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Design and Simulation of Photovoltaic Modules Performance Improvement Under the Effect of Partial Shading Using MATLAB/Simulink.

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Abstract: To discuss the exploitation or investment of solar energy correctly, it is important to take into account the clear and significant influence of the natural conditions of the Earth, in particular (temperature and intensity of solar radiation). The solar cell is the smallest component in the structure of a photovoltaic cell (PV), and it has faced several obstacles from the beginning of solar cell manufacturing until this moment, including manufacturing, design, economic challenges, as well as natural and unnatural. These difficulties include both natural and artificial elements, such as partial shade to which the solar cell or solar cells are exposed within the solar system, which has direct or indirect effects on the process of generating electrical energy from solar cells. Due to the above issues, solar energy cannot be exploited to its full potential or at its best. Through the results of this study, a new approach was discovered, which is to create a completely new solar array by adding a new electronic system connected to the solar structure in order to improve the efficiency of work and production within the solar array. The new system is an electronic system that works to improve the efficiency of the new solar system in producing electrical energy, and this electronic system can be linked to become a crucial component of it. The new solar system works in all lighting conditions, whether normal or abnormal, and under any type of partial shading of the solar cell. Through this new. System, we can see that under normal and abnormal conditions, the electrical energy generated in the new solar system is equivalent to one-third of the energy produced by the previous solar system. In addition, solar radiation tracking uses non-critical techniques or is seen as a catalyst for the solar system after this system, since it is the strategic comparison used to learn more about MPPT technology and different production conditions in low light with an emphasis on the results of shading conditions on solar PV panels, this strategy (MPPT) did not succeed in maintaining productivity, but the proposed model or productive systematic strategy helped sustain the effectiveness of the solar cells or solar energy system. Thus enhancing electric power generation under poor exposure conditions of solar system. The proposed model was chosen because it may be possible to replicate the different non-standard PV frame scales regulated by a new solar system with useful multi-functional applications. The work could provide a new and useful resource in future power generation (PV).

Keyword : *Partial Shading, bypass diode , Full Shading , hotspot, Photovoltaic (PV), Maximum Power Point Tracking (MPPT), Air Mass (AM) Radiation (G) ,Temperature (T) , Series Connection ; Parallel Connection , I_{SC}(Issue short circuit current) , Mixed Connection (B.C) , Total Cross-linked*

1. Introduction.

The need and demand for electric power increased in the first half of this century, which in to an increase in the demand for fossil fuels. This growth has led to in demand and subsequent need, The amount of emissions rose. that polluted the environment as of increased combustion and industrial of fossil fuels. As a result, there was an increase in the cost of producing electricity and market tensions. These and other concerns have led developed nations to look for alternative, environmentally safe, renewable sources of electrical energy. Solar energy is one of the available energy sources. was chosen because it does not generate emissions that contribute to environmental degradation, is clean, affordable, and readily available. To achieve this, a solar cell (photovoltaic) was created. A solar cell (PV) is a small gadget that uses the photovoltaic (PV) effect to convert solar energy directly into electrical energy. Solar panels, which harness the energy of the sun by arranging solar cell arrays on a single surface, are constructed as a single unit. This cell is interconnected with one another using a variety of interconnecting techniques, includes "mixed connection,"(B-C) "parallel connection,"(P-C) and "series connection" (S-C) , to obtain a high voltage or high current. The photocell is affected by a variety of conditions and elements, including both natural and unnatural elements. When photovoltaic cells produce electrical energy this effect can be seen in the productivity of photovoltaic (PV) cells. Among the most important factors affecting the efficiency and performance of the solar cell are the temperature(T).One of the ideal requirements for a photovoltaic cell to produce electrical energy under standard conditions is the value of incident solar radiation within (1000 watts / m^2), temperature (25) Celsius, and an Air mass (1.5) during the day, so that we can reach Renewable energy sources. The

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Maximum Power Point Tracking (MMPT) is used to obtain the ideal solar radiation in order to achieve higher efficiency and better performance, and the photovoltaic model is used analysis and measurement[1]. When the photovoltaic unit is typically affected by partial shade or full shade, it can still generate electrical energy, but not to the level that can be used. However, when the photovoltaic unit is routinely exposed to solar radiation (G) & temperature (T), within the typical working conditions (STC), the photovoltaic unit works to produce continuous electrical energy. [2]If the partial shade decreases, it affects more than only energy perception along the photovoltaic (PV) structure. The maximum strength settings and the fixed shape of the partial shade ultimately lose their sensitivity. The strongest point received is thought to be at this position (MMP). When they collide at a specific crucial point, Both shading particles in PV systems and shading gravity are affected. [2], Partial shadowing could prevent the reverse biased solar cells in the photovoltaic model from doing their job. leading to an accumulation of these cells and affecting solar cell output productivity within the solar structure. As a result, The peak power is greatly diminished, This

