A Comparison Study a Mong Optimization Methods for Solar PV Hybrid System

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Abstract. The maximum output power can be obtained from sun energy to supply grid tie system .The highest output power that leads to an improvement in the efficiency of the solar system related to the weather conditions when the panel exposed solar radiation uniform and changed.In this paper a comparison study of different optimization methods including P&O ,PSO and GWO. This study obserive the best optimization methods giving the highst power . This means that the grey optimizations technologies lead to increase the power received from the PV that's led to increase the efficiency.

Keywords: Perturb and observe,(P&O), particle Swarm Optimization,(PSO) ,solar PV system ,maximum power point tracking, (MPPT), Grey Wolf Optimization (GWO).

List of symbols

I_d: diode current.

I_{sh}: current through shunt resistor R_{sh}.

I : output current.

I_{ph}: light generated current.

q : electric charge (1.60217646 × 10^{-19}columb).

V: voltage.

K: is the Boltzman's constant = 1.3807 × 10-23 Joule/Kg.

T: is the temperature in Kelvin of p-n junction.

D: duty cycle.

AC: alternating current.

w: inertia weight.

C_1,C_2 : learning parameters.

AC: alternating current.

A: ideality constant for the diode.

Where t: current iterations.

X_p: position of the prey.

$\vec{X}$: position of the Grey Wolf.

$\vec{A}.\vec{C}$: coefficient Vector.

V_{PV}: voltage of photovoltaic array.

I_{PV}: current of photovoltaic array.

r_1,r_2 : random Vector.

a: component decrease linearly within the period [0,1].

P_{best} : personal best experience of each particle

G_{best} : global best or social experience of whole swarm

Introduction

Solar energy is a natural, renewable and free source that can be used. Solar energy can be divided into two types: the first is electrical energy by photovoltaic cells that produce electrical energy, and the second type is solar thermal energy, which can use the sun's heat to heat water, where the sun is the main source of light and heat. In 1839, the scientist Henri Becquerel was the first to discover the conversion of solar radiation into electricity. The focusing on the PV effect, that is, addressing the photovoltaic energy that produces electrical energy, as well as the effect of solar radiation change. The PV effect can be explained where semiconductor materials absorb sunlight and this absorption creates a potential difference and is known as the energy of the electrons and thus the circulating electrons generate an electric current [1].

1. PV of The Solar System Components

PV systems consist of several elements, each element performs its specific role in the solar system, the type and purpose of the system depends on the type of components that make up the system. PV Direct consists of two units or an array connected with some of the solar panels and the load where this system produces a DC. This type of PV is generally used in the operation of pumps and ventilation fans, as well as in submersible water. There is also a type that uses storage batteries because photovoltaic cells produce direct current that can charge batteries to store energy and used the energy in other time. Figure1 shows the block diagram of PV connected with grid. This paper explained the components of the PV system [2]:

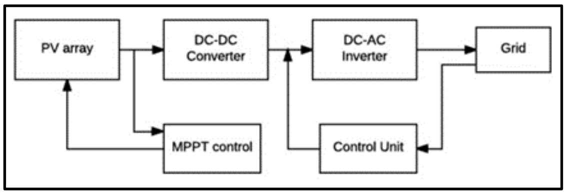

Figure 1. Block diagram of PV solar array connected with the grid

1.1. Solar Module

Most of the solar modules consist of crystalline silicon for solar energy systems used in residential and commercial purposes, where the solar cells are installed in an aluminum frame, and multiple chains of positively and negatively connected solar cells are linked to form the modules [3]. The output of each solar cell is about 0.5 volts. The 36-cell unit produces 18 volts. Units that contain 36-72 cells are classified as large units that are square or rectangular in shape which cell consist the modules and modules consist the PV array. Figure 2 represents the solar array formed from the module consisting solar cells.

