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Mini-Review

Exergy Assessment of Roof Integrated Photovoltaic Thermal (RIPvT) System for Sub Saharan Tropical Regions

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ABSTRACT

Photovoltaic systems when integrated in the building structure can satisfy the world's energy requirements at competitive cost by providing onsite electrical and thermal energies for domestic appliances. The energy yield of the photovoltaic system is affected by the intensity of the solar radiation, wind speed, tilt angle, orientation, geographical location, etc. This paper presents a thermal modeling of a Roof Integrated Photo Voltaic Thermal System (RIPVT). A methodology has been developed to optimize the tilted angle of the roof for higher exergy output including the intensity of solar radiation, wind speed, tilt angle, orientation, geographical location, cost of cleaning dust, etc. For a system installed in the city of Douala, Cameroon, it's recommend that RIPVT should inclined at an angle between 10° to 20° South facing for economic output. The cost per unit electricity between the tilt inclination angles from 0° to 20° with South orientation is USD 0.04 per kWh. The cost of electricity loss due to 20° tilt inclination angle can be compensated with the labour cost and work required for cleaning the RIPVT system of the horizontal roof. The system installed over an effective area of 8 m^2 is capable of producing annual net exergy of 2195.81 kWh/year at an efficiency of 11.8 percentile.

Keywords: Solar energy; Optimization; Exergy efficiency; Tilt inclination angle; Dust accumulation

INTRODUCTION

Energy is the property that must be transferred to an object in order to perform work or heat the object. Energy is neither created nor destroyed during a process. Its derives from different sources such as oil, Sun, coal, water, wind, natural gas and exists in many different forms like heat, light, electrical, motion, gravitational, sound, chemical, atomic energy or nuclear, etc. each of these forms of energy are able to be transformed and transferred between one another.

According to International Energy Outlook (U.S. Energy Information Administration (EIA), 2020) the total world energy consumption raised from 145 PWh in 2008 to 160 PWh in 2013. The projected energy consumption by region during 2012-2040, where it estimates that energy consumption will further rise to 185 PWh in 2020 and 240 PWh in 2040 i.e. at a rate of approximately 48 percentage. By the end of 2019, the amount of the primary total energy consumption was 28.5 PWh which consist of 11 PWh consumed by the electric power sector; 8.1 PWh for the transportation sector; 9 PWh by the industrial sector; 5.3 PWh by the commercial sector and 6 PWh by the residential sector. However, this consumption contributes to over a quarter of greenhouse gas emissions. These gas emissions making the Earth warmer than normal, and affecting the planet's weather patterns, creating global warming and climate change. These effects can be effectively reduced through the renewable energy consumption.

LITERATURE REVIEW

Renewable energy is an energy that is collected from resource which is naturally replenished on a human timescale, i.e. that is

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replaced by a natural process at equal rate or faster than the rate at which that resource is being consumed. There are five commonly used renewable energy sources: Solar, Biomass, hydropower, geothermal, wind. Solar energy is widely available over the world and is considered as a solution towards sustainable development. The energy arriving from Sun on the Earth is very gigantic: in the range of 10 000 times the current worldwide energy consumption [1]. Every day the Sun provides approximately 170,000 terawatt hours of energy, about 2,850 times the energy required by people around the world [2]. In 40 minutes of clear daylight, the Sun releases upon the earth approximately amount of energy that is consumed in one year by the entire population of the planet. The great challenge is to collect more solar energy and efficiently convert this energy in useful work. One of the promising solar energy applications technologies is Photo Voltaic (PV) systems.

Photovoltaic system converts Sunlight (photons) directly into electricity (voltage) through the PV effect. Using Photovoltaic with an efficiency of 10 percent, solar energy can be converted directly into enough electricity to provide 1000 times the current global consumption. Large surface is requiring for the quarter of the earth surface area have a potential of 250 times the current energy consumption. This fraction of land is much smaller than the one we use for agriculture (International Energy Agency, 2011) [3]. By the end of the year 2016, more than 303 GW of installed PV power was operational over the world. IEA reported that the largest market of PV at this year where China, United States and Japan with 34.5 GW, 14.7 GW and 8.6 GW in new additions respectively and with currently cumulative capacity installed of 78 GW for China followed by Japan (42.8 GW), Germany (41.2 GW), United States (40.3 GW), and Italy (19.3 GW).

Tilt angle and orientation

Photovoltaic Solar panels are installed differently throughout the world based on their geographic locations. Panels need to be directed according to the position of the Sun. The ideal situation is when the Sun rays are hitting the panels at a perfectly perpendicular angle [4].

