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Mathematical modeling of solar radiation curves as well as the design of an intelligent system for their detection using PV.

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Abstract— The rapid increase in demand for PV systems is due to the fact that they produce electricity without damaging the environment, converting solar radiation directly into electricity. However, solar radiation never stays constant. The need to provide sufficient electricity throughout the day, load and network regardless of atmospheric conditions is a major problem. To solve the keye problem it is necessary to connect the PV panel with an intelligent device to help it achieve higher performance. In this paper an intelligent circuit is shown to approximate the point of maximum energy during the day, which is directly connected to the PV panel and at its heart is the decreasing increasing amplifier. Our main task will be to study the output characteristics of the PV panel. As a concretization, a real module is taken to study these characteristics. These features are built using some MATLAB / SIMULINK algorithms, which simulate the PV system and realize the mathematical modeling of the solar curves of this system.

Index Terms— PV; panel ; solar radiation; intelligent system; intelligent circuit;.

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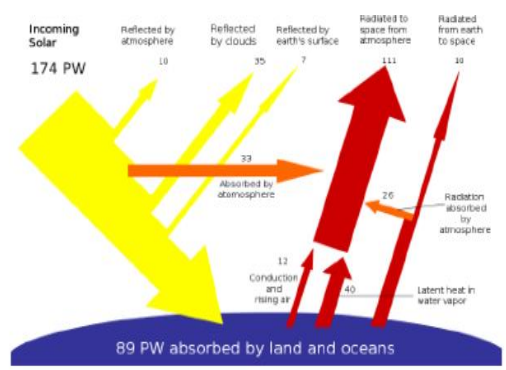
RENEWABLE ENERGY

Renewable energy sources called unconventional type of energy are sources that are constantly replenished by natural processes. Such as, solar energy, wind energy, hydropower, etc., are some examples of renewable energy sources. A renewable energy system converts energy emitted by sunlight, water on the move, wind, sea waves in the form of heat or electricity. Most sources in the world are conventional sources such as coal, natural gas, oil, etc., which are non-renewable energy sources. Although, the available amount of these resources is large, due to their great use after a few years they will run out.

SOLAR ENERGY

Solar energy is an unconventional type of energy, used by people since ancient times using various technologies. Solar radiation along with sources such as waves and wind power, hydroelectricity and biomass, make up the bulk of the unconventional type of energy available on earth. The electric power generation of the solar is based on the photovoltaic system (PV) and the heating motors. To obtain solar energy, the most common way is to use photovoltaic panels, which take photon energy from the sun and convert it into electricity. Solar technologies are widely classified as solar passive or solar active depending on how they capture, return and distribute solar energy. Solar asset involves the use of PV panels and solar thermal collectors to obtain energy. Solar passivity includes the orientation of the building towards the sun, the selection of materials with favorable thermal mass or light scattering properties. From the figure we see that, the earth receives 174 petawat () of solar radiation that penetrates into the atmosphere. Approximately 30% is reflected back into space and absorbed by the oceans and land masses. The spectrum of sunlight on the earth's surface is mainly scattered in the visible and infrared area, only a small part is close to the ultraviolet area.The total solar energy absorbed by the earth's atmosphere, oceans and earth masses is approximately $3,850,000EJ$ per year.



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STANDARD TEST CONDITIONS (STC)

The comparison between different photovoltaic cells can be made on the basis of their performance and characteristic curve.

The standard test (STC) conditions are:

Temperature $(T_n) = 25^0 C$

Lighting $(G_n) = 1000 W/m^2$

Spectrum of $x = 1.5$ p.sh.AM.

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PV CELL

The solar cell is essentially a p-n junction realized in a thin wafer or in a semiconductor layer. Electromagnetic radiation of solar energy can be converted directly into electricity through the photovoltaic effect. Being exposed to sunlight, photons with energy greater than the energy of the semiconductor energy energy are absorbed and create electron-hole pairs proportional to the fallen photons. Under the influence of the internal electric fields of the p-n junction, these means of transport work separately and create a photovoltaic which is proportional to the solar radiation. The physics of PV cells is very similar to the classical diode with p - n switching (Figure 1). When light is absorbed by the passage, the absorbed energy of the photons is transferred to the electron system of the material creating charge carriers that are separated in the passage. Load carriers can be electron-ion pairs in a liquid electrolyte, electron-hole pairs in a semiconductor material. Load carriers in the transition zone create a potential gradient, accelerate under the electric field, and current circulates in the external circuit. The direct current in the circuit resistance is the energy converted to electricity. The residual energy of the photon increases the temperature of the cell. The source of photovoltaic potential is the difference in chemical potential, called the Fermi level, of electrons in two isolated materials. When they merge, the transition approaches a thermodynamic equilibrium. Such an equilibrium can only be achieved when the Fermi level is equal in both materials, this happens by passing electrons from one material to another until a voltage difference is established between two materials which have potential equal to the Fermi level difference. This potential drives the fluoride current.

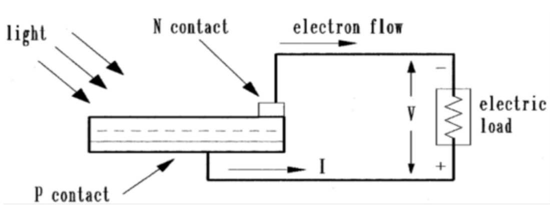

Fig. 1. Radiation into space from the atmosphere p-n.

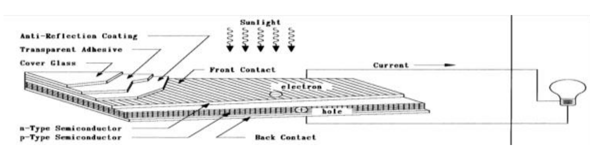

Fig.2. PV cell construction with enlarged component parts.

Figure 2 shows the PV cell construction. For photoresisting collection, metal contacts are insulated on both sides of the switch to collect the electric current generated by the photon shock on one side. The thin conductor grid located at the edge of the surface collects current and allows light to pass through it. Conductor space is a compromise issue between maximizing electrical conductivity and minimizing light blockage. In addition to the basic elements, there are some other features such as, for example, the front of the cells has anti-reflective coating to absorb as much light as possible, to minimize reflection. Mechanical protection is provided by a layer of glass bonded with transparent adhesive. To produce higher efficiency at low cost, cells are of different types in relation to PV technology, to make them available to the market, in terms of conversion efficiency and cost of the module. The main types are shown below.

PURE SILIC CRYSTAL

Pure silicon crystals are very useful as cell material. The simplest method of producing this material is by taking the impure silica by melting it and cleaning it in the respective equipment. An embryo crystal is placed on the molten silicon and by pulling the embryo slowly to its edge, we have solid, pure crystal rods (Fig. 3). The production process is slow and high energy, resulting in a high cost raw material. The rod is made into slices using a diamond cutter in wafers about 200 to 400 μm thick. Wafers are further cut into rectangular cells to maximize the number of cells that can be mounted together in a rectangular panel. Unfortunately, almost half of the silicon rod goes to waste by cutting it into slices and by forming square cells. Material residues can be minimized by making round cells in full shape from cylindrical rods (Fig.4). Another way to minimize losses is to grow the crystal into strips which are laser cut to eliminate debris.

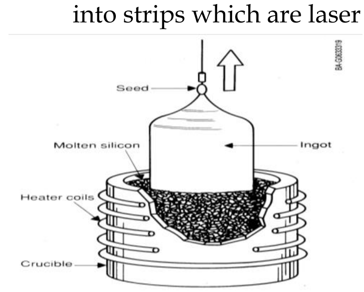

Fig.3. Pure crystals obtained in rods by the Chokralski method

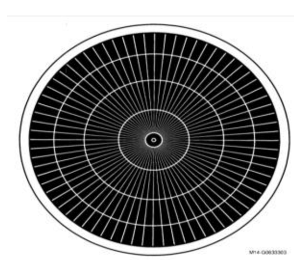

Fig. 4. The circular shape of PV cells.

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POLYCRYSTALS AND SEMI-CRYSTALS

This is a relatively fast and low cost process for the production of complete crystal cells. Instead of pulling the pure crystal using the embryo, molten silicon is thrown into the molds. Based on this process, polycrystals are formed. The conversion efficiency is lower but also the cost is much lower, giving a cost reduction for watts of power.

THIN FILMS

These are the new types of PV launched on the market. Biselen Indium Copper, Cadmium Teluri and Arsenide Gallium are the materials that make up the thin film, usually a few µm is the thickness cast on a layer of glass, steel, ceramic or other similar materials. This technology uses much less material per square foot cell, so it is less expensive per wat generated.

AMORF SILICA

In this technology, vaporized amorphous silicon is deposited in a thick pair of amorphous (glass) material wrapped by a thin, stainless membrane, usually 2,000 feet long and 13 inches wide. Compared to crystalline silicon, this technology uses only 1% of the material. The efficiency of this is as much as half that of crystalline silicon, but the cost per wat generated is much lower.

SPHERICAL

This is a technology that is still being experimented in laboratories. The base material is low-grade crystalline silicon beads, currently costing about $ 1 per kilogram. The beads are placed on a thin perforated aluminum sheet with a surface area of 4 inches square. In the process, impurities come to the surface, from where they are removed from the material. Each sphere works independently, especially sphere failure has a negligible impact on the average performance of the large surface area. According to an estimate by manufacturing companies, the 100 square foot spherical panel can generate 2000 kWh each year in an average climate.

CONCENTRATED CELLS

In an effort to improve conversion efficiency, sunlight is focused tens or hundreds of times at normal sun intensities focused on a small area using low-cost lenses (Figure 5). The main advantage is that such cells require a small part of the surface compared to the cell standard, significantly reducing the demand for PV material. However, the total surface area of the module remains the same to collect the power required by the sun. In addition to increasing power, decreasing cell size and number, such cells have the great advantage of increasing efficiency under focused light. Another advantage is that they can use a small cell surface. It is easier to produce high-efficiency cells with small surfaces than to produce large cells with efficiencies comparable to the former. On the other hand, a major disadvantage of focused cells is that they require optical focusing equipment, increasing the **cost**.