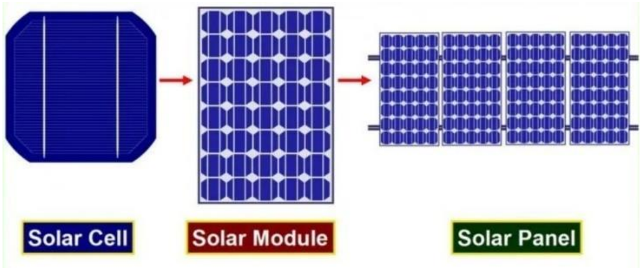

Figure 2. The solar array formed from the module consisting of solar cells.

1.1 Boost Converter (DC-DC)

dc-dc boost converter is an important part of the solar system that connects the photovoltaic array and the inverter. It is known that the current produced by the PV cells is a fluctuating current, and this current depends on solar radiation. The function of dc-dc boost converter increases the Low to high current voltage according to the load needs. Figure 3 shows the boost converter [4].

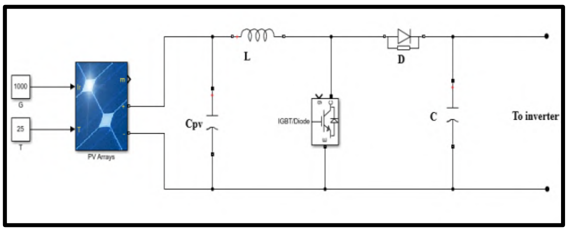

Figure 3. Boost converter

The dc-dc boost converter can be designed and the capacitance and inductance value calculated according to the following equations [5]:

$$T = {}^{1}/_{f} \qquad \text{...(1)}$$

$$L = \frac{D(1-D)R}{2f} \qquad \text{...(2)}$$

$$C = \frac{D}{2fR} \qquad \text{...(3)}$$

1.2. Inverter (AC-DC)

The inverter is used after the conversion booster for the purpose of converting the DC power that the cells produce to PV and processing in the DC-DC conversion booster to obtain constant DC power as needed by the load. This unit converts the DC power to the grid voltage with a frequency of (50-60) Hz and (230-240) V AC from single phase to three phases. Figure 4 is a model of three-phase DC-AC Inverter [6].

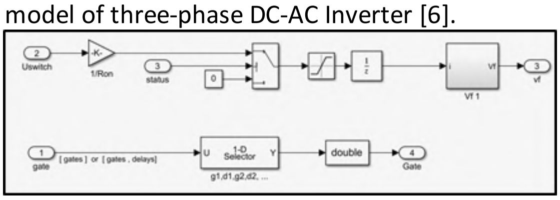

Figure 4. Modeling of single-phase DC-AC Inverter

1.3. Battery

It consists of one or multi electrical cell with outer connection to electrical apparatus. Some photovoltaic systems use batteries in their formation in order to store the excess capacity produced by the solar panels. The energy stored in the batteries can also be used at another time to prepare the load when the energy produced from the solar panel decreases as a result of weather conditions which may lead to a decrease in the amount of radiation falling on the solar panels. Figure 5 shows the modeling connection the battery unit that used to store surplus PV power [7].

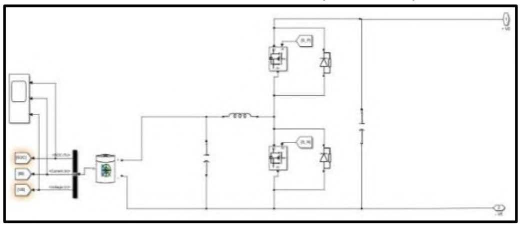

Figure 5. Modeling of a battery storage bank.

2. MPPT

The quantitate of power produced by the PV system depends on various factors including radiation and temperature and weather condition. The current and voltage of the PV modules are in a non-linear relationship. It contains specific maximum energy points that are mainly related to radiation and temperature. MPPT algorithms can be used to get the fullest power from the PV array based on a boost converter that gives a constant voltage and voltage and a higher voltage in different weather conditions than the PV modules. In this paper, the power that can be obtained from different algorithms is discussed including P&O, PSO and GWO [8].

