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Maximizing Output Power for Solar Panel Using Grey Wolf Optimization

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Abstract. The objective of this paper is to obtain the maximum output power which delivered from solar array and to improve the efficiency of the solar PV system according to the weather conditions specially the effect of solar radiation which fell on this array. The optimization in the solar system efficiency by MPPT is performed using the gray wolf optimization method by applying the proposed algorithm in order to maximize the output power. This means that the gray wolf technologies worked to increase the power received from the solar panels in order to increase the efficiency.

Keywords: 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 ($1.60217646 \times 10^{-19}$colume).

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

A: represented 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].

Introduction

Solar radiation is one of the useful energy elements emitted by the sun, which is the main energy source for solar radiation in the wave radiation of the electromagnetic range [1]. There is a large amount of radiation in the visible wave to produce electricity. This means converting sunlight into electrical energy through the solar panel. Figure1 shows the PV cell with load [2]. The traditional energy industries increase the carbon emissions that are harmful to the environment, and the use of solar energy removes that pollution [3].

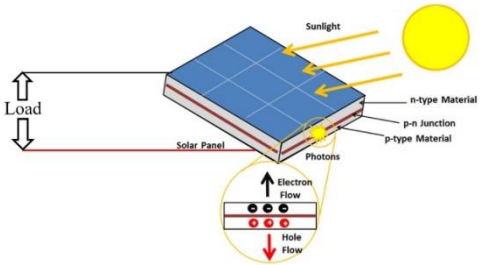
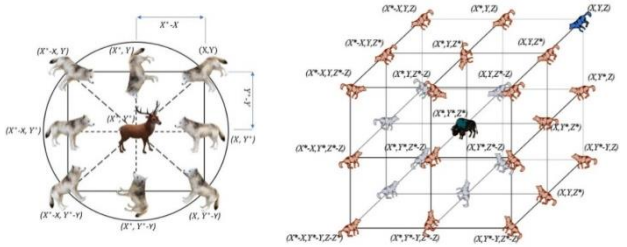


Figure 1: PV Cell [1]

In the past 20 years, optimization techniques have begun to be very common to improve the efficiency of systems. There has been great interest from scientists in algorithms in many areas of improvement, especially in the field of solar energy, including different algorithms. Some of them such as genetic algorithm (GA), particle swarm optimization (PSO) [4] and Ant colony optimization (ACO) [5], they are very famous to some extent, not limited to use by computer scientists where It has been used and applied in many studies and theoretical works. One of the reasons for its spread is the inference and remarkably due to several reasons. The first of which is a simple, flexible principle, free of derivation, and simulations that represent the reality of the behavior followed. Among the algorithms that were proposed in 2014 by Lewis and others simulate the behavior of gray wolves in the hunting process. It focuses on four important elements; the search for Prey, tracking prey, encircling and attacking prey. The implementation and optimization design for gray wolves is inspired by the hunting disposal of gray wolves. Figure 2 represents a simulation GWO from reality according to the hierarchy of a pack of wolves and the potential and updated locations that the wolf can occupy [6], which are shown below and 3D images that represent the hunting process, living and working together as a pack.



(a) (b)

Figure 2. Possible locations for wolves
(a)Potentialand update location.
(b)3D image of hunting process [4].

Figure3 represents the Hierarchy of pack simulations of a leadership hierarchy where gray wolves are categorized into four types according to fitness and functions alpha (α), beta (β), delta (δ), and omega (ω)[4].

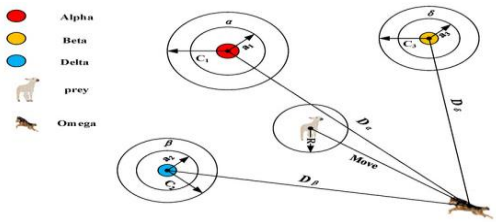


Figure3. Hierarchy of grey wolf with Position updating in GWO.[4]

• The source current is the current resulting from the separation of the gaps and electrons by the effect of the incident light photons, as the light produces a current I_{ph}.

• The diode connected in parallel with the source current of the photocell which represented the p-n junction.