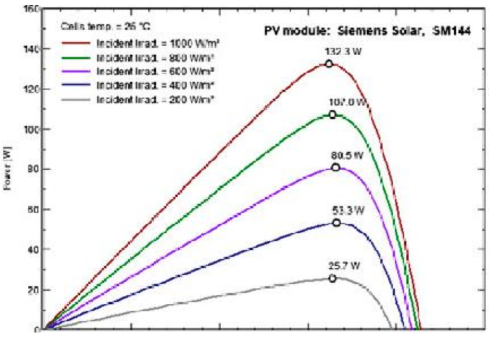


Fig (1) : radiation's influence on solar cells' (I-V) characteristics.

The features of the solar cell are depicted in Figure 2 along with how temperature influences its performance. We see that changes in the solar cell's temperature have little effect on its characteristics. When a single solar cell is operating at maximum efficiency at a temperature of (25) Celsius, it typically produces between (0.5 and 0.6) volts under normal circumstances.

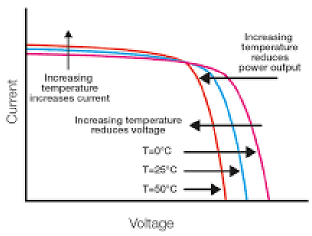


Fig (2) : temperature's influence on solar cells' (I-V) characteristics.

decreases the solar system's design and output capacity. When partial shade causes the power output of the PV unit to decrease, Due to the PV cell' current response being greater than the shaded cell group's short circuit current (I_{SC}), there will be gain and heat generation. Due to this restriction, shaded or shaded cell arrays are compelled to use reverse bias to dissipate energy, which overheats the solar cells and could reduce the productivity of the PV modules[3]. The main source of energy in the solar system is photovoltaic (PV) energy. Heat from the sun, sunlight emissions and buildup of dust velocity, and partial or complete shadowing all have an impact on photovoltaic installations. Figure (1) shows the characteristics of the voltage-current relationship curve produced by the photovoltaic cell. Solar radiation (G) is the basic and most important component in the production of energy in the solar cell, Furthermore, we see that, in the absence of solar cell shading conditions, solar cell's peak for electricity production is in the radiation range of (1000) W / m^2 , but the electrical energy Generated from the photovoltaic cell at any time in unusual circumstances. when the solar radiation (G) decreases as a result of shading some or all of the solar cells one by one.

II. PhotVoltic System Characteristics with Partial Shading.

Solar energy is an important part of renewable energy because it is so simple to access the source A photovoltaic cell is the key component required transform solar energy into electrical energy. As shown in Figure (3), There are irregular shadowing conditions in the photovoltaic (PV) when photovoltaic cells are partially shaded by a range environmental elements, such as trees, high structures, clouds, tree leaves (3). The performance of the solar photovoltaic (PV) module is significantly influenced by how well the system performs in various shadowing scenarios and types [4]. [5] addition to the above mentioned variables. Longitude, climate, and angle of sunlight incidence all affect how much energy is produced inside solar system. [5] The average solar energy available, according to the makers' calculations, is (1000) watts / m^2. The proportion of energy converted into electrical energy determines how effective a solar panel is. [6]. The illumination of PV arrays is commonly obscured entirely or in part. As well as emphasizing lower costs and more efficiency, research into solar technology has sought to increase the effectiveness and dependability of the systems in use. When mismatches arise as a result of partial shading, irregular radiation, pollution, and, As well as emphasizing lower cost and more efficiency, research solar technology has sought to increase the effectiveness and dependability of systems. [2]. The effect of partial shade in the production of photovoltaic energy has received a lot of attention and focus [3].