2.1. Perturb and Observe (P&O)

One of the most common and easy-to-implement algorithms known as perturbation is to move the operating point of the array toward MPP when the PV array operating point of voltage is perturbed in an assigner direction and dP/dV > 0. Also, the algorithm running continuously in the same direction leads to the perturbation of the PV array voltage. The operating point is the PV array transfer away from MPP when dP/dV < 0. Its most important characteristic is the ease of implementation, the disadvantages of which are slow response and fluctuation around the operating point when the weather changes suddenly, the tracking is wrong [9].

2.2. Particle Swarm Optimization (PSO)

Discovered by Kennedy and others were worked on swarm intelligence algorithms. It is used in engineering applications to solve complex and non-linear problems and is one of the ways to improve the tracking technology in photovoltaic units. The space for the search as well as the particles are randomly configured as these particles participate in the search process to find the best solution.P_{best} is the best subjective particle that influences the positions of all particles and G_{best} is considered to be the best particle in the entire population. The PSO can also be mathematically represented by the following equations that determine the velocity and position of the particles:

$$V_i^{(t+1)} = w \times V_i^t + C_1 \times r_1 \times (P_{best} - X_i^t) + C_2 \times r_2 \times (G_{best} - X_i^t) \quad \text{...(4)}$$

$$X_i^{(t+1)} = V_i^{(t+1)} + X_i^t \quad \text{...(5)}$$

Figure 6. shows the movement of particles in space represent the research process.

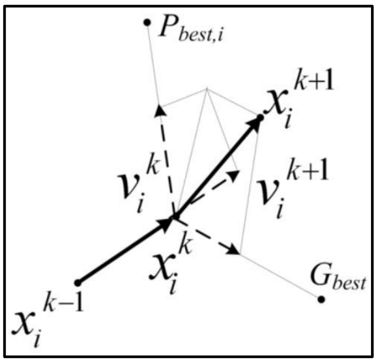

Figure 6. Movement of particles in space represent the research process [11].

2.3. Grey Wolves Optimization(GWO)

The grey wolves' algorithm is inspired by the behavior of grey wolves living in the wild as a very regular herd of 5-10 individuals, where the herd is classified into four species depending on fitness. They are classified as follows: alpha (α), beta (β), delta (δ), and omega (ω) as shown in the grey wolves hierarchy as shown in Figure 3-4.

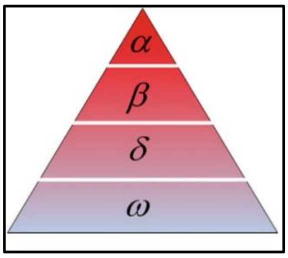

Figure 7. Hierarchy of grey wolves[13]

A mathematical model must be developed for the purpose of designing the model based on the behavior of hunting wolves, including searching for prey, following up on the prey, encircling it, and then attacking the prey. It can be represented by the following equations:

$$\vec{D} = \left| \vec{C}.\vec{X_p} - \vec{X}(t) \right| \quad ... (6)$$

$$\vec{X}(t+1) = \left| \vec{X_p}(t) - \vec{A}.\vec{D} \right| \quad ... (7)$$

The vectors $\vec{A}$ and $\vec{C}$ are calculated as follows:

$$\vec{A} = 2.\vec{a}.\vec{r1} - \vec{a} \quad ...(8)$$

$$\vec{C} = 2.\vec{r2} \quad ...(9)$$

The grey wolves' algorithm is implemented on MPPT to obtain the highest power as well as the least loss in power and calculate the value of D through Equation (3) Then fitness is calculated for each wolf if the value of A < 1 This indicates that the condition has been met and the hunting process ends with an attack on The prey is calculated and the convergence value, which represents the duty cycle gives the highest power through the following equation:

$$\vec{X}(t+1) = (\vec{X}_1 + \vec{X}_2 + \vec{X}_3)/3 \quad ...(10)$$

But if A > 1, this indicates that the wolves are far from the prey, the process must be repeated to obtain rapprochement between the prey and the wolf for the purpose of preying on the prey and achieving the condition to obtain the highest power. Figure 3-4 illustrates the hunting process for grey wolves through searching, tracking, encircling and then attacking the prey [12].