• A shunt resistance (R_{sh}) is caused by leakage currents and a series resistance (R_{se}) forms from the resistance of the materials that make up the cell. Shunt resistance ($R_{sh}$are the currents or leakage currents recombinated around the edges of devices due to the leakage of current, and series resistance such as ohmic loss in the front surface. Ideally, the metallic contacts should be zero as show in Figure 4. it illuslites the equvelent circuit of PV cell. [7]

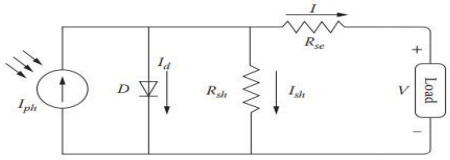


Figure 4. Equivalent circuit of PV cell.[7]

The use of two diodes in the model connected in parallel instead of a single diode is to improve the model. The first diode represents the diffusion current of the junction of the quasi-neutral region with the first idealization factor and the second diode is a junction to generate the charge region and space with the idealization factor two. The circuit led to the formation of a complex model in terms of the output for both current and voltage, which made the current represented by two equations for the diode from the circuit, we get the following relationships [8].

$$I = I_{ph} - I_d - I_{sh} \quad \dots (1)$$

Where photocurrent I_{ph} is,

$$I_{ph} = [I_{sc} + K_i(T_{op} - T_{ref})]I_{rr} \quad \dots (2)$$

From the basic equation for I-V characteristics an ideal PV cell which depend on the theory of semiconductor we get is:

$$I = I_{ph} - I_d\left\{\exp\left(\frac{qV+IR_{se}}{AKT}\right) - 1\right\} - (V + IR_{se})/R_{sh} \quad \dots (3)$$

3.V-I Characteristics

Maximum Power Point Tracking (MPPT): is one of the techniques that enhance the value of the linear current where the input voltage follows the difference in the output voltage of the photovoltaic array under variable conditions of temperature, radiation falling on the panel and load to obtain the largest possible capacity of solar

energy where the sun is the center of radiation [9]. That is, obtaining the photoelectric current (I_{mp}) and voltage (V_{mp}), as the maximum available energy from a PV cell or unit is located on the I-V curve, which represents the maximum power point [10]. It is clear from Figure.5 that it represents a non-linear curve of the current-voltage characteristic for the photovoltaic system. Through the current and voltage curve, MPP occurs with the knee region shown on the voltage and current curve V-I.

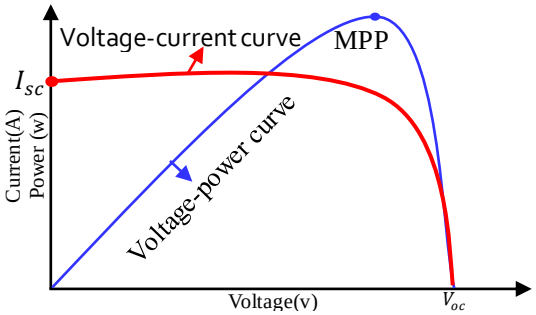


Figure 5. Characteristics of a photovoltaic system for voltage-current and power-voltage curves under different conditions [13]

Figure 6 shows the photovoltaic operating point on the voltage and current curve V-I that changes with the change of radiation intensity and temperature throughout the day, demand and types of loads where A resistive load was used throughout a sunny day.

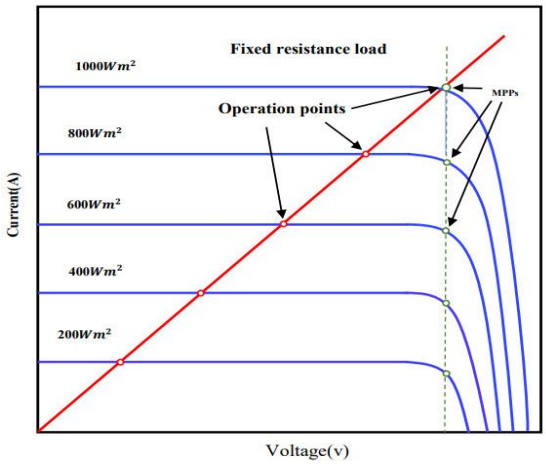


Figure 6. Characteristics of a photovoltaic system for voltage-current curves under different conditions to obtain maximum power at a constant resistive load [14]