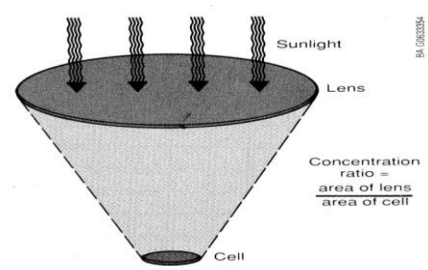
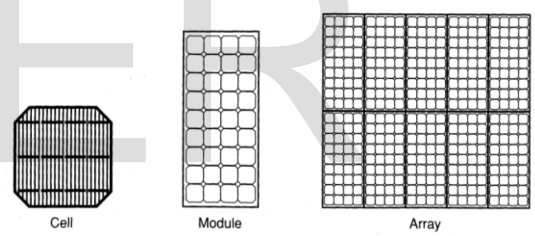


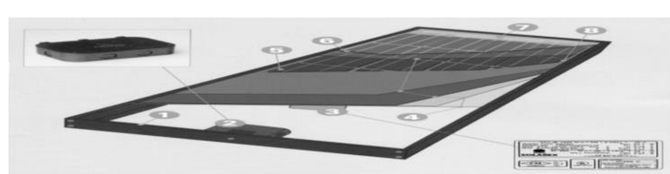
Fig.5. Lenses concentrated on a small surface of the active cell

MODULE AND TABLE

The solar cells described above are the foundation of building the PV power system. To obtain higher energy, many cells are connected in circuits in series and parallel to the panel (module) surface (Figure 6).



The solar panel or panel is a set of electrically connected modules in series and parallel to generate the required current and voltage. Figure 7 shows the construction of the module in a frame that can be mounted on a structure. **Figure 7.** Construction of the PV module: 1) skeleton, 2) junction box that does not introduce water, 3) rating plate, 4) weather protector for 30 years of life, 5) PV cell, 6) glass cover with conductivity top, 7) external electric bus, 8) cleaning facility.
Mounting the modules can be in various forms, as shown in **Fig. 8.** In the recently developed technology of amorphous silica, PV surfaces can replace roofing, providing a better economy.



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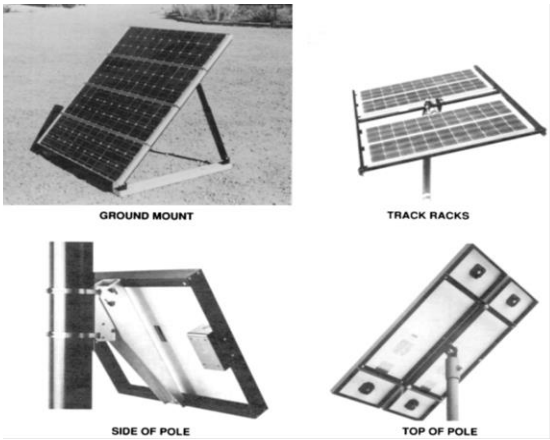

CALCULATION OF PV EFFICIENCY

The efficiency of photovoltaic solar panels is measured by the panel's ability to convert sunlight into energy usable for human consumption. Knowing the efficiency of the panel is important in order to determine the right panels for the photovoltaic system. For smaller roofs, more efficient panels are needed, due to limited space. How do manufacturers determine the maximum efficiency for a solar photovoltaic panel?

First, let's give the maximum power (), for a 200w panel is 200w despite its efficiency. Panel efficiency determines the power output of the panel per unit area. The maximum efficiency for a solar photovoltaic cell is obtained from the following equation:

$$\eta_{max}(efikasiteti\ maksimal) = \frac{P_{max}(energjia\ maksimale\ e\ prodhuar)}{(E^{SW}_{S,\gamma}(fluksi\ i\ rrezatimit\ te\ rastit) * A_c(siperfaqa\ e\ kolektorit)}$$

The radiation flux under standard test conditions (STC) is 1000W / m2. The maximum efficiency of the solar panel should not be confused with the minimum that can be found in the panel manual. If we have a large surface roof, which is ideal for laying solar panels, the cost will be lower and lower efficiency panels will be needed. If the surface is limited, we could determine the efficiency for which the panels would need to obtain the desired energy for that surface.

EQUIVALENT CIRCUITS FOR CELL, MODULE AND PV TABLE

EQUIVALENT CIRCUIT

The complex physics of the PV cell can be represented by an equivalent electrical circuit shown in Figure 9. The circuit parameters are as follows:

The current at the output terminal is equal to the current generated by the light I_L, without diode current I_d and the shunting current of the earth I_{sh}. Resistance in series R_s represents the internal resistance of the leakage current and which depends on the magnitude of the passage p – n, impurities and contact resistance. Shunting resistance R_{sh} is connected in reverse to the current flowing into the ground. In an ideal cell PV, $R_s = 0$ no series losses) and(no ground leakageThe PV conversion efficiency is sensitive to small changes R_s but is insensitive to changes R_{sh}. A small increase R_s can significantly reduce PV production .The open circuit voltage V_{oc} of the cell is taken when the electric current is zero, for example, when $I = 0$ and is calculated as:

$$V_{oc} = V + IR_{sh} \qquad (1)$$

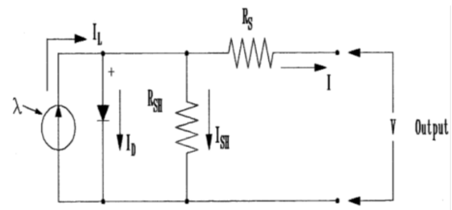

Fig. 9. Equivalent electrical circuit of PV module.

The diode current is given by its classic expression:

$$I_d = I_D\left[\frac{QV_{oc}}{AKT} - 1\right] \qquad (2)$$

where: I_D - diode saturation current
Q - electron charge
A - the appropriate curve constant.
K - Boltzmann's constant.
T - absolute temperature in ^oK.

The electric charge current is given by the expression:

$$I = I_L - I_D\left[e^{\frac{QV_{oc}}{AKT}} - 1\right] - \frac{V_{oc}}{R_{sh}} \qquad (3)$$

The saturation current of the diode can be determined experimentally by applying voltage in the dark and the calculated current goes to the cell. This current is often called the dark current or the reverse saturation current of the diode.

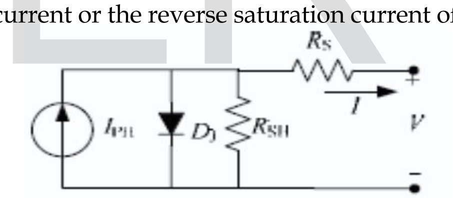

Fig. 10. General model

Electricity depends on solar radiation and the operating temperature of the cell, which is given as:

where is the short circuit current of the cell in 250C and 1kW/m2, is the short-circuit current temperature coefficient of the cell, reference temperature of the cell, dhe and is solar radiation in kW/m2. The cell saturation current changes with the change in cell temperature and is given as:

where is the reverse current of saturation of the cell at a reference temperature and at a given solar radiation is the energy crack of the semiconductor used in the cell.

An even more accurate mathematical description of a solar cell, called the dual exponential model as shown in Figure 11, is derived from the physical behavior of the solar cell constructed of polycrystalline silicon. This model consists of a light source generated by light, two diodes, one resistor in series and one in parallel. This model is used very little in this paper and is not considered to generalize the PV model.

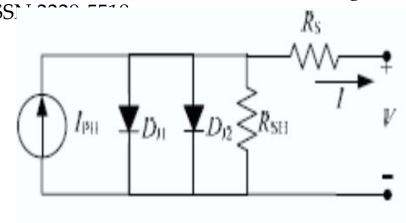

Fig. 11. Double exponential model.

The shunt resistance is inversely related to the current flow in the ground. The efficiency of PV is insensitive to changes and the shunting resistance can be assumed infinite, consequently we have no current leakage in the ground. On the other hand, a small change of i will greatly affect the PV output power.

The suitable model for PV solar cells is shown in Figure12. Equation (1) can be rewritten in the form:

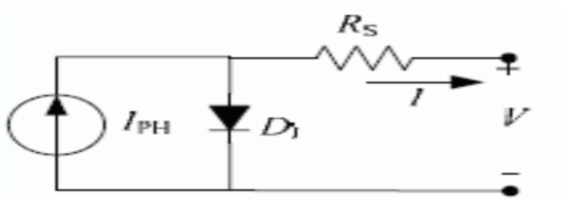

Figure 12. Convenient model

For an ideal PV cell, there is no loss in series and no loss in ground, i.e , and . The above equivalent circuit of the PV solar cell can be simplified, as shown in Figure 13.

