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MPPT Control of a Flyback Converter in a Photovoltaic System

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الإهداء

إلى سدنة العلم و أرباب الكلمة ، إلى كل إنسان يؤمن بأن العلم والمعرفة هما الأساس لحل كل معضلة ، إلى كل من يؤمن بأن الاختلاف رحمة وليس نقمة ، إلى كل متبتل في محراب العلم.

إلى كل من كان له علينا فضل حتى ارتقينا هنا.

إلى كل هاؤلاء نهدي هذ العمل المتواضع.

وبالأخص لوالداي والأستاذين الكريمين عبد القادر مرسلي وعبد الحليم تلمساني.

Thanks

first of all we hold on at thank Allah who we has helped at finish our modest work.

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our work.

And a big thank you at all those

who we have helped of close Where of far

ملخص :

يهتم هذا العمل بتعقب نقطة الاستطاعة القصوى الخاصة بالألواح الكهروضوئية كما يهتم ببعض التقنيات الكلاسيكية والحديثة الموجودة في المؤلفات. و على سبيل المثال "التذبذب و الملاحظة"، و"المنطق الضبابي "المستعمل منها ضمن محتوى هذه المذكرة غير أن اهتمامنا منصب أكثر على نوع جديد من المحولات المسمى ب "flyback" وقد سمحت لنا بتجسيد فكرة ناجحة في المنطق الضبابي على حساب باقي الطرق الكلاسيكية.

الكلمات المفتاحية : نظام متابعة نقطة الاستطاعة القصوى- مولد كهروضوئي-التجريب والملاحظة- الناقلية-المنطق الضبابي- الذكاء الاصطناعي.

Abstract :

This work is concerned with the continuation of the maximum power point (MPPT) of the photovoltaic generators and some classical and modern MPPT commands existing in the literature such as: "Perturb & Observe" and "Fuzzy logic" ,Our interest has focused on a topical command that is part of artificial intelligence.

The application was based on a study followed by a simulation under MATLAB/Simulink, which allowed us to reinforce the idea of the best performance of Fuzzy logic to their modern and classic counterparts. By using a new converter called « Flyback ».

Key word**:** MPPT controller , photovoltaic generators , Perturb & observe , Fuzzy logical , artificial intelligence.

Résumé :

Ce travail s'intéresse à la poursuite du point de puissance maximale (MPPT) des générateurs photovoltaïques et de certaines commandes MPPT classiques et modernes existant dans la littérature telles que : "Perturbation & observation" et "Logique floue". Notre intérêt s'est porté sur une commande d'actualité qui fait partie de l'intelligence artificielle.

L'application était basée sur une étude suivie d'une simulation sous MATLAB/Simulink, ce qui nous a permis de renforcer l'idée des meilleures performances de la logique floue par rapport à leurs homologues modernes et classiques. En utilisant un nouveau convertisseur appelé « Flyback ».

Mots clés **:** Contrôleur MPPT, générateurs photovoltaïques, Perturbation & observation, Logique floue , intelligence artificielle

LIST OF ACRONYMS AND SYMBOLS ACRONYMS

DC/DC Direct Curent Conversion
PVG Photovoltaic Generators
PPM Maximum power point
DC Direct current
MPPT Maximum Power Point Tracking
P&O Perturb and observe
FL Fuzzy Logic
PV Photovoltaic
FF Full Factor
I-V Current-Voltage
P-V Power-Voltage
PS Panels Sola
CST Condition standard Temperature

SYMBOLS

V_{pv}: PV module (V) output voltage ;

V_{oc}: Open circuit voltage ;

I_{sc}: Short circuit current ;

Ipv: PV module (A) output current ;

T_r: reference temperature, such that 298 K, T is the module operating temperature (in Kelvin) ;

I_{ph}: PV module (A) light-generated current ;

I_s: PV module saturation current (A) ;

$A = B$ = ideality factor = 1.6 ;

K: Boltzmann constant ($1.3805*10^{-23}$ J/K) ;

q: Electron charge ($1.6*10^{-19}$ C) ;

R_s: PV module series resistance ;

I_{scr}: PV module short-circuit current (25ºC and 1000W/m^2 = 17A) ;

K_i: short-circuit current temperature coefficient (I_{scr} = 0.0017A / ºC) ;

λ: PV module illumination (W/m^2) (1000W/m^2) ;

E_{go}: band gap for silicon (1.1 eV) ;

N_s: number of cells connected in series ;

N_p: number of cells connected in parallel

I C : Current of the cell PV [A].
V C : Voltage of the cell PV [V].
I D : The diode current [A].
G : Radiation Solar
CT : the cell temperature [C°]
Rs : Series Resistance [Ω].

Rep : Parallel resistance [Ω].
Id_1: The current of diode 1 [A].
I_{D2} : The current of diode 2 [A].
I Rp : The parallel resistance current [A].
P_{max} : Maximum power at the terminals of the PV cell [W].
A : The area of the PV module [m^2].
η : The effeciency [%].
V max : The voltage at the maximum power point [V].
I max : The current at the maximum power point [A].
D : The duty cycleI.
S : Cell saturation current [A].
Tck : Cell temperature [K°].
S : Percentage Sun stroke [%].
C: The capacitance of the capacitor [F].
V_{dc} : The voltage unlike a capacitor [V].
E : The error
ΔE : The change error

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General Introduction

General Introduction :

Since the last century, the consumption in energy has increase of way considerable. But our fossil energy resources (oil, coal, gas, etc.) are not Eternal and it is also better not to burn them more so as not to aggravate the pollution. The solution consists in use energies renewable (hydraulic, wind turbine, solar biomass, etc.) [1].

Algeria, conceals at this effect significant renewable energy resources who can overcome in particular in the context of the production of electrical energy, a vector major of everything development economic and social. The deposit solar constitutes the main of these resources.

The use of this "random and diffuse" renewable energy requires the combination of means of storage and of control of management of Powerful where each PV generator should operate at an optimal point, called the maximum power point(MPP), who is suborn ant to the variation of the temperature and sunstroke.

To increase the power yield of a PV module or array of modules PV, a controller electronic is incorporated Between the generator PV and the charge, whose the rolemajor is the surveillance and pursuit in continued from point of Powerful maximum fromgenerator PV called commonly MPPT (Maximum Power Point tracking) and that ingeneral per share on a device of DC-DC conversion.

In the literature, there are algorithms based on the following methods, such as : Disturbance & Observation 'P&O', etc. [2]. Or by intelligence artificial as the logic fuzzy 'FL'

These techniques present smart approchées for improving and optimizing of the control performance of a photovoltaic system.

In this memory, we to analyse the modelization and the simulation from functioning electric of one system photovoltaic adapted by a ordered digital ensuring the continuation of the maximum power supplied by the photovoltaic generator. The objective of this work is to contribute to a better understanding of converter performance DC-DC.

This memory is organized in four chapters as follows:

- The first chapter is reserved for a generalization on solar energy. And presents the principle of the photovoltaic effect, the PV cell and its settings.
- In the second chapter, we study all the techniques of MPPT commands proposed in this dissertation classics (P&O and artificial intelligence (FL).
- In the third chapter The is reserved for modeling the PV system some types of converters DC-DC (Boost and Flyback).
- In the fourth chapter, we make a simulation by MATLAB / Simulink from system photovoltaic without and with orders MPPT (P&O and FL). Finally, we made a comparative study between these methods following the results of simulation that we have found.

Ultimately, we ends with a conclusion general

Chapter I

The Solar Photovoltaic System

CHAPETR I: The Solar Photovoltaic System

I.1 Introduction:

One of the most important forms of large-scale centralized and efficient use of solar energy is PV power generation technology [18–21]. PV cell modeling is a critical component of PV power generation and related technology research. PV modules have been the subject of a lot of model study by many academics. The ideal model is the simplest, consisting of a diode and a current source. Short circuit current and open circuit voltage are the most essential metrics; however, their precision is poor. To more properly represent the properties of PV modules, the series resistance is added to the ideal model to generate the Rs-model, which takes into account the material's resistance characteristics and losses. However, in certain conditions, such as high temperature and low irradiation intensity, the output accuracy of this model is not very good. To solve these issues, a shunt resistor Rsh is added to the Rs-model, which is also known as a single diode model, and it can basically match the engineering precision criteria. A parallel diode is added to the single-diode model to make a double-diode model with improved accuracy, but its solution parameters are raised from 23 to 25. Under conventional test settings, PV cell manufacturers typically only offer open circuit voltage Voc, short-circuit current Isc, maximum power point voltage Vmmp, and maximum power point current Immp. Other parameters cannot be consulted directly from the instructions, making the model difficult to use in real-world engineering. Solar cell models based on single-diode mathematical models have been proposed and improved in recent years. References [22–25] create engineering solar cell models based on 5-parameter models of solar cells IL, Io, Rs, Rsh, and, adopted test data of solar cells or solar cell modules, and rely on engineering manuals. Ref. [26] proposes a reasonably straightforward method for determining Rs and Rp, however it increases the difficulty of determining the parameters IL and Io. The mass trajectories of three different gravitational fieldsG0, G1, and G2 were utilized to substitute the PV cell output characteristic curve in reference [27], which incorporated the similarity of the solar cell output characteristics and the mass flat throw motion. A simple to calculate engineering mathematical model of a PV cell is proposed. Two detailed methods for obtaining engineering simplified model parameters of solar cells are given in reference [28], which simulates the output volt–ampere characteristics of solar cells as a function of light and temperature based on the four parameters provided by the manufacturer under standard test conditions. Ref. [29] proposed a back propagation (BP) neural network model based on particle swarm optimization for the nonlinear features of PV cell output characteristics (PSO) This enhances PV cell model identification accuracy, but it necessitates a large amount of random sample test data, limiting its application to some extent. An engineering mathematical model of the compensatory parameter fitting correction approach is proposed in Ref. [30] to lessen the difficulty of solving by taking into account features of related parameters changing with changes in light intensity or temperature. Most PV cell engineering models are currently based on electrical data supplied by solar cell manufacturers (such as open circuit voltage, short circuit current, maximum power point voltage and current, etc.

I.2 The solar resource

To design and analyze solar systems, we need to know how much sunlight is available, set of equations can be used to predict where the sun is in the sky at any time of day for any location on earth, as well as the solar intensity (or *insolation: in*cident *sol*ar Radi*ation*) on a clear day. To determine average daily insolation under the combination of clear and cloudy conditions that exist at any site we need to start with long-term measurements of sunlight hitting a horizontal surface. Another set of equations can then be used to estimate the insolation on collector surfaces that are not flat on the ground [1]

I.2.1 The solar spectrum

The source of insolation is, of course, the sun—that gigantic, 1.4 million kilometer diameter, thermonuclear furnace fusing hydrogen atoms into helium. The resulting loss of mass is converted into about 3.8 × 1020 MW of electromagnetic energy that radiates outward from the surface into space.

Every object emits radiant energy in an amount that is a function of its temperature.

The wavelengths emitted by a blackbody depend on its temperature as described by *Planck's law*:

$$E\lambda = \frac{3.7410^{8}}{\lambda^{5}\left[e^{\frac{14.400}{\lambda T}}-1\right]} \qquad \text{(I.1)}$$

where $E\lambda$ is the emissive power per unit area of a blackbody (W/m2 μm), T is the absolute temperature of the body (K), and λ is the wavelength (μm). Modeling the earth itself as a 288 K (15◦C) where the wavelength is in microns (μm) and the temperature is in kelvins [2].

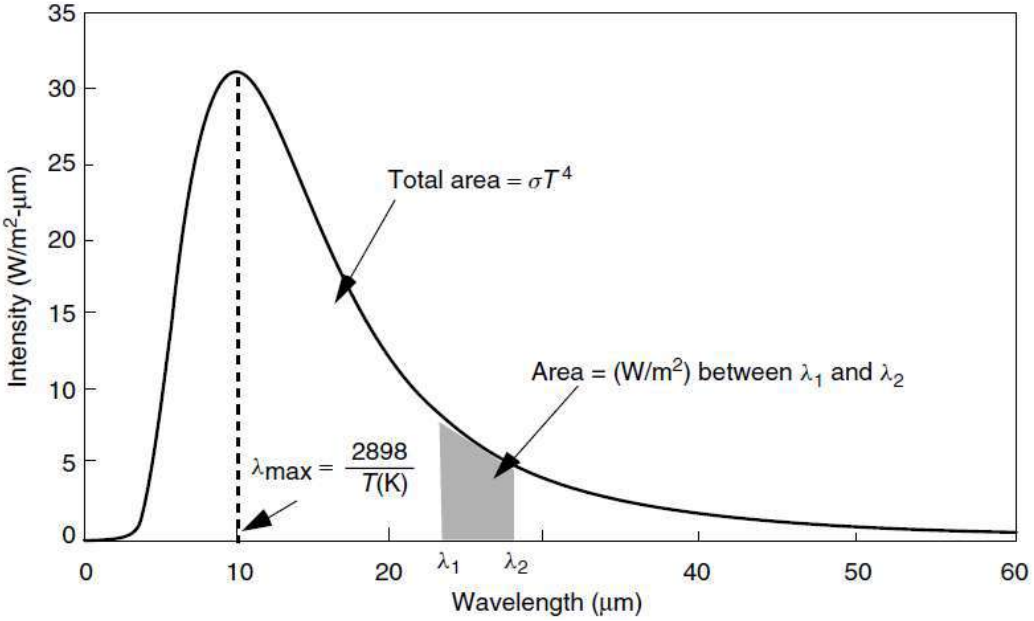


Fig I.1The spectral emissive power of a 288 K blackbody.

While the interior of the sun is estimated to have a temperature of around 15 million kelvins, also shown are the areas under the actualsolar spectrum that corresponds to wavelengths within the ultraviolet UV (7%), visible (47%), and infrared IR (46%) portions of the spectrum. The visible spectrum, which lies between the UV and IR, ranges from 0.38 μm (violet) to 0.78

µm (red).

As solar radiation makes its way toward the earth's surface, some of it is absorbed by various constituents in the atmosphere, giving the terrestrial spec- trum an irregular, bumpy shape. The terrestrial spectrum also depends on how much atmosphere the radiation has to pass through to reach the surface. The length of the path h_2 taken by the sun's rays as they pass through the atmo-sphere, divided by the minimum possible path length h_1, which occurs when the sun is directly overhead, is called the *air mass ratio*, *m*. As shown in Figure I.3, under the simple assumption of a flat earth the air mass ratio can be expressed as :

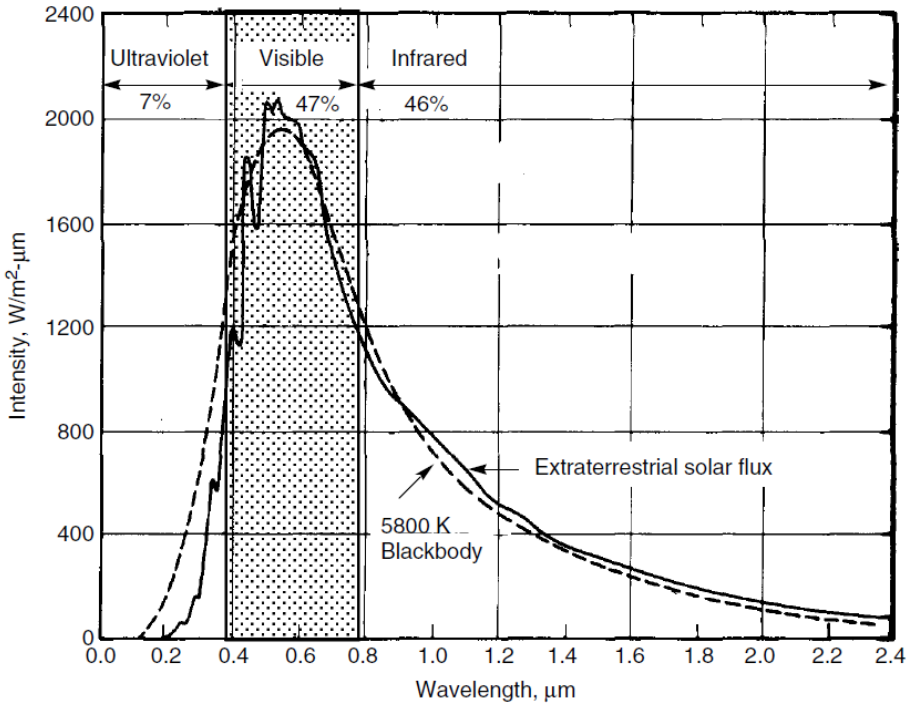


Fig I. 2 The extraterrestrial solar spectrum compared with a 5800 K blackbody

Air Mass ratio : $$m = \frac{h_2}{h_1} = \frac{1}{\sin\beta} \quad \text{(I.2)}$$

where h_1 path length through the atmosphere with the sun directly overhead, h_2 path length through the atmosphere to reach a spot on the surface, and β the altitude angle of the sun (see Fig. I.3) [3].

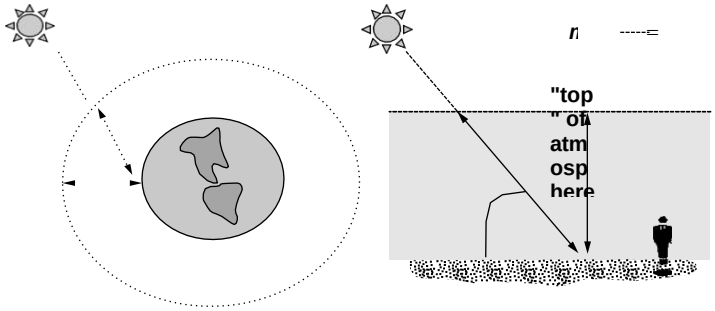


Fig I. 3 The air mass ratio m is a measure of the amount of atmosphere the sun's rays must pass through to reach the earth's surface. For the sun directly overhead, m = 1.