Figure 7 shows solar panels under partial shading, it may be a shadow as a result of the shadow of a material part, trees or clouds, etc., which can be represented by the voltage and current curve V-I, this case is known as the partial shading condition. Some points represent the local maximum points to increase according to

the case of Partial shading can be called global MPP (GMPP), which represents the point with maximum value, and the other points are called local MPP (LMPP). GMPP is considered the best operating point. MPPT controllers extract energy from photovoltaic generators to obtain the maximum available power regardless of the constant difference in temperature and irradiation or partial shading conditions affecting the efficiency of the panel. The purpose of this process is to obtain GMPP under any condition such as shading Partial, which is accomplished by an output command from MPPT to be used in the switching of the DC-DC converter, which plays an important role in enhancing the DC output voltage of the PV system [11,12].

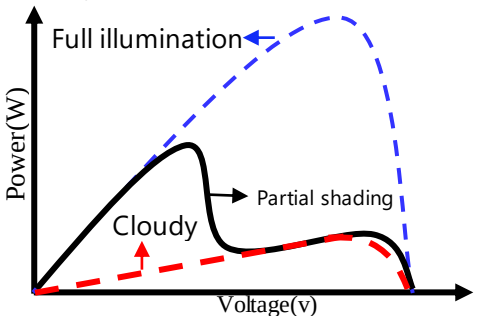


Figure.7 Characteristics of a photovoltaic system for power-voltage curves under the influence of three conditions in full radiation, partial shading, and cloudy conditions [13]

4.GWO Mathmetical Model

In order to design GWO, a mathematical model must be developed by relying on the hierarchy of gray wolves, their behavior and coexistence together on the ground as a highly organized pack, where alpha (α) is considered the most appropriate solution, and both beta (β) and delta (δ) are considered the best second and third solutions on the ground. Respectively. As Omega (ω) is imposed on the rest of the nominated solutions, as mentioned previously, it is modeled based on the behavior of the wolf in the hunting process through prey search, prey follow-up and prey encirclement through the following equations:

$$\vec{D} = \left| \vec{C}.\overrightarrow{X_p} - \vec{X}(t) \right| \quad \ldots (4)$$

$$\vec{X}(t+1) = \left| \overrightarrow{X_p}(t) - \vec{A}.\vec{D} \right| \quad \ldots (5)$$

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

$$\vec{A} = 2.\vec{a}.\overrightarrow{r1} - \vec{a} \quad \ldots (6)$$

$$\vec{C} = 2.\overrightarrow{r2} \quad \ldots (7)$$

Where, during iteration, the values of a component decrease linearly within the period [0,1], and r1, r2 is called random vector. By using the GWO oscillation algorithm, which increases the output value, reduces the energy lost and increases the efficiency of the system, in contrast to the use of the traditional algorithm. Gray Wolf considers the work cycle of either MPPT to be implemented based on GWO in order to obtain higher power. Therefore, it can be changed

into equation (4) to determine the values of $\vec{D}$ from equation (4) and then calculating the fitness for each wolf according Hierarchy of grey wolves excepting omega wolf because omega wolf didn't share encircling process after that determine the values of the position of grey wolves. if it achieved the condition A<1 the hunting process is finished and attacked the prey. if A>1 the position of grey wolves is updated as:

$$\vec{X}(t+1) = (\vec{X}_1 + \vec{X}_2 + \vec{X}_3)/3 \qquad \ldots(8)$$

The behavior of gray wolves in the hunting process is usually carried out by the pack leader called alpha (α), as well as the rest of the lower rank, subleaders called beta (β) and delta (δ) who participate in the hunting process and contribute to the search and encirclement where the wolves Omega (ω) which It is considered weaker and less fitness than the rest of the pack members, as it plays its role in caring for the wounded wolves in the pack. As the alpha wolves possess all the details about the location of the prey, the wolves try to exhaust the prey until the prey stops moving and then is attacked by the alpha wolves and ends the hunting process. Figure 8. shows the hunting process for grey wolves, including searching, encircling and attacking prey [17].