Equation (1) can be rewritten in the form:

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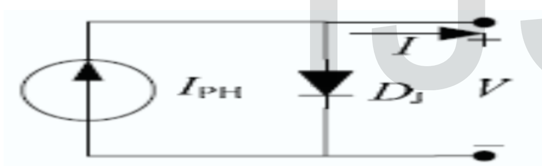


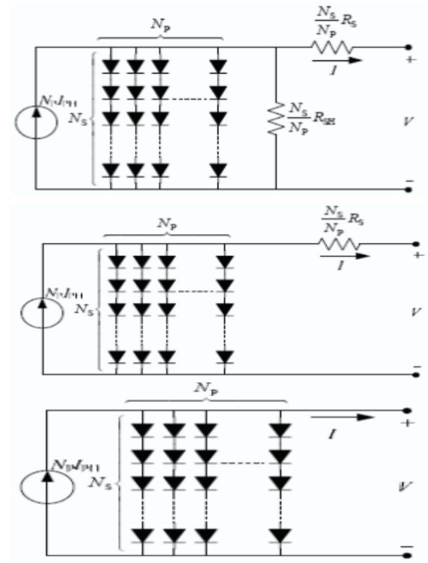
Figure 13. Simplified model

MODULE AND TABLE MODEL

A PV board is a set of PV modules where the circuits are electrically connected in series and in parallel to generate the required current and voltage. The equivalent circuit for the solar module connected in parallel and in series is shown in Figure 14 (a). The equation of the table current is given as follows:

For a PV module or table, the series resistance becomes significant and the shunt resistance approaches infinity which is assumed to be open. An equivalent circuit suitable for all cells, module and PV table is generalized and expressed in Figure 14 (b). It is shown that for a PV cell, for the module and the number of PV cells connected in series and for the table and the serial and parallel number of PV cells. The generalized mathematical equation has the form:

The simplest model for the PV module is described in Figure 14 (c). The equivalent circuit is described by the equation below:



(a) General model (b) General model (c) Appropriate model

Figure 14. Models of generalized equivalent PV circuits.

DEFINITION OF MODEL PARAMETERS

The most important parameters that are widely used to describe the performance of the electric cell are the open circuit voltage and the short circuit current. The above equations are implied nonlinear, so it is difficult to arrive at an analytical solution for a set of model parameters at a specific temperature and radiation. Since and ignoring the small diode and ground currents at the zero voltage end, the short-circuit current is approximately equal to the current-voltage:

The maximum photovoltaic is created according to the open circuit voltage. Again, ignoring the earth leakage current and the generated current, we obtain the open circuit voltage:

Constant is the absolute temperature expressed in voltage ().

Given the voltage of the PV open circuit at the reference temperature and ignoring the earthing current, the reverse saturation current at the reference temperature is given by the equation:

From where, the maximum power is expressed as:

where and are the voltage across the edges and the current produced for the PV module at the maximum energy point (MPP), and is the factor of the cell material.

I-V AND P-V CURVES

The PV system exhibits nonlinear characteristics I-V and P-V which differ in radiation intensity and cell temperature. Figure 15 shows the I-V characteristic of a PV module under two conditions, in radiation and in darkness. To the upper left of the I-V curve at zero voltage is called the short circuit current. At the bottom right of the zero current curve is called the open circuit voltage. In the left colored area, the cell works as a constant current source, creating voltage equal to the electrical charge of the resistor. In the colored area on the right, the current decreases very quickly for a small voltage rise. In this area, the cell works as a constant voltage source with an internal resistance. Between the two colored areas, the curve has a knee-shaped slope.

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PHOTOVOLTAIC MODELS

SOLAR CELL MODEL

A general mathematical description of the I-V output characteristic for a PV cell has been studied for more than four decades. This equivalent circuit is based on the model used primarily for MPPT technologies. The equivalent circuit of the general model consists of a photovoltaic current, a diode, the resistance in parallel expressing the current loss, and the series resistance describing an internal current resistance resistor, is shown in Figure 10. The equation of the volt- ampere characteristic for a cell solar is given as:

where is the current generated by radiation or phototherm, is the saturation current of the cell in the dark, is the charge of the electron, is the Boltzmann constant, cell working temperature, is an ideal factor, is the shunting resistance and is the resistance in series .

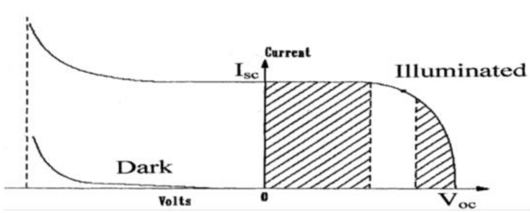


Fig. 15. Characteristics I-V of the PV module in radiation and in darkness.

The power output of the panel is the product of the output voltage and current. In Figure 16, the P-V characteristic is shown.

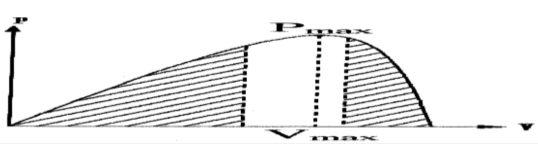
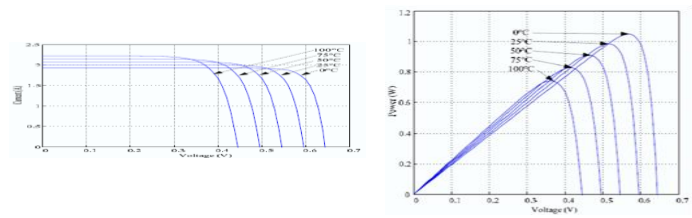


Fig. 16. P-V characteristic of PV module under lighting.

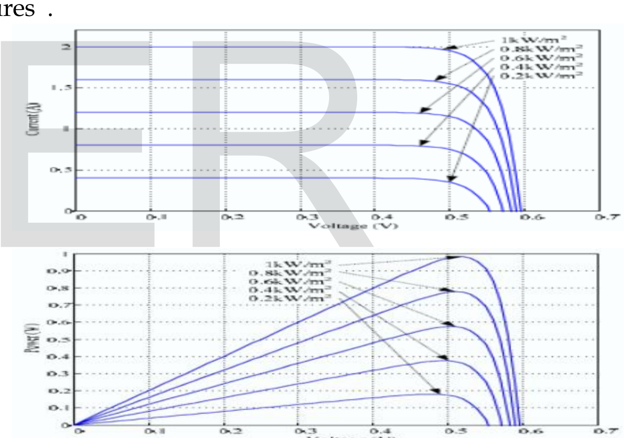
Note that the cell does not produce power at zero voltage and zero current and produces maximum power at the voltage value corresponding to the knee point of the I-V curve, therefore PV power circuits are designed to operate at this point.

The nonlinear nature of the PV cell is clearly shown in Figure 16, i.e. the power output and power of the PV cell depend on the voltage applied to the ends of the cell, its temperature, and solar radiation. From Figures 17 (a) and (b) we understand that as the operating temperature increases, the short-circuit current for the PV cell increases while the maximum power produced decreases. Since the increase in current output is much smaller than the decrease in voltage, the power decreases at high temperatures. On the other hand Figures 18 (a) and (b) show that with increasing solar radiation, the short circuit current for the PV module increases, the maximum power produced increases, the reason is that the open circuit voltage depends logarithmically on solar radiation.



a) I-V b) P-V

Fig. 17. Output characteristics at different temperatures .



a) I-V **b)** P-V

Fig.18. Output characteristics λ in different.

TABLE DESIGN

The main factors that affect the electrical design of the solar panel are:

1. Intensity of the sun.
2. The angle of the sun.
3. Shadow effect.
4. Working temperature.
5. The effect of the atmosphere.
6. Selected electric charge for maximum energy.
7. Following the sun.
8. Power point of the working point.

SUN INTENSITY

Fotorryma is greatest under full bright sun. On a partly sunny day, the fluorescence decreases in direct proportion to the intensity of the sun. Characteristic I-V changes with decreasing sun intensity, as shown in Figure 19. On a cloudy day, the

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short-circuit current decreases significantly, the open-circuit voltage is small.

The photoconversion efficiency of the cell is insensitive to solar radiation, meaning that the conversion efficiency is the same on a bright sunny day and on a cloudy ‹ Intensiteti lowest energy production on a cloudy day just ... low solar energy that hits the cell.

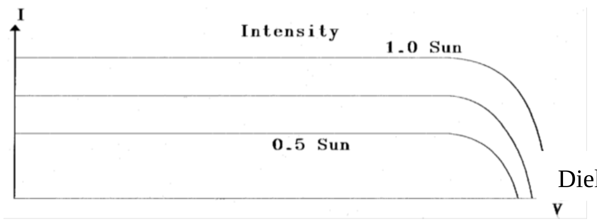

Figure 19. The I-V characteristic of the PV module changes with decreasing solar intensity

SUN ANGLE

Prodhimi i rrymës së qelizës është dhënë nga,

$$I = I_0 \cos\theta$$

ku I_0 është rryma e prodhuar nën diellin referues dhe θ është këndi i vijës së diellit i matur nga normali. Ky ligj kosinusoidal vlen edhe për kënde diellli nga 0 deri në 50°. Lakorja kënd-energji e qelizës PV është quajtur kosinusi Kelley dhe tregohet në Figurën 20.

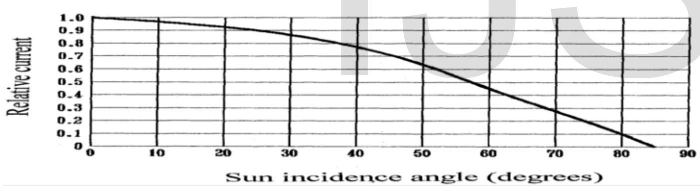

Figure 20. Kelley cosine curve for PV cell.

TABLE I. Kelley cosine values of fluorescence in silicon cells**.**

The angle of the sun falling	The value of cosine mathematical	The value of cosine Kelley
	0.866	
30	0.643	0.866
	0.500	
50	0.174	0.635
	0.087	
60		0.450
80		0.100
85		0

Beyond 50°, the electrical output deviates significantly from cosineusoidal law and the cell does not generate energy beyond 85o, although cosineusoidal mathematical law predicts 7.5 percent of the desired energy.

