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Different types of cooling technique applied on a photovoltaic panel: The performance response

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Abstract- The different use of solar energy - solar heat, solar photovoltaic, solar thermal electricity, and solar fuels offer a clean, climate-friendly, very rich and in-exhaustive in-thorough energy asset to humanity. Photovoltaic panel uses solar light energy to produce electricity. This paper provides a comprehensive overview of an elective cooling method for photovoltaic (PV) panel that includes water flow and water spray on panel surface. The present paper gives far reaching review to the ongoing examinations that have talked about the design and cooling observations to construct high performance hybrid Photovoltaic/Thermal (PV/T) system. The acceptability is also be resolved for of the proposed both cooling procedures, where the main advantage of the analysed cooling technique is regarding the PV panel's surface and its self-cleaning effect, which also acts as a booster to the average delivered electricity.

Keywords: *Hybrid PV/T, surface cooling, electricity, PV panel and efficiency.*

1. INTRODUCTION

Solar energy is the most used renewable energy source around the world. Solar energy technology is pollutant free during operation, diminishes global warming issues, lowers operational cost, and offers minimal maintenance and highest power density compared to the other renewable energy technologies [1], [2]. Solar panels are used widely as an efficient mean to harness solar energy. However, the efficiency of a typical solar panel reduces throughout its operation due to excess heating of the solar photovoltaic system. Every 1 °C surface temperature rise of the PV module causes a reduction in efficiency of 0.5% [3]. Proper cooling of PV systems improves the thermal, electrical and overall efficiency, which in turn also reduces the rate of cell degradation and maximizes the life span of the PV module [4]. In order to utilize solar energy up to its full potential, there needs to be a efficient cooling system for the solar panel which will increase the overall conversion efficiency. The operating surface is needed to be maintained at a relatively cool temperature to improve the electrical efficiency, and decrease the rate of cell degradation with time, resulting in maximization of the life span of photovoltaic modules [5]. The excessive heat removed by the cooling system can be used in domestic, commercial or industrial applications [4].

This paper provides a brief insight to the different cooling systems used for solar photovoltaic system. Several research papers are reviewed and classified based on the type of technology used to achieve the cooling of photovoltaic panels. The performance of each cooling technology is highlighted and their efficiency was compared while mentioning the problems associated with each technique. The presented review can prove to be helpful in selecting the suitable cooling system based on operator's demand.

2. PROSPECT OF SOLAR ENERGY IN BANGLADESH

Renewable and clean energy resources have become a demanded research area due to the increasing energy demand and fast depletion of natural resources. The world electricity demand will increase by almost 80% from 2012 to 2040 in the (IEA) International Energy Agency's New Policies Scenario [6]. Renewable energy harvesting can be a felicitous alternative for existing energy generation methods that depend on natural resources for electricity generation. The energy demand is increasing significantly in Bangladesh as well. A sustainable long-term power development plan has been prepared for mitigating the growing demand to reach the generation capacity of 24000 MW by 2021 [7].

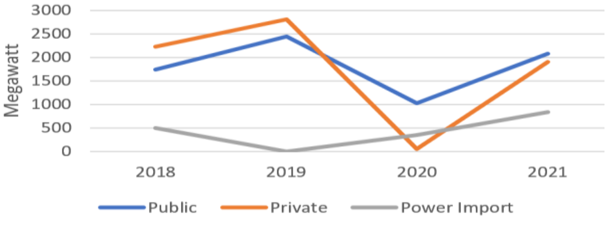

Fig.1. Year wise generation projects to be completed (From 2018 to 2021)

Revised generation expansion plan updated in August 2018 targeting about 15,000 MW generation additions from 2018 to 2021 is shown in figure 1 [7]. Solar energy can serve as an efficient mean of supplying the increasing energy demand of Bangladesh. However solar energy varies based on geographical location. In order to fully comprehend the prospect of solar energy in Bangladesh the standard solar radiation, sunlight hour and cloud coverage of Bangladesh is provided below.