I.2.2 The earth orbit

The earth revolves around the sun in an elliptical orbit, making one revolution every 365.25 days. The point at which the earth is nearest the sun, the perihelion, occurs on January 2, at which point it is a little over 147 million kilometres away. At the other extreme, the aphelion, which occurs on July 3, the earth is about 152 million kilometres from the sun. This variation in distance is described by the following relationship:

$$d = 1.5 \times 10^8 \left[1 + 0.017 \sin \frac{360(n-93)}{365}\right] \quad \text{km} \qquad \text{(I.3)}$$

where *n* is the *day number*, with January 1 as day 1 and December 31 being day number 365.

As shown in Fig. 1.4, the plane swept out by the earth in its orbit is called the ecliptic plane. The earth's spin axis is currently tilted 23.45° with respect to the ecliptic plane and that tilt is, of course, what causes our seasons. On March 21 and September 21, a line from the center of the sun to the center of the earth passes through the equator and everywhere on earth we have 12 hours of daytime and 12 hours of night [4].

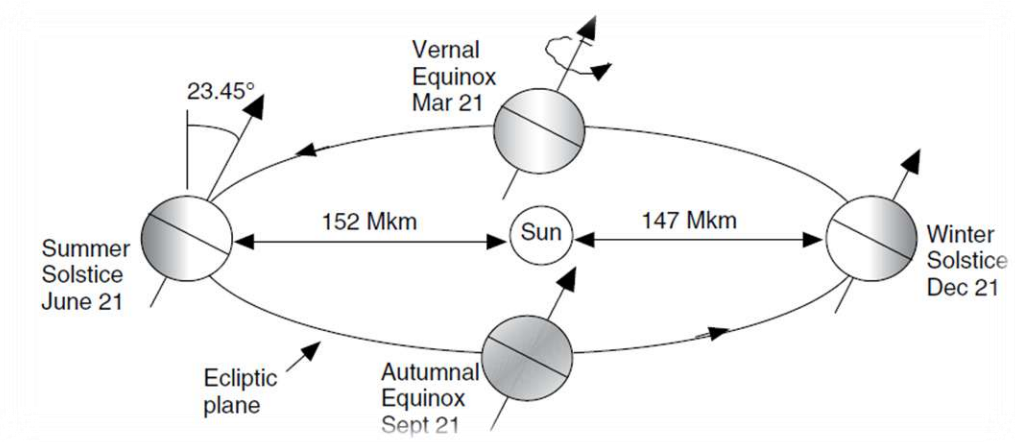


Fig I. 4 The tilt of the earth's spin axis with respect to the ecliptic plane

Is what causes our seasons. "Winter" and "summer" are designations for the solstices in the Northern Hemisphere.

I.2.3 Altitude angle of the sun at solar noon

In the context of photovoltaics, we can, for example, use knowledge of solar angles to help pick the best tilt angle for our modules to expose them to the greatest insolation. While Fig. 7.5 correctly shows the earth revolving around the sun. On June 21 (the summer solstice) the sun reaches its highest point, and a ray drawn at that time from the center of the sun to the center of the earth makes an angle of 23.45° with the earth's equator. On that day, the sun is directly over the Tropic of Cancer at latitude 23.45°. At the two equinoxes, the sun is directly over the equator. On December 21 the sun is 23.45° below the equator, which defines the latitude known as the Tropic of Capricorn.

As shown in Fig. I.5 the angle formed between the plane of the equator and a line drawn from the center of the sun to the center of the earth is called the solar declination, δ. It varies between the extremes of 23.45°, and a simple sinusoidal relationship that assumes a 365-day year and which puts the spring equinox on day *n* 81 provides a very good approximation. Exact values of declination, which vary slightly from year to year, can be found in the annual publication *The American Ephemeris and Nautical Almanac* [5].

$$\delta = 23.45 \sin\left(\frac{360[n-81]}{365}\right) \qquad \text{(I.4)}$$

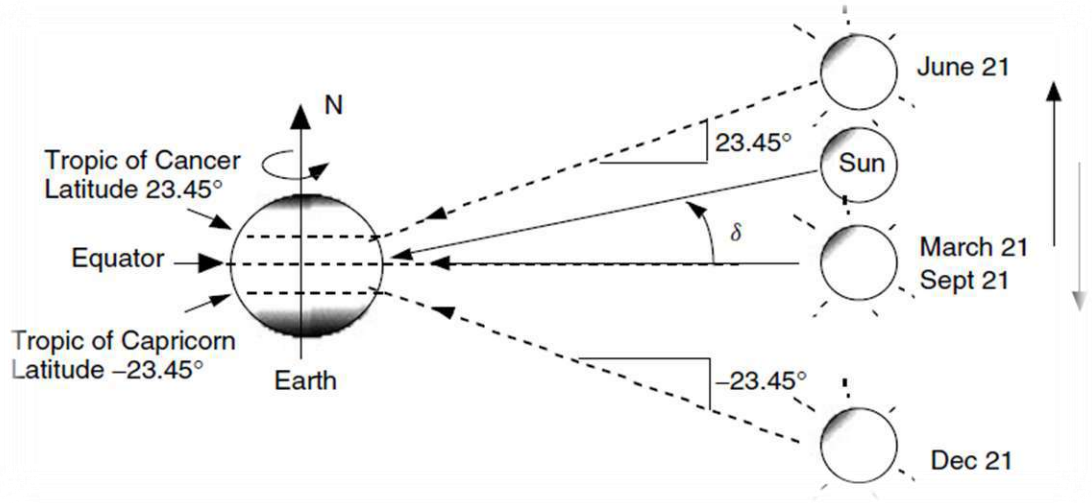


Fig I. 5 An alternative view with a fixed earth and a sun that moves up and down. The angle between the sun and the equator is called the solar declination δ.

Table I. 1 Solar Declination δ for the 21st Day of Each Month (degrees)

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
δ	−20.1	−11.2	0.0	11.6	20.1	23.4	20.4	11.8	0.0	−11.8	−20.4	−23.4

As suggested in Fig. 1.6, during the summer solstice all of the earth's surface above latitude 66.55° (90° 23.45°) basks in 24 hours of daylight [6].

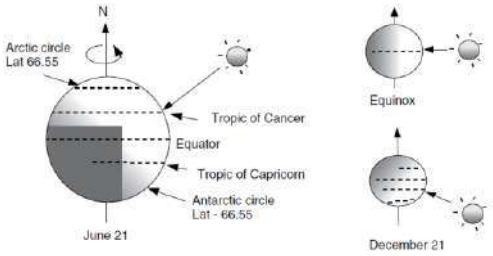


Fig I. 6 Defining the earth's key latitudes tipped up to is perpendicular to the sun's rays at solar noon.

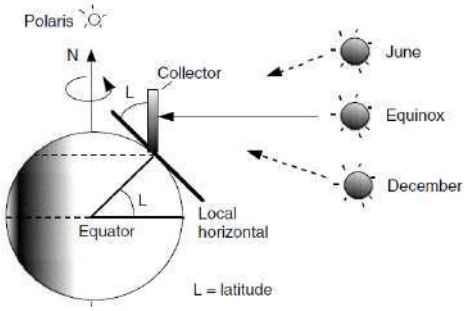


Fig I. 7 A south-facing collector an angle equal to its latitude.

On the average, facing a collector toward the equator (for most of us in the Northern Hemisphere, this means facing it south) and tilting it up at an angle equal to the local latitude is a good rule-of-thumb for annual performance. Of course, if you want to emphasize winter collection, you might want a slightly higher angle, and vice versa for increased summer efficiency.

The altitude angle is the angle between the sun and the local horizon directly beneath the sun. From Fig. 1.8 we can write down the following relationshipby inspection:

$$\beta_N = 90^\circ - L + \delta \qquad \text{(I.5)}$$

where L is the latitude of the site. Notice in the figure the term *zenith* is intro- duced, which

refers to an axis drawn directly overhead at a site [7].

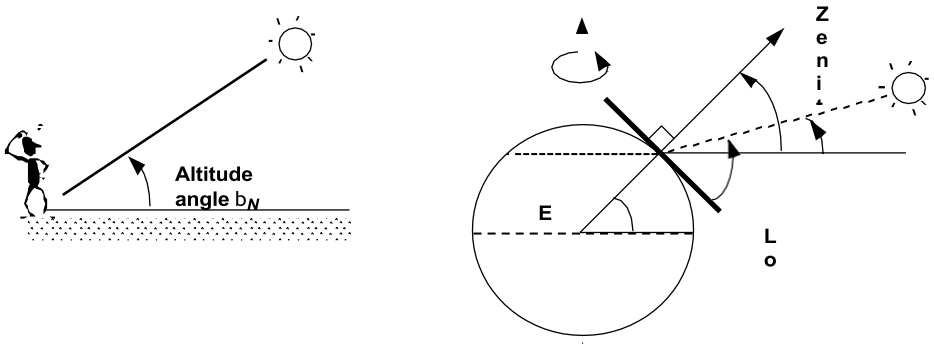


Fig I. 8 The altitude angle of the sun at solar noon.

I.2.4 Solar position at any time of day

The location of the sun at any time of day can be described in terms of itsaltitude angle β and its azimuth angle φ_s as shown in Fig. 7.10. The subscript *s* in the azimuth angle helps us remember that this is the azimuth angle of the sun. Later, we will introduce another azimuth angle for the solar collector and a different subscript *c* will be used. Notice that the azimuth angle shown in Fig. I.9 uses true south as its reference, and this will be the assumption in this text unless otherwise stated. For solar work in the Southern Hemisphere, azimuth angles are measured relativeto north [8].

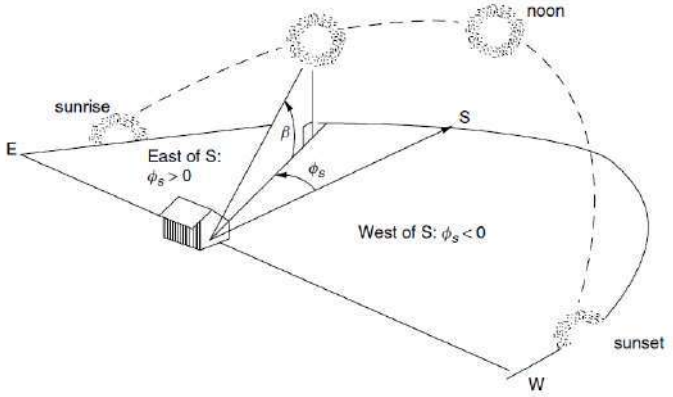


Fig I. 9 The sun's position can be described by its altitude angle β and its azimuth angle φS. By convention, the azimuth angle is considered to be positive before solar noon.

The azimuth and altitude angles of the sun depend on the latitude, day number, and, most importantly, the time of day. For now, we will express time as the number of hours before or after solar noon [9].

$$\sin\beta = \cos L \cos\delta \cos H + \sin L \sin\delta \quad (I.6)$$

$$\sin\varphi s = \frac{\cos\delta \sin H}{\cos\beta} \quad (I.7)$$

Notice that time in these equations is expressed by a quantity called the *hour angle*, *H*. The hour angle is the number of degrees that the earth must rotate before the sun will be directly over your local meridian (line of longitude Hour angle.

$$H = \frac{15°(Hours\ before\ solar\ noon)}{hour} \quad (I.8)$$

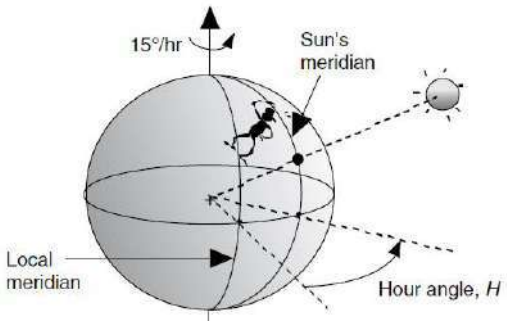


Fig I. 10 The hour angle is the number of degrees the earth must turn before the sun is directly over the local meridian.

It is the difference between the sun's meridian and the local meridian. There is a slight complication associated with finding the azimuth angle of the sun from (7.9). During spring and summer in the early morning and late afternoon, the magnitude of the sun's azimuth is liable to be more than 90◦ away from south (that never happens in the fall and winter). Since the inverse of a sine is ambiguous, sin x = sin (180 - x), we need a test to determine whether to conclude the azimuth is greater than or less than 90◦ away from south. Such a test is :

If $$\cos H \geq \frac{\tan\delta}{\tan L} \quad then\ |\varphi_s| \leq 90°\ \ other\ wise\ |\varphi_s| \geq 90° \qquad \text{(I.9)}$$

Solar altitude and azimuth angles for a given latitude can be conveniently portrayed in graphical form, an example of which is shown in Fig. 1.11 Similar sun path diagrams for other latitudes are given in Appendix B. As can be seen, in the spring and summer the sun rises and sets slightly to the north and our need for the azimuth test given in (7.11) is apparent; at the equinoxes, it rises and sets precisely due east and due west (everywhere on the planet); during the fall and winter the azimuth angle of the sun is never greater than 90◦.

I.2.5 Sun path diagrams for shading analysis

Not only do sun path diagrams, such as that shown in Fig. I.11 help to build one's intuition into where the sun is at any time, they also have a very practical application in the field when trying to predict shading patterns at a site— a very important consideration for photovoltaics, which are very shadow sensitive.

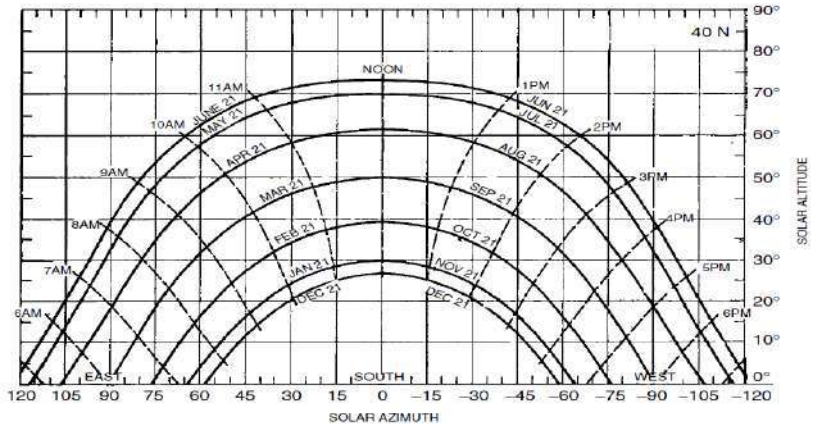


Fig I. 11 A sun path diagram showing solar altitude and azimuth angles for 40◦ latitude. Diagrams for other latitudes are in Appendix B.

I.2.6 Solar time and civil (clock) time

Solar time (ST), (when the sun is on our line of longitude). There are occasions, however, when local time, called civil time or clock time (CT), is needed. There are two adjustments that must be made in orderto connect local clock time and solar time. The first is a longitude adjustment that has to do with the way in which regions of the world are divided into time zones. The second is a little fudge factor that needs to be thrown in to account for the uneven way in which the earth moves around the sun [10].

Since the earth rotates 15° per hour (4 minutes per degree), for every degree of longitude between one locationand another, clocks showing solar time would have to differ by 4 minutes. The only time two clocks would show the same time would be if they both were due north/south of each other. The second adjustment between solar time and local clock time is the result of the earth's elliptical orbit, which causes the length of a *solar day* (solar noon to solar noon) to vary throughout the year. As the earth moves through its orbit, the difference between a 24-hour day and a solar day changes following an expression known as the Equation of Time, E:

Table I. 2 Local Time Meridians for U.S. Standard Time Zones (Degrees West of Greenwich)

Time Zone	LT Meridian
Eastern	75°
Central	90°
Mountain	105°
Pacific	120°
Eastern Alaska	135°
Alaska and Hawaii	150°

$$E = 9.87 \sin 2B - 7.53 \cos B - 1.5 \sin B \quad \text{(minutes)} \tag{I.10}$$

Where,

$$B = \frac{360}{364}(n - 81) \quad (degrees) \tag{I.11}$$

As before, n is the day number is given in Figure I.12.

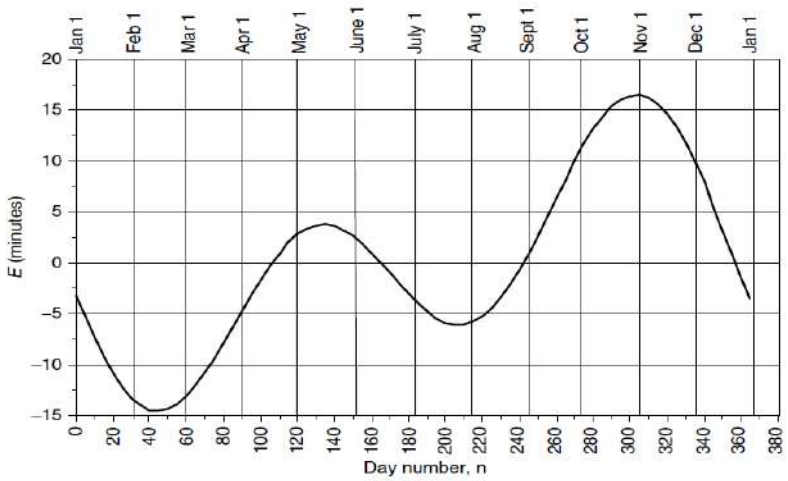


Fig I. 12 The Equation of Time adjusts for the earth's tilt angle and noncircular orbit.

Putting together the longitude correction and the Equation of Time gives us the final relationship between local standard clock time (CT) and solar time (ST).