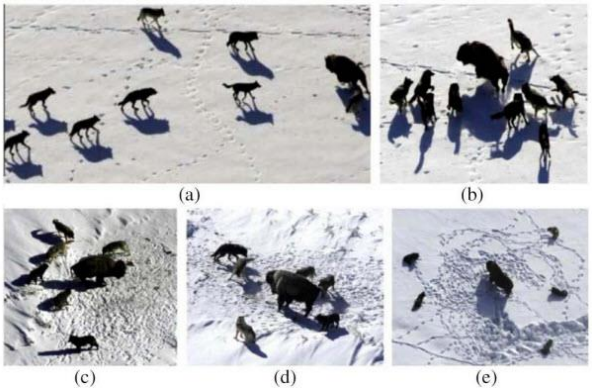


Figure. 8 hunting disposal for grey wolves(a)-(c) including tracking and chasing the prey, (d) represent encircling ,(e) attacking prey.[3]

5.Flowchart of GWO

Through the hierarchy of grey wolves of leadership , its shows the levels of leadership, where gray wolves are classified into four levels: alpha (α), beta (β), delta (δ) and omega (ω), where the alpha is the one who decides the time and place of sleep and wake up as well as hunting either beta (β) is considered the second leader and delta (δ) is considered the third leader where they participate in the alpha (α) in making decisions, while omega (ω) is subordinate to the leader and if something goes wrong, he is a scapegoat[15]. GWO is one of the modern algorithms in improving tracking The rapid oscillation is more stable, this leads to improving the efficiency of the system, as the GWO algorithm was applied to the seismic system and contributes to improve the efficiency. Where Figure 9 is a GWO flowchart when tracking to get the highest possible power.[16]

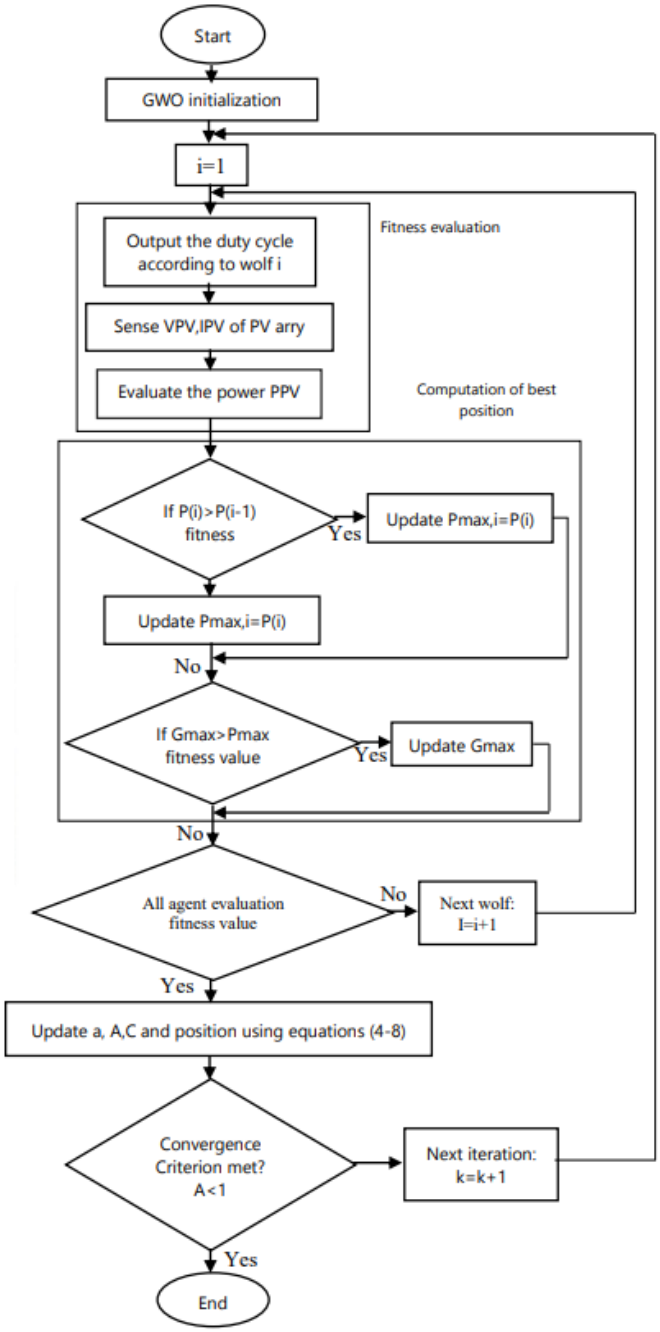


Figure 9. Flowchart of GOW [15]

