking system for the tracking of power in variable irradiation situation. The weather irradiation data is varied in the system with the help of signal creation, whereas the power optimization and tracking alogortihm is designed with the help of improved particle swarm opttimization .The particle swarm optimization with imptoved parameters of PSO enables the tracking of power instantly and it avoid the problem of early convergence and stable response of the power point tracking as per given condition of temperature and irradiance. The purpose of particle swarm optimization is to look after the optimum duty cycle of the proposed system under given condition of irradiance and temperature..

Table 3: Comparative Assessment of MPPT Methods in Partial Shading Condition

Method	Peak Power Tracked
P and O Method	70 Watts
INC Method	80 Watts
Improved PSO Method (Proposed)	**95Watts**

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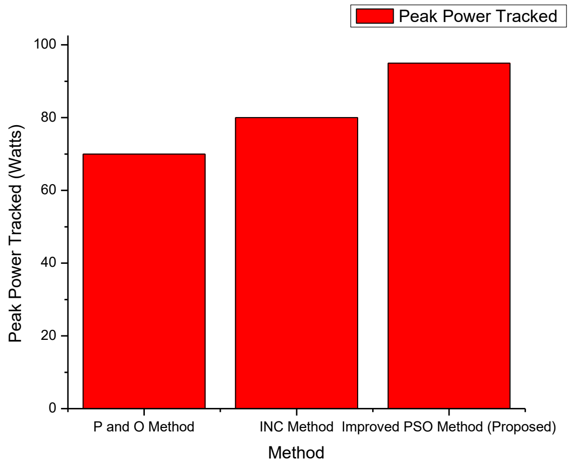

Fig.5.4 Comparative Assessment of Maximum Power Tracked by the Proposed System Under Given Condition

Figure 5.1 indicates the plot of irradiation with respect to simulation time. Figure indicates that the temperature is varied between the simulation time. Figure 5.2 indicates the plot of power with respect to simulation time. Figure 5.2 indicates that there is direct correlation of power tracked with respect to the change in irradiation. Figure 5.3 indicates the plot of duty cycle with respect to simulation time. Duty cycle is responsible for tracking maximum power Table 3 and figure 5.4 explains the comparative assessment of peak power tracked by the proposed system as compared to the conventional system designed on the basis of perturb and obserce method and incremental conductance method.

VI.CONCLUSION

In this research work a charge controller having boost configuration and duty cycle controlled by soft computing based controller which is based on improved particle swarm optimization which is programmed to track maximum power point from I-V characteristics of PV system under variable irradiance and complex operating condition efficiently and with stability has been simulated. The charge controller is connected to the output of PV modules and the output of charge controller is connected to battery under storage applications and to the inverter under high power applications. Thus according to the aspects of present research it is provided with the with the enhancement of operating efficiency of solar photovoltaic system using efficient power converter equipped with soft computing based MPPT controller system. It improves the operating efficiency of solar photovoltaic system by implementation of efficient charge controller based on intelligent maximum power point tracking control system.Charge controller can be interfaced with the battery for storage applications of solar photovoltaic system and with the inverter system for high power applications..

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