SHADOW EFFECT

Two arrays of the solar chart are shown in Figure 21. A large group may have partial shadows due to interference with the solar line. If a cell in the string connected in series gets shaded completely, it will lose phototension, but it must keep the string at work. In this case it acts as an electric charge, producing loss and heat. The remaining cells in the array must work at high voltage to compensate for the loss of voltage of the cell that is in the shade. The current lost is not proportional to the surface covered by the shadow and can be neglected due to the light shadow on a small part of the surface. However, if more cells are covered by the shadow, the I-V curve is taken beyond the string voltage, causing the string current to go to zero, thus losing all of the string power. To eliminate string loss due to the shadow effect we divide the circuit into several sub-circuits with shunt diodes (Figure 22). Consequently, we have a proportional loss of voltage and current of the string, without losing all the power of the string

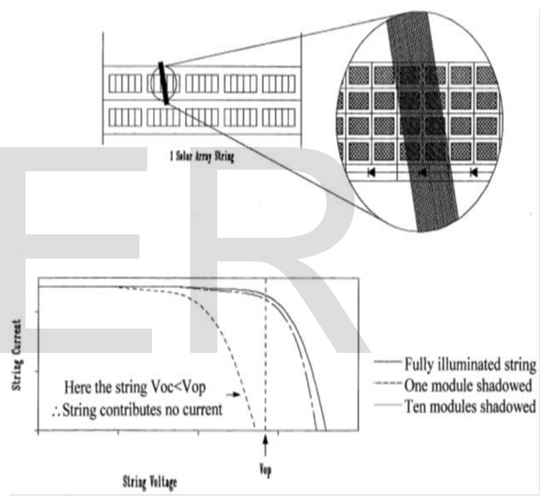

Fig. 21. Shadow effect on a string of a PV table.

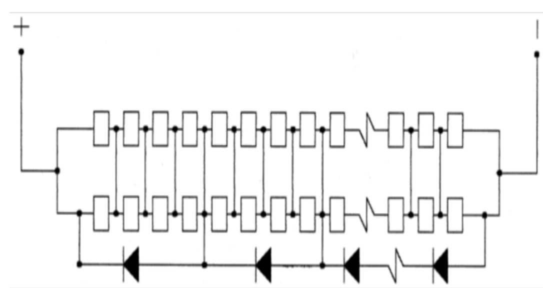

Fig. 22. Shunt diode in PV array minimizes lost power.

EFFECT OF TEMPERATURE

As the temperature increases, the short-circuit current of the cell increases, while the voltage of the open circuit decreases. The effect of tempe... 1 Varg i tabelës diellore ...ated by controlling the effects of curr... V_0 are the short-circuit current and the open-circuit voltage at the reference temperature T, α and β are their respective temperature co-

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efficients. If the operating temperature increases by ΔT , then the current and voltage are:

$$I_{sc} = I_0(1+\alpha\cdot\Delta T)\ dhe\ V_{oc} = V_0(1-\beta\cdot\Delta T) \qquad (16)$$

Then the power is calculated as:

$$P = V\cdot I = I_0(1+\alpha\cdot\Delta T)\cdot V_0(1-\beta\cdot\Delta T) \qquad (17)$$

Ignoring the short term, we have:

$$P = P_0\cdot[1+(\alpha-\beta)\cdot\Delta T] \qquad (18)$$

1.4.1 ATMOSPHERE EFFECT

On a clear day, the PV module can produce up to 80% of the power, while on an extremely cloudy day, it can produce about 30% of the power. Snow usually does not collect in modules because they are angled to catch the sun, if it collects it can melt quickly. Mechanically, the modules are designed to withstand hailstones the size of a golf ball.

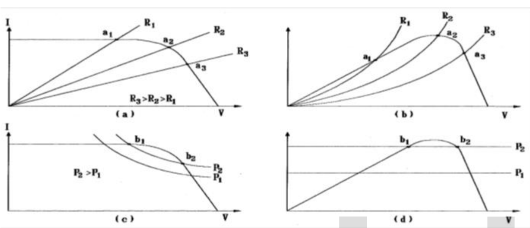

Figure 23. Working point stability and choice of load resistance with resistive load and constant power load. The necessary condition for the electrical stability of the working point is given by:

$$\left[\frac{dP}{dV}\right]_{ngarkeses} > \left[\frac{dP}{dV}\right]_{burimit} \qquad (19)$$

Some loads such as heaters have constant resistance, with variable power. On the other hand, some loads such as induction motors behave more like constant power loads, emitting more current at low voltage. In larger systems with mixed loads, the power varies in direct proportion to the voltage.

2.6.2 SUN TRACKING

More energy is collected if the PV module is installed in a tracker, with an actuator following the sun. There are two types of sun followers:

• A single-axis follower, which follows the sun from east to west during the day.

• Two-axis follower, which follows the sun from east to west during the day and from north to south during the seasons of the year (Figure 24).

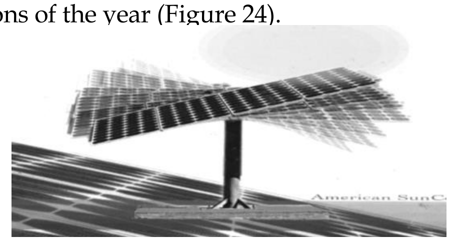

Fig. 24. The two-axis sun follower follows the sun here and there.

A sun tracker can increase the power produced by up to 40% during the year compared to the fixed table. Two-axis tracking is performed by two linear actuator motors, which follow the sun within a degree of accuracy (Figure 25). During the day, he follows the sun from east to west, at night he returns to the east ready for the next morning sun. Older followers do this after sunset using a small battery. New projects eliminate battery demand by making it in dim sunlight.

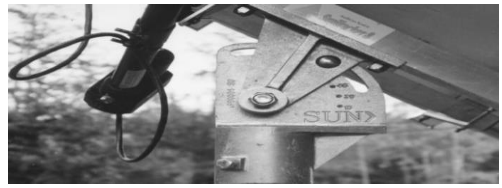

Figure 25. Solar tracker actuator motor.

One method of designing solar trackers is to use two PV cells in two 45o triangular sections (Figure 26) and connecting them in series via an actuator motor.

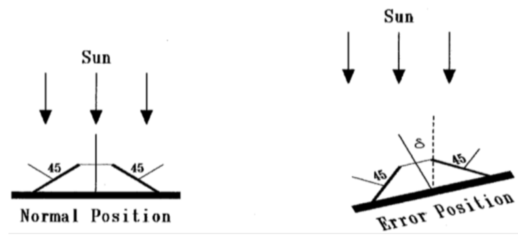

Figure 26. Actuator principle in tracking the sun. Two sensors connected at 45o generate a proportional signal to indicate the error.

When the sun is perpendicular to the table, the current in both cells is equal to . Since they are connected in series, the current in the motor is zero and the table stays in place. On the other hand, if the table is not perpendicular to the sun, the sun angles of the two cells are different, giving the currents:

and

Consequently the motor current is:

Using the expression of the Taylor series:

we can express the two currents as follows:

Then the motor current is:

Large boards are divided into small modules, each mounted on one axis or with two follower axes. This simplifies the structure and eliminates the problems associated with large movements.

POINT OF WORK POINT POWER

The solar tracker causes the module to face the sun to collect maximum solar radiation. However, by itself it does not guarantee maximum power output from the module. The module must operate electrically at a certain voltage which corresponds to the power peak point according to the given operating conditions. We first consider the electrical principle of action of the power roof.

If the table is operating on voltage and current in curve i-v, the power generated is . If the table moves from the point above, such that the current becomes and the voltage becomes , the power will be:

Ignoring the short term, we have:

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should be zero at the power peak point. Therefore, at the power peak point, the above expression goes to the limit as follows:

We have considered here that is the total dynamic resistance of the source and is the complete static resistance.

There are three electrical methods of extracting the power roof from the module:

1) In the first method, a small current signal is injected through the table bus and the total dynamic resistance of the bus and the full static resistance of the bus are the same. The operating voltage increases or decreases until , thus , maximum power is obtained from the source.

2) In the second method, the working voltage increases as long as it is positive , if it is in the negative sense, the working voltage decreases. The voltage is kept unchanged if it is close to zero, within certain limits.

3) The third method, uses the fact that for most PV cells, the ratio of the voltage at the point of maximum power to the voltage of the open circuit is approximately constant . The operating voltage of the table is then set to , which can produce maximum power.:

PV SYSTEM COMPONENTS.

The board itself does not constitute the PV power system, we must also have a structure to place it, the components that accept the DC power produced by the board and the return of power to the form that is usable by the load. If the load is AC, the system needs an inverter to convert DC power to AC, usually at 50 or 60 Hz.

CHOICE OF ELECTRICAL CHARGE

The operating point of any power system is the interruption of the source line and the load line. If the PV source has the I-V and P-V characteristics shown in Figure 23 (a) the resistance load power is provided R_1, it will operate at the point a_1, if the load resistance increases to or R_2, R_3 the working point moves to a_2 and, a_3 respectively. Maximum power is obtained from the module when the load resistance is R_2 (Figure 23 (b)).

Operation under constant power loads is shown in Figure 23 (c) and (d). The constant power load curve intersects the source curve at two points, denoted by and, only this point is stable, i b_1 e b_2 the system will operate at b_2.

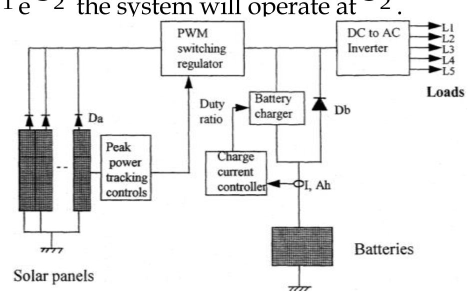

Fig.27. Photovoltaic power system of the power peak follower together with its main components.

Figure 27 shows the required components of a single position PV power system. The follower power peak directs the voltage and current produced by the board and continuously adjusts the operating point to obtain maximum power. The output of the table goes to the inverter, which converts DC to AC. The output of the table that "leaves" the load serves to charge the battery. The Db diode of the battery discharge is to prevent the battery from charging when the charge is fully supplied and not allow excess power to go to the battery. The panel diode Da is to isolate the panel from the battery. The central controller collects system signals, such as switchboards, battery currents and voltages, keeps the state of the charged battery, the converter discharge, and the heat dissipators on or off.