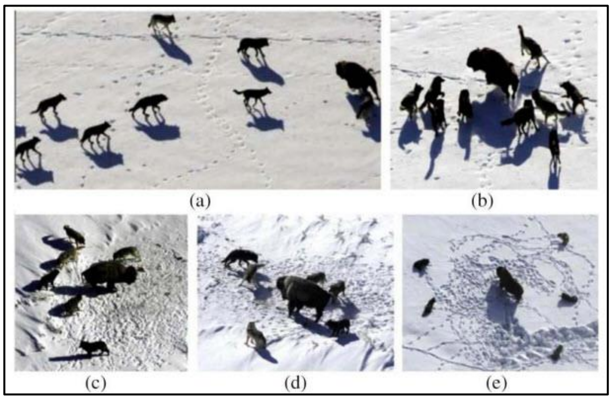

Figure 8. hunting disposal for grey wolves(a)-(c) including tracking and chasing the prey, (d) represent encircling ,(e) attacking prey.[14]

3. Modeling of PV System Connected With Grid

A solar PV system model has been simulated in the Matlab program for the proposed algorithms as shown in Figure 9, where the objective and purpose of this simulation is to obtain the maximum power when there is a uniform radiation of 1000 w/ m^2, as well as when the radiation is variable.[15]

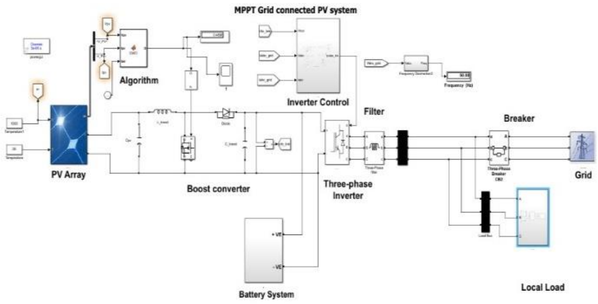

Figure 9. Modeling of solar PV system

Case one : when the radiation is uniform 1000 w/ m^2.

Figure 10. repersents the relationship between power and time for P&O.

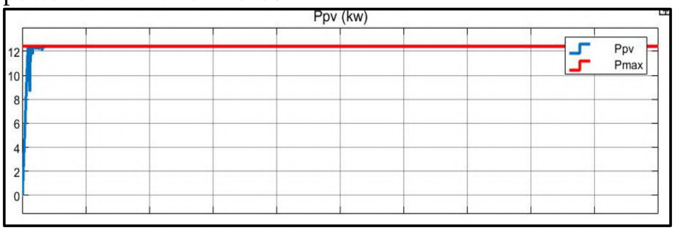

Figure 10. The relationship between power and time for P&O

Figure 11. repersents the relationship between I_{abc} and time for P&O.

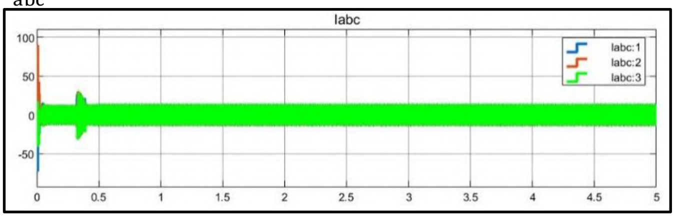

Figure 11. The relationship between I_{abc} and time for P&O.

Figure 12. repersents the relationship between duty cycle and time for P&O.

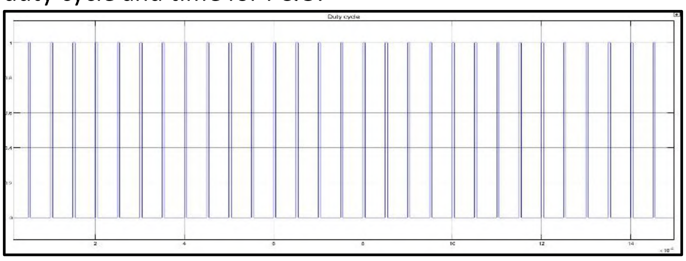

Figure 12. The relationship between duty cycle and time for P&O.

Figure 13. repersents the relationship between power and time for PSO.