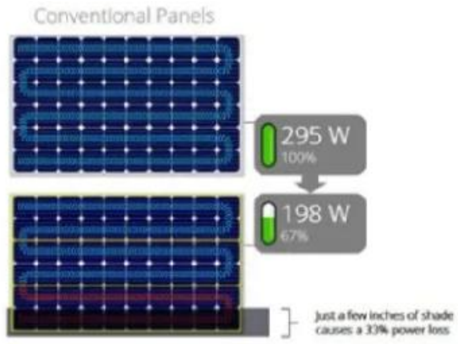


Fig (3) : the solar cell's ability to produce electricity is reduced when shaded.

III. Effect partial shading.

if shading is not taken into account, the solar panel system may have issues. Because of shadowing, the solar system may only be able to produce about 40% of its potential solar energy. [7]This is so that if a shade is placed on the panel, less sunlight will enter it. don't reach the PV cells, which will decrease their capacity to generate electricity. Figure (3) displays a sequence of solar cells, and by looking at Figure (6), we can see how rapidly and dramatically the power output of the photovoltaic module varies. if part or all of the solar module's individual cells are in the dark. The bright solar cell's ability to produce electrical energy starts to decrease at that point due to the photovoltaic unit's limited capability to do so. Commonly, 36 to 40 separate solar cells are consecutively connected to create a solar array. The voltage necessary to fully charge a 12-volt battery is increased by each individual cell in this series connection by approximately (0.5) to (0.6) volts. The other solar cells may experience an impact if the cell is lost because of shade. The solar cells are unable to fully recharge the battery or drive the load as a result. The connections between solar panels are made up of multiple parallel "strings," according to testing. As a result, if a solar panel is shaded by a tree, a tall building, or a chimney, the remaining solar panels will still generate power energy, all of the solar array connected inside the will also lose the electricity power produced.[8] This is because the panels are connected together, reducing the output of the solar system to the PV system's weakest panel. power output of the entire unit is reduced when just one cell is entirely or partially shadowed. If only one of the series-connected cells full shading, the output power in solar array, no matter how many are linked, will be equal to zero.

IV. Methodology for research.

B. Simulation of partial shading

Solar panels make up the majority of the components of solar energy systems generate electrical. Silicon and semiconductor are used to make solar cells because of their well-known ability to absorb solar energy through a solar array, also referred to as a solar panel array is a group

A. A System Proposed.A PV cell is another name for a solar cell. It converts incoming electrical energy directly from light by using the phenomenon of the photoelectric effect, which is a natural and chemical phenomenon together. It is known that solar emissions, such as incident radiation and heat, should stimulate photovoltaic (PV) cells to produce continuous electrical energy. As a result of this photovoltaic effect, electrical energy is produced by the solar arrays, which is equivalent to the output from the power system. Shade is a problem and one of the factors affecting solar energy output such as voltage and electric current[9] . The shading process affects the effectiveness of the photovoltaic system. The photovoltaic cell is connected to many other cells to form the solar array, which collectively constitute the "solar panel", so that the amount of current(I)t and voltage(V) generated by the PV array is negatively related to the conditions and size of the shading, which also affects this negative performance, the same thing happens to the value of the current and voltage of the other photovoltaic cell [10] in the solar array. The efficiency of solar panels decreases because the solar cell are connected in series. proposed strategy and new is connecting the booster system to the output of the solar array, the proposed strategy reduction the effect of partial shading on the solar array. This system then becomes part of new solar array, increasing the value of the power produced by the PV array by amplifying and stabilizing the voltage generated by the system. The solar system in which the new solar system operates is described as follows:

- No partial shadowing of any type has any impact on the solar system.
- Improving the capacity and capability of the new solar array to generate electrical energy in comparison to its capacity prior to the installation of the booster system.

The solar system's output can be connected to the booster system as indicated in. Figure (4) shows the components of the new solar system.

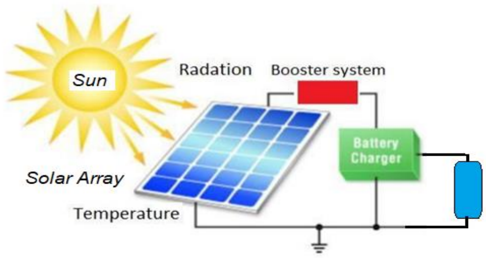


Fig (4): linking the solar panel and the booster system.

of solar cell linked together consisting of photovoltaic (PV) cells [11] . Solar or photovoltaic cells with different structures are associated with formats such as start, end, end and start. Solar cells are connected by three types of bonding, namely bonding (SP), bonding (BL), and bonding (TCT) . characteristics of solar unit under shading constraints are shown in Figure (5), along with techniques used to reduce shading. The solar module featured an end-mounted diode coupling, and while they succeeded in avoiding black dots, they failed to recover lost energy under deflection. Here is a summary of how solar system bypass diodes work under all operating conditions:

- When a cell is partially shaded, its current and voltage behavior is more similar to that of a load than a generator, which results in the formation of a hot spot and an attempt to turn cell from a producer to a consumer of

Figure (5): solar cell connections techniques.

