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Bypass Diodes to Improve Solar Panel Efficiency for Certain Module

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The *p-n* junction is a small solar cell component that can create power. When photons clash with the *p-n* junction, electrons are absorbed by atoms and holes are released in the *n*-type region. The bypass diode method can boost a solar panel output power that has been lowered due to shading. In the current-voltage and power-voltage characteristics, new peaks and maximum power points were seen. The maximum notable meaningful output power without bypass diodes was observed in the 51.1 W ranges. After bypass diodes were fitted, the first peak at 116.1 W and the second peak at around 151.1 W appeared at voltages of roughly 31.1 V and 41.2 V, respectively. During periods of bright sunlight, photovoltaic solar panels (PV panels) are efficient energy sources. Excess energy can be stored and used later, such as during night or when the weather is cloudy. This proposed work investigates the use of mathematical approaches and fuzzy logic models to predict energy efficiency generation for PV panels. Analytic equations link PV panel power to temperature and solar radiation in mathematical models. This site-specific angle is defined by the sun's daily, monthly, and annual cycles. Forecasting generation and demand for power is the foundation for being on the electricity market. Power generators and distributors are the most likely to employ short-term forecasting. The primary concern of energy producers is external factors that influence output levels, such as weather.

Keywords: Solar panel efficiency, Bypass diodes, Amplification, Sun light, Technology.

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1. INTRODUCTION

The demand for energy will increase as the world's population expands. Today, the enormity of energy cannot be overlooked. It is required in every aspect of life. There are two sorts of energy sources: renewable and nonrenewable [1]. The limited renewable resources will be gradually replaced by nonrenewable resources. The most important factor to consider when using them is the impact on the environment.

Solar energy refers to the Sun's radiant light and heat that may be taken in various methods, conclude “solar power generation, solar thermal energy, solar water heating, and solar architecture” [2]. It is an important source of renewable energy, and its solar technologies are categorized as passive or active depending on how it collects, distributes, or converts solar energy into solar power. Photovoltaic systems that generate concentrated solar electricity and heat water are examples of active solar technology. Orienting a structure toward the Sun, employing materials with high thermal mass or light-dispersing qualities, and constructing rooms with natural air circulation are all passive solar choices. The volume of a solar panel determines how effective it is at converting sunlight into useful energy. When a solar panel with a 20 % efficiency rating is illuminated by the sun, it transforms 20 % of the sun energy into solar energy. When the same quantity of sunshine hits two solar panels with varying efficiency ratings, the result is the panel with the higher efficiency generates more electricity. The efficiency of solar panels is determined by the amount of energy generated by solar cells, which is impacted by the cells' composition, electrical setup, surrounding components, and other factors.

2. PHOTOVOLTAIC CELL CONSTRUCTION

2.1 Concept

When exposed to sunlight, photovoltaic (PV) solar produce DC cells electricity, exactly like a cell or a battery. When no external circuit or load is connected to its terminals, most PV solar cells produce a maximum "no-load" open circuit voltage (V_{OUT}) of roughly 0.5 to 0.6 V, which is significantly less than a conventional 1.5 V dry battery cell. By connecting many PV cells in series, similar to how batteries are connected, higher voltages can be obtained. When exposed to sunlight, a PV cell generates a current (I) that is proportional to the amount of light falling on its surface. The short-circuiting current I_{SC} is the highest current a PV cell can produce when its terminals are shorted together. The terminal voltage, however, would be zero at these highest current levels, $V_{OUT} = 0$. The load current demands from I_{SC} to I_O have a significant impact on the output voltage of a solar cell. From this perspective, a PV cell is nothing more than a low-voltage, high-current gadget.

2.2 Research Methods

Fig. 1b depicts a solar cell's equivalent circuit. By connecting a current source to a diode in parallel, a perfect solar cell can be created [15]. In reality, however, there is no such thing as an ideal solar cell. This equivalent circuit is supplemented with series resistance and shunt resistance in practice. I_L (load current) is the current created by the entry of light into the cell. I_D (diode current) describes the existing situation that has been displaced as a result of recombination. The current loss due to shunt resistance is deno-

