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Analysis of Solar Power Generation Performance Improvement Techniques

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Abstract

The performance of solar power generation systems broadly depends upon the effectiveness of the solar cell placed in the architecture. The performance of the solar cell may vary with respect to the heat generated over its surface. Hence different types of cooling methods are employed over the solar power generation system to improve its power efficiency. Apart from solar cell cooling method, different types of optimization techniques are also implemented to the solar power generation unit for extracting a good power output. The maximum power point tracking algorithm is one of the primary methods used for matching the generated power to reach the required power in the connected battery system. The paper analyzes the research attainments and limitations of the various cooling models employed for the solar power generation system to develop an efficient system in future.

Keywords: Effective cooling, solar cell lifespan, energy converter, maximum power point tracking, power forecasting

1. Introduction

The solar power generation system converts the light and heat energy received from the sun into an electrical energy through a photovoltaic (PV) cell. This is achieved by making a photovoltaic effect in the solar cells. In general, the PV cells are made by combining two different semiconductors called ‘p’ and ‘n’ type semiconductors to form a p-n junction. The p-n junction creates an electrical field over the area and allows the electrons to move from one junction to another. Basically, the light energy is a combination of photons consists of electromagnetic radiation and the PV cells are having the ability to observe such photons from the light for transferring it as an atom to reach the p-n junction. Therefore the light energy reaches the electron as an atom to make the electrons to flow between the junctions for enabling a power supply. The electrons make a bond with their neighboring atoms for

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holding the semiconducting material when there is no way for the light energy to reach the p-n junction. In general the solar power system is categorized into three types as on-grid, off-grid and hybrid solar power system.

1.1 On-grid solar power system

The on-grid solar systems are widely used for home and industrial applications where the power generation is beyond the required amount. The excess power that are generated by the solar power system is directly transferred to the grid system. Similarly the user will get the power supply from the grid system when the solar power system underperforms. Hence the reliability of the on-grid system is high and therefore it is implemented on various industries to avoid interruption in their production line due to power supply limitation. Similarly the on-grid system is not connected with a battery unit and it saves the installation and maintenance cost to certain extent. The architectural view of the on-grid power system is shown in figure 1.

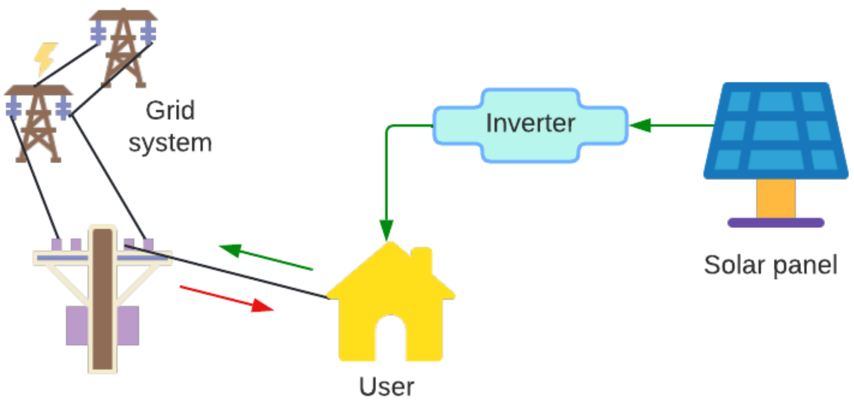

Figure 1. Architecture of an on-grid solar power system

1.2 Off-grid solar power system

The off-grid systems are not connected with a power grid. Therefore its power requirement at critical time is managed by the power saved in the battery backup. Figure 2 explores the architecture of an off-grid power system where a battery is connected in between solar panel and inverter. A power controller is utilized in the circuit for regulating the charging power requirement for the battery unit. The power saved in the battery unit will be taken by the user when there is no adequate sunlight of generating the solar power. This kind of model requires a heavy battery unit for backup power supply and that improves the cost for installation. At the same time, the battery unit requires regular checkup and maintenance. The off-grid solar systems are widely employed in the areas where the power grid lines are not available.