In Figure (6), the current generated from the solar array can travel through the un shaded part because it is in the un shaded area, in this case the bypass diode is forward biased, and this shows how the bypass diode works. The amount of electrical energy generated is determined in the (I-V) and (P-V) properties curves due to the intersection of the shaded units. We note that the amount of the effect of the shade on the output of photovoltaic panels in solar systems was significant. [12]. Scientist Jill Masters of Stanford University provides an example of how the effect of shading a single cell in a solar panel of solar panel cells (36) can reduce energy production by more than 75%. Only 1/36 of the cells can be shaded, resulting in a 75% reduction in solar panel power output. The performance of the solar array was improved, and the photovoltaic cell or solar array continued to be produced, but this work could not reduce the effect of shading on the productivity of the improved solar array.

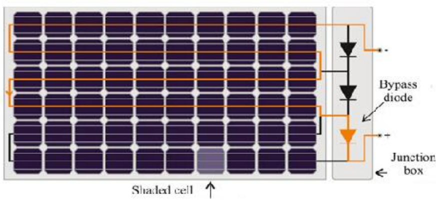


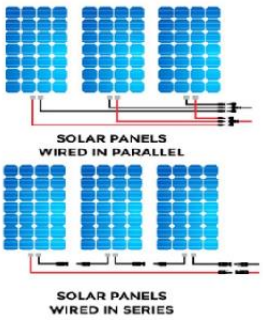
Fig (6): Partial shading bypass operation.

D. Description of the system.

Temperature (T) and solar radiation (G) affect the nonlinear characteristics of a solar cell in a photovoltaic module. For a photovoltaic (PV) module to produce the most amount of electrical energy at any given moment, the greatest ratio of radiation (G) and naturally ideal temperature (T) must be achieved. For a photovoltaic

energy. By cutting off the current across the matrices that are un shading, the hotspot method can be avoided.

- When photovoltaic PV units are un shaded, the bypass diodes are forward biased, as shown in Figure (5.a), causing the generated current to flow to each PV unit.



C. Proposed Algorithm.

Researchers should consider finding methods that work on how to identify partial and complete shade of solar cells and deal with shading and determine the best strategies and means to reduce the impact of shading on ability of solar cell to the obstetric from solar unit . I Created an electronic system that booster system the voltage and tries to address of electrical power lost from the partial shading. The algorithm used relies on amplifying & stabilizing voltage coming out of the solar unit, regardless of value of the current generated by the solar system.

Figure (7) shows the steps for connecting the solar unit to the augmented system

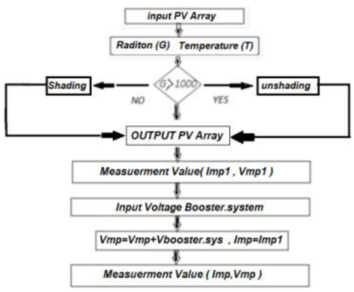


Fig (7): Diagram of the suggested algorithm.

(PV) module to produce the most electricity at any given moment, the large ratio of radiation & naturally ideal temperature must be attained. Using Maximum Power Point Tracking techniques to solar radiation is one of the finest ways to improve work the solar cell. Under standardized irradiation conditions, peak strength is frequently assessed using established procedures like perturbation and observation, incremental conduction, and hill climb. None of these options can address the problem of partial shading, which is caused by overlaying bypass diodes and causes multiple peaks to appear. Therefore, partial shading is a serious problem that reduces the efficiency of the photovoltaic system and causes a large amount of energy loss. In order to solve this problem and raise the production capacity of the photovoltaic system, a booster system. With this technology, the energy output loss brought on by shade on PV

The actual solar energy conversion circuit is shown in Figure (8) as a series of parts connected to each other in the system before connecting the booster system, which consists of the battery, voltage regulator, and inverter (DC / AC) through a voltage converter and a separate channel connecting the inverter. The power factor (PF), which also regulates the crossover voltage, and the inverter work together to manage the unit's output (DC) sinusoidal current. The constant voltage (DC) regulator is located on the outside of the two rings that make up the regulator, in addition to the output current regulator being on the inner ring. The reference current (I_{pv}) generated by the MPPT calculation is then supplied to the control unit (PI), which maintains the PV system output voltage at ideal levels . at comparing circuit in Figure (8) with improved circuit in Figure (9), we can see that circuit in Figure (9) has fewer elements and components because it also included the booster system. As the capacity of the PV units increases, output of this circuit balances lift voltage it outputs from the new solar system and is unaffected by partial shade.

