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OPTIMUM OPERATION OF SOLAR PHOTOVOLTAIC SYSTEM USING GREY WOLF OPTIMIZATION METHOD

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Abstract*-There is continuous demand of energy. It is crucial to come up with innovative solutions to reduce and conserve energy. There is a not able interest in creating an environmentally friendly system that will save investment on electricity and maximize the return cost on investment for solar modules. The photovoltaic industry continues to obtain to make efficient and less expensive systems that can be competitive with other conventional sources. The irradiation and panel temperature are un-stable for a PV module, therefore the electricity generations of the PV panel is not stable. So the maximum power point tracking (MPPT) technique is used to extract the maximum power from PV modules. A DC to DC converter has been used to match the impedance between PV module or array of modules to extract maximum power from PV module or strings of PV module. Although a approaches have been discussed in literature, the method based upon perturb & observe (P&O), Particle swarm optimization (PSO) and Grey wolf optimization (GWO) has been used in this work. GWO algorithm is a new approach used in the proposed area. The performance of these algorithms has been verified for MPPT in MATLAB /Simulink environment.*

Keyword:*Maximum power point tracking , Perturb and obserb(P&O),Partical swarm optimization method(PSO),Grey wolf optimization method(GWO)*

1. INTRODUCTION :

Renewable energy resources play important role in electric power generation. There are various renewable resources. which is used for electric power generations, such as solar energy, wind energy, geothermal etc. Solar Energy is good choice for electric power generation, since the solar energy is directly converted into electrical energy by solar photovoltaic modules. These modules are made up of silicon cells. When many such cells connected in series .we get a solar PV module. Increases current rating of the modules when the area of the individual cells is increased, and vice versa. When many PV modules are connected in series and parallel combinations we get a solar PV array, which is suitable for obtaining higher power output.

The applications of solar energy are increasing, and many researches are done to improve the materials and methods used to harness this power source. Main factors that affect efficiency of the collection processing are solar cell efficiency intensity of source radiation and storage techniques. The efficiency of a solar cell is limited by materials used in solar cell manufacture. It is particularly difficult to make considerable

improvements in the performance of cell, and hence restricts the efficiency of the overall collection process. Therefore the increase the intensity of radiation received from the sun is the most attainable method of improving the performance of solar power. There are mainly two major approaches for maximizing power extraction in solar systems. They are sun tracking, maximum power point (MPPT) tracking or both. In this thesis, MPPT tracking techniques are studied and comparison has been done between Perturb & Observe (P&O), Particle Swarm Optimization (PSO) and Grey Wolf Optimization for finding maximum power point.

[1] Maximum Power Point Tracking algorithms (MPPT) are used to track maximum power, a DC-DC Boost converter is used to obtain the impedance matching between the PV array and the load. Although huge number of approaches have been proposed in literature. This methods based on the perturb and observe (P&O) technique are the most widely employed in commercial products. This reason lies in the fact that P&O can be implemented in cheap digital devices by ensuring high robustness and a good MPPT efficiency. This paper aims to presents the design and development of a photovoltaic system based on the enhanced P&O algorithm that allows improving efficiency, stability and accuracy of solar systems. The effectiveness of the proposed solar regulator system is verified by the simulation by Power Sim simulator and experimental results under our developed system using three MPPT algorithms, classical P&O and a new enhanced PSO algorithm and GWO .[2] Maximum Power Point Tracking (MPPT) that focuses mainly on Incremental Conductance Method (Inc .Cond) with direct control. For this purpose dsPIC30F2010 microcontroller has been used for programming of MPPT Method. dsPIC30F2010 programming has been performed on MPLABIDE Software. The MATLAB/SIMULINK and hardware study has been done using photovoltaic (PV) panels, Cuk converter and battery. Comparative studies between hardware and MATLAB/SIMULINK has been performed and conclusions have been drawn.[3]four maximum power tracking techniques. Perturb and Observe (P&O), Incremental Conductance (Inc), fuzzy logic based tracking technique and a, less known, method using only the photovoltaic current measurement is propose by author. [4] One of important factors to maximize the utilization and efficiency of any Photo-Voltaic (PV) system is the Maximum Power Point Tracking technique (MPPT). MPPT is specifically used to extract the maximum Power available form the PV array, maximum power can be achieved by tracking the Maximum Power Point (MPP) using specialized algorithms ,such as a Perturb and Observe (P&O) and Incremental Conductance (INC). These algorithms are the most common used due to its simplicity in implementation compared to other algorithms. This paper illustrates the positive effect of the MPPT technique on the PV system. In addition, it illustrates the theory of operation of both P&O and INC algorithms In [5] author has proposed two main drawbacks with PV plants, the high cost of PV cells and their conversion efficiency. In the I-V characteristics of PV module which is non-linear but has a unique maximum power point. To increase or to maximize the output power of photo-voltaic system Maximum power point tracking (MPPT) techniques are used. These techniques give maximum output power, irrespective of the irradiation condition, temperature and load electrical characteristics. For the purpose of tracking the maximum power the MPPT techniques use some electronic converters. This paper presents comparative analysis of three well-known maximum power point tracking algorithms-perturb-and-observe (P&O), incremental conductance