6. MPPT Algorithm for Grey Wolves Optimizer

The gray wolf algorithm is one of the latest technologies to improve the efficiency of the photovoltaic array [18]. This algorithm has been

emerged from the behavior of gray wolves to hunt prey, where gray wolves live as a pack in the wild, the number of the pack ranges from (five to ten) individuals on average.Figure 10. represents the hierarchy of grey wolves.

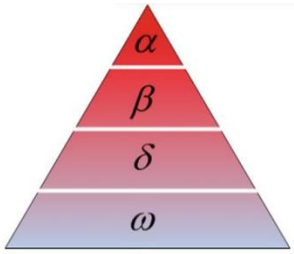


Figure 10. Hierarchy of grey wolves[19]

Each pack member has a dominant hierarchy [20]. Each member of the herd has a leadership level as well as fitness for each wolf where the alpha wolf (α) is the pack leader and it may be male or female , the second beta leader (β) and the third is the delta leader (δ). [20, 21]. Figure 7. represents the leadership hierarchy. Where the leadership hierarchy represents wolves from the highest level to the lowest level where the hierarchy includes the wolf alpha (α), beta (β), delta (δ) and omega wolf (ω) which are considered weaker [22].

Through the process of searching for prey, gray wolves are classified according to the fitness of each type and are classified into four types, where alpha wolves are considered to be the highest fitness, while the others are less fitness for beta and delta but omega are considered the weakest fitness. alpha wolf also contributes, follow and encircling the prey, the Beta wolf best candidate to be alpha wolf and Delta wolf provides food to pack and work for pack in case any dangers. The circluling and tracking behavior of the prey in the hunting process is to perform the gray wolf optimization algorithm GWO. The gray wolf optimization algorithm GWO can be applied to get the maximum power that we can capture from the solar panel. As the number of gray wolves participating in a hunt for prey and (MPPT) represents the prey that was hunted.

7.Modeling of Proposed PV System

The propsed grey wolf model is simulated in Matlab as shown in Figure 11. the aim of this simulation show to get the maximum power point tracking and shown the dynamic response to get stability system when radiation changed.

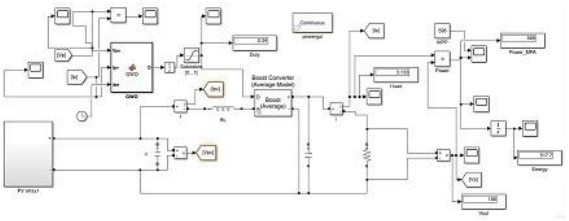


Figure11. Simulation model of grey wolf system.

8.Parameters of Boost and Results

For DC-DC Boost Converter Table1 represent the parameters of Boost circuit that used in Matlab simulation.

Table1. Represent the parameters of Boost circuit.

Power (w)	Value
inductor (L_boost)	1.4mH
PV array capacitor (Cpv)	10µF
Boost capacitor	470µF
Switch frequency(f_boost)	50kHz

The type of load used is resistive load(60Ω). The simulation is carried out under variouse irradiance (500,450,400,1000) W/m² with temperature T (45-25)ºC. we used in circute resistive load 60 ohm.The Boot desgin according to the eqautions :

$$T = {}^{1}/_{f} \quad \text{...(9)}$$

$$L = \frac{D(1-D)R}{2f} \quad \text{...(10)}$$

$$C = \frac{D}{2fR} \quad \text{...(11)}$$

Table 2. represents the results which latted from circuit included power,duty cycle,output volage and cureent by the load and the boost parameters.