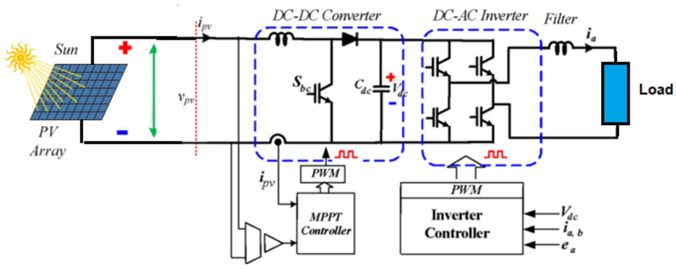


Fig (8): PV system that is grid-connected.

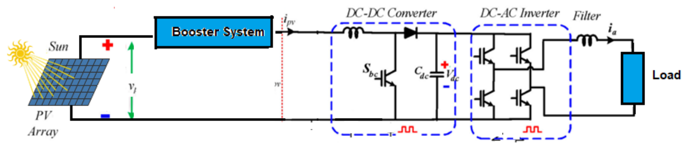


Fig (9): Combined solar and booster system.

E. Results and Analysis(R&A).

When attaching booster system to solar units' analyzing the results. we observe booster system's (optimizer's) role in enhancing, raising, and stabilizing the solar system's output voltage in order maintain the max power in the PV unit at a value higher than the solar system's design value without impairing the effectiveness of other components. As a result, the booster system becomes part of the solar system. To illustrate, a boosting system optimizes the voltage at the output of a shaded unit of the electric power production system to make up for the output voltage loss by matching the voltage going through the un shading components. The darkened unit might not produce enough energy. to be added to the energy of the un shading units, but the booster system worked on adding an electrical voltage that balances the voltage generated for the solar system when there is no shading state without reducing the production of other units thanks to this technology. Figure (10) shows the solar panels whose electric energy production value was affected by different partial shading values.

Fig (10): The impact of shade on solar panels.

E. 1. Effect of Partial Shading on Power Output.

It is important to know the analysis of the performance of the photovoltaic unit in most cases of partial shading as shown in Figure (10) to study the performance and work behavior of the photovoltaic cell at partial shading. It also important to understand and study the behavior and performance of shading conditions and their impact energy generated by the PV module through shading . [13], must take into account shading conditions (vertical, horizontal , inclined) , how shading condition affects one cell, We compare the results extracted from the electrical energy generated from the photovoltaic unit , the electrical energy generated is under the influence of partial shading and the shading is represented by Where the incident solar radiation and energy generated by the solar cell are shown in Figure (11).[14] Due to the decrease in solar radiation falling on the photovoltaic module due to shading, it is clear that the electrical power generated by the solar modules is decreasing. In addition, at any shadow level, the electrical energy was greatly affected.

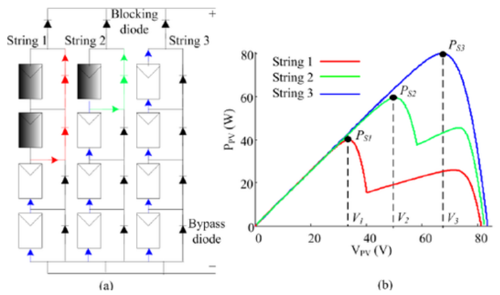


Fig (11): shading's impact on solar cell productivity.

Under normal and abnormal conditions (shading), we conducted an experiment to detect the behavior and performance of a solar panel by operating a photovoltaic panel consisting of (60) solar cells. One circuit was used to perform a solar panel test that does not include the optimization case (boost system), and the previous circuit was tested but does contain the optimization circuit (boost system). The test was conducted and the results were recorded and compared between the two sections. The output results for the solar system that lacks a booster system are presented in Table (1). Figure (14) shows the effect of shade on the performance and operation of the photovoltaic unit at the fixed and variable radiation level [15]. Tables (1) and (2) show the results and spectrum values. , and shows how shading affects the output of solar panels and solar energy unit.