Solar Time (ST) = Clock Time (CT) + 4min degree (Local Time Meridian − Local Longitude)+E(min) (I.12)

When Daylight Savings Time is in effect, one hour must be added to the local clock time ("Spring ahead, Fall back") [11].

I.2.7 Sunrise and sunset

A sun path diagram, such as was shown in Fig. 7.12, can be used to locate the azimuth angles and approximate times of sunrise and sunset. A more careful estimate of sunrise/sunset can be found from a simple manipulation of (7.8). At sunrise and sunset, the altitude angle β is zero, so we can write

$$\sin\beta = \cos L \cos\delta \cos H + \sin L \sin\delta = 0 \quad \text{(I.13)}$$

An adjustment factor Q that accounts for these complications is given by the following (U.S. Department of Energy, 1978):

$$Q = \frac{3.467}{\cos L \ \cos\delta \ \sin H_{SR}} \quad \text{(min)} \quad \text{(I.14)}$$

Since sunrise is earlier when it is based on the top of the sun rather than the middle, Q should be subtracted from geometric sunrise. Similarly, since the upper limb sinks below the horizon later than the middle of the sun, Q should be added to our geometric sunset.

I.2.8 Clear sky direct-beam radiation

Solar flux striking a collector will be a combination of direct-beam radiation that passes in a straight line through the atmosphere to the receiver, diffuse radiation that has been scattered by molecules and aerosols in the atmosphere, and reflected radiation that has bounced off the ground or other surface in front of the collector (Figure I.13). The preferred units, especially in solar–electric applications, are watts (or kilowatts) per square meter [12].

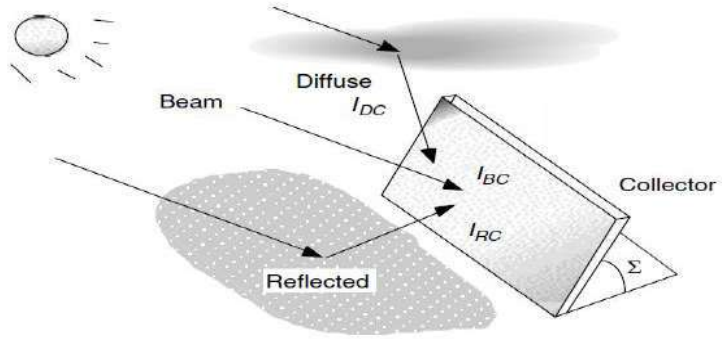


Fig I. 13 Solar radiation striking a collector, IC, is a combination of direct beam.

IBC, diffuse, IDC, and reflected, IR The starting point for a clear sky radiation calculation is with an estimate of the extraterrestrial (ET) solar insolation, I_0, that passes perpendicularly through an imaginary surface just outside of the earth's atmosphere as shown in Fig. I.14. This insolation depends on the distance between the earth and the sun, which varies with the time of year.

$$I_0 = SC\left[1 + 0.34\cos\frac{360n}{365}\right] \quad (W/m^2) \tag{I.15}$$

where SC is called the solar constant and n is the day number. The solar constant is an estimate of the average annual extraterrestrial insolation [13].

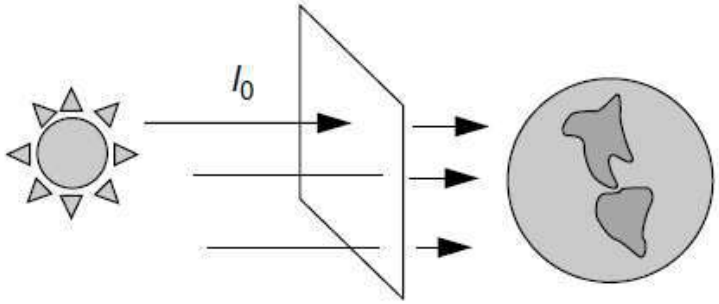


Fig I. 14 The extraterrestrial solar flux.

Table I. 3 Optical Depth k, Apparent Extraterrestrial Flux A, and the Sky *(Source: ASHRAE (1993)).*

Diffuse Factor *C* for the 21st Day of Each Month												
Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
***A* (W/m^2)**	1230	1215	1186	1136	1104	1088	1085	1107	1151	1192	1221	1233
k	0.142	0.144	0.156	0.180	0.196	0.205	0.207	0.201	0.177	0.160	0.149	0.142
C	0.058	0.060	0.071	0.097	0.121	0.134	0.136	0.122	0.092	0.073	0.063	0.057

such as dust, air pollution, etc.

$$I_B = A^{-Km} \tag{I.16}$$

where I_B is the beam portion of the radiation reaching the earth's surface (normal to the rays), A is an "apparent" extraterrestrial flux, and k is a dimensionless factor called the *optical depth*.

$$m = \frac{1}{\sin\beta} \tag{I.17}$$

where β is the altitude angle of the sun.

$$A = 1160 + 75 \sin (360 /365 (n - 275)) \ (\text{W/m}^2) \tag{I.18}$$

$$k = 0.174 + 0.035 \sin (360/ 365 (n - 100)) \tag{I.19}$$

where again n is the day number.

I.2.9 Total clear sky insolation on a collecting surface

I.2.9.1 Direct-Beam Radiation

The translation of direct-beam radiation I_B (normal to the rays) into beam insolation striking a collector face I_{BC} is a simple function of the angle of incidence in Fig. I. 15.

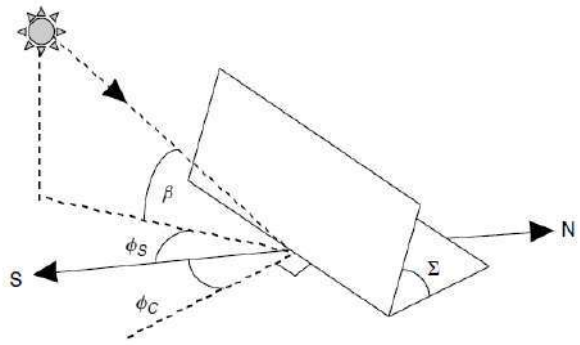


Fig I. 15 Direct-Beam Radiation

$$I_{BC} = I_B \cos\theta \quad \text{(I.20)}$$

The angle of incidence θ will be a function of the collector orientation and the altitude and azimuth angles of the sun at any particular time

$$\cos\theta = \cos\beta \cos(\varphi S - \varphi C) \sin\sum + \sin\beta \cos\sum \quad \text{(1.21)}$$

I.2.9.2 Diffuse Radiation

The diffuse radiation on a collector is much more difficult to estimate accurately than it is for the beam.

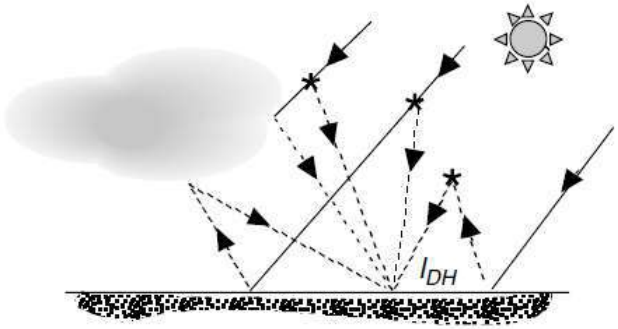


Fig I. 16 Diffuse radiation Multiple scatterings are possible

horizontal surface

$$I_{DH} = C\, I_B \quad \text{(I.22)}$$

$$C=0.095+0.04\sin\left[\frac{360}{365}(n-100)\right] \quad \text{(I.23)}$$

I.2.9.3 Reflected Radiation

The final component of insolation striking a collector results from radiation that is reflected by surfaces in front of the panel [14].

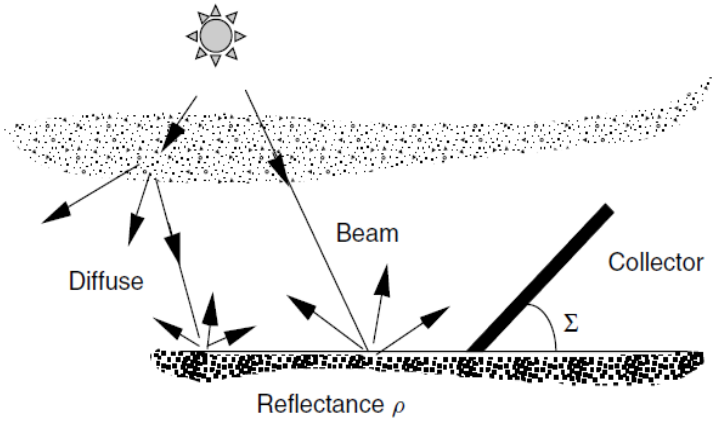


Fig I. 17 Diffuse radiation can be scattered by atmospheric particles and moisture or reflected from clouds. Multiple scatterings are possible

$$IRC=\rho(IBH+IDH)\left(\frac{1-\cos\sum}{2}\right) \quad \text{(I.24)}$$

I.3 The Photovoltaic

I.3.1 Materials and electrical characteristics

1) **definition:** A material or device that is capable of converting the energy contained in photons of light into an electrical voltage and current is said to be photovoltaic.
   Refers to the energy recovered and transformed directly into electricity from sunlight by photovoltaic panels. It results from the direct conversion in a semiconductor (silicon, CdTe, AsGa, CIS, etc.) of a photon into an electron.
   In addition to the advantages linked to the absence of maintenance of photovoltaic systems, this energy perfectly meets the needs of isolated sites where connection to the electricity grid is too expensive.
2) **History of the photovoltaic cell:** You should know that the photovoltaic effect, on which the operation of the solar cell is based, was discovered in the 19th century by Antoine and Edmond Becquerel, French physicists. It was then used in 1883 by Charles Fritts, who developed the first photovoltaic cell. However, it was not until the 1950s that the development of solar cells accelerated and became known to the general public.
3) **The role of the photovoltaic cell :** The photovoltaic cell is used to generate solar energy. Its purpose is to capture the radiation Photovoltaic of the sun, i.e. its light, in order to transform it into electricity.
4) **What constitutes a solar panel? :** The photovoltaic cell is solid-state device composed of thin layers of semiconductor materials which produce an electric current when light falls on it. It contains number of cell filled by photovoltaic material. Mono-crystalline Si, Poly-crystalline Si, amorphous Si, Cu-indium sulfide, and Cd-telluride are materials which are currently used for PV. Generally, Poly-crystalline Si and Mono-crystalline Si are extensively used in India. Silicon gives optimum result so it is extremely suitable for PV applications among all the materials available in the earth [31].
   The primary element that makes up a solar panel is its solar photovoltaic cell which does the conversion from the sunlight to electricity. Accordingly, 80% of solar panels are made up of solar cells made of crystalline silicone meaning "monocrystalline, polycrystalline, amorphous silicon, or hybrids". The cells are placed in a grid like design.
   Silicon is a semiconductor and the fourteenth component in the periodic table. It has 4 valences (electrons at the outer shell). Silicon particles offer valence electrons to achieve stability. To aggravate this stability, doping atoms are embedded into the silicon.
   Furthermore, the 20% are made up of solar cells which are made mostly from Cadmium Telluride and a small portion of CIGS or Copper Indium Gallium Selenite. These cells have an advantage of being low cost and therefore can be made into large single sheets.

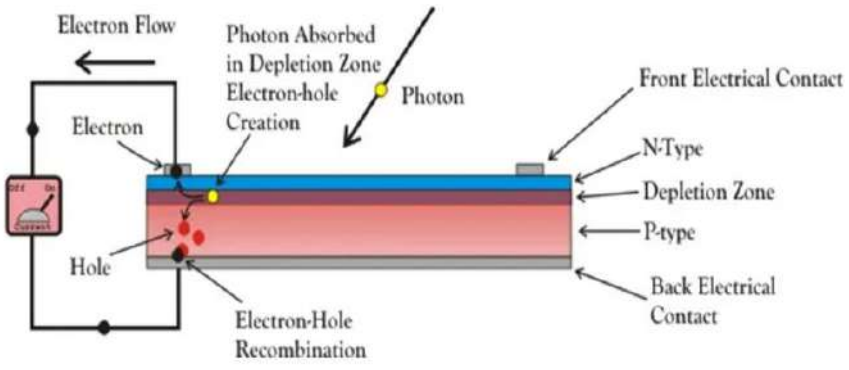


Fig I. 18: construction of solar cell

Solar panels are sealed hermetically or in an airtight manner in order to protect them, and are then covered in a glass that is non-reflective which protects the cells against environmental damage. The composite is then put into a frame that is rigid and sturdy. This frame prevents deformation due to freezing weather as well as strong winds. Also, the frame would include a hole that allows drainage and prevents water

from building up on the device which can cause a reduction in what is outputted. The solar panel's back is also sealed and is the area in which you can find the junction box.

5) **Efficiency of Solar panels :** The amount of Electricity used is dependent on a number of factors such as the solar panel itself and the cell technology underlying it as well as the material used in making it; the sunlight exposure at the specified location per year. The efficiency of solar panels depends on the insolation, the irradiance, the heat, and the cleanliness in addition to some other factors that don't have a significant effect on the efficiency.

Insolation: this is based on the amount of solar energy that reaches an area or" spot on the earth".

Irradiance: This is the amount of solar energy that hits the earth.

Heat: The heat aspect can reduce the amount of power made.

Cleanliness: This factor can affect the amount of power outputted. [32]

6) **The effect of seasons and the weather conditions on solar panels :** Many people believe that solar panels operate better in the summer, but this is not true for a variety of reasons.

1- The temperature has an effect on the amount of power that a solar panel produces, even though the temperature has no effect on the amount of solar radiation that the panel receives. To clarify, as a solar panel heats up, it produces less power with the same amount of sunlight. The "high energy" of the sun generally excites electrons that are at rest or in a "low energy" phase. The voltage that you can fairly expect to receive from the solar panel is the difference between the low and high energy of electrons. Heat can also excite electrons, like when something is heated gives it energy, which causes the rest energy of the electrons to grow. As a result, at rest, cooler electrons have less energy than warmer electrons.

Because power is generated by the difference between the electrons' rest and excited states, which is aided by the sun, the power output will be lower in the scenario where the electrons are at a higher energy level at rest due to a hotter solar panel.

2- Light is made up of a vast number of photons, which are particles that transmit the light's energy. When they make contact with the solar cell, they collide with an electron and transfer their energy to the electron. The electron is triggered as a result of this. a transition from a low-energy to a high-energy state The solar panel system's cell is constructed with the goal of capturing this electron in its high-energy form. It then runs it via an electrical circuit to use the electrons' energy.

Extra vigour Before leaving the solar panel system, a high-energy electron may collide with atoms in the cell, causing the electron to lose its excess energy and convert it to heat instead of electricity. The vibrating of molecules and atoms causes heat. The fact that the solar cell is at a higher temperature means that the atoms are vibrating quicker. As a result, releasing an electron without colliding with these atoms is more challenging. Therefore, when a solar cell is heated, the power output drops because energy is wasted before it reaches the solar panel system's cell. The current J_{sc} increases as the solar cell heats up, but the voltage V_{oc} decreases. Unfortunately, the voltage drops quicker than the current rises, resulting in a loss in overall efficiency [33].

I.3.2 Mathematically speaking

$$P=J*V \quad \text{(I.17)}$$

P the power produced ;

J the current;

V the voltage.

We calculate the efficiency of a solar panels when P reaches its maximum value

$$n=J_{max}*V_{max}/P_{in} \quad \text{(I.18)}$$

n the efficiency;

J_{max} the current at the maximum power;

V_{max} the voltage at the maximum power;

P_{in} is the power incident on the solar cell (the power from the light shining on it).

In another way $$n=J_{sc}*V_{oc}*FF/P_{in} \quad \text{(I.19)}$$

J_{sc} the current at short circuit (when V = 0);

V_{oc} the voltage at open circuit (when J = 0);

FF is a factor.

when the solar cell is heated, the current J_{sc} increase while the voltage V_{oc} decrease. Unfortunately, the voltage decreases faster than the current increases, the result is that the overall efficiency goes down.

I.3.3 Photovoltaic modeling

Many PV cells are linked in series and parallel in a photovoltaic module (panel). These connections are configured to boost output power to meet the load. A photovoltaic cell is a large-area forward-biased diode with a photo voltage. The dissociation of electron-hole pairs formed by incident photons within the built-in field of the diode's junction produces photo voltage.

A typical photovoltaic cell is made up of a thin rectangular or circular wafer of phosphorous-dropped silicon sandwiched between two wafers of boron-dropped silicon. The p-n junction is the point of interaction between these two layers. This junction creates a constant electric field that guides light-simulated electrons and allows direct current electricity to flow [34].

I.3.4 Modeling of PV cell

$$\mathrm{I} = n_p * I_{ph} - n_p * I_{rs}\left[\left(e^{\frac{q*V}{k*T*A*ns}}\right) - 1\right] \quad \text{(I.25)}$$

$$I_{rs}=I_{rr} * \left(\frac{T}{T_r}\right)^3 \left[\left(e^{\frac{q*EG*\left(\left(\frac{1}{T_r}\right)-\left(\frac{1}{T}\right)\right)}{k*A}}\right)\right] \quad \text{(I.26)}$$

$$I_{ph}= [\ I_{scr} + \mathrm{ki}(\mathrm{T} - T_r)]*\frac{G}{1000} \quad \text{(I.27)}$$

where (I) is the PV array output current, (V) is the PV array output voltage, (I_{ph}) is the photo-

current, (I_{rs})is the cell reverse saturation current ,(I_{rr}) is the reverse saturation current at T_r ,(T_r) is the reference temperature, (I_{scr})is the cell short circuit current at T_r , (A) is the ideality factor for a p-n junction, (q) is the electric charge ,(E_G) is the band gap energy of the semiconductor used in the cell, (K) is the Boltzmann's constant ,(K_i) is the short circuit current temperature coefficient, (T) is the junction temperature in Kelvin, (n_p) is the number of modules connected in parallel, (n_s) is the number of PV cells connected in series,(G) is the solar irradiance .