(INC), and fractional open-circuit voltage (FOVC).In [6] author has proposed Circuit for maximum power point tracking (MPPT) is a among several equally important subsystems of a standalone photovoltaic (PV) system. In this paper we will implement three algorithm for maximum power point tracking and comparison, based on the maximum simplicity criteria, into the whole PV system. SPICE circuit simulation of the complete standalone PV system will be performing in order to verify the proposed algorithm. Different working conditions will be examined [7-21]. In [22] proposed hybrid genetic algorithms method for loss reduction in distribution systems. Seyedali Mirjalili et al proposed a Grey Wolf Optimizer in[23] for optimization problems. In this paper Grey Wolf Optimization algorithm is used to find the optimal capacitor size.

2. EQUIVALENT CIRCUIT AND MATHEMATIC MODEL

A current source type PV model is discussed in this section. The equivalent circuit is shown in Figure 1.

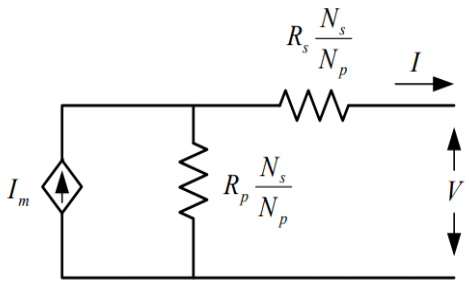

FIG.1. PV Module Equivalent Circuit

$$I_m I_{pv} N_p \_ I_o N_p \left[\exp\left(\frac{V + R_s\left(\frac{N_s}{N_p}\right) I}{V_t a N_s} \right) - 1 \right] \qquad (2.1)$$

Where Rs is the array series resistance, R_p is the array parallel resistance, N_s and N_p are the number of series and parallel modules respectively, I and V are the output current and voltage of the array and I_m is the module current and can be obtained from the following equation:

Where, a is the diode ideality constant, V_t is the thermal voltage of the array and can be obtained from the equation:

$$V_t = \frac{N_{cs} KT}{q} \qquad (2.2)$$

N_{cs} is the number of cells connected in series, q is the electron charge, k is Boltzmann's constant and T is the temperature of the P-N junction in Kelvin's. I_{pv} is the photovoltaic current and can be expressed by:

$$I_{pv} = \left(I_{pvn} + K_i \Delta T\right) \frac{G}{G_n} \qquad (3.3)$$

And I_o is the reverse leakage current of the diode and can be calculated from

$$I_o = \frac{I_{scn} + K_i \Delta T}{\exp\left(\frac{V_{ocn} + K_v \Delta T}{aV_t}\right) - 1} \qquad (4.4)$$

Where: I_{pvn} is the generated current at 25oC and 1000W/m2 (nominal conditions), K_i , K_v the current and voltage temperature confidents respectively, G is the irradiance and G_n is the irradiance at nominal conditions, I_{scn} ,V_{ocn} are the short circuit current and open circuit voltage respectively at nominal conditions and T is the difference between the actual and the nominal temperatures in Kelvin's.

.Power can be calculate and varying the duty cycle of the DC-DC converter is done until the MPP is achieve. As the name of the P&O method .The process starts by operating the DC-DC converter with the initial set duty cycle, and then starts increasing the duty cycle with a certain step width , and the Power is observed with the addition of each step. If at a certain point t Power gets less than its previous value that means that the duty cycle should get one step in the opposite direction i.e. getting to the MPP again and etc.