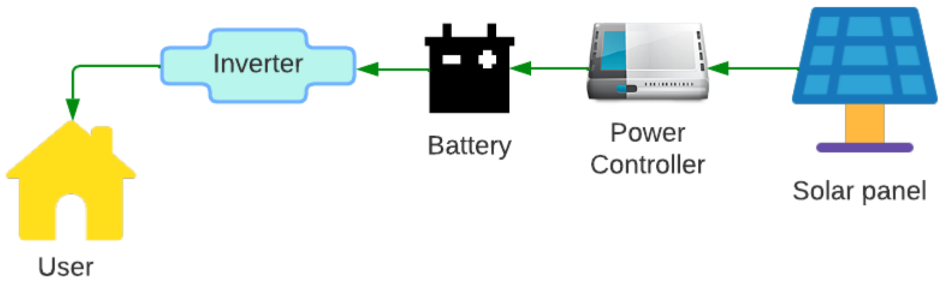

Figure 2. Architecture of an off-grid solar power system

1.3 Hybrid solar power system

The hybrid solar power system models were developed to reduce the cost expenses on power utilization from the grid systems. It is done by merging the architecture of on-grid and off-grid power systems. A battery unit is employed in this system to give power supply backup to the user when there is no supply generation from the solar panel. Hence this kind of system avoids the power utilization by the user from the grid systems. In general, the hybrid power systems are employed at the place where the power utilization cost is high. Though the circuit architecture seems to be complicated in such systems on attending the faults and maintenance.

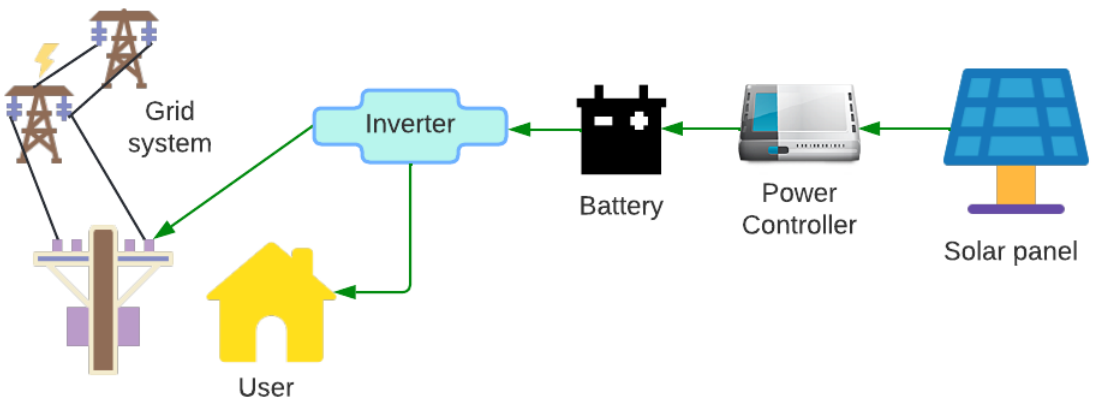

Figure 3. Architecture of a hybrid solar power system

2. Literature Survey

There are many ways available to improve the performances of a solar power system. In that the utilization of high Concentrated Photovoltaic (CPV) cells to the model makes it as more efficient one. The CPV cells are having a lens kind of mirror over its field that allows the sunlight to reach the p-n junction in an efficient way. In most cases the CPV modules are implemented with a solar tracking system and cooling module for improving its efficiency nearby 45%. The cleanliness of solar cell improves its outcome up to 5% and in the places where there is no rainfall makes the efficiency to decrease by 20%. Basically the solar panels are used to clean once in a year in their routine maintenance. All the performance characteristics of large scale solar power systems are monitored by energy management software and that allows the user to monitor the power generation performances of the system. Table 1 explores the performances of CPV modules with different methodologies.

Table 1. Performance of solar power systems with CPV cells

Reference	Design Model	Experimental Outcome
Valera et al. [1]	CPV with passive cooling	10.8% of improved relative efficiency
Wang et al. [2]	CPV with spectral beam splitting technology	76.3% of improved optical efficiency
Wang et al. [3]	CPV with a linear fresnel reflector	14.7% of improved energy conversion efficiency
Alzahrani et al. [4]	CPV with pre-illumination cooling	12% of improved cell efficiency
Widyolar et al. [5]	CPV with hybrid concentrating solar power	23% of improved energy conversion efficiency

The CPV solar cells are costlier than the traditional model cells but these kinds of cells are implemented at the places where the reliability is more important. The effectiveness of CPV cells are further improved by merging it with different control strategies. The performance analysis on CPV at table 1 indicates that the energy conversion efficiency is improved by making customized solar reflectors. The relative and cell efficiencies are improved by adding a cooling system to the CPV panels to avoid excess heating. Table 2 explores the recent techniques that are designed to track the solar energy for moving the PV modules.