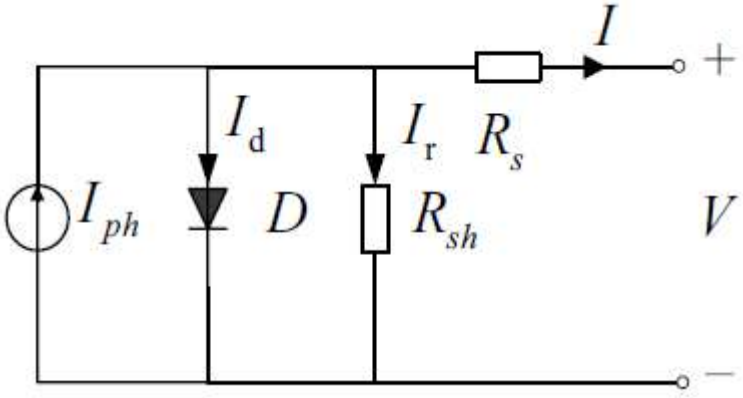


Fig I. 19 PV Electric Model

Fig (I.19) depicts the PV cell's electric model. As a result, subtracting the photocurrent, saturation current and current going through the shunt resistance yields the PV cell's output current. As seen in equation, there is a linear relationship between photocurrent and solar irradiance (I.20). Figure 1 depicts the photovoltaic I-V characteristics curve (I.20). The output current and voltage of the PV cell have a nonlinear relationship, as can be shown.

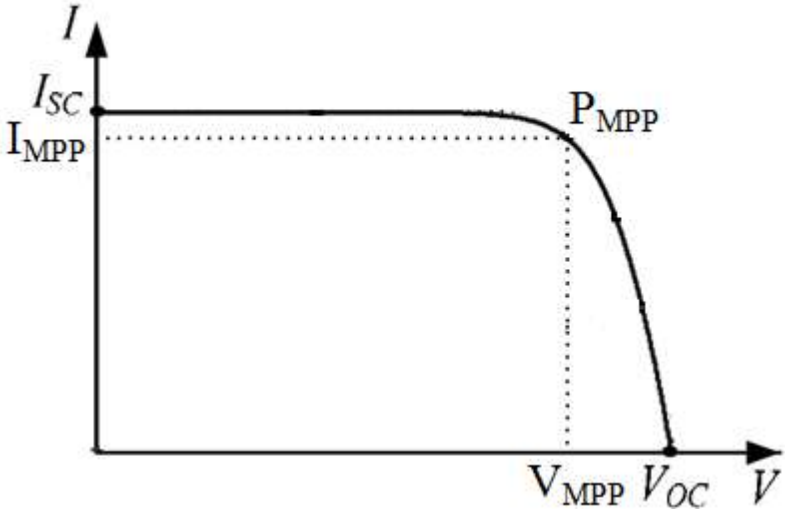


Fig I. 20 I-V Characteristics for a PV module at specific atmospheric conditions

I.3.5 The influence of the solar irradiance intensity on PV I-V characteristics

The PV cell's photocurrent (I_{Ph}) is related to solar irradiance, but the saturation current is unaffected by solar irradiance. As a result, as illustrated in Figure (I.20), the PV cell's output current increases as solar radiation increases.

Figure (I.20) shows the rise in solar irradiation from 10 to 100 mw/cm^2 (at T=25^{o}C).

I.3.6 The influence of temperature on PV I-V characteristics

Temperature has a significant impact on the I-V properties of solar cells. With an increase in cell temperature, the photo-current increases marginally. Otherwise, as seen in Figure (I.20) the open-circuit voltage drops as the cell temperature rises.

The even values in Figure (I.21) indicate how the temperature of the PV cell rises from 25°C to 50°C as solar irradiation rises.

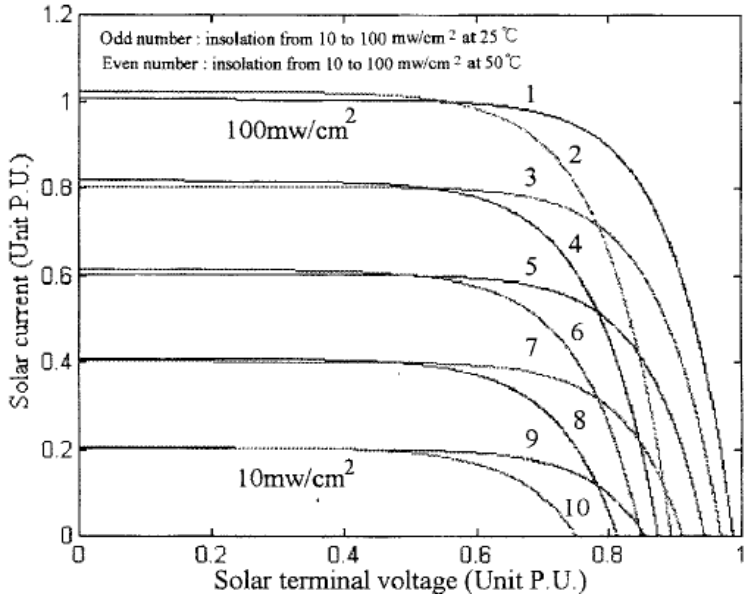


Fig I. 21 The Effect of Solar Irradiance and Cell Temperature on PV Characteristics

As a result, as illustrated in Fig. 1, solar irradiance has a considerable impact on PV output power (I.22). The output power of the solar cell, on the other hand, diminishes as the open circuit voltage lowers as the cell temperature rises.

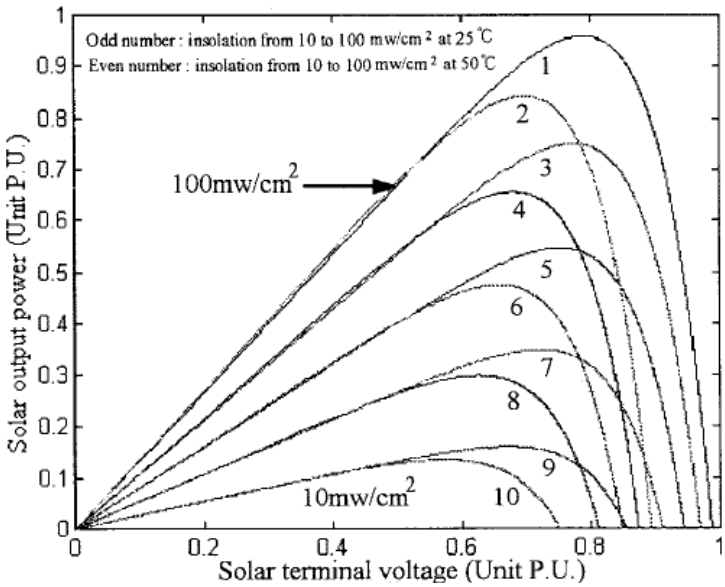


Fig I. 22 The Effect of Solar Irradiance and Cell Temperature on The Output PV Power

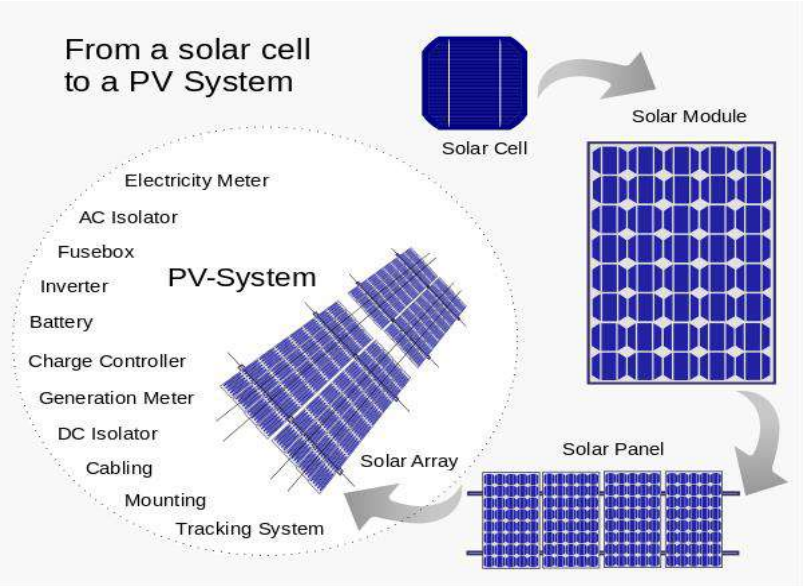


Fig I. 23 from a solar cell to a pv system

I.3.7 Maximum power operation

The operating point will be defined by the junction of the I-V characteristics of the solar cell and the load, assuming constant ambient circumstances (solar irradiance and cell temperature) and connecting the terminals of the PV module to a variable resistive load (R). As illustrated in Fig. (I.23), the load characteristics are a straight line with a slope of 1/R (where I/V = 1/R).

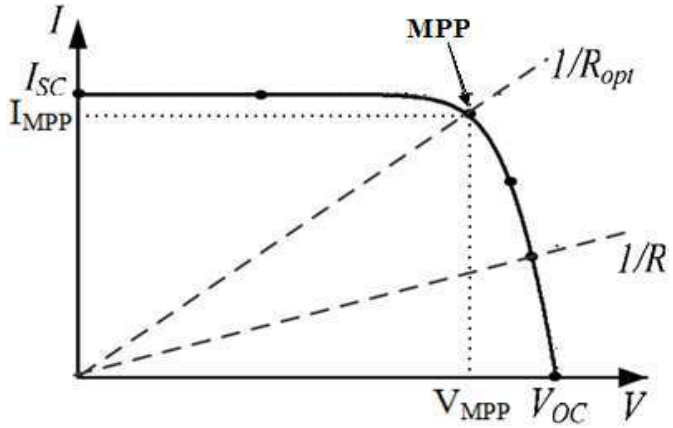


Fig I. 24 A Typical Current-Voltage I-V Curve for a Solar Cell at constant atmospheric conditions

When the load (*R*) is low, the cell operates as a constant current source, producing a current that is nearly equivalent to the short circuit current. When the load (*R*) is large, the cell functions as a constant voltage source, with a voltage that is nearly equal to the open circuit voltage.

Only the resistance (*R*) determines how much power is delivered to the load (at constant solar irradiance and cell temperature). As illustrated in Fig. (I.23) the highest power may be attained for ($R = R_{opt}$) When the load changes from R=0 to R=∞, the power delivered to the load changes as well, until it reaches its maximum at $R = R_{opt}$.

I.3.8 Why did we choose solar panels as a source of alternative energy?

1. High reliability: Even in the face of adversity, photovoltaic systems remain highly reliable. Photovoltaic arrays ensure that important power supply run continuously and without interruption.
2. Unwavering perseverance: The majority of modules in a PV system have a guarantee period of up to 25 years and are still functional after that time.
3. Low-cost maintenance: Photovoltaic systems require just routine inspections and minor repairs, which are incredibly inexpensive when compared to traditional fuel systems.
4. Consumption of no fuel: Photovoltaic systems do not require fuel and can save money on purchasing, storing, and transporting it.
5. There is very little noise pollution: With minimum mechanical action, the photovoltaic system can run silently.
6. Photovoltaic monitoring is in place: Photovoltaic systems may require the addition of specific modules to improve energy efficiency.
7. High-level security: Photovoltaic systems do not require fuel and can be run safely if properly designed and installed.
8. Strong self-reliance: The adoption of this new technology in many residential locations is due to the fact that photovoltaic systems preserve energy production independence and are thus unaffected by utilities.

I.3.9 Problem definition

1. **Expensive start-up**: Each PV installation should be assessed in terms of cost and compared to current options. Solar systems have a relatively high construction cost at the moment, but with lower photovoltaic system building costs and rising traditional energy prices, photovoltaic systems will have a significant economic competitiveness.
2. **Instability of available solar radiation**: Weather fluctuations have a significant impact on the amount of electrical energy produced by any solar system. As a result, changes in climate and location must be factored into the system design.
3. **Have criteria for energy storage**: Batteries are used as energy storage devices in some photovoltaic systems. This increases the system's footprint, cost, and complexity.
4. **There is a need to improve efficiency**: In order for PV systems to be cost-effective, we must distribute the energy generated during use in an efficient manner. However, they are increasingly frequently used to power inefficient alternative appliances.
5. **Inadequate knowledge and abilities**: Photovoltaic technology is still in its infancy. The development of its markets and technology is hampered by a lack of essential information [34].

I.4 Conclusion

Seasons and weather have an impact on the amount of sunlight that reaches the roof. The amount of sunshine varies based on the time of day. In many circumstances, relying just on the maximum power rating will result in an erroneous estimate of the power that can be expected. Regardless of your location, you will be able to determine the estimated production of solar panels.[15]

The solar system will lose energy on average due to factors such as power, inverter efficiency, and wiring, and will only provide up to 80% of its capacity.

A solar calculator will generate a table with an estimate of the quantity of solar power to expect based on the watt rating of a solar panel, its location, and the cost of energy produced on the grid [17].

> The actual energy conversion efficiency of PV systems is rather low due to its initial high manufacturing cost of solar module and its non-linear I-V characteristics under different atmospheric conditions. The conversion efficiency typically is in the range 12: 20%. Moreover the range of efficiency can be dropped further during varying solar irradiation, panel temperature and load conditions [24].

When the PV module is directly connected to a load, the operating point of the system will be at the intersection of the I-V curve of the PV module and the load line. The PV system efficiency can be increased by operating the PV module at its maximum power available and thus the operating costs can be reduced [25].

In most conditions, the operating point doesn't locate at the Maximum Power Point (MPP) of the PV array. To overcome this problem, there are many MPPT methods can be used to maintain the operating point of the PV array at the MPP [26].

> It can be achieved by using a dc-dc converter, located between the PV array and the load. This converter changes the operating point of the PV array till reaches to the MPP. The different MPPT methods aim is to produce a suitable duty cycle pulse to the dc-dc converter to move the operating point towards the MPP. Thus, the value of the load seen by the PV array will be almost equal to the optimum load (R_{opt}) under the operating atmospheric conditions.

Chapter II

The MPPT Methods Control

Chapter II : The MPPT Control

II.1 Introduction

The photovoltaic cell has a maximum power point (PPM) which varies according to sunshine and temperature. This is achieved through the MPPT commands, "Maximum Power Point Tracking" analogue or digital. A significant number of MPPT control systems have been developed for years, starting with techniques simple as voltage or current.

Currently, of the orders MPPT, analogue and digital, are proposed. Inthe case of the orders MPPT analogue, to laid the problem of the divergence of the size of the electronic components used. In the case of MPPT commands numerical, several algorithms have been used in the literature, namely: the method of Disturbance and Observation "P and O' traditional, the method of fuzzy logic (Fuzzy Logic Control), the one based of the networks of neurons (Neural Network) and the method of sliding mode [35].

II.2 Perturb and Observe Control Algorithm

Because of its simplicity and ease of implementation, the Perturb and Observe (PO) algorithm is one of the most often used. The Hill Climbing (HC) algorithm is another name for this MPPT approach. The distinction between PO and HC is that the HC requires a change in the converter duty cycle, whilst the PO disturbs the PV panel's operational voltage; nonetheless, the basic principle is the same for both [38].

II.2.1 Working Principle

PO works by incrementally perturbing the panel operating voltage on a regular basis, allowing the power output to be recorded and compared over perturbing cycles. If the power difference is positive, the operational voltage is perturbed again with the same increase. The output power is measured once more. This agitating process continues until the power is restored. The distinction is negative. As a result, the direction of the operating voltage perturbation must be reversed. When As shown in Figure II-1, the operational point is positioned on the left side of MPP. The PO method works by boosting the voltage, resulting in a boost in power output When the operational point has been reached PO will work in the opposite way to the right of the MPP, PO will work in the opposite direction by decreasing the voltage; this results in an increase in power output. If a perturbation results in an increase of power $\frac{dP}{dV} > 0$, it means that the operational point is positioned quite close to the MPP The subsequent disturbance must be kept in mind.to bring the operational point closer to the MPP until the MPP is achieved in the same direction If, on the other hand, a perturbation results in a loss of power, $\frac{dP}{dV} < 0$, meaning that the operating point The direction of the perturbation must be reversed because the MPP has moved away from it. The PV panel's voltage is regulated by the PO algorithm to the MPP voltage. (*VMPP*). This MPP is tracked and updated to satisfy the mathematical equation of the power slope $\frac{dP}{dV} = 0$.

The slope $\frac{dP}{dV}$ can be calculated digitally by sampling the PV panel output current *I* and voltage *V*at previous and current time intervals (i-1) and (i),

as follows:
$$\frac{dP}{dV}(i) = \frac{P_{(i)} - P_{(i-1)}}{V_{(i)} - V_{(i-1)}} \quad \text{(II.1)}$$

In the above equation II.2, *P (i)* is the power product of voltage *V (i)* and current *I (i)*

measurements. The PO algorithm uses only two sensors to measure the operating voltage V and current I of the panel [38-39]. Table II-1 provides a summary of this approach.