In the mains-connected system, heat dissipators are not needed, as all the extra power goes to the mains lines, the battery is also eliminated. DC power is converted to AC by the inverter, fluctuations are filtered and then power is fed into the mains. For PV applications, the inverter is an important component, which converts the DC power of the board to AC for load supply or network interconnection. Recently a new product has been introduced to the market, the AC-PV module, which has the built-in AC inverter.

INTRODUCTION TO MAIN TYPES OF PV SYSTEMS.

We focus on the analysis and design of PV systems, in their three most common forms: systems that directly supply the grid, single-position systems that charge batteries, and applications in which the load is directly connected to the PV, the case of water pumping systems. Figure 28 shows a simplified sketch of the grid-connected system or utility interactive system (UI) in which PV supplies power to a building. The PV board can be mounted on the pillar, or attached to the outside of the roof, or it can be part of the cladding of the building itself. PV roofing of buildings serves dual purposes, energy and structure construction, in this case the system is called integrated photovoltaic building (BIPV).

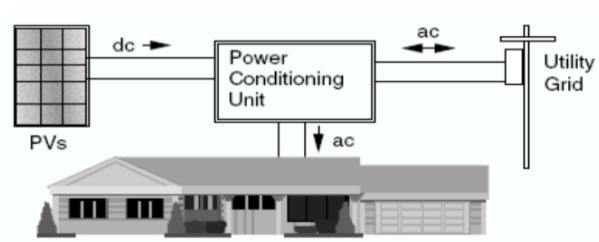

Fig. 28. Simple grid PV system.

PVs in a grid-connected system distribute DC energy to the power conditioning unit (PCU) that converts dc to ac and sends energy to the building. If the PVs supply less than the building demand, the PCU gets the right power from the grid. If PVs produce more energy than is needed, the excess is sent to the grid, by an energy meter. The energy conditioning unit also helps to force PVs to operate at many efficient points on their I-V curves as conditions change.

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The relative simplicity of these systems; their maximum power follower unit ensures a high PV efficiency; their ability to integrate into the building structure, meaning that there is no additional cost for the terrain and PV materials replaced in the buildings; and finally, their ability to provide energy during the middle of the day, when the need is very high, increases the economic value of their kWh. All of these contribute to the cost-effectiveness of these systems because they have to compete with the relatively low price of energy.

Figure 29 shows the second system, which is not mains, the system with only one position for charging the battery and a generator for reversing energy. In this system, an inverter converts the dc voltage of the battery to ac, but in many simple systems anything can work in dc and the inverter may not be needed. The inverter charging function allows the generator to fully charge the batteries when the sun is insufficient. Single-position PV systems can be very efficient in remote locations.

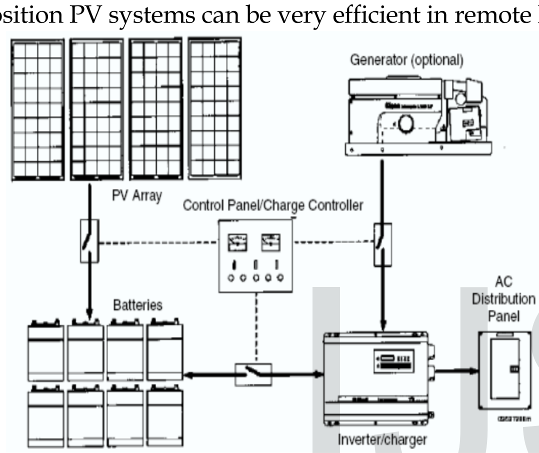

Figure 29. PV system with only one position.

The third type of system that we will pay attention to that has PV directly connected to their loads, without batteries and without the power conditioning device. The most common example is the pumping of water with PV in which the conductors from the table are connected directly to the pump motor (Figure 30). These systems do not have electricity storage, but potential energy can be stored in a water tank, these are less costly systems.

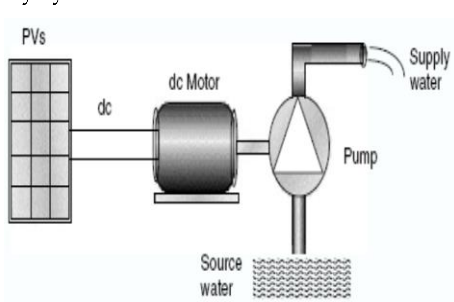

Figure 30. Photovoltaic water pumping system.

LOAD CURVES I-V.

Although the I-V curve for a PV cell, module, or table determines the voltage and current combinations that are allowed, it tells us nothing but the curve where the system will operate. In Figure 31, the same voltage acts on both PV and load, and the same current passes through them. Therefore, when the load curve I-V is plotted on the same graph of the curve I-V for PV, the breakpoint satisfies PV and the load. This is called the work point.Figura 30.

I-V CURVES FOR THE LOAD

Although the I-V curve for a PV cell, module, or table determines the voltage and current combinations that are allowed, it tells us nothing but the curve where the system will operate. In Figure 31, the same voltage acts on both PV and load, and the same current passes through them. Therefore, when the load curve I-V is plotted on the same graph of the curve I-V for PV, the breakpoint satisfies the PV and the load. This is called the work point.

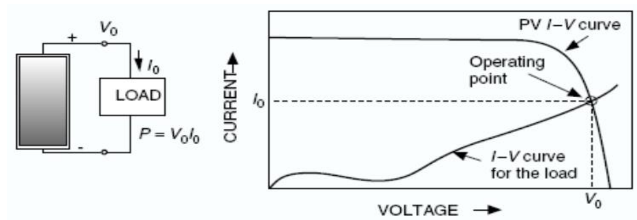

Fig. 31. The working point is the interruption of current-voltage curves for the load and PV.

SIMPLE RESISTANT LOAD CURVE I-V

To illustrate the importance and need for load curves, we obtain a simple resistive load, as shown in Figure 32. For the load,which, when drawn is a straight line with slope . When mounted , the working point is where the PV and resistance curves I-V intersect. In fact, it suggests a simple way to actually measure the PV module I-V curve. Using variable resistors, we can obtain current-voltage pairs, which can be plotted to give us the modulus I-V of the module. There will be no specific resistance value that will result in maximum energy:

where and are the voltage and current at the maximum power point (MPP).

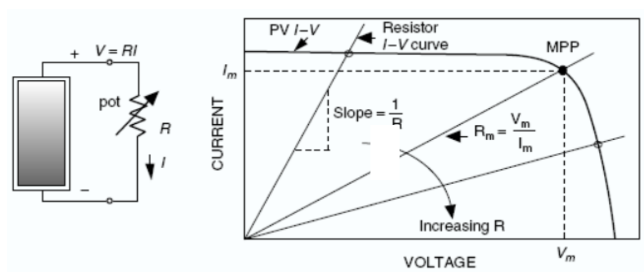

Figure 32. When the resistance changes, the working point moves along the I-V curve of PV.

In Figure 33 we have a fixed resistance, the system operates outside the operating point and the module is less efficient. Next will be introduced a mechanism called the maximum energy point follower (MPPT), which serves to keep the PV operating at all times at their highest point of efficiency.

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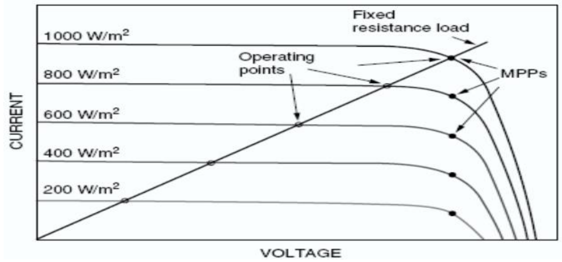

Figure 33. Efficiency of a PV module with constant resistance load.

DC MOTOR CURVE I-V

Although this is not often a load, dc motors, such as those used in PV water pumping systems, do not exhibit a current-voltage relationship that is similar to that of a resistor. Most are permanent magnet dc motors, which can be modeled as shown in Figure 34. From the equivalent circuit, the voltage-current connection for the dc motor is simple

$$V = IR_a + k\omega \quad (30)$$

where the electromotive force is opposite and is the resistance of the rotor.

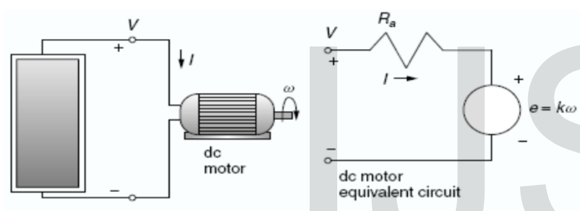

Figure 34. Electric model of a dc motor with permanent magnet.

Based on equation (30), the I-V curve of the dc motor is superimposed on a set of PV I-V curves (Figure 35). Note that the motor does not have enough current to overcome static friction until the solar radiation reaches less than 400 W/m2. Once the rotor starts, it only needs about 200 W/m2 to operate.

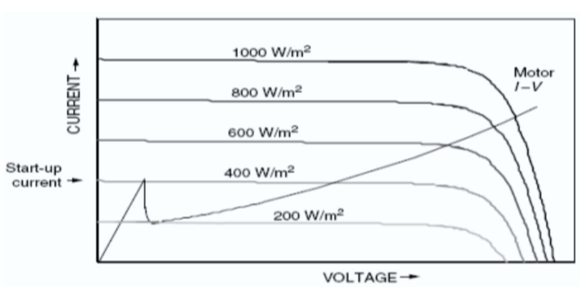

Figure 35. The I-V curve of the dc motor and the I-V curves of the PV for different solar radiation.

To avoid this loss, a device called a linear current amplifier (LCB) is installed in the system, which serves to eliminate this problem. From the figure we notice that the working points are not near the knee of the solar radiation curve. At these work points, PV may be able to overcome friction, but not without some electronic equipment. In addition, the engine with LCB will not stop in the afternoon, although it will slow down.