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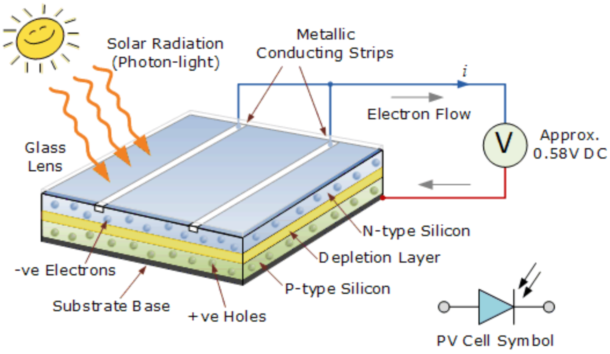
ted by R_{SH}, whereas I_{SH} denotes the current loss due to shunt resistance. The ideal shunt resistance R_{SH} and series resistance R_S values are, respectively, infinite and zero. If the shunt resistance is infinite, the I_{SH} will be 0, indicating no current flows.



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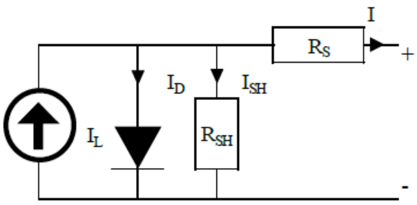

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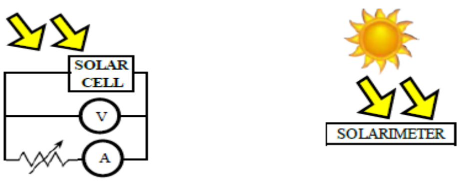
Fig. 1 – PV solar cell construction (a) and solar cell equivalent circuit (b)

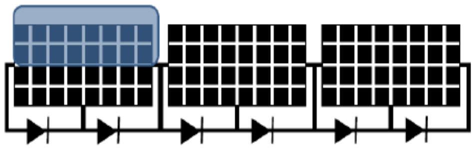
A PV cell measurement and solar irradiance are shown in Fig. 2. Direct current is produced when a solar cell is exposed to light; it produces electricity (DC). A variable resistance box, two multimeters for voltage and current measurements, and wires are all necessary for measuring the *I-V* curve of a solar cell [17]. The resistors that are used to test solar cells must be chosen with care. Small resistors, such as 12 W resistors, would overheat and burn out if used to measure the output of a solar panel. Understanding how much sunlight reaches the solar cell's surface is crucial. Solar radiance, measured using a solarimeter, is the most widely used method for quantifying sun radiation [18]. Solar radiation has a value that varies from 0 to around 1001.1 W/m^2. The weather and location influence the brightness of the sun.



(a) (b)

Fig. 2 – Solar cell (a) and solar irradiance (b) measurements

A schematic of bypass diodes with shading is shown in Fig. 3a. A series array should have the same current flowing through all its cells. When one cell is shaded, the outcome is reverse bias, which works as a burden and can cause issues such as hotspots that might affect the system [19]. Uniform and non-uniform shading are the two forms of shading [20].



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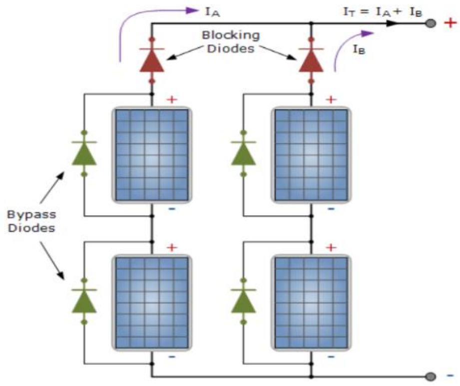

b

Fig. 3 – Bypass and shading diodes (a) and PV arrays using bypass diodes (b)

3. BYPASS DIODE

PV modules utilize bypass diodes to prevent high reverse voltage from being applied across the cells in the event of shade. The following are the prerequisites.

It should be able to switch fast and have a low forward voltage. Schottky diodes, which are semiconductor-metal junctions, are used in solar modules. The leakage current of bypass diodes should be low. A bypass diode's maximum recurring reverse voltage (V_{RRM}) is proportional to the number of cells it connects

Diodes, as previously stated, are devices that only allow one way current to flow. The green diodes in the diagram above are called "bypass diodes," and to create a low-resistance circuit, they are connected in series with each solar panel. Solar panels and arrays must include bypass diodes that can safely carry the short circuit current shown in Fig. 3b.

Blocking diodes are two red diodes that are connected in with each branch of the series Blocking diodes is an expression used to designate diodes that are being used are not the same as bypass diodes, but they are physically similar in most circumstances. They are, however, implanted in a different manner and serve distinct applications.