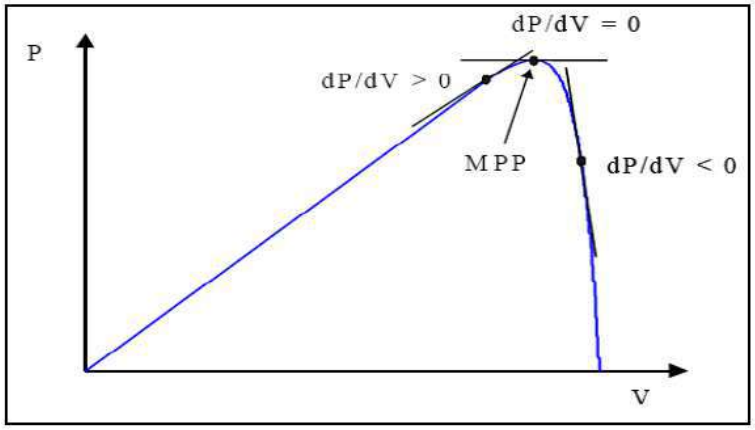


Fig II 1: *Characteristics of the PV panel power curve (With the location of the operating point)*

Table II 1: Summary of the working principle of the PO algorithm

Case	Perturbation dV	Change in power dP	Next Perturbation (Action)
1	$dV > 0$	$dP > 0$	positive
2	$dV > 0$	$dP < 0$	negative
3	$dV < 0$	$dP > 0$	negative
4	$dV < 0$	$dP < 0$	positive

The flowchart in Figure II-2 can help you understand the details of the PO method. Case 4 demonstrates that decreasing the operating voltage reduces output power; thus, the next required action must be positive, i.e., increasing the voltage.

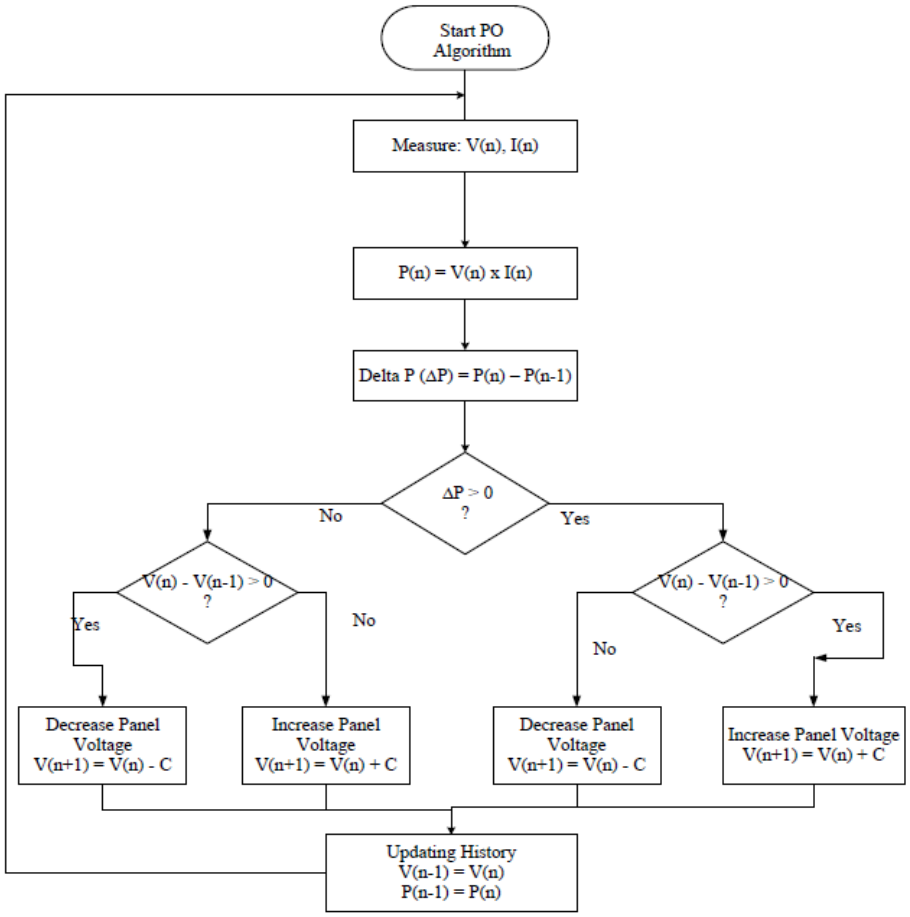


Fig II 2*: Flowchart of the PO algorithm[II,3]*

The power is estimated sequentially at past and current states using voltage and current data, according to the PO algorithm. A test is then carried out to determine the level of fluctuation in power and voltage throughout a series of perturbing cycles. If the difference between power and voltage is positive, the algorithm raises the operational voltage. If this is not the case, the voltage is reduced. If the difference between the power and voltage is negative, the algorithm raises the voltage; otherwise, it lowers the operational voltage.

II.2.2 Analysis of the PO algorithm

The uniqueness of this algorithm lies in the fact that in order to track the MPP, the operational voltage V must be disrupted in each MPPT cycle. It will continue to oscillate around the ideal reference voltage VMPP once the MPP is obtained. This causes the system to oscillate about the MPP, resulting in power loss, which is proportional to the step width of a constant disturbance. In the event that the fixed step increment selected is large, the PO algorithm will speed up its response under transient greater variations in operational circumstances as a trade-off The oscillations can be reduced by reducing the perturbation step size, which minimizes power losses. However, when the system is subjected to fast changes in weather conditions, this causes the system to slow down, reducing its dynamic performance. A tiny constant step perturbation size impeded dynamic performance, but a large one resulted in poor steady-state performance. At steady state, there is always a trade-off between high precision (low power fluctuation) and quick response due to dynamic changes in atmospheric conditions. As discussed by Xiao [38], the value of the optimal step width of the perturbation is a function of the system utilized and is usually tuned

experimentally. Moreover, the PO control algorithm may go in the wrong direction and fail to react properly when subjected to sudden changes in environmental parameters. In this specific condition, The PO algorithm is unable to accurately understand the increase in power, which could be caused by a previous voltage disturbance or a rise in insolation.

II.2.3 The benefits of the PO method are as follows:

It is simple and easy to implement.

It is cheap, requiring only panel voltage and current measurements.

It is effective when the insolation changes slowly over time.

II.2.4 The drawbacks of PO method are as follows:

Although the MPP is reached, the operating point continues to oscillate around the MPP, resulting in PV power losses.

The PO fails to work properly under a sudden increase in insolation level, exhibiting erratic behavior.

It lacks accuracy in finding whether the MPP is reached. A small constant step perturbation size leads to high accuracy but hampers dynamic performance. A large constant step perturbation size leads to fast tracking, but the accuracy of the tracking suffers (poor steady-state performance).

It, then fails to react in order to avoid the operating point going away from the MPP as explained by Hohm [36].

II.3 Fuzzy logic controller

II.3.1 Working Principle

Fuzzy Logic's performance in MPPT applications has also been documented in the literature [41], [42], [43], [44], . Figure II.10 shows the block diagram that explains how this strategy works. The PV panel voltage and current are monitored and supplied to the digital controller, which calculates the input power, as shown in Figure II.3. The FLC's inputs are next**.** Which are typically the Error Er = $\Delta P/\Delta V$ or $\Delta P/\Delta I$ and the change in Error (CEr), are calculated. The fuzzy system takes Er and CEr as inputs and outputs the duty cycle D. Fuzzy logic controller (FLC) based MPPT systems have a higher efficiency compared to NN based controllers [44]. Moreover, FLC based systems perform well under varying atmospheric conditions [42]. However, their effectiveness highly depends on the experience of the control engineer in choosing the right inputs and tuning the rule base table [42-43- 44].Several approaches for improving FLC performance have been proposed in the literature, including the use of non-uniform membership functions (denser at the center to give better sensitivity to variations in the PV terminal voltage) [44].Another approach is to employ adaptive fuzzy logic controls, which constantly tune the membership functions and rule base table to get the best possible performance [44]. PI controllers [45], adaptive tuning factors [43-44], genetic algorithms, variable universe controllers and self-organizing controllers [44] are some of these adaptive fuzzy techniques.

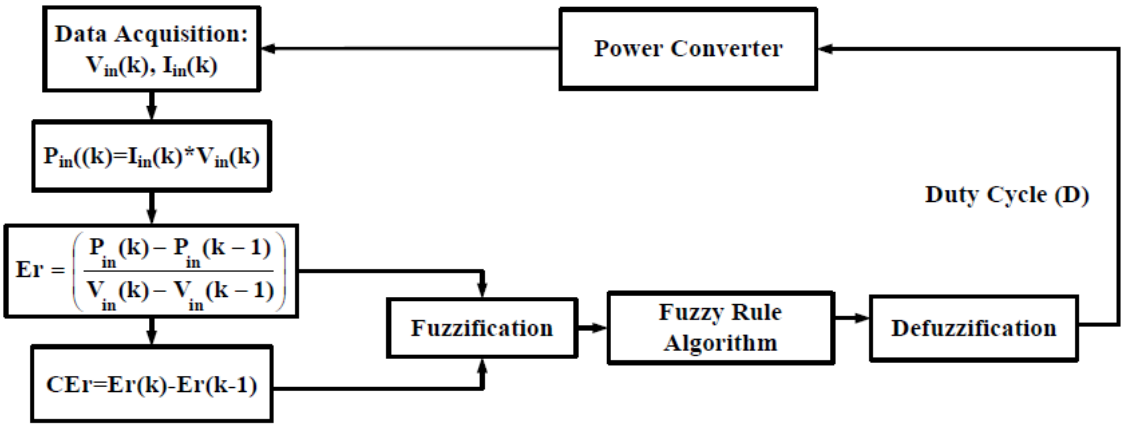


Fig II 3: *Fuzzy logic control generally consists of three stages*

Fuzzification, Rule Base Table Lookup, and Defuzzification. During fuzzification, the numerical input variables are converted into linguistic variables based on a membership function as in Fig (II.4) [48].

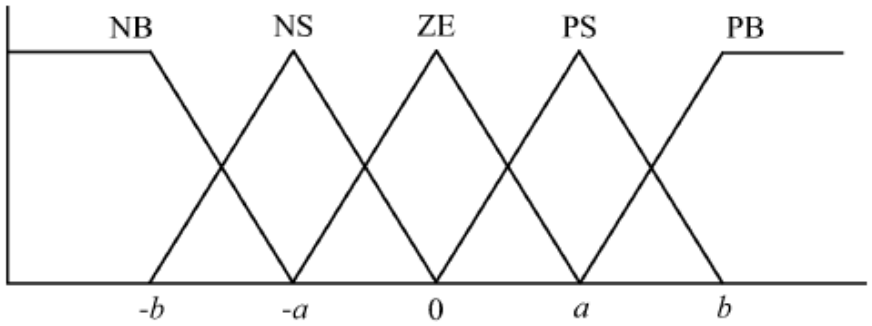


Fig II 4 : *Membership Function for an Input Variable of a Fuzzy Logic Controller*

There are five fuzzy levels are usually used: NB (Negative Big), NS (Negative Small), ZE (Zero), PS (Positive Small), PB (Positive Big). Seven fuzzy levels are used, probably for more accuracy. In Fig (II.4), the values "a "and "b" are based on the range of the numerical input variables [46]. The membership function is sometimes made less symmetric to give more importance to specific fuzzy levels. The inputs to the MPPT fuzzy logic controller are usually an error signal (E) and a change in error (ΔE). The (E) and (ΔE) can be calculated as shown in equ. (II.7) and (II.8). E (n) = $(P\ n - P(n-1))/ (V\ n - V(n-1))$ (II.7) ΔE (n) = E(n) – E(n-1) (II.8) Where E (n) is the instantaneous error, ΔE (n) is the instantaneous change of error, p (n) is the instantaneous PV array's power, and v (n) is the instantaneous PV array's voltage. Once (E) and (ΔE) are calculated and converted to the linguistic variables, the Fuzzy Logic Controller gives a suitable change in the duty ratio (ΔD) for the power converter, based on the Rule Base Table as shown in Table (II.2).

Table II 2 Fuzzy Rule Base [10]

E \ ΔE	NB	NS	ZE	PS	PB
NB	ZE	ZE	NB	NB	NB
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS
PS	PS	PS	PS	ZE	ZE
PB	PB	PB	PB	ZE	ZE

The linguistic variables are assigned to (ΔD) for the different combinations of (E) and (ΔE) at different atmospheric conditions. The change in the duty ratio also depends on the power converter being used and also on the knowledge of the user. Fuzzy Rules are designed to achieve zero Error Signal (E=0) at the steady state of the MPP. The main idea of the rule is to bring operating point to the MPP by increasing or decreasing the duty ratio, depending on the position of the operating point from the MPP. If the operating point is deviated from the MPP, the duty ratio will be increased or decreased. [45][46] To get the output of inference, many methods are proposed by the researchers. There are some known methods such as Mamdani, Sugeno, Larsen, and so on. But the Mamdani's method is the most commonly used.

II.3.2 Why Use Fuzzy Logic?

There are many reasons.

1. Fuzzy logic is used to control the complex, and nonlinear systems without making analysis for these systems.
2. Fuzzy control enables engineers to implement the control technique by human operators to make ease of describing the systems [47].
3. Fuzzy logic is flexible with any given systems [48]. If any changes are happening in the system we do not need to start from the first step, but we can add some functions on top of it.
4. Fuzzy logic can be blended with conventional technique to simplify their implementation.

II.3.3 Applications of Fuzzy Logic

The Japanese used fuzzy logic in many applications, such as (subway train and water-treatment control), but in these years there are many more applications of fuzzy logic.

1. Fuzzy logic is used to control the Camcorder to make stabilization in image if there is any rock [48].
2. In washing machine, there is a soft and bad manner clothes, and there are different quantities of laundry. Control of washing cycle is based on these date.
3. Robotics controls, Refrigerators for temperature control.
4. Engine Control in the modern cars.
5. Other usages of fuzzy logic is in image processing, such as image identification, representation, and description.

II.4 Conclusion

Different order algorithms have been studied for the pursuit of the maximum point of power in order to increase the efficiency of PV systems. The teaching of common approaches such as disturbance and observation was the first step in this project. As a result, two artificial intelligence techniques, fuzzy logic, was used.

Chapter III

The DC-DC Converters

CHAPETR III: DC-DC converters

III.1 Introduction

III.1.1 definition:

Power for the boost converter can come from any suitable DC source, such as batteries, solar panels, rectifiers, and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power ({\display style P=VI}) must be conserved, the output current is lower than the source current.

III.1.2 History:

For high efficiency, the switched-mode power supply (SMPS) switch must turn on and off quickly and have low losses. The advent of a commercial semiconductor switch in the 1950s represented a major milestone that made SMPSs such as the boost converter possible. The major DC to DC converters were developed in the early 1960s when semiconductor switches had become available. The aerospace industry's need for small, lightweight, and efficient power converters led to the converter's rapid development. Switched systems such as SMPS are a challenge to design since their models depend on whether a switch is opened or closed. R. D. Middlebrook from Caltech in 1977 published the models for DC to DC converters used today. Middlebrook averaged the circuit configurations for each switch state in a technique called state-space averaging. This simplification reduced two systems into one. The new model led to insightful design equations which helped the growth of SMPS.

III.2 Boost converter (choppers)

III.2.1 What is the boost converter?

DC-DC converters are also known as Choppers. Here we will have a look at the Step Up Chopper or Boost converter which increases the input DC voltage to a specified DC output voltage. A typical Boost converter is shown below.

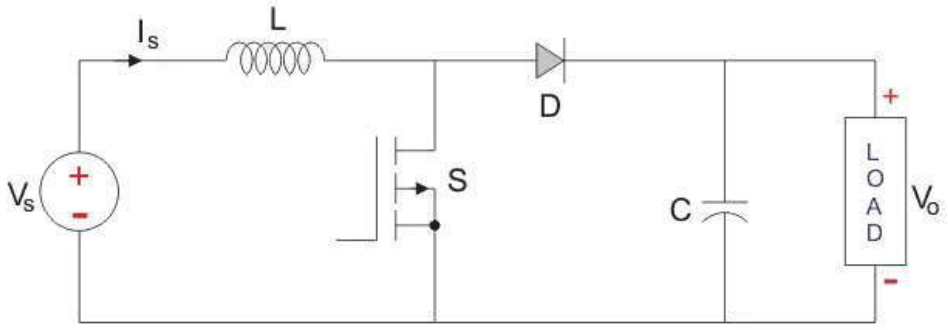


Fig III 1 Boost converter

The input voltage source is connected to an inductor. The solid-state device which operates as a switch is connected across the source. The second switch used is a diode. The diode is connected to a capacitor, and the load and the two are connected in parallel as shown in the figure above.

The inductor connected to input source leads to a constant input current, and thus the Boost converter is seen as the constant current input source. And the load can be seen as a constant voltage source. The controlled switch is turned on and off by using Pulse Width Modulation(PWM). PWM can be time-based or frequency based. Frequency-based modulation has disadvantages like a wide range of frequencies to achieve the desired control of the switch which in turn will give the desired output voltage.

III.2.2 How its work

Time-based Modulation is mostly used for DC-DC converters. It is simple to construct and use. The frequency remains constant in this type of PWM modulation. The Boost converter has two modes of operation. The first mode is when the switch is on and conducting.