I-V BATTERY CURVES

Since PVs provide only energy during daylight hours and applications require a lot of energy when the sun is absent, an energy conservation mechanism is needed. For grid-connected systems, the grid itself is thought of as a storage mechanism: the PV energy supplied to the grid during the day is taken back at night. For off-grid systems, power is stored in batteries for use whenever necessary. An ideal battery is a unit in which the voltage remains constant no matter how low the current. This means that it will have an I-V curve a straight vertical line, as shown in Figure 36.

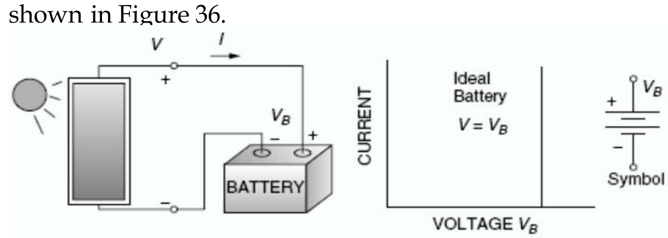

Figure 36. An ideal battery has a vertical I-V curve.

A real battery has several internal resistances and is often modeled with an equivalent circuit containing an ideal voltage V_B battery in series with some internal resistances R_i, as shown in Figure 37. During the charging cycle, positive current flows in batteries, we can write:

$$V = V_B + R_i I \quad (31)$$

which is a straight line with a slope $1/R_i$. During loading, the applied voltage must be greater than V_B, which increases, consequently the line I-V slides to the right, as shown in Figure 37 (a). During discharge, the output voltage of the battery is less than V_B, the slope of line I-V is reversed and the curve I-V moves back to the left, as shown in Figure 37 (b). In fact the battery voltage (V_B) depends not only on the charging condition, but also on the battery temperature and how long it has been "resting". Internal resistance is also a function of temperature, charging condition, age and battery condition.

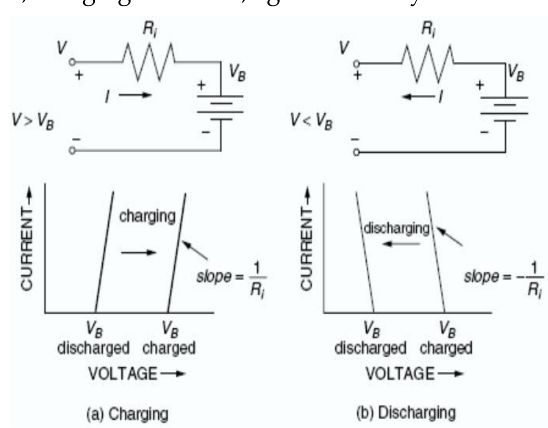

Figure 37. The real battery is modulated as an ideal battery in series with its internal resistance.

During loading / unloading the slightly sloping I-V curve slides to the right or left, as a result of which the PV working point will start to slide out of the knee. Of course this is a bad thing, however, the current is low when a battery is fully charged.

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MAXIMUM ENERGY POINT FOLLOWERS

We can get high efficiency if the working points for the resistor, dc motor and battery loads can be kept close to the bend of the curve during changing conditions. The devices that do this, called maximum power trackers (MPPTs), are an important part of many PV systems, especially those connected to the grid. There are some completely simple circuits that are at the heart of not only MPPT but also linear current amplifiers (LCBs), their purpose is to be able to convert dc voltage from one level to another. At the heart of variable mode dc to dc converters is the FET and IGBT transistor unit, which are used as simple on-off switches that allow current to flow or not.

An increasing converter is a circuit commonly used to increase the voltage from a dc source, while a reducing converter is often used in reducing the voltage. The circuit of Figure 38 is a combination of these two circuits and is called a step-down converter. A step-down converter is capable of increasing or decreasing the dc voltage from its source to any dc voltage required by the load. The source in this case is a PV module and the load is a dc motor, but this conce in many other cases.

To analyze the decreasing incremental converter, we rely on the concept of energy equilibrium for the magnetic field of the inductor. There are basically two situations to consider: the closed-circuit and the open-circuit.

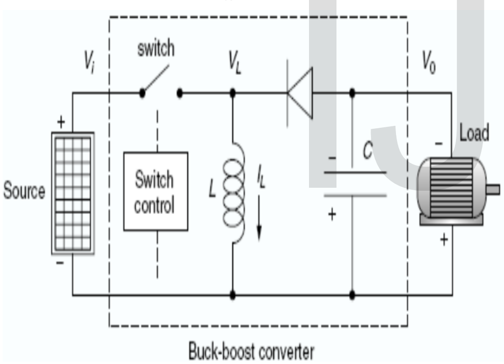

Figure 38. A decreasing incremental converter is used as the heart of the maximum power follower.

When the switch is closed, the input voltage is applied to the coil, so all current passes through the coil since the diode blocks the rest of the circuit. During this cycle, energy is added to the magnetic field of the coil as the current increases. If the switch stays closed, the coil will act as a short circuit and the PV will distribute the short circuit current to zero volts.

When the switch is opened, current in the coil continues to flow now through the capacitor, charge and diode. The coil current while charging the capacitor provides a voltage to the load that will help secure the charge power before the switch closes again.

If the switch opens and closes too quickly, the current through the coil is unlikely to decrease too much while the switch is open before the next electric shock from the source. With a very fast switch and a very large coil, the circuit can be said to have an almost constant current coil, i.e. the coil current is essentially constant.

If the switch opens and closes too quickly, the voltage across the capacitor is unlikely to drop too much while the switch is closed before the next electric shock from the inductive load it creates backup again. Capacitors, can not have an immediate change of their voltage, so, if we have a very fast switch and a very large capacitor, the output voltage between the capacitor and the load is almost constant, so the output voltage is V_0 essentially constant .

For this simple description, all components in the converter should be considered ideal. As such, the coil, diode and capacitor do not consume power. Therefore the average energy in the converter is equal to the average energy distributed by the converter. Real MPPT is about 90% efficient, so these are not a bad assumption.

Now we focus on the coil. As the switch is closed, $t=0$ from time to $t=DT$, the voltage across the coil is unchanged with V_i. The average energy in the magnetic field of the coil during a complete cycle is given by:

$$\bar{P}_{L,in} = \frac{1}{T}\int_0^{DT} V_i I_L \, dt = \frac{1}{T} V_i \int_0^{DT} I_L \, dt \qquad (32)$$

Assuming the coil current is constant, the average energy in the coil is:

$$\bar{P}_{L,in} = \frac{1}{T} V_i I_L \int_0^{DT} dt = V_i I_L D \qquad (33)$$

When the switch is opened, the magnetic field of the coil begins to drop, returning the energy gained. Steering diode, which means that the voltage across V_L the coil is the same as the voltage across the load V_0:

The average energy dissipated by the coil as a result is:

$$\bar{P}_{L,out} = \frac{1}{T}\int_0^{DT} V_i I_L \, dt = \frac{1}{T}\int_0^{DT} V_0 I_L \, dt \qquad (34)$$

Both V_0 and I_L are essentially constant, so the average coil output energy is::

$$\bar{P}_{L,out} = \frac{1}{T} V_0 I_L (T - DT) = V_0 I_L (1 - D) \qquad (35)$$

During a complete cycle, the average energy in the coil is equal to the average output energy of the coil. So, from (33) and (35), we get:

$$\frac{V_0}{V_i} = -\left(\frac{D}{1-D}\right) \qquad (36)$$

Equation (36) tells us that we can get dc voltages up or down (there is a sign change) only by changing the incremental converter cycle. Larger cycles allow more time to charge the capacitor and less time to discharge it, so the output voltage increases as it increases.

One way to predict the impact of MPPT is to reformat PV I-V curves using as a parameter. For the MPPT output voltage and current, one goes up and the other goes down compared to the original PV curve I-V, as shown in Figure 39.

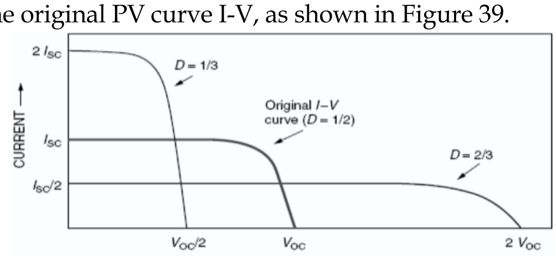

Figure 39. Drawing of PV I-V curves with an MPPT.

CURVES I-V HOURS AFTER HOURS

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The ambient temperature and the available sunlight are always changing. This means that the I-V curve for a PV table is always variable and the working point for each load is always in motion, so the need for curves arises hour by hour. For the most part an I-V PV curve, the current at any voltage is proportional to the brightness of the sunlight. This generalization is completely true for short circuit current. However, since the open circuit voltage decreases as the brightness of the sunlight decreases, so the simple assumption of the current that exists in proportion to the illumination of the sunlight almost ceases with the fall of. In many circumstances, the operating voltage of a system is close to the knee of the I-V curve.

The simple assumption that current is proportional to radiation makes it easy to draw I-V curves hour after hour. Since the I-V curve of the sun itself depends on the cell temperature, and the cell temperature depends on solar radiation and ambient temperature, we can imagine arranging a reference sun curve based entirely on an hour-by-hour curve.

In Figure 40, the I-V curves hour by hour of PV are obtained using the corresponding radiations of a collector. By superimposing these I-V curves on the I-V curves of three different types of loads: a dc motor, a 12 V battery and a maximum power point follower (MPPT).