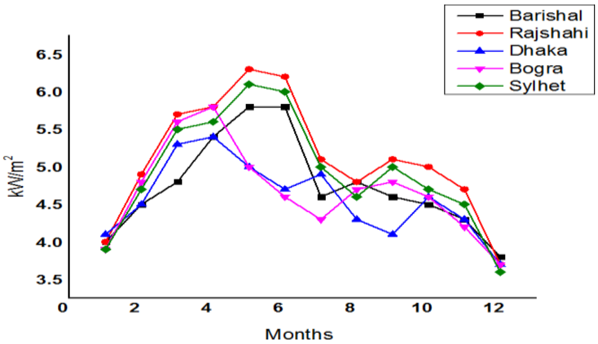

Fig. 2. Standard solar radiation of the big cities in Bangladesh [8]

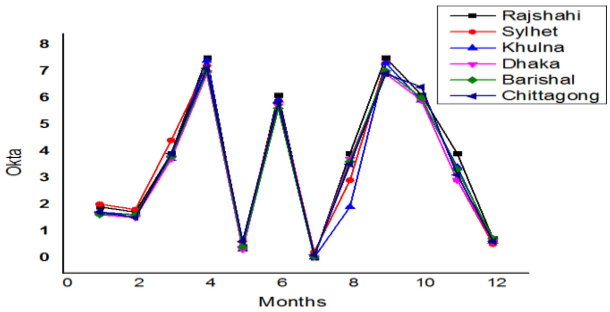

Fig. 3. Standard cloud coverage over three years in six divisions [9]

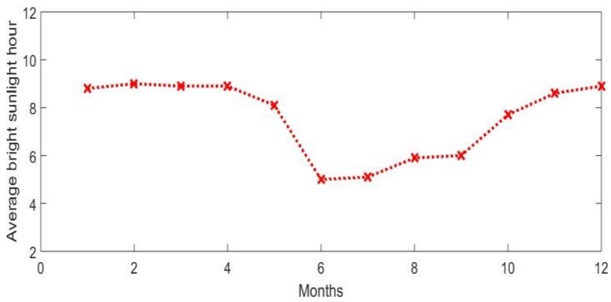

Fig. 4. Average sunlight hour of Bangladesh [10]

3. LITERATURE REVIEW

From the premise of solar energy, the conceivable plans that could be actualized in Bangladesh are: Ranhuraman and Cox [11], [12] experimented on Hybrid PVT/W system and focused on mainly PV panel cooling. The study described analytical calculations on PV panel and hybrid photovoltaic/thermal system and evaluated different design parameters of hybrid PV/T system. Hamdy et al. [13], O'leany et al. [14] and Al-Baali [15] investigated on light concentrating PVT/W system. In these studies, solar light was concentrated on PV panel and got more efficiency than typical one that time. The effect of evaporative cooling implemented on PV panels and the maximal detected total increase in power output was around 19% [16]. Direct PV panel cooling with an established water flow over the front side of the panel was investigated and it was possible to increase power output by 9.5% [17]. Furthermore, authors investigated a water spray cooling technique implemented just on the front side of the PV panel and significant improvement of electrical efficiency was established [18]. A back-surface water cooling method was investigated in [19] for hot climate conditions and it recorded an increase in electrical efficiency by around 9%. In addition, alternative cooling techniques that include water as a coolant were studied in [20]–[22], where the average achieved increase in power output ranged from 10% to 20%, depending from the specific implemented cooling technique.

4. COMMON SOLAR PANEL COOLING TECHNIQUES

For better performance solar panel should be used with a cooling system. Each cooling system comes with its own advantages and disadvantages and thus must be used after considering all the factors associated with installing a solar panel system. A brief insight into some of the prevalent cooling systems are mentioned below.

4.1. Hybrid solar Photovoltaic/Thermal (PV/T) system cooled by water spraying

Water spray cooling system is a well-known solar panel cooling system. Water spray cooling can usually be done in the following manners.

- Front side cooling of the PV panel.
- Backside cooling of the PV panel.
- Simultaneous front and backside cooling of the PV panel.

A typical water spray cooling system is shown in figure 5.

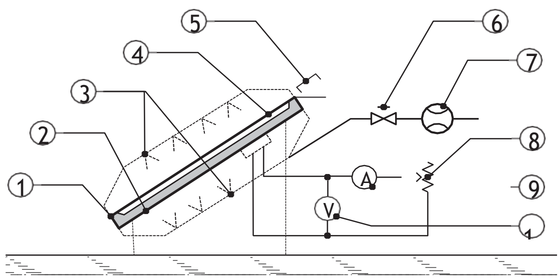

Fig. 5. Water Spray Cooling System [23]

Here, the numbering represents
(1) Photovoltaic panel
(2) Temperature Sensor (Back)
(3) Nozzles
(4) Temperature Sensors (Front)
(5) Pyranometer
(6) Water flow regulating valve
(7) Water flow meter
(8) Rheostat
(9) Ammeter
(10) Voltmeter

PV panel mean performance parameters for different examined cooling circumstances.