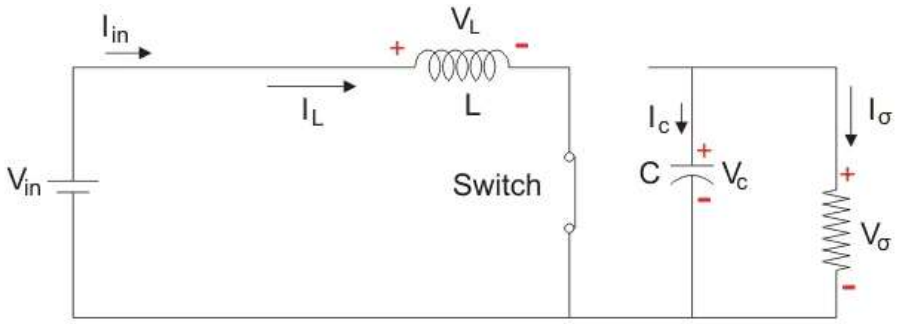


Fig III 2 *Mode I : Switch is ON, Diode is OFF*

III.2.2.1 phase(1): the switch is on

The Switch is ON and therefore represents a short circuit ideally offering zero resistance to the flow of current so when the switch is ON all the current will flow through the switch and back to the DC input source. Let us say the switch is on for a time TON and is off for a time TOFF. We define the time period,

$$T = TON + TOFF, \quad \text{(III.1)}$$

as and the switching frequency,

$$f_{switching=\frac{1}{T}} \quad \text{(III.2)}$$

Let us now define another term, the duty cycle,

$$D = \frac{T_{on}}{T} \quad \text{(III.3)}$$

Let us analyze the Boost converter in steady state operation for this mode using KVL.

$$V_{in} = V_L \quad \text{(III.4)}$$

$$V_L = L\frac{di_L}{dt} = V_{in} \quad \text{(III.5)}$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_{in}}{L} \quad \text{(III.6)}$$

Since the switch is closed for a time $T_{ON} = D_T$ we can say that $\Delta t = DT$

$$(\Delta i_L)close = \left(\frac{V_{in}}{L}\right) DT \quad \text{(III.7)}$$

While performing the analysis of the Boost converter, we have to keep in mind that :

1. The inductor current is continuous and this is made possible by selecting an appropriate value of L.
2. The inductor current in steady state rises from a value with a positive slope to a maximum value during the ON state and then drops back down to the initial value with a negative slope. Therefore the net change of the inductor current over anyone complete cycle is zero.

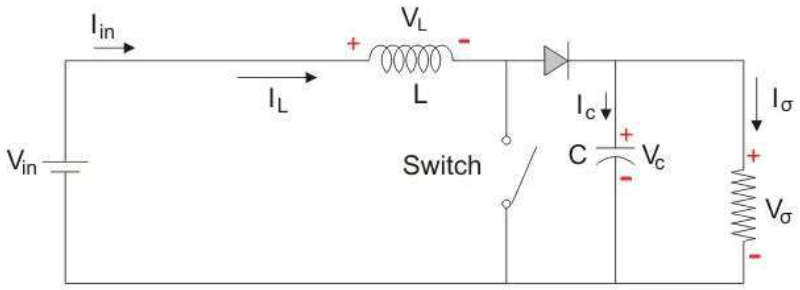


Fig III 3 *Mode II : Switch is OFF, Diode is ON*

III.2.2.2 phase (2): switch is off:

In this mode, the polarity of the inductor is reversed. The energy stored in the inductor is released and is ultimately dissipated in the load resistance, and this helps to maintain the flow of current in the same direction through the load and also step-up the output voltage as the inductor is now also acting as a source in conjunction with the input source. But for analysis, we keep the original conventions to analyze the circuit using KVL, Let us now analyses the "Boost converter" in steady state operation for Mode II using KVL.

$$V_{in} = V_L + V_0 \quad \text{(III.8)}$$

$$V_L = L\frac{di_L}{dt} = V_{in} - V_0 \quad \text{(III.9)}$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{V_{in}-V_0}{L} \quad \text{(III.10)}$$

Since the switch is open for a time :

$$T_{off} = T\text{-}T_{on} = T - DT = (1-D)T \quad \text{(III.11)}$$

we can say that

$$\Delta t = (1-D)T \quad \text{(III.12)}$$

$$(\Delta i_L)open = \left(\frac{V_{in}-V_0}{L}\right)(1D)T \quad \text{(III.13)}$$

It is already established that the net change of the inductor current over any one complete cycle is zero.

$$(\Delta i_L)closed + (\Delta i_L)open = 0 \quad \text{(III.14)}$$

$$\left(\frac{V_{in}-V_0}{L}\right)(1-D)T + \left(\frac{-V_0}{L}\right)DT = 0 \quad \text{(III.15)}$$

$$\frac{V_0}{V_{in}} = \frac{1}{1-D} \quad \text{(III.16)}$$

We know that D varies between 0 and 1. But as we can see from the equation above that if D = 1 then the ratio of output voltage to input voltage at steady state goes to infinity, which is not physically possible. In fact as the Boost converter is a non-linear circuit, in a practical Boost converter the duty cycle, D, if kept at a value greater than 0.7 will lead to instability [54-55]

III.3 Flyback converter

III.3.1 What is a Flyback Converter

The flyback converter is a power supply topology that uses mutually coupled inductor, to store energy when current passes through and releasing the energy when the power is removed. The flyback converters are similar to the booster converters in architecture and performance. However, the primary winding of the transformer replaces inductor while the secondary provides the output. In the flyback configuration, the primary and secondary windings are utilized as two separate inductors.

III.3.2 Principle of operating of a flyback converter

When the current flowing through an inductor is cut off, the energy stored in the magnetic field is released by a sudden reversal of the terminal voltage. If a diode is in place to conduct the stored energy somewhere useful, the diode is called a flyback diode. This only requires one winding on the inductor, so the inductor would be called a flyback transformer. This arrangement has the interesting property of transferring energy to the secondary side of the power supply only when the primary switch is off [56].

The basic flyback converter uses a relatively small number of components. A switching device chops the input DC voltage and the energy in the primary is transferred to the secondary through the switching transformer. A diode in the secondary rectifies the voltage while the capacitor smoothed the rectified voltage. In a practical circuit, a feedback circuit is used to monitor the output voltage and while a control circuit switching device [56].

III.3.3 Operation of a PWM flyback converter in continuous mode

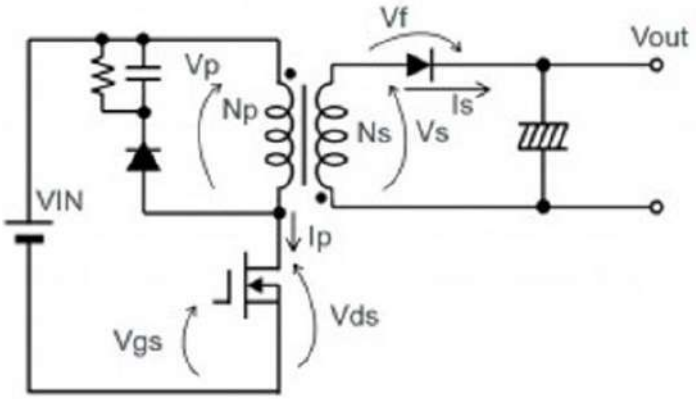


Fig III 4 *Basic circuit of a flyback converter*

In a typical application, a switching device such as a transistor is turned on and off usually by a pulse-width-modulated signal. The transformer polarity is usually reversed such that when the transistor is on, current flows in the primary winding, however, the secondary diode is reverse biased and current does not flow in this winding. The energy is stored in the transformer until when the MOSFET is turned off. The stored energy produces a current that forward biases the diode which rectifies it to produce a DC output.

III.3.4 How does a flyback controller work ?

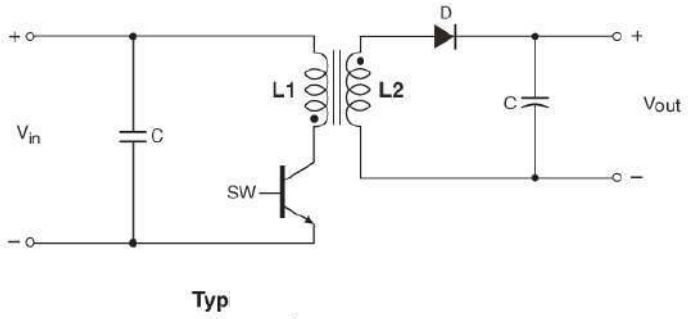


Fig III 5 *flyback schematic*

The flyback topology is based on a buck-boost topology, with the transformer providing isolation and, if needed, voltage transformation by turns ratio. The schematic shown in Figure III.5 represents a typical flyback circuit. The most commonly used switch (SW) in a flyback converter is a MOSFET Metal Oxide Semiconductor Field Effect Transistor), but occasionally a bipolar transistor and sometimes GaN (gallium nitride) or SiC (silicon carbide) are used [57]. The flyback controller opens and closes the switch with the appropriate duty cycle to achieve the required output voltage. The duty cycle of flyback transformers typically does not exceed Various combinations of turns ratios and duty cycles can be used to achieve the required output voltage according to this equation:

$$V_{out} = V_{in}*(N_s/N_p)*(D/(1-D)) \quad \text{(III.17)}$$

where:

V_{out} is the output voltage ;

V_{in} is the input voltage ;

N_s = secondary turns ;

N_p = primary turns.

$$D = \text{duty cycle} = t_{on}/(t_{on} + t_{off}) \quad \text{(III.18)}$$

III.3.4 The basic flyback cycle includes the following portions:

1. When the FET (Field Effect Transistor) SW is closed (ON), current is conducted through the transformer primary. This sets up a magnetic field in which energy is stored in the core. The combination of winding polarity (identified by the polarity dots) reverse biases the output diode to ensure that no energy is transferred to the secondary (load) when the switch is closed. During this portion of the cycle, current in the primary is ramping up over time to store energy (= $½LI^2$).

2. When the FET is opened (OFF) the magnetic field collapses, transferring the stored energy to the secondary winding and, ultimately the load. At the close of the switch, current in the secondary is at its peak and ramps downward as the stored energy is transferred to the load.

If the FET is turned back on before all of the flyback energy is transferred to the secondary, the secondary current never reaches zero. This is referred to as continuous conduction mode (CCM). An example of a CCM waveform is shown in the **Figure 2**. If the stored flyback energy is completely emptied to the secondary before the FET is turned back on, the secondary current reaches zero before the end of the period, creating an "idle time" (t_{idle}) during the cycle. This is called discontinuous conduction mode (DCM). An example of a DCM waveform is shown in the **Figure III.**6 Transformers may be designed for CCM, DCM, or both. Flyback transformers may operate in both CCM and DCM modes, depending on the input voltage and load conditions.

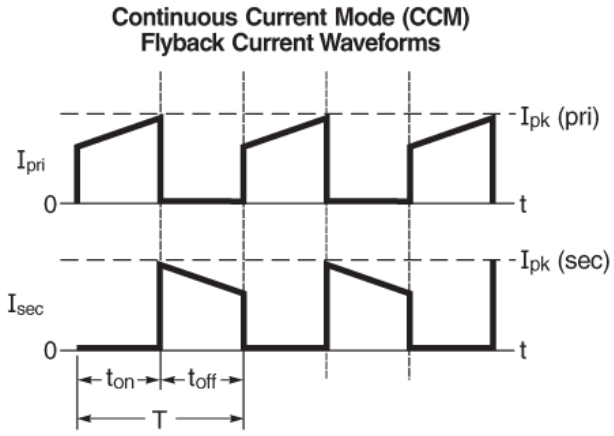


Fig III 6 ***Continous Current mode (CCM) Flyback Current Waveforms***

When designing a flyback transformer, the worst-case condition of maximum load at the minimum input voltage creates the highest (peak) primary current requirement. Select a transformer that has a peak primary current (I_{pk}) or primary saturation current (I_{sat}) that is well above the expected primary current peak for your application. If the application's peak primary current draw exceeds the transformer rating, core saturation will cause the primary inductance to drop. If the load requires more energy at this point, the energy storage capability of the transformer will be exceeded and the load will not receive the required energy. This will lead to loss of regulation, therefore the peak primary current (I_{pk}) or primary saturation current (I_{sat}) of a flyback transformer is a critical parameter [56].

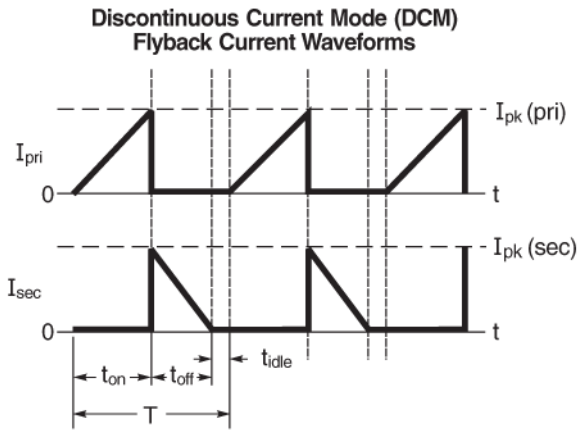


Fig III 7 ***Discontinous Current mode (DCM) Flyback Current Waveforms***

III.3.5 The flyback converter advantages

- The primary is isolated from the output.
- Capable of supplying multiple output voltages, all isolated from the primary.
- Ability to regulate the multiple output voltages with a single control.
- Can operate on a wide range of input voltages.
- The Flyback converters use very few components compared to the other types of SMPSs.

III.3.6 The flyback transformers

- The flyback transformer is more like two coupled inductors and therefore different from the conventional transformer. The flyback is designed to store energy while the conventional doesn't. In addition, it operates at high frequencies of about 50 kHz. Its core is usually made of ferrite and includes a non-magnetic air gap across which the energy is stored. The conventional transformer is made of an iron core.
- For the transformer to store energy during the period the current is flowing in the primary and later transfer the energy to the secondary winding when the switching device is off, the two inductor coils must be magnetically coupled.

III.3.7 Considerations when design the flyback

- The turn's ratio influences the peak primary and secondary currents as well as the duty cycle. For example, when the turns ratio is low, the duty cycle is shorter and the current in the primary winding will increase.
- The transformers are usually custom made since it is not possible to get perfect turns ratio in the market. When it is difficult to obtain a perfect transformer with the required transformer turns ratio, the best thing is to start by looking for the available transformers and choose what is closer to the desired ratings. This is then followed by choosing the other components in a way to compensate the slight difference that the transformer may introduce between say the required voltage and the transformer output.

III.3.8 The applications of flyback

The flyback converter are used for a wide range of electronics applications such as:

- Television sets which consume small amount of power of up to about 250W;
- Standby power supplies for computers;
- Cell phone and mobile device chargers;
- High-voltage supplies in TV and Monitor CRTs, Lasers, Xenon flashlights, copiers, etc. [57].

III.4 Conclusion

In the end we can say the flyback is good enough to be more popular because of its advantages.

Chapter IV

The simulation and Results

CHAPTER IV : THE SIMULATON AND RESULTS

IV.1. Introduction

Impedance matching between a photovoltaic generator (GPV) and a load is a technical problem which essentially means transferring the maximum power from the photovoltaic generator to the load. The latter is controlled by different MPPT techniques allowing a better source/load adaptation with the standard conditions (T =25° C and irradiation =1000 W)

In this chapter we develop 2 techniques of MPPT namely:

- MPPT perturb and observe (P&O) control algorithm;
- Fuzzy logic (FL) control algorithm;

IV. 2. Simulation of the photovoltaic system by the two MPPT commands (P&O, FL)

Now let's analyze or take it step by step:

IV.2.1. the PV panel:

