Design & Implementation of Heuristic based MPPT Algorithm under Partial Shading Condition

Akshay Varma[1], Parag Pandit[2], Palak Mishra[3]

Abstract - *Solar energy is radiated light and heat, coming from the sun which is harnessed using a wide range of technologies such as passive solar heating, photovoltaic cells which convert sunlight into electricity, solar thermal technology, solar architecture and it is an important and never-ending source of renewable energy. These technologies are broadly classified as either passive or active depending on how they capture and distribute solar energy or convert it into solar power. Effectiveness of different solar technologies mainly depends on the maximum amount of sunlight which they could be provided with for the purpose of extracting maximum power. Partial shading conditions have become a huge challenge for the effectiveness of solar energy. In order to extract the maximum power from PV modules, the Maximum Power Point Tracking (MPPT) technology has always been applied in PV modules. Currently numerous MPPT control methods have been suggested and presented. The perturb and observe (P&O) and conductance increment methods are the most popular and widely used under the constant irradiance. However, these methods exhibit fluctuations among the maximum power point (MPP). Furthermore, the frequent changes in the environmental conditions such as cloud cover, plant shelter, depositing dust and also the building blocks, leads to the change in radiation and then have a direct effect on the position of MPP. The performance of the proposed GWO algorithm will be evaluated by comparing it with the conventional P&O method in terms of tracking speed and accuracy.*

***Key Words*: Maximum Power Point Tracking (MPPT) Algorithms, Enhanced Grey Wolf Optimization, Partial Shading Conditions (PSCs), Solar energy, Photo Voltaic.**

1.INTRODUCTION

There is a lot of energy packed in the Sun. Solar energy is non-polluting, clean and highly reliable. But the solar panel system converts around 40% of solar radiation into electrical energy. The rest of the sunlight that is incident on the panel is wasted as heat energy. Also, their efficiency drops drastically even when a small portion is blocked by fallen debris or a film of dust. The primary obstacle with solar power that weakens its use is the fact that energy production only takes place when the Sun is up and shining. Design and development of large storage systems is necessary to provide a constant and reliable source of electricity when the Sun isn't present at night or when any other environmental conditions strike. To overcome this, various batteries have been used to store the power. New technologies and algorithms are being invented and modified to improve the battery efficiency. Renewable energy has recently attracted increasing attention of the researchers due to cleanliness, on-site availability, and absence of greenhouse gas emission. The power of Sunlight is converted into DC electricity through photovoltaic (PV) cells which are usually made of semiconductor materials. The output characteristics of the PV arrays are dependent on solar irradiation and cell temperature as the independent variables of the system. However, solar irradiation on a certain array may not be uniform due to partial shading caused by the shadows of passing clouds, trees, or nearby buildings. Maximum Power Point Tracking (MPPT) is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. Many algorithms such as Perturb and observe, Incremental conductance, Hill climbing method, Current sweep, Constant voltage etc. are implemented to improve the efficiency of solar tracking. The basic concept of maximum power point tracking (MPPT) is to adjust the operating point of a converter up to the maximum in real time such that the system can constantly operate at the maximum power point (MPP). Working this way, MPPT enhances conversion efficiency and degrades power loss. However, the MPP changes with the changes in the external environment, thereby further increasing the complexity of tracking the maximum power point. Recognition and knowledge of the characteristics of PV system is not necessary for the traditional P&O algorithm. Thus, this algorithm is straightforward to develop. It works by commanding a fixed step perturbation on a reference voltage or current, calculating the output power generated by the PV system, and analyzing the values before and after disturbance to determine the direction of the disturbance for the next step. If PV power increases, then the direction of the disturbance is similar to as that of the last step (i.e., the system is moving in right direction and towards the MPP); otherwise, a direction reversal occurs. Despite the uncomplicated structure of the P&O algorithm, the fluctuation along the MPP is unavoidable. Recently the bio or nature inspired such as Particle Swarm Optimization (PSO) algorithm, firefly algorithm, bat algorithm etc. have shown their ability to extract maximum power from an array under any shading condition. Another similar nature inspired algorithm proposed known as the Grey Wolf Optimization (GWO) algorithm, which is based on the wolf's abilities for hunting in nature. GWO which is a new type of bioinspired algorithm and in this project this algorithm will be used to track the MPP of a PV module. To evaluate the performance of the algorithm, the proposed GWO-based MPPT method will be implemented on a buck converter, and its performance will be compared with that of the traditional P&O algorithm.