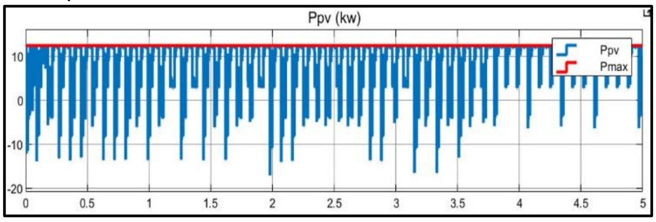

Figure 13. The relationship between power and time for PSO.

Figure 14. repersents the relationship between I_{abc} and time for PSO.

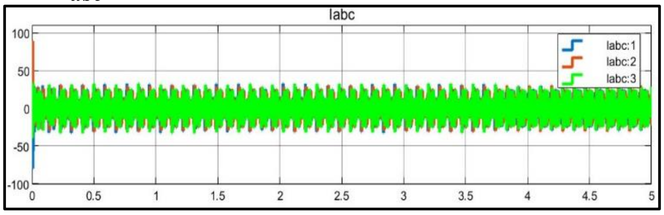

Figure 14. The relationship between I_{abc} and time for PSO.

Figure 15. repersents the relationship between duty cycle and time for PSO.

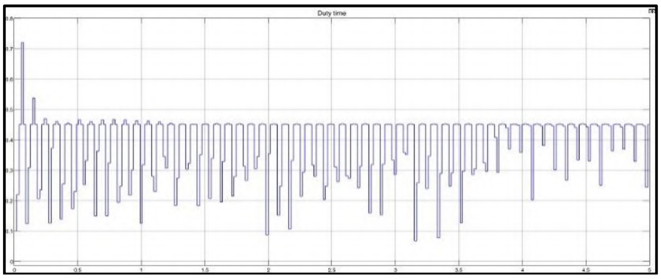

Figure 15. The relationship between duty cycle and time for PSO.

Figure 16. repersents the relationship between power and time for GWO.

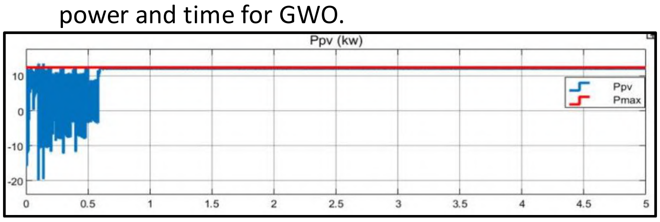

Figure 16. The relationship between power and time for GWO.

Figure 17. repersents the relationship between I_{abc} and time for PSO.

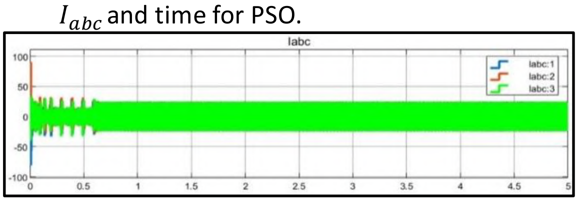

Figure 17. The relationship between I_{abc} and time for PSO.

Figure 18. repersents the relationship between power and time for GWO.

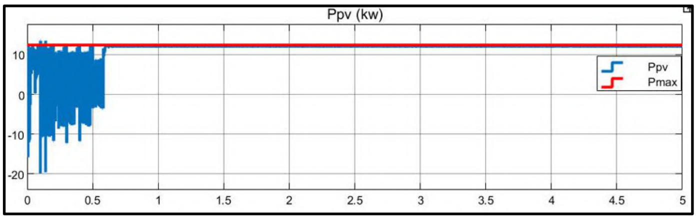

Figure 18. The relationshipbetween power and time for GWO.

Figure 19. repersents the relationship between I_{abc} and time for GWO.

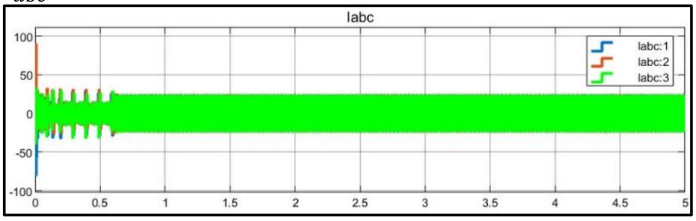

Figure 19. The relationship between I_{abc} and time for GWO.