Applied cooling options	Maximal power output (W)	Relative increase in power output (%)	Effective increase in power output (%)	Average panel temperature (°C)	Electrical efficiency (%)	Effective increase in el. efficiency (%)
Without cooling	35	–	–	56	13.92	–
Back surface cooling	39.9	14.0	5.4"	33.7	15.59	3.6"
Front surface cooling	40.1	14.6	6.0"	29.6	15.42	2.5"
Simultaneous cooling	40.7	16.3	7.7"	24.1	15.92	5.9"

Fig. 6. Mean performance parameter for different examined cooling circumstances [23]

From figure 6 it can be seen that best electrical efficiency can be obtained from simultaneous cooling i.e. both back and front surface cooling.

In hybrid solar Photovoltaic/Thermal (PV/T) system cooled by water spraying, the solar panel is cooled by spraying water through a nozzle. A centrifugal pump is used to supply the water needed. Better cooling can be achieved by spraying the cooling agent, i.e. water, on the surface area of the PV panel by using a fan [24]. A schematic diagram of a typical PV/T system cooled by water spraying is provided in figure 7.

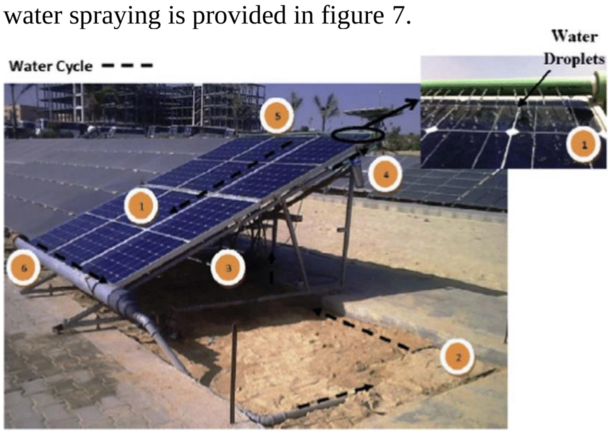

Fig. 7. Hybrid solar Photovoltaic/Thermal (PV/T) system cooled by water spraying [24]

A problem of this cooling system is that water is wasted and heat could be utilized to harvest more solar radiation [4]. If the heat carried away by the water can be utilized the system will become more efficient.

4.2. Floating Tracking Concentrating Cooling

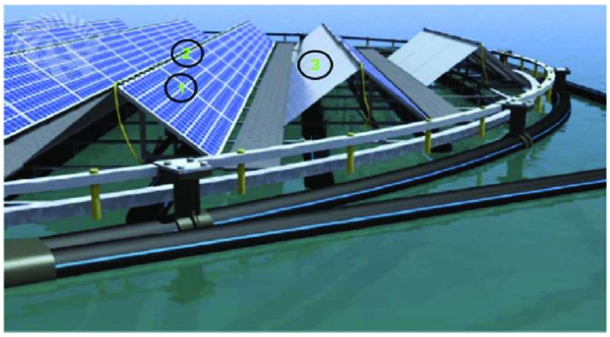

Fig. 8. Floating tracking concentrating cooling (FTCC) [4]

A typical FTCC system can be seen in figure 8, where the following numbering represents:

(1) PV modules.
(2) Sprinklers
(3) Solar reflectors

One method of cooling PV module is by sprinkling water on it in a floating solar plant. Artificial basins are used to install floating plant. Floating plants are built of a platform with PV modules a set of reflectors and a solar tracking system. Cooling of PV module is done through sprinklers. For concentrating the solar radiation to increase the energy harvesting reflector is used and to control the positioning of the reflector a tracking system is provided. This type of plant is called floating tracking concentrating cooling (FTCC). FTCC system is smart solar concentrators lightweight, low cost and generate electricity [25] and advantageous for high thermal applications [26].