3. GREY WOLF OPTIMIATION

The GWO algorithm is mimics the leadership hierarchy and hunting mechanism of grey wolf in nature proposed by Mirjalili .et al.,2014,Four types of grey wolves such as alpha, beta, delta, and omega .Alpha grey wolf are leaders in the group. The leader may be male and female. Alpha grey wolfs are mostly responsible to take decisions about hunting . The beta grey wolfs are subordinate wolf which are helping in decisions or activities for alpha grey wolfs which are helping in decisions or activities for alpha grey wolves. The omega grey wolfs play the role of Victim sccuts, hunter, caretaker etc came to delta grey wolf category. According to hierarchy the wolf have to submit to the all other wolfs. The main steps of grey wolf hunting are as following.

3.1MAIN STEP OF GWO :

A SOCIAL HIERARCHY:

Consider the fittest solution as the alpha. Next second and third best solutions are beta and delta grey wolfs respectively. Left over assumed to be omega. omega grey follow the other three wolfs

B TRACKING: Grey wolf encircle prey during the hunt. The mathematical equations representing encircling behaviour are

$$X(t+1) = X_p(t) \_ AD \qquad (3.1)$$

$$D = [CX_p(t) - AD] \qquad (3.2)$$

$$A = 2a_{r1} - a \qquad (3.3)$$

$$C = 2r_2 \qquad (3.4)$$

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Where indicates the current iteration. A,C are coefficient vector Xp is the position vector of the prey .X denotes the position vector of grey wolf a is linearly decreased from 2 to 0. R1,r_2 are the random vectors.

C HUNTING: Hunting is usually guided by alpha grey wolfs. First three best solution are saved for alpha, beta and delta. Alpha, beta and delta have better knowledge about the potential location of prey. The position update represented by following equation.

$$D_\alpha = |C1X_\alpha - X| , \quad (3.5)$$

$$D_\beta = |C2X_\beta - X|, \quad (3.6)$$

$$D_\delta = |C3X_\delta - X| \quad (3.7)$$

$$X1 = X_\alpha - A1(D_\alpha) \quad (3.8)$$

$$X2 = X_\beta - A1(D_\beta), \quad (3.9)$$

$$X3 = X_\delta - A1(D_\delta) \quad (3.10)$$

$$X(t+1) = \frac{X_1 + X_2 + X_3}{3} \quad (6.11)$$

D ATTACKING PREY: When the prey is stop moving then the wolf finishes its hunting. A is the random value in the interval [-a,a]. The solution are incline to device from the prey when A>1 and join toward the prey when A>1.

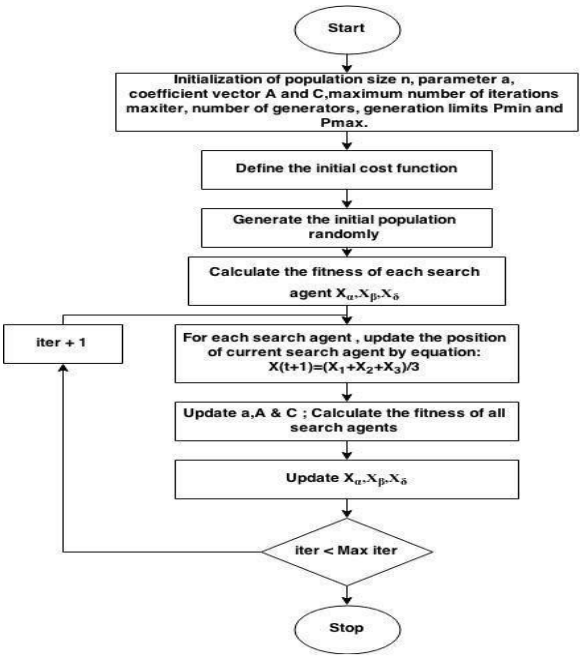

Fig.2.Flowchart of grey wolf optimization algorithm

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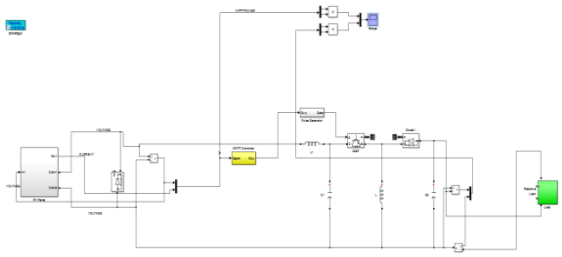

Fig.3. Simulink model of MPPT controller with PV module

Here PV module , Mppt Controller and DC to DC converter are cascaded together . PV is shown in left side in the form of Matlab Subsystem . In yellow box MPPT controller is shown. Resistive load in shown in green block . Power extracted from PV module are shown in Scope (Blue block) . Duty of IGBT switch is controlled by MPPT controller which can change based upon the load or any change in environmental condition .