Description	INPUT PV Module			OUTPUT PV Module		
	RADIATION (w/m²) Cells (1-20)	RADIATION (w/m²) Cells (21-40)	RADIATION (w/m²) Cells (41-60)	Max. Current (Amper)	Max. Voltage (Voltage)	Max. Power (W)
UN SHADING	1000	1000	1000	8.06	30.9	249.83
P.SHADING	1000	1000	900	7.48	30.9	235.9
P.SHADING	1000	1000	800	6.67	32.2	215.1
P.SHADING	1000	1000	700	5.85	32.7	191.5
P.SHADING	1000	1000	600	5.02	33.1	166.4
P.SHADING	1000	1000	500	8.055	19.9	160.88
P.SHADING	1000	1000	400	8.055	19.9	160.88
P.SHADING	1000	1000	300	8.055	19.9	160.88
P.SHADING	1000	1000	200	8.055	19.9	160.88
P.SHADING	1000	1000	100	8.055	19.9	160.88

Table (1): The output of a simulation circuit by MATLAB/Simulink without booster sys.

By seeing a decrease in the production of the solar system with the growth of partial shade, the results of the solar model in Table (1) showed that the solar system was affected by shade, as shown in Figure (8). Shade restrictions had an impact on the output of the solar structure. Table (2) shows the operational results of a solar system containing the booster system. The operational value of the solar system when it is not shaded without including the booster system is around (249.8) watts, but the operational value of a solar system when adding the booster system with the solar system in the case of no shading was about (326.9) watts, and this is a value very good power output value, as he added to booster system is a value for the solar system and compared to similar cases in the shading cases for both circuits, we notice a decrease in the power generated in circuit without booster system by increasing the shading condition , However, the output results of the circuit are fixed by adding booster system to the solar panel, and the results are shown in Tables (1) and (2).

	INPUT PV Module	OUTPUT PV Module

Description	RADIATION (w/m²) Cells (1-20)	RADIATION (w/m²) Cells (21-40)	RADIATION (w/m²) Cells (41-60)	Max. Current (Ampere)	Max. Voltage (Voltage)	Max. Power (Watt)
UN SHADING	1000	1000	1000	8.61	37.9	326.8
P.SHADING	1000	1000	900	8.61	37.9	326.7
P.SHADING	1000	1000	800	8.61	37.9	326.7
P.SHADING	1000	1000	700	8.61	37.9	326.7
P.SHADING	1000	1000	600	8.61	37.9	326.7
P.SHADING	1000	1000	500	8.61	37.9	326.7
P.SHADING	1000	1000	400	8.61	37.9	326.7
P.SHADING	1000	1000	300	8.61	37.9	326.7
P.SHADING	1000	1000	200	8.61	37.9	326.7
P.SHADING	1000	1000	100	8.61	37.9	326.7
P.SHADING	1000	1000	100	8.61	37.9	326.7

Table (2): The output of a simulation circuit MATLAB/Simulink with booster system.

Solar energy system modeling.

A. Model of a Solar cell.

Figure (16) shows the single circuits in a solar cell. To achieve the highest power value, latest values for these variables must be found because PV systems depend in their performance on solar radiation (G) and solar temperature (T). The open circuit voltage (V_{OC}) and short circuit current (I_{SC}) noted in the photovoltaic manufacturer's data plate also change the mathematical model of the photocell. From which the value of the short-circuit current, the value of the resistors and the diode can be determined using Kirchhoff's law (KCL).

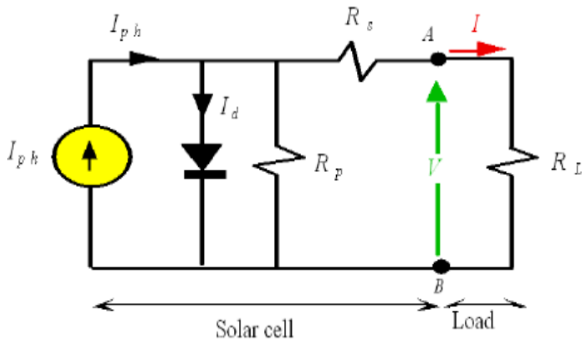


Fig (12): PV cell equivalent circuit.