Power (w)	589w
Duty cycle	0.34
Output Voltage (V)	188V
Output Current (A)	3.133A
Enery (Jole)	571J

Figure 12. repersents the relationship between power and time illuslited with their reference.

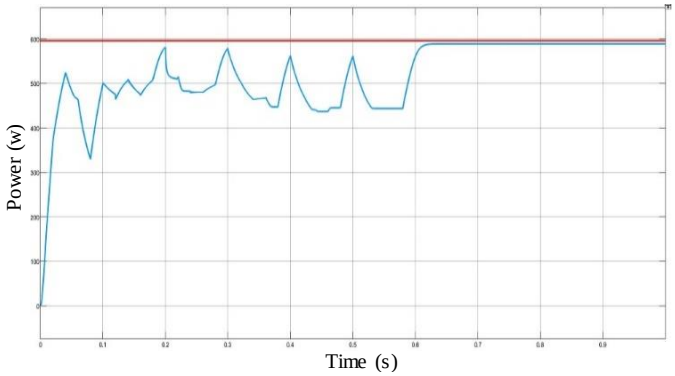


Figure 12. Power demand with their reference.

Figure 13. repersents the relationship between duty cycle and time illuslited.

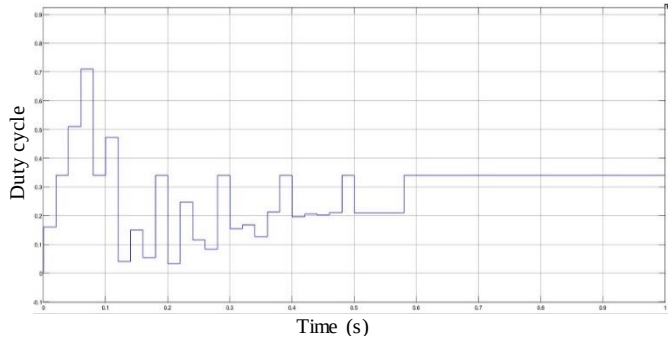


Figure 13. Duty cycle vs time.

Figure 14. repersents The relationship between output voltage and time illuslited.

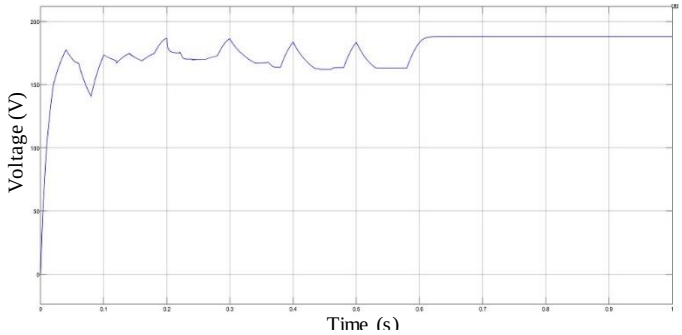


Figure 14. Output Voltage vs time.

Figure 15. repersents the relationship between output current and time illuslited.

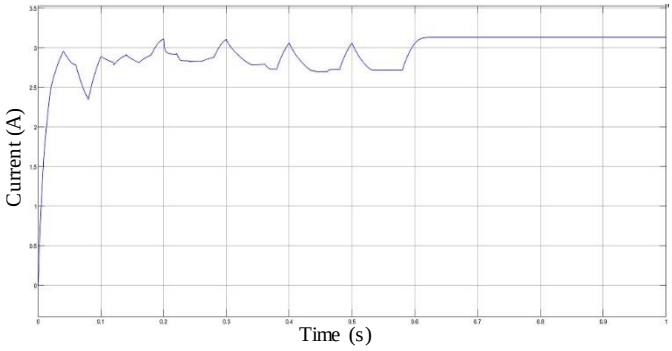


Figure 15. Output Current vs time.

Conclusion

From the simulation results it has been concluded from adopt MPPT controller based GWO:

The different weather conditions in terms of temperature and radiation affect the solar panels ,which in turn will affect the amount of power generateded.The duty cycle that obtined by grey wolf enhance the maximum output power and efficiecy.The power will arrive to a maximum point at (0.6)Sec.The best value of duty cycle that gave maximum voltage and current was (188V,3.133A) and cause system is stability in short time.

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