Only one path of electrical current travels "OUT" external load, controller, or batteries in a series, array, thanks to these blocking diodes, also known as series diodes or isolation diodes.

This is done to prevent current from recirculating through a weakened (shaded) network generated by additional PV panels in the same array that are connected in parallel, as well as to protect batteries that are fully charged from being discharged or at night, the water is drained back through the array. In each parallel connected branch, blocking diodes must be employed when numerous solar panels are connected in parallel.

When there are two or more parallel branches in a PV array, or when as the sun goes across the sky during the day, sections of the array may be partially obscured, blocking diodes are often used. The size and type of blocking diodes utilized depends on solar array type.

The Schottky barrier diode and the *p-n* junction semiconductor diode are both semiconductor diodes with a *p-n* junction are used in solar panels and arrays can be used as bypass diodes. Both have a wide variety of current ratings. The forward voltage drop of a Schottky barrier diode is roughly 0.4 V, compared to 0.7 V for a *p-n* diode in a silicon device.

The solar arrays series branches can save one full PV cell due to the lower voltage drop, making the array stronger because the blocking diode dissipates less power. The majorities of solar panel manufacturer's use their panels contain both blocking and bypass diodes, simplifying the design. The number of cells connected through the bypass diode is proportional to the total of the cells connected through the bypass diode. With bypass diodes, both short- and open-circuit failures are conceivable. A short-circuited diode decreases the power of a PV module by one-third compared to three bypass diodes. When the power level falls below 80 %, the PV module fails. A bypass diode cannot flow current in an open circuit; therefore, it does not affect the solar PV module's power production. If the solar cell component lacked a bypass diode, the situation would be the same. Shaded cells may be subjected to a high level of reverse bias uncertainty. In the worst-case situation, the open-failed diode shades a substring of cells, resulting in cell failure, overheating, and fire danger. Modules by open-failed diodes are likewise considered failed due to the potential for safety issues.

There are two failure modules for bypass diodes in solar modules: catastrophic and wear out. Arcing electrostatic discharge and thermal runaway are examples of catastrophic failures. Bypass diodes wear down due to thermal cycling, high-temperature forward bias action, and high-temperature reverse bias operation.

4. METHODOLOGY

Fig. 4 depicts the panel *I-V* (curve a). When the irradiance was augmented from 201.1 to 1001.1 W/m^2 at a set temperature of 25 °C, the output current design changed knowingly, but the voltage stayed practically constant. "The panel current rose by 44 % as the irradiance climbed from 400 to 600 W/m^2. This means that irradiance has a more significant impact on output current than output voltage" [21]. In a short circuit, the current (I_{SC}) surges as the radiation intensity increases, whereas the modification in open-circuit voltage (V_{OC}) is minor [22]. Fig. 4 displays a solar panel's *P-V* (curve b). The graph illustrates how the panel's output power grew significantly when the irradiance augmented from 200 to 1000 W/m^2 at a constant temperature; the panel power increased by 60 % once the irradiance was increased from 400 to 600 W/m^2.

The quantity of solar irradiation that strikes the panel surface controls its power. The features of *I-V* are displayed in Fig. 5a of a PV panel with 980 W/m^2 irradiation. As illustrated in Fig. 5a, I_{SC} is set to 4 A, and V_{OC} is set to 48 V. Fig. 5 depicts the *P-V* characteristics that resulted (b). The I-V characteristics include numerous steps, and the *P-V* characteristics have several peaks, as seen in Fig. 5. Current will flow through the unshaded cells if bypass diodes are used. The shaded cells will restrict the output current of the unshaded cells if the bypass diodes are not coupled. The effect of partial shadow on electricity generation is seen in Fig. 6.

Time is represented on the horizontal axis. The vertical axes on irradiance in W/m^2 and PV output in W, respectively, are represented on the left and right. The average sun intensity for the next few hours was 426 W/m^2, sun radiation varies by hour from 0 to 1001.0 W/m^2. PV generation, on the other hand, ranged from 0 to 151.1 W per hour, with an average of 68.1 W. Furthermore, techniques like as cooling and reflection via a mirror can increase output power. [23]. Pentacene, an organic semiconductor, has lately been investigated for use in solar cells [24]. The light energy is converted into voltage by the absorber layer [25], is another important solar cell component.