The PV cell can potentially be modeled.

• The straightforward mathematical equation "(1)" represents the output current of the PV cell.

$$I = I_{ph} - I_d \ldots\ldots.. \quad (1)$$

$$I = I_{pv}$$

I_{ph} : Photocurrent t, & (I_d) : diode current, is

Equation "(2)" describes the saturation current of the bypass valve .

$$I_d = I_o\left[\exp\left(\frac{V+IR_S}{a1V_T}\right) - 1\right] \quad \text{-----------} \ (2)$$

Equation (3) is obtained by substituting in equation "(1)" .

$$I = I_{pv} - I_d - \left(\frac{V + IR_S}{Ro}\right) \quad \text{-----------} \quad (3)$$

Where

$$I_{D1} = I_1\left(\exp\left(\frac{V + IRs}{a1VT1}\right) - 1\right. \quad \ldots\ldots.... \quad (4)$$

Following is a definition of other variables:

$$VT_1 = \frac{NsKT}{q} \quad \ldots\ldots\ldots.. \quad (5)$$

, [16][14] where (q) is the electron charge (1.6021764 * 1019 C), and (k) is the Boltzmann constant (1.3806503 * 1023 J/K), and (T) is the temperature of the (p-n) junction , is the thermal voltage of the PV module containing (Ns) cells connected in series.

$$I = I_{pv} - I_{o1}\left[\exp\left(\frac{V + IR_s}{a_1 VT_1}\right) - 1\right] - \left(\frac{V + IR_s}{R_d}\right) \quad \ldots..(6)$$

B. Partial Shading of an Array.

The solar energy system includes photovoltaic solar panels, which consist of solar cells connected inside fixed panels. They form a number of solar units connected to each other in a series or parallel way. The solar system also contains a system that regulates charging and storage to the battery and a conversion system (converts direct current to alternating current) to provide electricity to the site to be operated .[14].

$$P = VI = V\left(I_{pv} - I_o\left(e^{\frac{VD}{AVT}-1}\right) - \frac{V + R_s I}{Rp}\right) \ldots (7)$$

The final voltage of the solar panel is obtained by adding the voltage (V_{PV}) coming out of the solar panel to the booster system ($V_{Booster}$), and summing the above two values as shown in equation "(8)" .

$$P_{(POWER)} = \sum(V) * I = \sum(V_{PV}, V_{Booster}) * I_{pv} \ldots. \quad (8)$$

V. Applications.

According to the current energy needs of the world, solar energy systems and solar arrays are used to produce large amounts of solar energy. The International Energy Agency (IEA) estimates that by 2050, solar energy systems will supply nearly 45% the world energy needs. Solar thermal energy can also be used to generate electricity. It can be used in all fields of industry, textile, and many businesses, to run lights, motors, pumps, fans and water heaters. Solar energy is also widely used in water desalination telecommunications. And to enhance the stability of energy demand, and solve problems related to improving the performance and demand of solar energy, we can provide energy solutions and the use of solar energy for a range of applications. These steps will also improve solar system efficiency, reduce diversion and enhance energy sustainability. The current research attempts to consider potential solutions to the problems of solar energy systems that use them. In addition to identifying practical solutions to solve these problems and improve the effectiveness and performance solar energy and use solar system as much as possible in generating electrical energy. It has developed a system to enhance and improve the efficiency of work to obtain the energy produced by solar energy systems. This new system helps to increase the capacity of the solar systems in production and reduce the effect of partial shading. This new system offers several advantages, including:

- The ability of the improved photovoltaic system to continuously produce and generate electric power at a constant value of voltage, despite changes in load.
- Increasing the new solar system's generating value above its deign value.
- All types of solar panels can be used with the booster system.

VII. Conclusions.

In this research, the effects of shading conditions on the work of the solar cell, were studied, and the problem of partial and total shading on the outputs of the photovoltaic system was studied, as well as the study of the variation in the data extracted from the solar system. A solar array consisting of (60) cells was taken and a test was conducted to studied the output results of the array cells without the booster system, with the same characteristic as the solar system identical to the previous system with the presence of the booster system. We see that the new solar system stabilizes the voltage output of the array cells and is not affected by partial shading conditions, whether when there is partial shading or when there is no shading. As a result, the new solar system will be reliable in its ability to produce consistent electrical power and will not be affected by any kind of shading.

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