Figure 20. repersents the relationship between duty cycle and time for GWO.

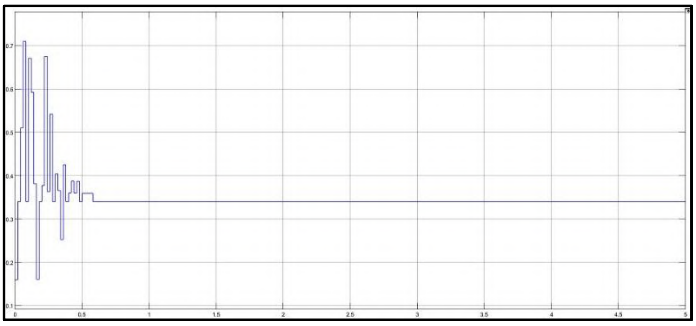

Figure 20. The relationship between duty cycle and time for GWO.

Case two: when the radiation is variable:

Figure 21. repersents the relationship between power and time for P&O.

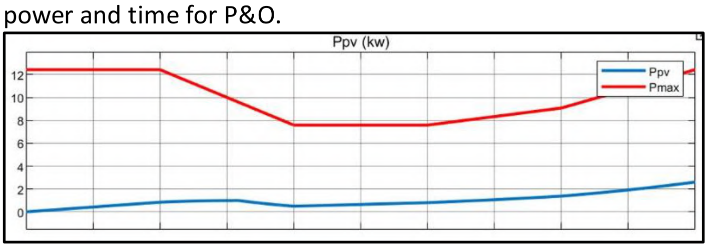

Figure 21. The relationship between power and time for P&O.

Figure 22. repersents the relationship between I_{abc} and time for P&O.

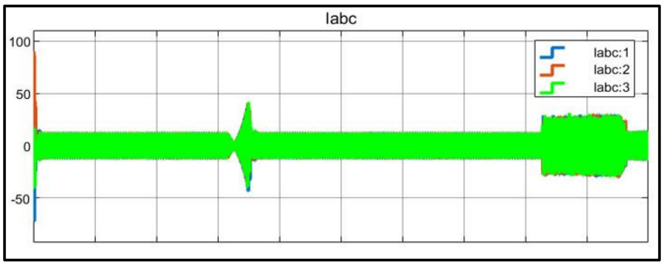

Figure 22. The relationship between I_{abc} and time for P&O.

Figure 23. repersents the relationship between duty cycle and time for P&O.

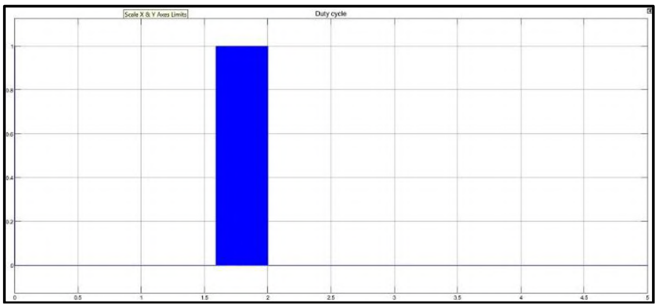

Figure 23. The relationship between duty cycle and time for P&O.

Figure 24. repersents the relationship between power and time for PSO.

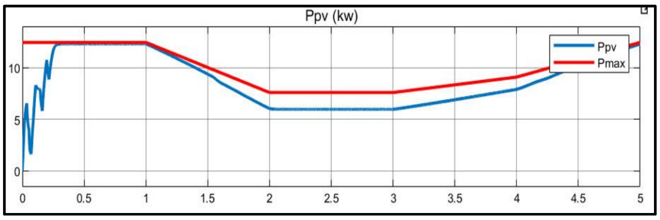

Figure 24. The relationship between power and time for PSO.

Figure 25. repersents the relationship between duty cycle and time for PSO.