Table 2. Performance of solar tracking system

Reference	Design Model	Experimental Outcome
Jamroen et al. [6]	Closed loop active control system using LDR	44.89% of improved electrical energy
Nadia et al. [7]	Adaptive neural fuzzy inference system on dual axis tracking system	MSE 1.520 x 10^{-4}
Zhu et al. [8]	Dual axis system with mathematic expressions based on the sun-earth geometric model	96.4% of solar radiation improvement found over the single axis model
Saeedi et al. [9]	Dual axis system with wheatstone bridge and LDR	48.2% efficiency gain over the fixed panel
Jamroen et al. [10]	Dual axis system with UV sensor	19.97% of efficiency improvement over the fixed system

Moving the solar panel towards the sunlight direction will improve the efficiency of the energy production to its maximum. In traditional systems, the solar panels were installed at the place where the sunlight will be for the long duration in a time. It is done by analyzing with a mathematical operation and the latitude and longitudinal position of the location. The modern system utilizes the sensors like LDR and photodiode for estimating the sunlight direction and moves the solar panel with the help of a dual axis motor. Table 2 indicates different methods that are improving the solar PV station efficiency using sunlight tracking methods.

All electrical systems require a perfect condition for its efficient operation. In the same way, the solar PV also requires a right temperature for its improved operation. In most of the cases the solar PV systems are employed at the place where the rainfall is minimum. Therefore the temperatures of such areas are slightly higher over the regular places. Hence different kinds of cooling methods are used for regularizing the temperature of the solar panel. Table 3 represents different kinds of cooling methods that uses water and heat exchanging procedures.

Table 3. Performance of solar PV cooling method

Reference	Design Model	Experimental Outcome
Alizadeh et al. [11]	Flat plate closed-loop pulsating heat pipe	23% improvement on passive cooling 35% improvement on active cooling
Laseinde et al. [12]	Automated water spraying method on polycrystalline PV	16.65 % of improvement on efficiency
Moh et al. [13]	Passing graphene particles as a liquid solution in multiple micro-sized channels	54% of efficiency improvement over the non-cooling method at 45°C
Mah et al. [14]	Water cooling method with flow rate of 6 L/min	15% of efficiency improvement over non-cooling method
Elminshawy et al. [15]	Buried heat exchanger system	40.65% of efficiency improvement at 45°C

Table 4. Performance of solar PV cleaning method

Reference	Design Model	Experimental Outcome
Myyas et al. [16]	Automated cleaner with recycling system	Recycles 80% of water and avoids manual refilling
Alagoz et al. [17]	Surface acoustic wave technique	Protects the panel from physical damage and removes dust with 0.2mm size

Zhang et al. [18]	Nylon brush with an actuator system	98.6% of accuracy attained at 0.693 gr/m^2 of dust
Kawamoto et al. [19]	Electrostatic force created with electrodes	80% of accuracy attained at 5 gr/m^2 of dust
Swain et al. [20]	Cleaning brush with dual axis DC motor	Energy without cleaning = 1.292kWh Energy without cleaning = 1.455kWh

As the solar PV systems are not placed in the rainfall areas, the possibility of dust particle deposit over the solar panel is very high. The presence of dust particles may reduce the performance of the power generation with respect to time by the addition of more dust particles. Therefore different kinds of solar panel cleaning methods are discussed in table 4. Water cleaning, electrostatic method and contact based cleaning are some of the methods that are widely used for solar panel cleaning.

3. Discussion

Solar PV power generation is one of the most trustable and easy to install non-renewable power generation system on the present days. The solar based systems are even installed to homes and small shops around us. The solar PV system occupies a huge space when it is required for a huge power generation. Similarly the power production of the solar PV system may vary with respect to time as the sunlight is not even all the time. Therefore the CPV modules are widely used in such applications. The efficiency of the solar PV system is also improved by having a solar tracking system or panel cooling system or cleaning system. The incorporation of such improving methods is decided with respect to the location of the PV station. The review work indicates a different type of methods that are used for such improving methodologies and suggests a combination of one or two improving method may improve the overall efficiency of the system.

4. Conclusion

Operating solar power system at its maximum efficiency was one of the challenging tasks certain years ago. Due to the development of optimization techniques, the efficiency is improved to a certain extent. Similarly, the addition of certain control strategy has also improved the power regularity in the solar PV systems. The review work performed in the paper reports the efficiency of the recent year solar tracking systems with its cooling and cleaning methods. Also, this work determines that a hybrid design with the combination of such improving methods may enhance the efficiency to next level. However, although the solar PV systems are widely recommended due to its cost efficiency, the hybrid enhancing techniques may not be economical. Therefore, the future hybrid technique must also consider such factors in its design process for reducing the operation and maintenance cost of a solar PV system.

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