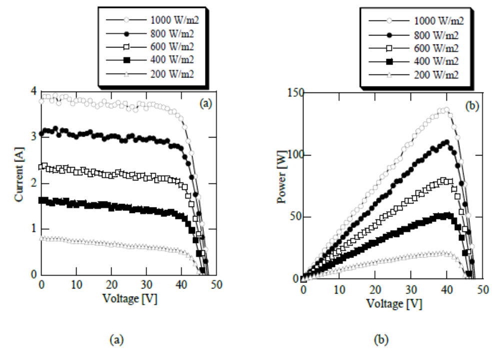

Fig. 4 – *I-V* curves (a) and *P-V* curves (b)

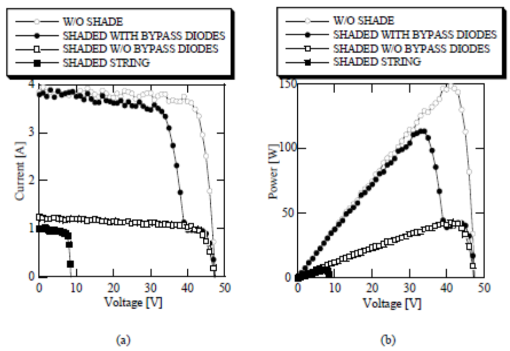

Fig. 5 – Shade's influence on *I-V* (a) and *P-V* (b) curves

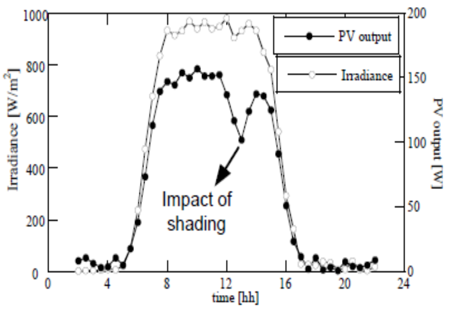

Fig. 6 – Partial shading has an impact

5. CONCLUSIONS

- The bypass diodes approach was used to boost a solar panel's output that had been lowered due to shading.
- The positioning of bypass diodes and the quantity of shadow cast over the PV panel significantly impacts the PV panel's output power characteristics.
- The output current grows as bypass diodes are added, resulting in new peaks and maximum power point.

The various mitigation approaches are explained to determine how to get the most power out of a PV system under varied irradiation situations while also considering the limitations of each strategy. Furthermore, the impact of PS on energy yield and its importance in the interconnection scheme and shade diffusion have been discussed. Under PS conditions, reconfiguration array techniques and associated switching combinations have provided an excellent solution for tracking maximum power.

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Зворотні діоди для підвищення ефективності сонячної панелі для певного модуля

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p-n-перехід є невеликим компонентом сонячного елементу, який може виробляти електроенергію. Коли фотони стикаються з *p-n*-переходом, електрони поглинаються атомами, а дірки вивільняються в області *n*-типу. Метод зворотного діода може збільшити вихідну потужність сонячної панелі, яка була знижена через затінення. На вольт-амперних характеристиках та характеристиках потужності від напруги були помічені нові піки і точки максимальної потужності. Максимальна помітна вихідна потужність без зворотних діодів спостерігалася в діапазонах 51,1 Вт. Після встановлення зворотних діодів перший пік при 116,1 Вт і другий пік близько 151,1 Вт з'явилися відповідно при напругах приблизно 31,1 В і 41,2 В. У періоди яскравого сонячного світла фотоелектричні сонячні панелі є ефективним джерелом енергії. Надлишок енергії можна зберігати та використовувати пізніше, наприклад, вночі або в похмуру погоду. У запропонованій роботі досліджується використання математичних підходів і моделей нечіткої логіки для прогнозування генерації енергоефективності для фотоелектричних сонячних панелей (ФЕ панелей). Аналітичні рівняння пов'язують потужність ФЕ панелі з температурою та сонячним випромінюванням у математичних моделях. Характерний для даної місцевості кут нахилу визначається добовими, місячними та річними циклами сонця. Прогнозування виробництва та попиту на електроенергію є основою перебування на ринку електроенергії. Виробники та дистриб'ютори електроенергії найчастіше використовують короткострокове прогнозування. Основною проблемою виробників енергії є зовнішні фактори, які впливають на рівень виробництва, наприклад, погода.

Ключові слова: Ефективність сонячної панелі, Зворотні діоди, Підсилення, Сонячне світло, Технологія.