2. METHODOLOGY

2.1 BLOCK DIAGRAM

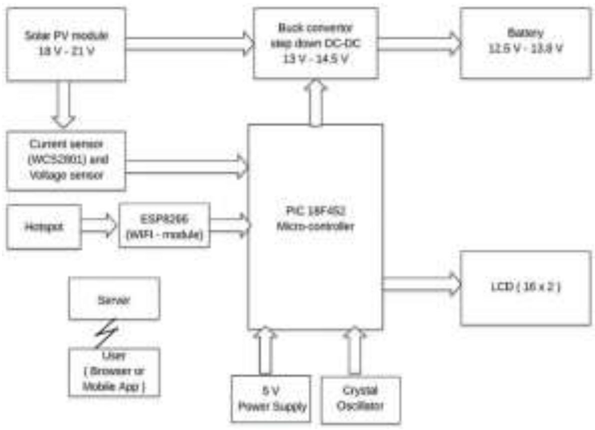


Fig -1: Block diagram of System

Along with all these components a battery is connected as load and a LCD is connected for taking respective readings. The proposed design configuration for photovoltaic module is mainly consisting of buck converter and controller. The schematic blocks of the designed system consisting of dc-dc converter with microcontroller PIC18F452 are developed using Proteus VSM software. The block diagram of proposed system is as shown in figure. Power stage input which is the output of PV module is sensed by using voltage sensor and current sensor (WCS2801) which is sent to the microcontroller which produces PWM pulses to switch on the MOSFET. The solar PV module is connected to the dc-dc converter to control the propagated dc voltage constant which in turn is connected the battery or dc load. The output voltage is sensed and sent to the microcontroller. The algorithm iterates continuously to find the global maximum point based on the initial search agents. The circuit algorithm compares the current voltage with the set point voltage. Also, PV module output and current which are the inputs to power stage are sensed by using voltage and current sensors respectively which are displayed by the LCD interfaced to the microcontroller. Pulse skipping modulation is provided to the gate of MOSFET to turn ON and OFF by the opto-coupler.