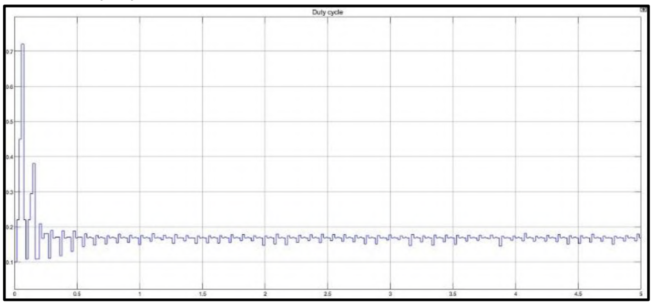

Figure 25. The relationship between duty cycle and time for PSO.

Figure 26. repersents the relationship between power and time for GWO.

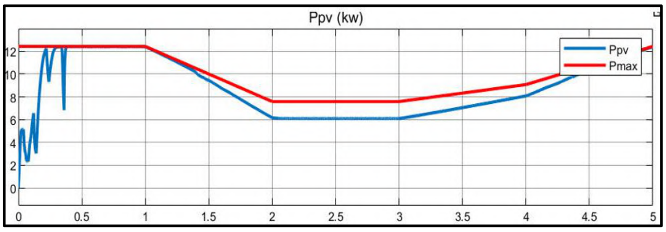

Figure 26. The relationship between power and time for GWO.

Figure 27. repersents the relationship between I_{abc} and time for GWO.

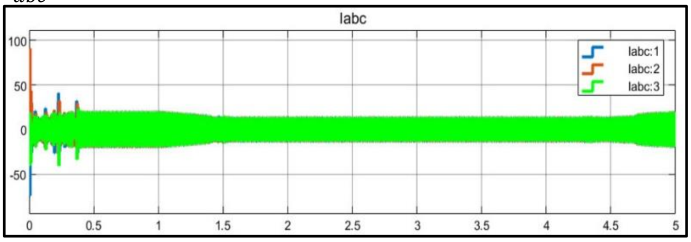

Figure 27. The relationship between I_{abc} and time for GWO.

Figure 28. repersents the relationship between duty cycle and time for GWO.

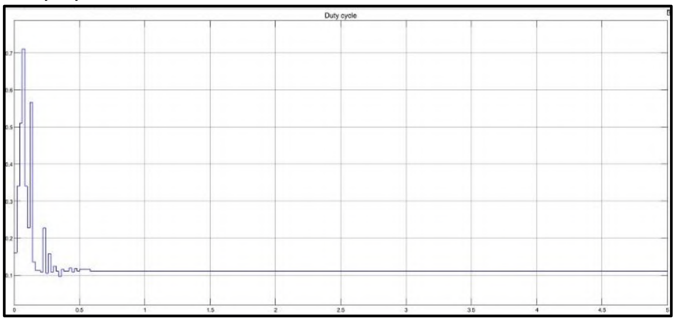

Figure 28. The relationship between duty cycleand time for GWO.

Table1. Repesent the result of optmazations methods (P&O,PSO and GWO).

Type methods	Pmax(w)	Duty cycle
Fixed Radaition		
P&O	12.41	1
PSO	11.41	0.45
GWO	12.4	0.1107
Variable Radition		
P&O	2.606	0
PSO	6.663	0.2541
GWO	12.4	0.1107

Conclusions

From three methods of optmazation P&O, PSO and GWO.

- At fixed radition:

1. P&O could alwaysed provides stable power without shading, but may be give a lower peack undershading.
2. Undershading GWO provided more power and stability as compared with PSO, where the power curve based GWO method was stable at time (0.6 Sec) but under PSO would have been unstable during time opertion.
3. No change in the duty cycle under P&O method it has been noticed that the duty cycle has been stable at time (0.1107 Sec) but under would be stable at (0.4 Sec). This means that the duty cycle base on GWO method reched the stady stable with short time as compared with PSO method.

- At Variable radition:

1. GWO provided more power and stablity as compared with the other two methods, where the amount of power was higher than the P&O and PSO by $9.794Kw$ and $5.737Kw$ respectively.

2. GWO provided stable duty cycle at time very neer to the origin time.

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