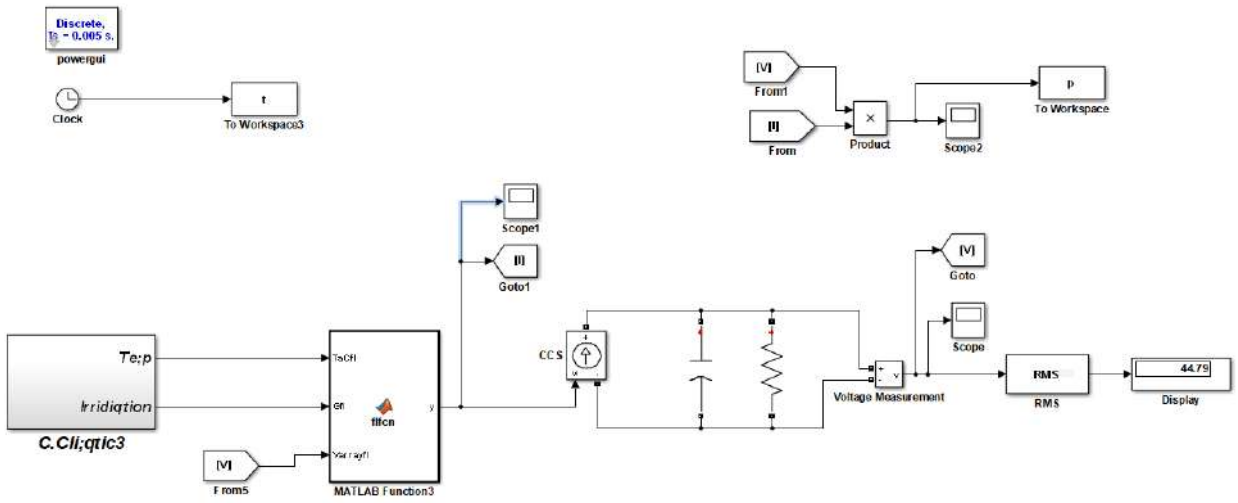


***Fig IV 1** : PV panel by Simulink matlab*

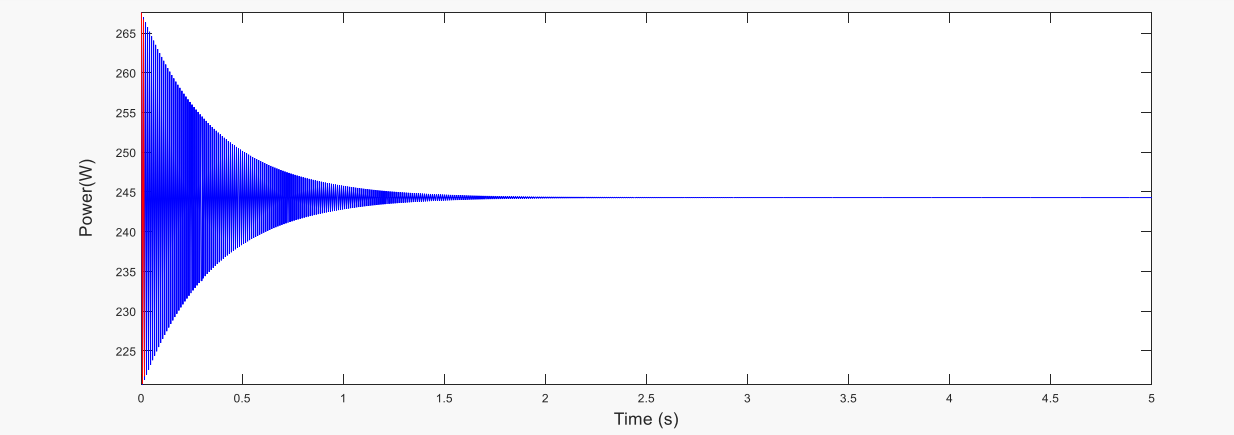


Fig IV 2 *power with time*

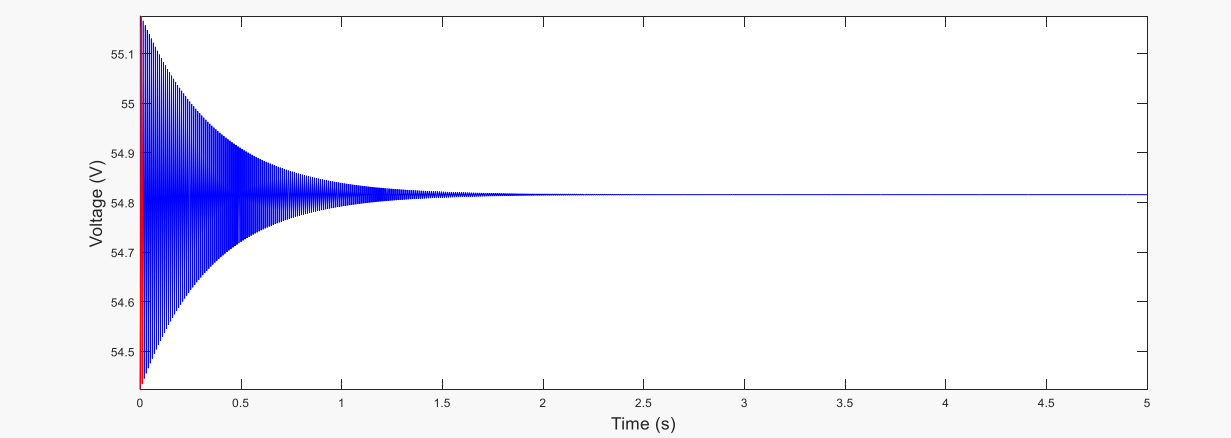


Fig IV 3 *Voltage with time*

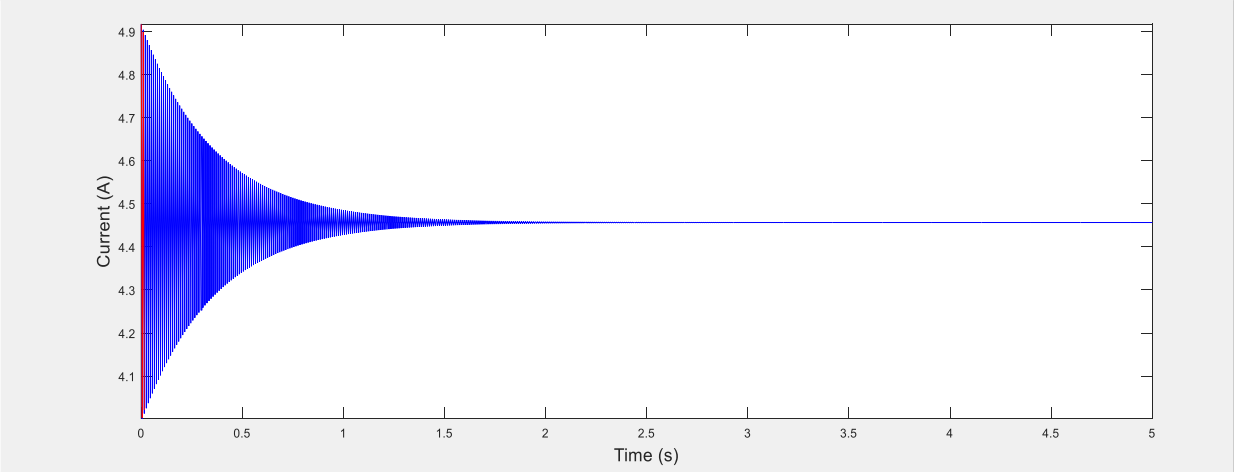


Fig IV 4 *Current with time*

As we sow previously the sun give as a 1000 W of radiation but the PV panel he could give us 245(w) just so we have to use the mppt methods and flyback converter to make it better.

IV.2.2 flyback converter

The main rezone we use it was to multiply the voltage

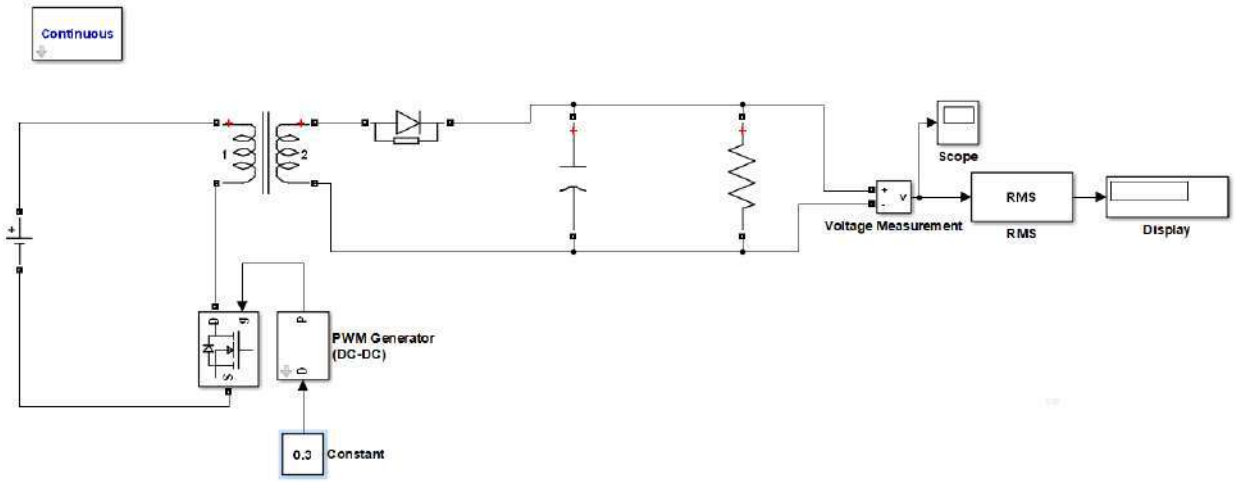


***Fig IV 5** flyback converter*

IV.2.3 PV panel with flyback

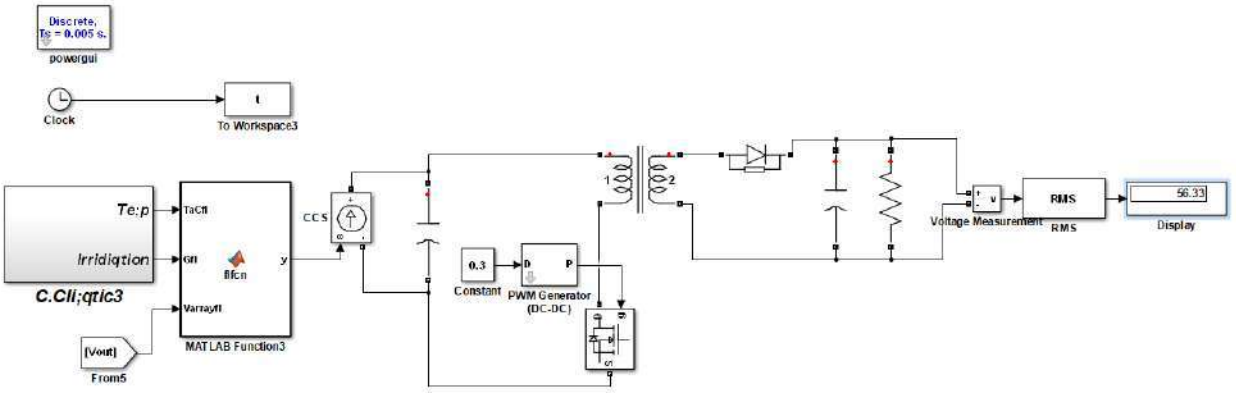


***Fig IV 6** panel with a flyback*

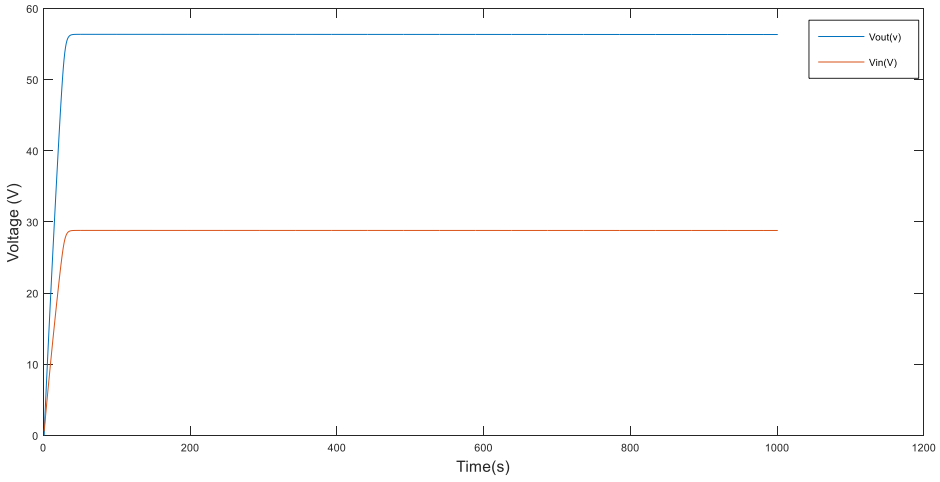


***Fig IV 7** a comparative between Vin & Vout (before and after flyback)*

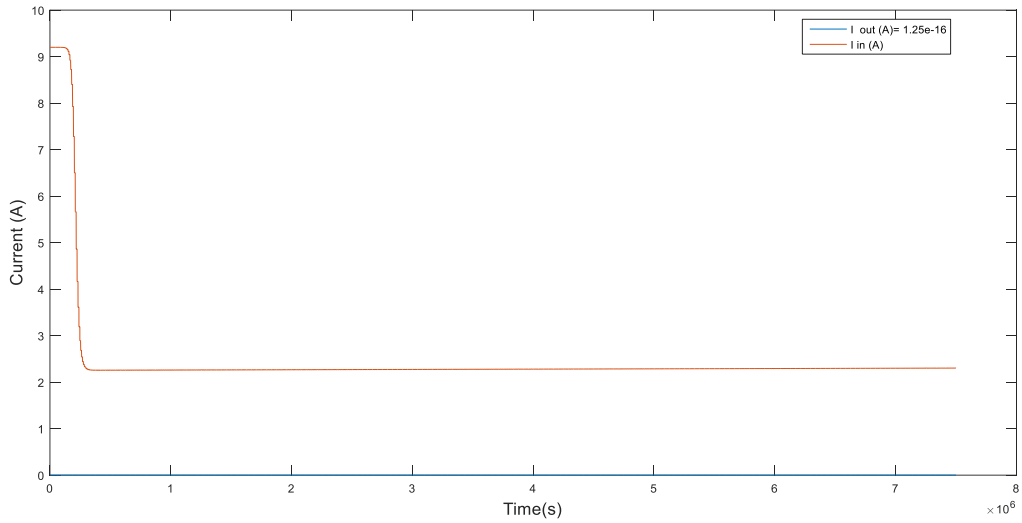


Fig IV 8 a comparative between Iin & Iout (before and after flyback)

IV.2.4 PV panel with flyback and mppt

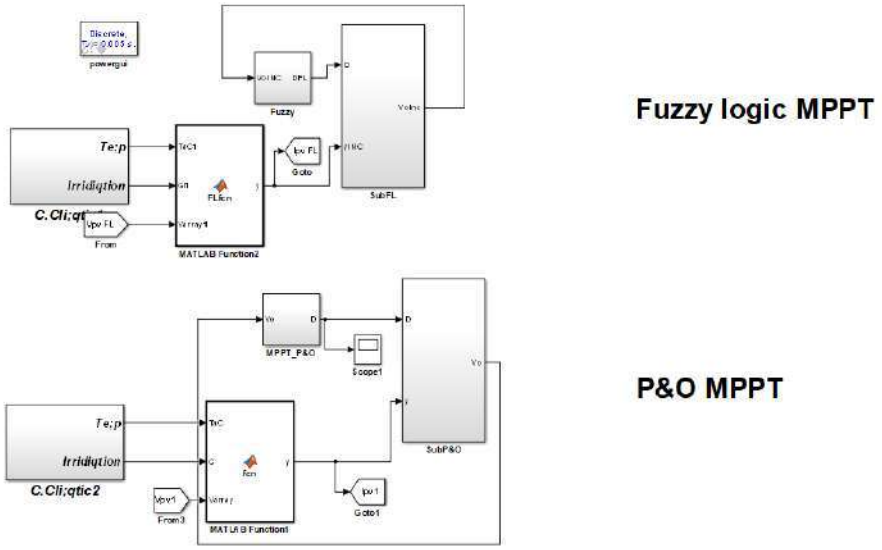


Fig IV 9 A solar panel with flyback with two different methods of mppt (Fuzzy logic and P&O)