2.2 CIRCUIT DIAGRAM

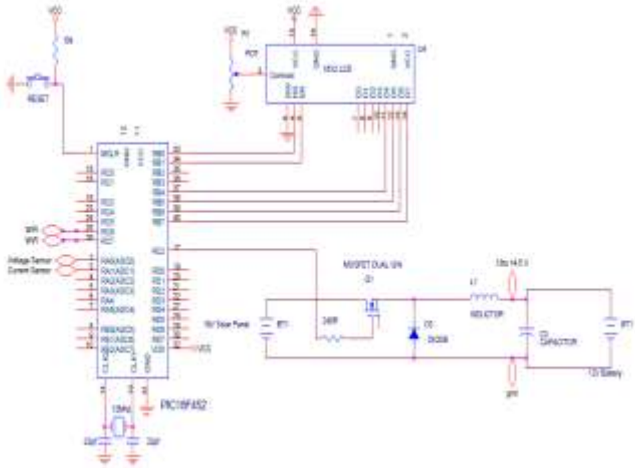


Fig -2: Circuit diagram of System

The above circuit diagram explains the designed circuit and also shows the various interconnections between different components. The various components that can be seen in the circuit diagram are the microcontroller, buck converter, LCD display, wifi module, voltage and current sensor. The buck converter as evident from the design is connected to the pin no. 17 of the PIC microcontroller. The 18V solar panels and a 12V battery is also connected to the buck converter. Buck converter is used for stepping down the voltage in circuit. Pin no. 1 of PIC is connected to the V_{cc} i.e., the power source and pin 38 is connected to ground. Furthermore, for easy monitoring purpose, we have used an ESP8266 Wi-Fi module and implemented IOT by interfacing it to PIC microcontroller. The ESP8266 is configured and the Current (in mA) and Voltage readings are directly displayed on the webserver. It is connected to the pin no. 25 & 26 of PIC. The voltage and current sensors which are used for sensing the respective parameters are connected to pin no 2 & 3 respectively. The LCD display connected has various operating modes for programming it and displaying respective outputs so its different peripherals are connected to pins 33, 34 and from pin 37 to 40. A 12MHz crystal oscillator is used for the control and generation of clock frequencies to the circuit and is connected between the pin numbers 13 & 14.

3. GREY WOLF OPTIMIZATION

Grey wolf optimization is a swarm intelligent technique developed by Mirjalili *et al.* 2014, which mimics the leadership hierarchy of wolves are well known for their group hunting. Grey wolf belongs to Canidae family and mostly prefer to live in a pack. They have a strict social dominant hierarchy; the leader is a male or female, called Alpha. The alpha is mostly responsible for decision making. The orders of the dominant wolf should be followed by the pack. The Betas are auxiliary wolves who co-operate the alpha in decision making. The beta is an advisor to alpha and discipliner for the pack. The lower ranking grey wolf is Omega which has to submit to all other dominant wolves. If a wolf is neither an alpha or beta nor omega, is called delta. Delta wolves dominate omega and reports to alpha and beta. The hunting techniques and the social hierarchy of wolves are mathematically modelled in order to develop GWO and perform optimization. The GWO algorithm is tested with the standard test functions that indicate that it has superior exploration and exploitation characteristics than other swarm intelligence techniques. Grey wolves encircle a pray when planning a hunt and this behavior can be implemented with the help of following equations-

$$\vec{D} = |\vec{C} \cdot \vec{X}_p(t) - \vec{X}_p(t)|$$
$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{A} \cdot \vec{D} \quad \text{……..(3.1)}$$

Where, t = current iteration,

D, A & C = coefficient vectors,

X_p = position vector of the prey,

X = position vector of wolf.

The vectors A & C are calculated as follows,

$$\vec{A} = 2\vec{a} \cdot \vec{r}_1 - \vec{a}$$
$$\vec{C} = 2 \cdot \vec{r}_2 \quad \text{………(3.2)}$$

Where a linearly keeps on decreasing from2 to 0 and $r1$ & $r2$ are random vectors in [0,1].
In this method, a combination between GWO and direct duty cycle control has been attempted i.e., at MPP the duty cycle remains steady and constant which leads to the reduction of steady state oscillations that exist in the traditional MPPT algorithms which in turn helps in reducing the power loss resulting in greater system efficiency.
The fitness function of the proposed GWO technique is calculated as –

$$P(d_i^k) > P(d_i^{k-1}) \quad \text{……(3.3)}$$

Where, P = power,
d = duty cycle,
I = number of current grey wolves,
K = number of iterations.

The pseudo code developed for the GWO algorithm is presented as,

1. Initially the search agents are generated Gi (i=1, 2…., j)
2. Vectors a, A and C are initialized
3. Fitness value of each hunt agent is estimated

✓ G(alpha) = the primary hunting agent
✓ G(beta) = the second-best agent
✓ G(delta) = the third best agent

4. I_{tr}=1
5. Repeat the steps
6. For i=1: Gs (grey wolf pack size) renew the location of the current hunt agent using Equation (3.1).
7. Again, estimate the fitness value of all hunt agents
8. Values of G(alpha), G(beta), G(delta) are updated
9. Vectors a, A and C are updated
10. I_{tr}=I_{tr}+1
11. Until I_{tr} >= highest number of iterations
12. Output G

The Algorithm according to the Pseudo code and flowchart is written in MikroC software and simulated on PIC 18F452 using the Proteus platform. Using Flash magic the hex file is dumped in the PIC IC.