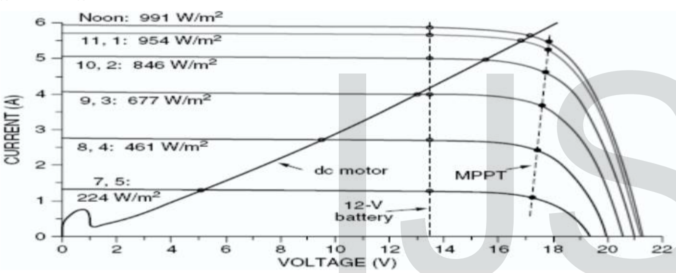


Figure 40. Hour-hour PV curves with three different types of loads.

NETWORK CONNECTED SYSTEMS

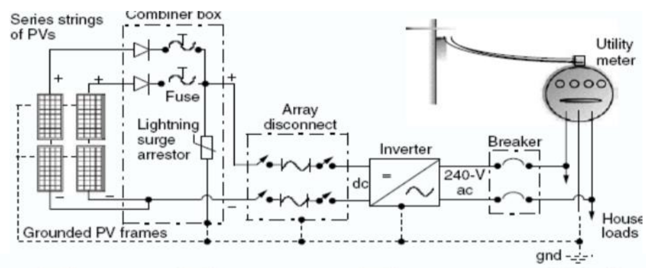
PV systems mounted on buildings are becoming more and more popular due to low prices and installation infrastructure becoming more and more sophisticated. As shown in Figure 41, the main components in the mains connection, the home PV system consists of two-conductor boards in each string connected in a combination box that includes blocking diodes, individual fuses for each string, and an automaton. The two conductors of the measuring instrument in the combination box transmit the dc energy to the panel automaton, which allows the PVs to be totally isolated from the system. The inverter sends ac power, by connecting its output edge to the opposite side of the panel, 120 V power is distributed to each grid family. The inclusion of the maximum power point follower (MPPT), the responsible earthing circuit breaker (GFCI) switch that closes the system if any current flows to ground and disconnects the PV system from the grid if power is lost. The system may also include a small storage battery to ensure the return of power in the event that the grid is down. The inverter, some of the fuses and switches, MPPT, GFCI and other power management devices are usually integrated into a power conditioning unit (PCU).

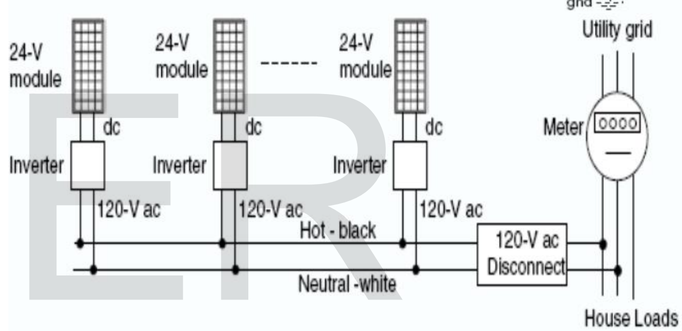
Fig.41. Key components in a grid-connected PV system.

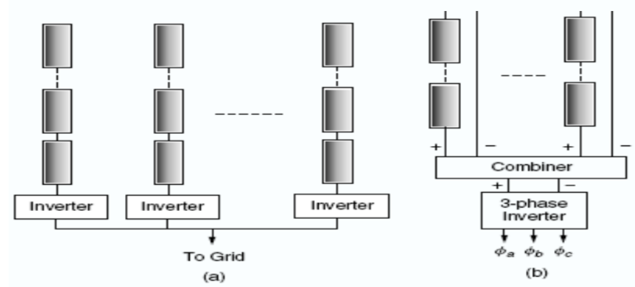
Module-mounted inverters are designed to work with separate 24 V modules, or with pairs of 12 V modules connected in series, as shown in **Figure 42**.

Figure 42. Each dc module has its own inverter, allowing system expansion at any time.

For large networked systems, arrays of PV modules can be connected to separate inverters (Figure 43 (a)). Since inverters are expensive, then a central inverter is used, which provides three phases of power to the grid (Figure 43 (b)) **Figure 43.** (a) Use of separate inverter for each range, (b) Use of central inverter.







NEED FOR CONNECTION

The ac output of a grid-connected PV system is supplied by the main electrical distribution line of the panel, which can supply energy to the house or realize the return of energy to the grid, as shown in Figure 44. In most cases, the system distributes more a lot of energy than the house needs, the electricity meter goes backwards, in other cases, when the demand exceeds the supply from PV, the network provides energy. A two-way electricity meter is called a net meter, which shows the net energy received from the grid or given to the grid. **Figure 44**. During the day, excess energy is sold, while at night it is bought.

When a grid-connected system is to provide power to customers during a power outage, a battery operating system may be included. If users really need uninterruptible power

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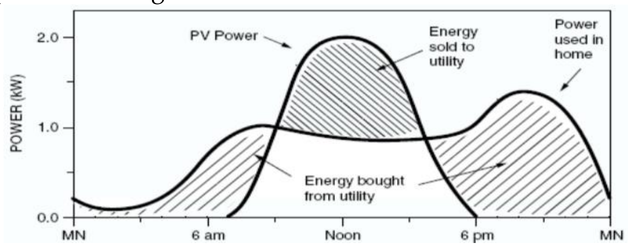
supply for long periods of time, the battery system can be replaced with a generator.



The grid-connected systems rest on a module board and a conditional power unit that includes an inverter to convert dc from PV to ac required by the grid. A good starting point for evaluating system performance is to adapt the dc power output of a module to standard test (STC) conditions.

DC AND AC ENERGY ADAPTATION

The grid-connected systems rest on a module board and a conditional power unit that includes an inverter to convert dc from PV to ac required by the grid. A good starting point for evaluating system performance is to adapt the dc power output of a module to standard test (STC) conditions.

Distributed ac energy (P_{ac}), can be taken as:

$$P_{ac} = P_{dc,STC} \times (Eficenca\ e\ konvertuar) \qquad (37)$$

where $P_{dc,STC}$ is the dc energy of the table taken from the module data in (STC).

An important factor that reduces the energy of the module is the cell temperature. To calculate the modulus energy change caused by the rise in cell temperature, the PVUSA (PTC) test conditions (sunlight in the table plan, ambient temperature 200C and wind speed of 1m / s) help us. .

We have another factor which is the inverter efficiency, which varies depending on the load, as

"POINT HOURS" APPROACH TO ASSESS PV PERFORMANCE

Performance forecasting is a matter of combining the characteristics of the main components of the PV table and the inverter under solar radiation and at given temperatures. If we know the ac energy distributed by a table, we can only multiply the nominal energy by the number of peak hours of the sun to get the kWh distributed. We can write the energy distributed at a time of day as:

$$Energjia(kWh/dite) = Ndricimi\ me\ rreze\ dielli\left(\frac{kWh/m^2}{dite}\right)\cdot A(m^2)\cdot \bar{\eta} \qquad (38)$$

where is the surface of the table PV and $\bar{\eta}$ is the average system efficiency during the day. Ac energy received from the system:

$$P_{ac}(kW) = \left(\frac{1kw}{m^2}\right)\cdot A(m^2)\cdot \eta_{1-diell} \qquad (39)$$

where is the efficiency of the system in 1-solar. The combination of (9.11) and (9.12) gives:

$$Energjia(kWh/dite) = P_{ac}(kW)\cdot\left[\frac{Ndricimi\ me\ rreze\ diell(kW/m^2/dite)}{1kW/m^2}\right]\cdot\left(\frac{\bar{\eta}}{\eta_{1-diell}}\right) \qquad (40)$$

If we assume that the average efficiency of the system during a time of day is the same as the efficiency when it is exposed to 1-sun, then the energy collected is:

$$Energjia(kWh/dite) = P_{ac}(kW)\cdot(ore/dite\ te\ "diellit\ pik") \qquad (41)$$

The main assumption in (9.14) is that the efficiency of the system remains constant throughout the day, this explains why these grid-connected systems have maximum power point followers that maintain the working point near the knee of the I-V curve throughout the day. Since the energy at the maximum point is approximately proportional to the brightness of the sunlight, the efficiency of the system will be approximately constant.

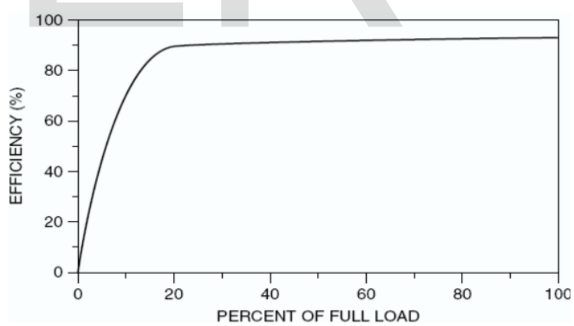
CAPACITY FACTORS FOR NETWORK-CONNECTED PV SYSTEMS

One way to represent the energy distributed by each electricity generating system is in terms of nominal ac energy and capacity factor (CF). A CF = 0.4, means that the system distributes the full rated power 40% of the time. The main equation for annual performance in CF terms is:

$$Energjia(kWh/vit) = P_{ac}(kW)\cdot CF\cdot 8760(h/vit) \qquad (42)$$

where 8760 is the production of 24 hours a day with 365 days of the year.

The combination of (9.14) and (9.15) leads to a simple interpretation of the capacity factor for grid-connected PV systems:



shown in Figure 45. The PTC ac rating system is more realistic than the usual STC rating, but it has the disadvantage of being less easy to define.

SIZE OF NETWORK CONNECTED SYSTEM

The need to provide energy storage and back energy, the size of grid-connected systems is not very large. Moreover, it costs approximately twice as much to install a system that will deliver twice as much power. The size of grid-connected systems is more a matter of building surfaces and the buyer's budget, because the goal is to combine supply with demand, this is done to predict if this investment is profitable. Some issues require not only technical data but also pricing data, such as whether a tracking system is more cost effective than a fixed chart.