4.3. Hybrid solar Photovoltaic/Thermal (PV/T) cooled by forced water circulation

With the goal of increasing the PV systems' efficiency, a hybrid Photovoltaic/Thermal (PV/T) system generates electrical energy and thermal energy simultaneously [27]. The system made of a PV module and thermal collecting pipe. To improve the contact area between the PV module and thermal collecting pipe rectangular collecting pipe are used. Water is used as circulating pipe which flows through the collecting pipe and is done by using a DC pump. The DC pump can be powered by the PV module or other sources. The system is shown below in figure 9.

Fig. 9. Hybrid solar Photovoltaic/Thermal (PV/T) cooled by forced water circulation [28]

Where the following numbering represents:
(1) PV modules
(2) Circulation pump
(3) Water storage tank

When the hybrid system is exposed to solar radiation waste heat is carried away by circulating water flowing through the collecting pipe. Electrical efficiency is increased through this process and also supplies hot water for domestic applications. A model developed to predict thermal-electrical performance of heat pipe and results show overall thermal, electrical and exergy efficiencies increased to 63.65%, 8.45% and 10.26% [29]. Experiments show air cooling increased electrical efficiency by 2.6% and water cooling by 3%, which indicates water cooling to be superior [30].

4.4. Hybrid solar Photovoltaic/Thermal system cooled by forced air circulation

Forced air circulation system is comparatively cheaper as there’s no need to use a pump for transfer of water. However, the cooling rate is comparatively lower than water cooled system.

Fig. 10. Hybrid solar Photovoltaic/Thermal (PV/T) cooled by forced air circulation (a) normal solar panel (b) solar panel with forced air circulation attachment

This system consists of a photovoltaic module, which is placed on top of a steel plate with an air channel underneath. Air is used as the working fluid, which is forced through the channels by a fan with a nozzle [4]. The heat from the PV panel is transferred to the air in the channels via convection, therefore reducing the surface operating temperature in order to reach a higher electrical efficiency [31].

4.5. Water immersion cooling technique

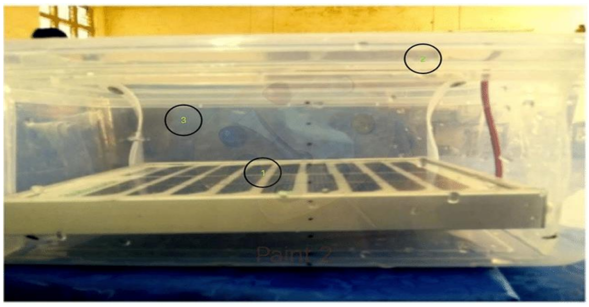

Fig. 11. Water immersion cooling technique [32]

Another technique to reduce the temperature of a PV panel involves implementing the water immersion cooling technique as seen in Fig. 10. The numbers on the figure above represent the following components:
(1) PV modules
(2) Plastic container
(3) Water

Water immersion cooling technique helps in obtaining high electrical efficiency. However, there is a risk of harming the solar panel by immersing in water. The PV module can be placed in rivers, oceans etc. Water helps in maintaining a constant surface temperate and consequently increasing the electrical efficiency of the system [4], [32].

5. Comparative analysis between the solar panel cooling systems

Even though all the cooling systems serve the same purpose, i.e. increasing the electrical efficiency of the PV module and keeping it at a constant surface temperature, the cooling system has to be selected based on the demand of the operator.

If operating and maintenance cost of the system is needed to be reduced, air forced circulation system can be applied. However, the electrical efficiency won’t increase as that of the water-cooling systems.

Solar panels installed in area near large water bodies can use water immersion cooling technique or FTCC system. However, extra precaution is needed to ensure the safe operation of the solar panel system for water immersion technique.

Generally, all the water-cooling systems will result in high thermal efficiency. But a problem of most water cooling systems is that water is wasted [4]. If the heat carried away by the water can be utilized the system will become more efficient.

6. Conclusion

A brief insight to various cooling techniques used to enhance the performance of a PV system are discussed in this paper. Proper utilization of solar energy will have a profound impact on incoming days to meet the efficient and fluctuated energy demand. Proper cooling of PV systems improves the thermal, electrical and overall efficiency, which in turn also reduces the rate of cell degradation and maximizes the life span of the PV module. The presented review can prove to be helpful in selecting the suitable cooling system based on operator’s demand. For better utilization of solar energy, solar PV panel with cooling system is surely the way to be forwarded.

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