4. FLOWCHART

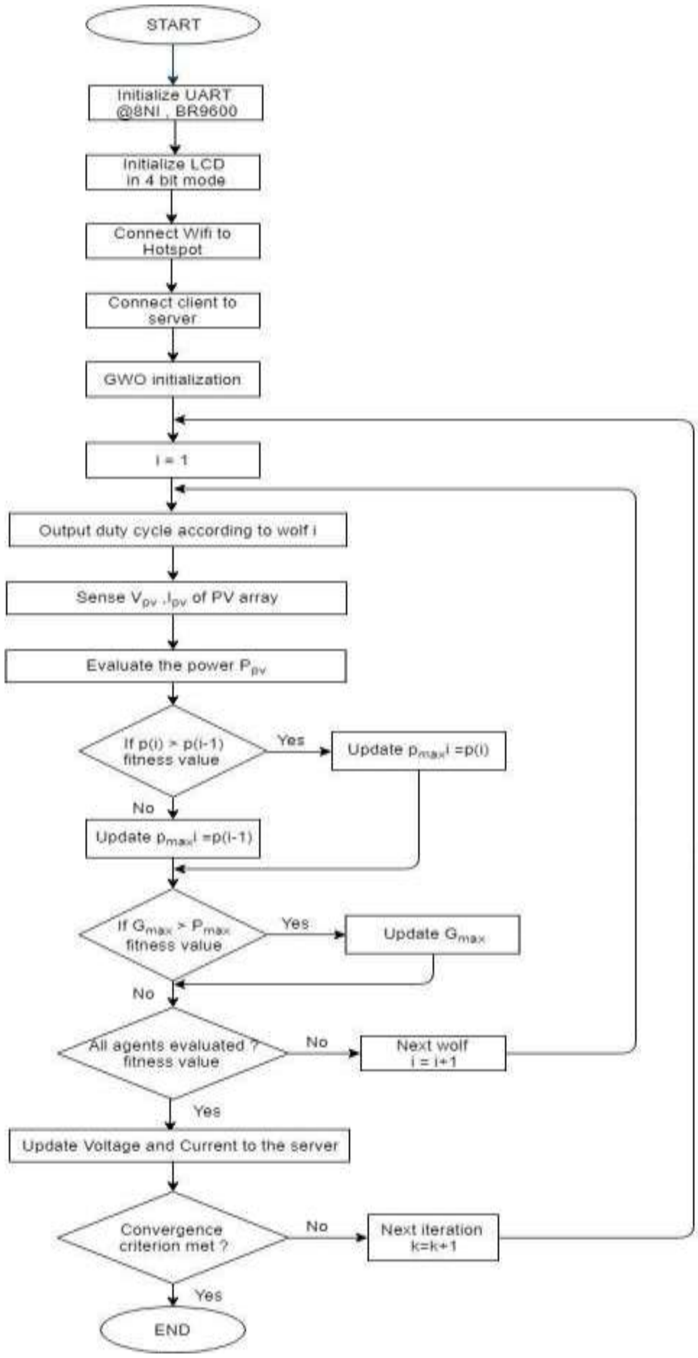
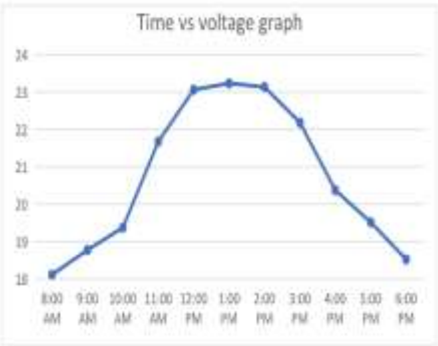


Fig -3: Flowchart of System

5. RESULTS

5.1 OBSERVED RESULTS

Below is the graphical representation of testing for a period of Ten (10) hours window (8:00 am to 6:00 pm) during one of the days in March.