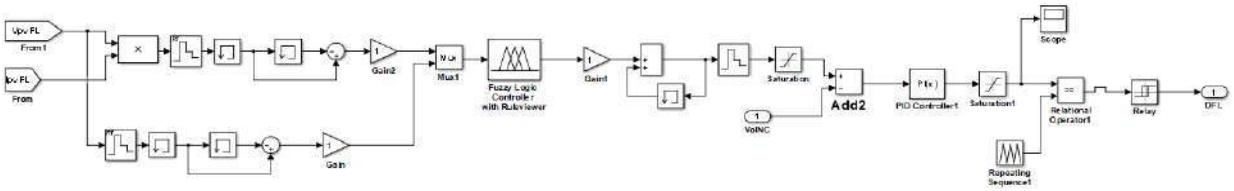


Fig IV 10 block diagram for fuzzy logic

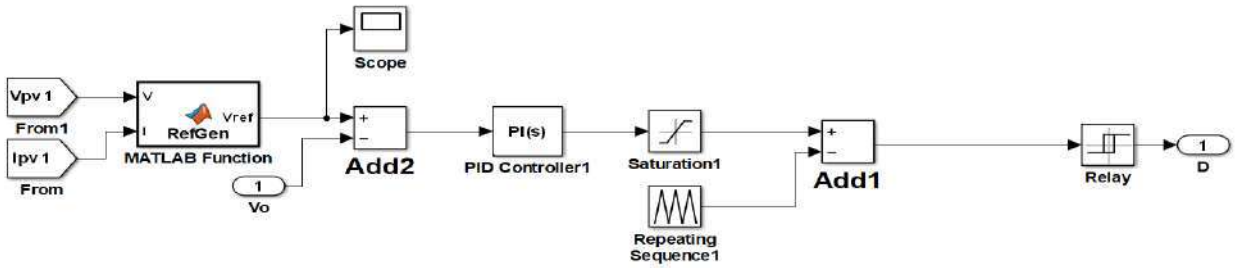


Fig IV 11 block diagram for P&O

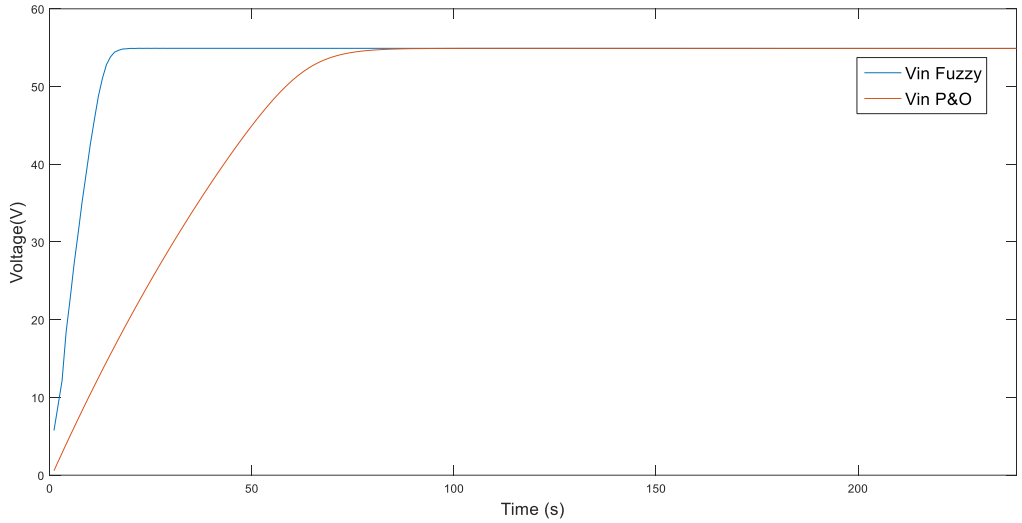


Fig IV 12 a comparative study for voltage of FL and P&O before flyback

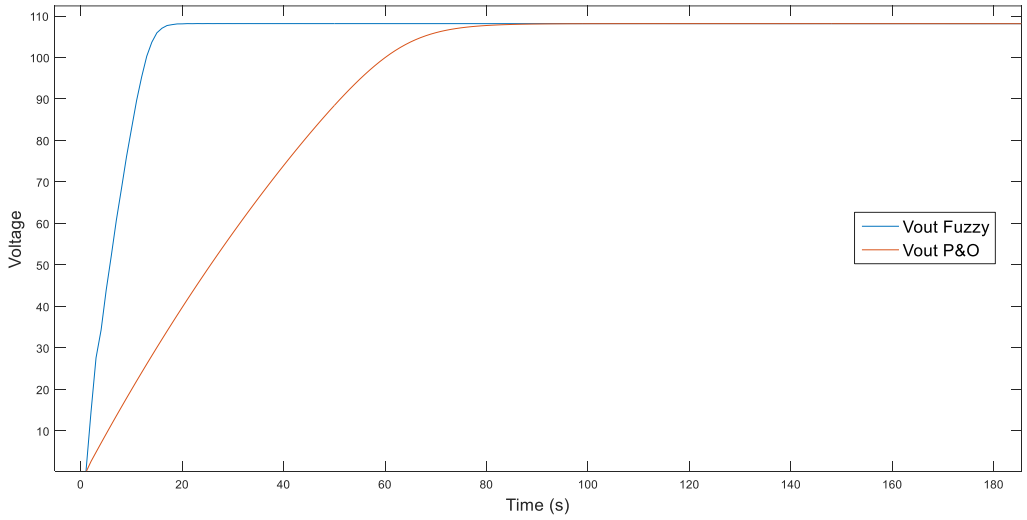


Fig IV 13 a comparative study for voltage of FL and P&O after flyback

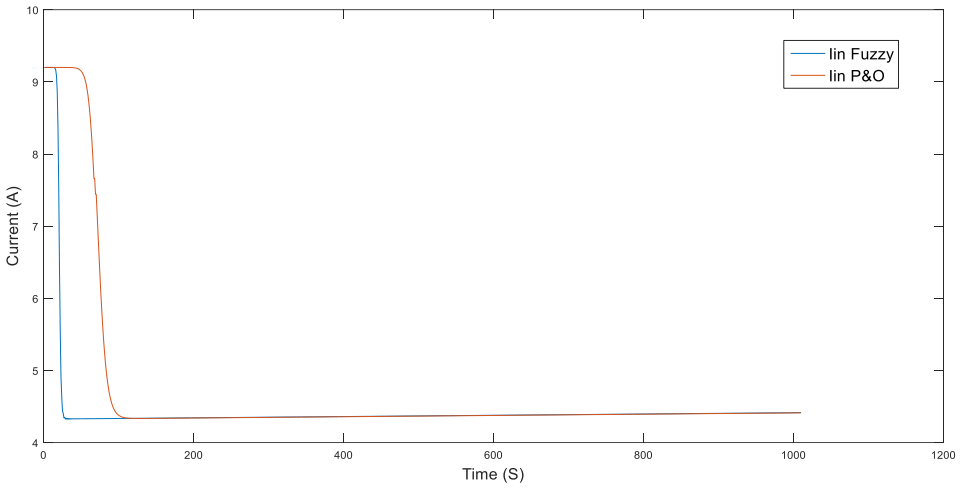


Fig IV 14 a comparative study for current of FL and P&O before flyback

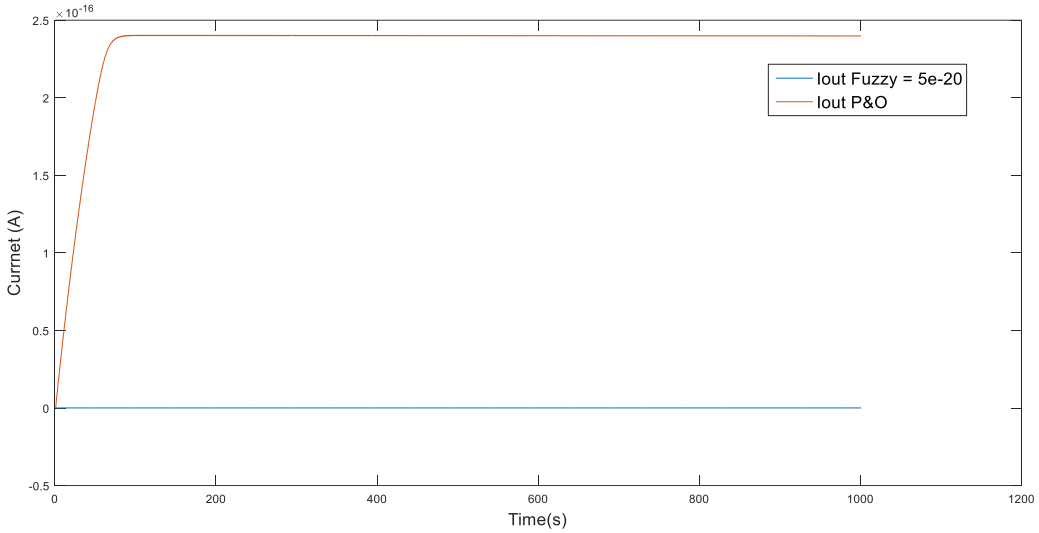


Fig IV 15 a comparative study for current of FL and P&O after flyback

The following table summarizes the main specifications of the different MPPT algorithms previously studied. We evaluated and compared these algorithms in terms of reaction speed (transient regime) and stability accuracy (steady state).

Table IV 1 . Comparison of MPPT techniques

Orders / Order states	P&O	FL
Response time (s)	12.85	2.87
Stabilities	Very oscillating	Very good

IV.3. What we notice

The P&O algorithm is a classic and simple algorithm. In general, this algorithm strongly depends on the initial conditions and it exhibits oscillations around the optimal value. The major drawback of this algorithm is its poor behavior following a sudden change in illumination (clouds for example).

The algorithm based on fuzzy logic is a robust and efficient algorithm. Indeed, this algorithm works at the optimal point without oscillations. Moreover, it is characterized by a good behavior in transient state. However, the implementation of this type of algorithm is more complex than the classical algorithms. Moreover, the efficiency of this algorithm is highly dependent on the inference table.

IV.4 CONCLUSION

In this chapter, we simulated the two MPPT algorithms (P&O and FL).

The simulation results show that the algorithm of 'P&O' at the level of classical controllers. the control based on fuzzy logic show good behavior and better performance compared to other methods.

The results of the simulation showed the efficiency of the algorithm developed to calculate the model of The parameters and the possibility of displaying the electrical behavior of the panel PV according to the irradiance And the temperature. The algorithm P&O depends strongly on initial conditions and it presents oscillations around the optimal value. The major inconvenience of this algorithm is its bad behavior further to an abrupt change of the illumination. Indeed, the algorithm Fuzzy seems an improvement of the algorithm P&O, it behaves better during a fast change of the weather conditions. However, it is more complex algorithm than the precedent. Among all these algorithms, the P&O is widely used, but the command based on the fuzzy logic shows a good behavior and the best performances with regard to the other methods.

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General Conclusion

General Conclusion

This work has as objective paramount improvement from yield of one system photovoltaic power supply. Thanks to the presence of a tracking process of the point of maximum power, known as MPPT controller, the latter is indispensable for a better adaptation source/load, allowing of produce the maximum power.

In a first time, we has given of the general on them systems PV.

Second, we modeled the photovoltaic system (PV panel, and choppers).

In the third step, we presented the MPPT methods based on the counter reaction of Powerful, as the method of Disturbance and Observation. it's are studied because of their simplicity, and they require only the PV panel voltage and current measurements. Then, we recalled the principle ofone other MPPT algorithms, fuzzy logic, which are based on the principle of artificial intelligence.

The last stage was based on the simulation under MATLAB/Simulink of the four methods modeled on the chapter previous.

We can tell from the results of the simulation obtained that:

- The performance of a PV generator is strongly influenced by the conditions climatic, especially irradiation solar and the temperature.
- Among all these algorithms, the 'P&O' is widely used, but the control based on fuzzy logic shows good behaviour and best performance compared to other methods.
- MPPT control either classic (P&O) or intelligent (FL) allows the best connection between the photovoltaic generator (GPV) and the load. She forces it to always run at the maximum power point, however, the comparative study of simulation results has shown that the command Fuzzy MPPT lead to better performance.

References

References:

1. Applebaum, J. (1981). Performance Analysis of D.C. Motor Photovoltaic Converter System II, *Solar Energy*, vol 27, no. 5, pp. 421–431
2. *Renewable and Efficient Electric Power Systems*. By Gilbert M. Masters ISBN 0-471-28060-7 2004 John Wiley & Sons, Inc.
3. Chang, A. (2000). *Residential Systems Summary Report: Analysis of TEAM-UP Residential Installations*, Utility Photovoltaic Group, Washington, D.C.
4. Patel, M. R. (1999). *Wind and Solar Power Systems*, CRC Press, Boca Raton, FL.
5. Real Goods Trading Corporation (2002). *Solar Living Source Book*, Ukiah, CA.
6. Roger, J. A. (1979). Theory of the Direct Coupling Between D. C. Motors and Photovoltaic Solar Arrays, *Solar Energy*, vol 23, pp 193–198.
7. Rosen, K., and A. Meier (1999). *Energy Use of Televisions and Videocasette Recorders in the U.S.*, Lawrence Berkeley National Labs, LBNL-42393.
8. Rosen, K., and A. Meier (2000). *Energy Use of U.S. Consumer Electronics At the End of the 20th Century*, Lawrence Berkeley National Labs, LBNL-46212.
9. T. H. Kuen et al. (1998):
10. Sandia National Laboratories (1991). *Maintenance and Operation of Stand-Alone Photovoltaic Systems*, U.S. Department of Energy, Albuquerque, NM.
11. Sandia National Laboratories (1995). Stand-Alone. *Photovoltaic Systems Handbook of Recommended Design Practices*, U.S. Department of Energy, Albuquerque, NM.
12. Scheuermann, K., D. R. Boleyn, P. N. Lilly, and S. Miller (2002). Measured Output for nineteen residential PV systems: Updated analysis of actual system Performance and net metering impacts, *Proceedings of the 31st American Solar Energy Society Annual Conference*, Reno, NV.
13. Thomas, M. G. (1987), *Water Pumping, the Solar Alternative*, Sandia National Laboratories,SAND87-0804, Albuquerque, NM.
14. Wiles, J. (2001). *Photovoltaic Power Systems and the National Electrical Code: Suggested*
15. *Practices*, Sandia National Laboratories, SAND2001-0674, Albuquerque, NM.
16. http://www.ecowho.com/tools/solar_power_calculator.php
17. H.L. Tsai, C.S. Tu, Y.J. Su, Development of generalized PV model using Matlab/Simulink, in Proceedings of the World Congress on Engineering and Computer Science, San Francisco, USA (2008), pp. 846–854
18. J.A. Gow, C.D. Manning, Development of a PV array model for use in power-electronics simulation studies. IEE Proc. Electr. Power Appl. 146(2), 193–200 (1999)
19. I.-S. Kim, M.-J. Youn, Variable-structure observer for solar array current estimation in a PV power-generation system. IEE Proc. Electr. Power Appl. 152(4), 953–959 (2005)
20. L.L. Peng, Y.Z. Sun, C. Meng, Y.J. Chen, Generalized PV array module using Matlab/Simulink. J. Donghua Univ. 37(1), 90–94 (2009)

21. B.Y. Liu, S.X. Duan, Y. Kang, Analysis and suppression of the second power disturbance in single-phase single-stage PV grid-connected generation system. Acta Energ. Sol. Sin. 29(4), 407–411 (2008)

22. J.H. Su, S.J. Yu, W. Zhao et al., Investigation on engineering analytical model of silicon solar cells. Acta Energ. Sol. Sin. 22(4), 409–412 (2008)

23. Z.H. Chen, M.R. Zhao, L. Ge et al., The simplification of mathematic model of silicon solar cell. J. Shanghai Univ. Electr. Power 22(2), 178–180 (2006)

24. C. Carrero, J. Rodriguez, D. Ramírez et al., Simple estimation of PV modules loss resistances for low error modeling. Renew. Energy 35(5), 1103–1108 (2009)

25. J.P. Charles, M. Zaghdoudi, P. Mialhe et al., An analytical model for solar cells. Sol. Cells 3(1), 45–56 (1981)

26. Y.Y. Sun, H.F. Xiao, S.J. Xie, Parameters solution and verification of solar cells' simplified model. Power Electron. 43(6), 44–46 (2009)

27. B. Geng, Z.Y. Gao, H.Y. Bai et al., PV generation forecasting combined with similar days and GABP neural network. Proc. CSU-EPSA 29(6), 118–123 (2017)

28. Z.J. Wu, G.H. Liu, Z.L. Liao, Optimization design of engineering analytical model for silicon solar cell. Chin. J. Power Sources 31(11), 897–901 (2011)

29. Dong L (2009) Research on waste crystalline silicon solar panels resource recovery

30. https://www.energy.gov/eere/solar/solar-performance-and-efficiency

31. https://iopscience.iop.org/article/10.1088/0031-9120/47/6/680

32. https://www.pveducation.org/

33. https://sungzu.com/advantages-disadvantages-photovoltaic-systems/

34. F. YADEN, M. El OUARIACHI, T. MRABTI, K. KASSMI, B. TIDHAF, E. CHADLI and K. KASSMI " Design and achievement of one system photovoltaic equipped of one ordered MPPT digital » Review of the energies Renewables Flight. 14 #1 (2011) 171 –186. Mohamed Premier University, Faculty of Sciences, LEPAS Laboratory, Oujda, Morocco 2011.

35. D.P Hohm & M.E Ropp "Comparative Study of Maximum Power Point Tracking Algorithms", Progress in Photovoltaic: Research and Applications page 47-62, November 2002.

36. V.Salas, E.Olias, A.Barrado, A.Lazaro, "Review of the Maximum Power Point TrackingAlgorithms for stand-alone photovoltaic systems", Solar Energy Materials & Cells 90, 2006.

37. W.Xiao, "A modified adaptive hill climbing MPPT method for photovoltaic powersystems", Master's thesis, Shenyang Polytechnic University, 1991.

38. T.Esram, and P. L.Chapman, "Comparison of Photovoltaic Array Maximum Power PointTracking Techniques", IEE transactions on Energy conversion, Vol. 22, No 2, June 2007.

39. D.Sera, T.Kerekes, R.Teodorescu, and F.Blaabjerg, "Improved MPPT method forrapidly changing environmental conditions", IEEE ISIE 2006, Montreal, Quebec, Canada,9-12 July, 2006.

40. A. Mellita and S. Kalogirou, "Artificial intelligence techniques for photovoltaic applications: A review," *Progress in Energy and Combustion Science*, vol. 34, pp. 574-632, 2008.

41. K.-H. Chao and C.-J. Li, "An intelligent maximum power point tracking method based on extension theory for PV systems," *Expert Systems with Applications*, vol. 37, pp. 1050-1055, 2010.

42. T. Patrick and P. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," *IEEE Trans. Energy Conv.*, vol. 22, no. 2, pp. 439-449, Jun. 2007.

43. V. Salas, E. Olias, A. Barrado, and A. Lazaro, "Review of the maximum power point tracking algorithms for stand-alone photovoltaic systems," *Solar Energy Materials & Solar Cells*, vol. 90, no. 11, pp. 1555-1578, Jan. 2006.

44. M. Momayyezan, G. Farivar, F.Miragha, "An Improved FLC Algorithm for Tracking Maximum Power Point in Photovoltaic Systems", Power Electronics and Drive Systems Technology (PEDSTC), 3rd, IEEE, 2012.

45. S.N. Sivanandam, S. Sumathi, and S.N. Deepa ,"Introduction to Fuzzy Logic Using Matlab" , Library of Congress Control , Springer Berlin Heidelberg New York, 2007.

46. Irwan Purnama, Yu-Kang Lo, "A Fuzzy Control Maximum Power Point Tracking Photovoltaic System", IEEE International Conference, 2011. Page(s): 2432 – 2439

47. B.Riza, Sheldon,T., ″Fuzzy Systems Design Principles Building Fuzzy IF-THEN Rule Bases", *IEEE* PRESS, 1997.

48. John Yen & Langari Reza, *Fuzzy Logic Intelligence Control and Information*, Prentic- Hall, Englwood Cliffs, 1999.

49. Mathur D (2014) Maximum power point tracking with artificial neural network. Int J EmergSci Eng (IJESE) 2(3). ISSN: 2319–6378

50. A.BETACHE, Y. ACHOUR "Application of the sliding mode technique for the tracking of the maximum MPPT point of a photovoltaic generator » Master in Automatic of the systems, Medea University. 2014

51. S. BELLAKEHAL "Design & Control of Permanent Magnet Machines Dedicated to Renewable Energies", Doctoral thesis, University of Constantine, Algeria,2010.

52. C. TOUZET "The networks of neurons artificial introduction and connectionism » BookPDF 1992

53. Sunpower UK

54. © Springer International Publishing Switzerland 2015 B.L. Dokić and B. Blanuša, Power Electronics, DOI 10.1007/978-III-III19-09402-1_4

55. Mammano, Robert A., 2017. *Fundamentals of Power Supply Design*. Texas Instruments. Colonel Wm. T. McLyman, 1988. *Transformer and Inductor design Handbook.* 2nd ed., Marcel Dekker.

56. © Springer International Publishing Switzerland 2015B.L. Dokić and B. Blanuša, Power Electronics,DOI 10.1007/978-III-III19-09402-1_4