The first step is to estimate the rated energy and area re-

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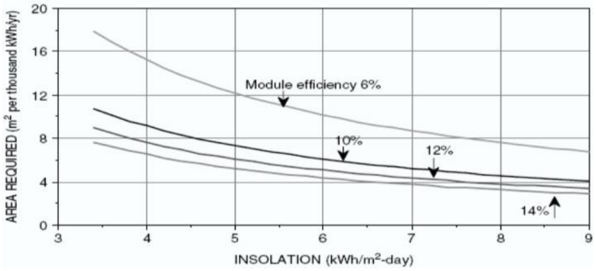
quired for the PV table. Figure 46 shows how much the estimate of annual power output depends on sunlight, while Figure 47 shows how the required area depends on the efficiency of the module. **Figure 46.** Annual energy distributed by a PV table.



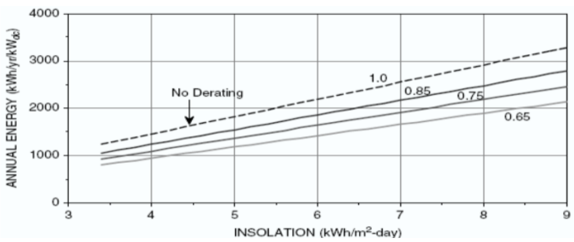


Fig.47. Area required to distribute 1000kWh / year with module efficiency as a parameter.

The next step is to explore the interaction between the choice of PV modules and inverters and how they affect the layout of the PV table. Finally, we need to consider the details about voltage and current ratings for fuses, switches and conductors. Similarly, inverters for networked systems are also different from those designed for battery charging applications. Network-connected inverters accept higher input voltages, and as we shall see, these voltages greatly limit the configuration of the PV table.

It is important to evaluate the maximum open circuit voltage of the string to be sure that it does not exceed the high dc voltage that the inverter can accept. Another reason for controlling the open circuit voltage of a grid connected panel is that the National Electrical Code limits all voltages for one and two family dwellings to be 600V, in addition, its proposal for PV systems specifies other restrictions on the choice of conductors, fuses and switches. KEK also recommends multiplying all PV currents by 1.25, to calculate it for two possibilities:

(1)The potential for sunlight to exceed the level of the sun 1000W/m2,

(2)increase in short-circuit current (approximately 0.1% / 0C) caused by cell temperature.

Finally, the allowable current that a conductor can handle is related to the particular type it has and the ambient temperature to which it is exposed. The design of the final system for the house is shown in Figure 48.

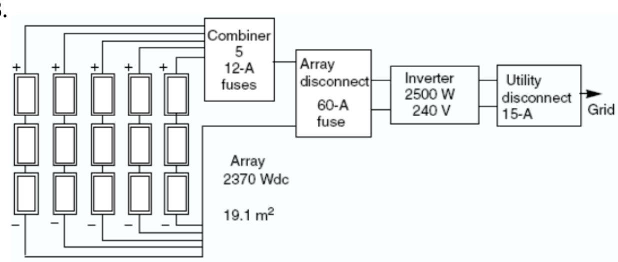


Figure 48. System design for example house.

ECONOMY OF NETWORK-CONNECTED PV SYSTEM

We now have the tools to allow us to calculate the energy dissipated by a grid-connected PV system, so the next step is to examine its economic viability. Two types of economic analysis need to be done. One helps to make decisions between different system options, for example, whether to use a tracking system or a fixed skeleton and the other helps a buyer decide if the investment is worthwhile.

FREE SYSTEM TRADE

To illustrate the decision between system options, we take the free trade of a mounted follower by comparing it to a simple fixed one. To know which system serves us is based on two conditions:

(1) The power received from the panel $P_{dc,STC}$ to be maximum.

(2) The cost of all system components to be minimal.

From the results of these two requirements we decide which of the two systems is economically viable.

UNCLEARS FOR THE DOLLAR INDICATOR FOR WATS

The most important data in any economic analysis of a PV system are the cost of the system and the amount of energy it will provide each year. Whether the system is economically viable depends on other factors, such as the price of energy displaced by the system, whether there are any taxes or other economic incentives, and how the system is repaid. A detailed economic analysis will include: performance appraisals and maintenance costs; future electricity service costs; the lending period and the application of income tax, if the owner buys it in full; system life, etc. There are two ambiguities with the $ / W indicator, which need to be clarified for the parameter to make sense. One is whether watts are based on dc power from PV or ac power from the inverter, while the other is whether or not a follower is used.

When a PV system uses the follower, a Power Generation Factor (EPF) should be included in order to simplify the $ / Wdc or $ / Wac description and directly compare it to those systems that have a fixed direction.

$$Ndjekesi(\$/W) = \frac{\$/W}{EPF} = \frac{\$/W}{Ndricimi\ me\ rreze\ dielli\ te\ ndjekura / Ndricimi\ me\ rreze\ dielli\ te\ \ fiksuara}$$

DEPRECIATION COSTS A simple way to estimate the cost of electricity generated by a PV system is to imagine taking out a loan to pay off the system and then using the annual payments divided by the annual kWh distributed to give c / kWh. If a loan is taken over a period of n (years) at an interest rate ‘i’, then the annual borrowing payment, A ($ / year), will be: $A = P \cdot CRF(i,n)$ (45)

where CRF (i, n) is the return on equity factor, which is given as:

$$CRF(i,n) = \frac{i(1+i)^n}{(1+i)^n - 1} \qquad (46)$$

An important factor that was ignored in the cost calculation is the impact of the income tax earned. During the first years of a long-term loan, almost all annual payments will be of interest, meaning that the benefit

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tax varies from year to year. For example, in the first year, the benefit tax is: $$Viti\ i\ pare\ i\ takses\ se\ perfitimit = i \times P \times MTB \qquad (47)$$

where MTB is the marginal tax interval.

CONSTRUCTION OF THE GENERAL PV MODEL

CONSTRUCTION OF THE GENERAL MODEL PV

A model for the PV module of medium complexity which includes the temperature independence for the photovoltaic source, the saturation current for the diode and a series resistance is based on the diode equation.

It is important to build a general model suitable for the PV cell, module, and table, which is used to design and analyze a maximum energy point follower.

A general PV model is constructed using Matlab / Simulink to illustrate and verify the nonlinearity of the I – V and P – V output characteristics for the PV module.

The proposed model is implemented and shown in Figure 49 (a) and (b). In order for the overall
model to be easy to use and understand, we will use a file similar to that of the pv icon, which is shown in

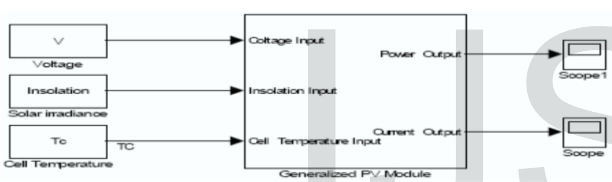

Fig. 49 (a). Generalized PV model.

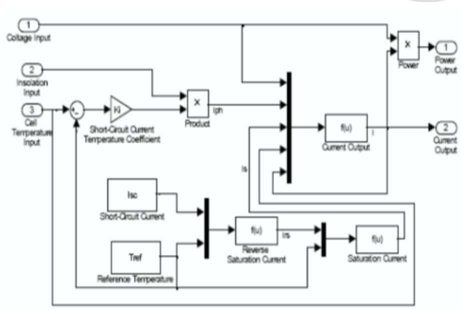

Fig. 49 (b). Implementation of the generalized PV model supersystem.

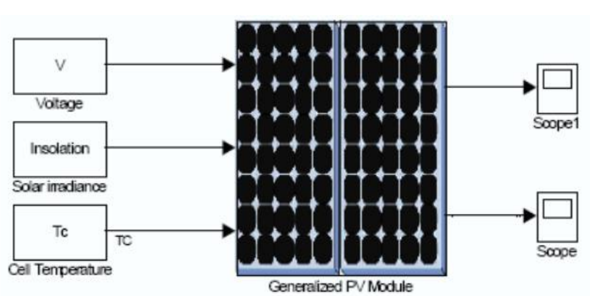

Fig. 50. Schematic implementation of the generalized PV model.

CONCLUSION

- Got acquainted with the construction of the PV cell, its material and how it worked. The PV panel is a group of modules connected in series and the PV module is composed of many cells connected in series and in parallel. The cell in a PV panel works only in one part of characteristic IV, near the working point where the current and voltage are maximum. The operating point of any power system is the interruption of the source line and the load line.
- Construction of equivalent circuits for the cell, module and PV panel, as well as their mathematical modeling. Evaluated models are used to maximize the output power of the PV converter system. The performance of a PV panel depends on two important parameters of the model which are the open circuit voltage and the short circuit current. As the temperature increases, the short-circuit current of the cell increases, while the open-circuit voltage decreases.
- The cell produces maximum power at the value of the voltage corresponding to the point of the knee joint I-V (MPP), therefore PV power circuits are designed to operate at this point. The power output and power of the PV cell depends on the voltage applied to the ends of the cell, its temperature and solar radiation.
- The photorecommissioning efficiency of the cell is insensitive to solar radiation, meaning that the conversion efficiency is the same on a bright sunny day and on a cloudy day.
- Two types of economic analysis need to be done in relation to interconnected PV systems; one helps to make decisions between different system options, for example, if we use a tracking system or a fixed frame and the other helps a buyer decide if the investment is I estimable.
- The output power of a PV panel can be maximized by using the MPPT control system, which finds the optimal code to withstand the PV panel with the sun. The proposed MPPT consists of an increasing and decreasing amplifier, which enables the arrival of the maximum power point. MPPT directs the voltage and current produced by the table and continuously adjusts the operating point to obtain the maximum power.
- Modeling and simulation of a generalized PV model by Matlab / Simulik, which is representative of the PV cell, module and panel and concretization with a real module. The simulation results show the effect of solar radiation and different temperatures on the characteristics IV and PV of the module.

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