Time	Voltage
8:00 AM	18.11
9:00 AM	18.77
10:00 AM	19.37
11:00 AM	21.67
12:00 PM	23.06
1:00 PM	23.23
2:00 PM	23.13
3:00 PM	22.18
4:00 PM	20.37
5:00 PM	19.51
6:00 PM	18.52

Fig -4: Time vs Voltage curve

As observed above, the maximum output was observed between 11:00 am to 3:00 pm. This duration was considered as a "Solar Window" for the project.

Tabulated Output for our GWO Algorithm under PSC in comparison to other fast converging algorithms like P&O and IPSO

Tracking technique	Maximum power (W) (I/P)	Maximum power (W) (O/P)	Maximum Voltage (V)	Maximum current (mA)	Tracking Efficiency (%)
PO	6.2	1.9	8.54	0.222	30.58
IPSO	6.2	5.9	13.83	0.438	95.47
GWO*	6.2	6.0	13.85	0.431	96.28

Table 1: Performance comparison of GWO

Our Grey Wolf optimization algorithm achieves an efficiency of 96.28% which as superior as compared to the other two algorithms taken into consideration.

5.2 EXPERIMENTAL RESULTS

Each solar panel has been divided into 6 columns and hence we can test different partial shading patterns by covering each column one by one and observing the output to check if we have successfully tracked the maximum power point to get constant voltage at the output.


(1) (2)


(3) (4)

(5)

Fig -5: Testing under different PSC patterns

Partial Shading Pattern (covering number of columns)	Input Voltage(V)	Output Voltage (V)	Current (A)	Power (watts)
1	20	13.36	0.464	6.21
2	19	13.37	0.463	6.22
3	17.4	13.37	0.463	6.22
4	17	13.36	0.464	6.21
5	16	13.36	0.464	6.21

Table 2: Results under different PSC patterns

We observe that under different partial shading patterns we are getting almost constant output with changing input voltage.

6. ADVANTAGES & APPLICATIONS

6.1 ADVANTAGES

- It does not consume much computational power.
- Can be implemented as analog or digital circuits.
- The temperature varies as per the time hence, there are no steady-state oscillations.
- Solar system is cost effective. The power purchase agreement of Gujarat solar plant is Rs.15/unit for first 12 years and Rs.5/unit for next 30 years.
- The system efficiency is about 95%.
- Enables the efficient use of renewable energy.
- System is implemented using microcontrollers which intelligent chips, that's why the system can be modified considering the need of application. Use of microcontroller ensures reliability of the system.
- Temperature sensors are usually very cheap.
- Robust against noise.

6.2 APPLICATIONS

- The solar energy is one of the most competitive sources of electrical energy, especially photovoltaic (PV) devices. PV panels are devices that convert solar energy into electricity in a clean way and offer an alternative solution of electric power generation in all industry sectors and domestic applications, particularly in remote areas.
- The effective implementation of the algorithm can help to improve harnessing of energy for agriculture, household and commercial requirements at less cost and lesser time.
- Easy installation and less complexity can attract even most consumers to use renewable sources of energy and spread awareness.
- Use of microcontroller in the project not only reduces the cost of the entire setup but also helps for easy debugging of code and use inbuilt libraries.
- The system efficiency is about 95%.

7. CONCLUSION

We, in our project have proposed a heuristic based MPPT algorithm which is based on the grey wolf hunting pattern and have acquired results with higher efficiency as compared to the traditional P&O and IPSO under partial shading conditions .It was observed that battery was charged faster using our algorithm as compared to the traditional way and the difference was around 40 minutes. We achieved the maximum power point even in shading patterns (implemented by partially covering up a solar panel). An efficiency of 96.28 % is achieved with the GWO algorithm which is superior as compared to the other implemented methods and hence we can conclude that the proposed heuristic algorithm can successfully detect the shading pattern variations and reinitialize the MPPT process displaying superior performance in terms of better tracking efficiency, steady-state oscillations nearly to null, faster convergence to GP, and faster and accurate tracking in PV system under PSCs.

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