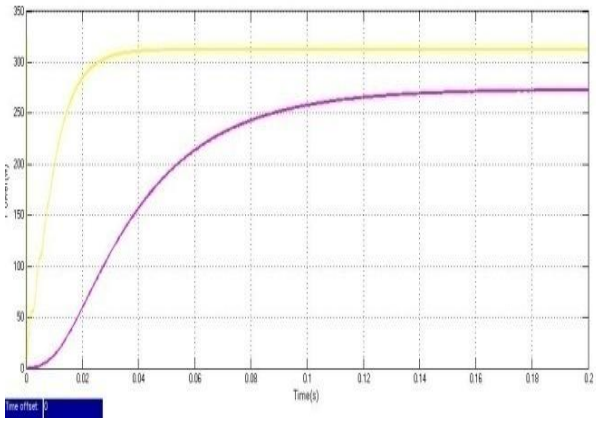

Fig.4.Maximum power and power dissipated in load by using P&O

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Fig.5.Maximum power and power dissipated in load by using PSO

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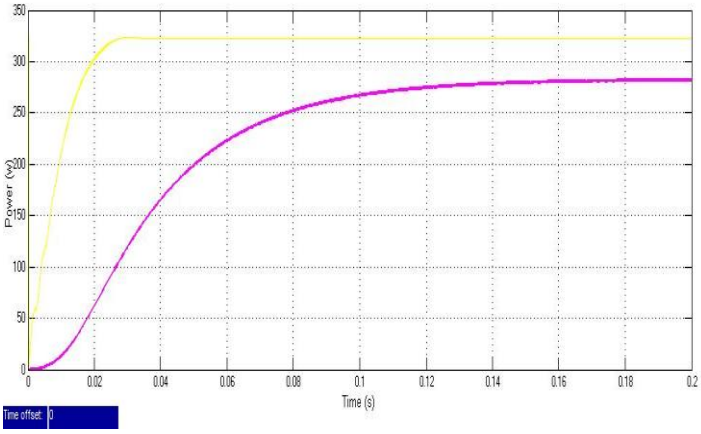

Fig.6.Maximum power and power dissipated in load by using GWO

Above plot shows the maximum power which can be extracted by PV module shown in yellow line and pink line shows power dissipated in resistive load. Simulation time was chosen to be 0.2 second. Step size is 1e-6 . After 0.14s simulation runs in steady state.

In this plot we get the maximum power from solar panel is 322.2W show in yellow line using optimum operation of solar photovoltaic system using grey wolf optimization method and pink line is resistive load and its value is 281.9W

4.RESULT

Table 1

TEMPERATURE	P&O		PSO		GWO	
(T^oC)	**Max Power (watts)**	**Power across Load (Watts)**	**Max Power (watts)**	**Power across Load (Watts)**	**Max Power (watts)**	**Power across Load (Watts)**
10	270.1	234	270.3	226.8	270.6	227
20	280	242	280.5	237.5	280.7	237.6
30	289	251	291.2	248.5	291.6	248.7
40	297.5	258	297.7	259.5	301.6	259.8
50	305	266	310	270	312.4	271
60	313	272.8	322	280	322.2	281.9

Table 1shows a comparison between result of different algorithm for different temperature. Temperature has been varied from 10 ^oC to 60 ^oC .It may be observed that both maximum power and power across load has

increased with increase in temperature for all three cases. GWO has show best result with 322.2W maximum power and 281.9W power across the load at 60 ^{o}C .

5.CONCLUSION

In this thesis, the simulation of MPPT of PV panel using Perturb & Observe (P&O), Particle Swarm Optimization (PSO) and Grey Wolf Optimization (GWO) methods has been presented. A comparison of PV panel output corresponding to all three algorithms and it's power dependence on temperature has been shown. The results obtained after using GWO technique is best compare to the other two technique. It has been seen that with increase the temperature, power also increases. So it may be said that maximum power is depend on irradiation temperature.

It may be concluded that Grey Wolf Optimization (GWO) technique shows better results and may be used MPPT of PV panel.

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