This maximizes the amount of energy output produced by the PV panels. Two factors that such an angle is controlled by are the azimuth angle (orientation of the panel toward North, South, East and West) and the tilt angle of the panels from the horizontal surface. The importance of these angle in solar energy application is shown through they review on tilt and azimuth angles [5]. They found that the photovoltaic systems that used optimum yearly tilt angle are showed a great gain in where the tracking system is not the preferred design because of leakage in maintenance in the developing countries. Analysation of the optimal choice of tilt inclination angle for the solar panel in order to collect the maximum solar irradiation in Madinah, Saudi Arabia and found that these angle can also be adjust according to the purpose of the system and the energy needs period. Some have presented a theoretical explanation demonstrating that the annual maximum output of a PV system is not always the optimal solution. A numerical approach to calculate the solar radiation on sloped planes has also been presented. They support that a solar collector with the tilt angle approximately equal to latitude of the place could receive maximum annual solar radiation. The tilt angle can be obtained by increasing latitude to 10 degrees for winter and reducing latitude to 10 degrees for summer if optimum daily solar irradiation is required. Demonstration that using the optimum tilt angle can reduce the coast and the number of solar panels in a residential solar cooling system. They identified longitude of a PV system's location by finding the difference between solar noon and local noon. The results indicate good accuracy for the detection of location, tilt and azimuth. The knowledge of the optimal orientation and tilt angle allow knowing the maximum exergy output of photovoltaic system. The evaluation of energy output of photovoltaic system integrated/nonintegrated on the roof top of building has been carry out by much research. Comparing two differential evolution algorithms ADHDEOA and GA to find the optimum tilt angle at which the power of PV panel is maximum in Taipei area [6].

It has been found that the computer simulated optimum angles is verified experimentally and ADHDEOA is much effective method in optimum tilt angle determination. Experimental measurements for monthly optimum tilt angles at the location of Hannover. The maximum power of PV panel has been found to be at 50-70° tilt angles in winter and 0-30° in summer months. Experimental setup to determined optimum tilt angles for building integrated photovoltaic design and applications at Kuala Lumpur, Malaysia. Four PV modules were inclined at North, South, East and West. For this location, the optimum tilt angle was found to be nearly equal to the latitude of the location. Determination of optimum tilts angles at which electrical energy generation becomes maximum for PV systems that are located in four towns in Reunion Island, France using the Hooke Jeeves algorithm. The discrepancy between latitude and optimum tilt angles show the need for determining optimum tilt angles for every location. Recent proposition of a modified anisotropic sky model in which many parameters like the effects of the surrounding buildings and obstacles in urban locations, latitude, weather conditions, and optimum azimuth are taken into account to determine the optimum angle of five different locations. It has been found that for small latitude, the optimum tilt angle is close to the location latitude. These studies show the evidence that optimum tilt angle for maximum solar radiation capturing needs to be determined accurately for any location [7].

Photovoltaic thermal systems

Falling costs of Photo Voltaic (PV) combined with improvements in the energy efficiency of end-use technologies such as bulbs and innovations in payment systems are helping the expansion of solar. The willingness to improve and optimize the electrical and thermal efficiency of PV solar cell by extracting the thermal heat at the back sheet of photovoltaic module lead to the birth of the Photo Voltaic Thermal (PVT) concept, integrated on the envelope structure of the building. Development of a thermal model of an Integrated Photo Voltaic and Thermal Solar (IPVTS) system with air duct for composite climates in India [7,8]. Analytical overall energy efficiency expression (electrical and thermal) has been developed. Good agreement was obtained between theoretical and simulated observations of overall energy efficiency of PVT system and they concluded that the amount of overall energy output is significantly influenced by the design of the system and the heat extracted. In order to improve the photovoltaic performance of BIPV systems by decreasing the module working temperature, applied a heat sink on the back side of PV module to improve its performance. They recommended a passive strategy solution for the increase of PV energy performance. Optimizing the opaque type building integrated PVT system for cold climatic conditions. The system fitted on the roof top of Srinagar over an effective area of 65 m^2 produces annually the electrical and thermal exergy of 16209 kWh and 1531 kWh. They have been observed that such system produces thermal energy with an overall thermal efficiency of 56.07 percentile [9].

CONCLUSION

Solar energy, particularly photovoltaic energy is one of the most important renewable energy sources and can satisfy the world's energy requirements. Photovoltaic Solar panels are installed differently throughout the world based on their geographic locations. Panels need to be directed according to the position of the Sun. The ideal situation is when the Sun rays are hitting the panels at a perfectly perpendicular angle. In this paper, the Roof Integrated Photo Voltaic Thermal System (RIPVT) has been modeled on the climatic condition of the tropical SSA region, particularly the region of Douala, Cameroon. The exergy analysis of the system with variable tilted surface has been perform to predict the optimum tilted angle of the roof for solar energy residential projects, considering minimum electrical need in residential sector for domestic purpose. The study shows that the horizontal orientation of PV panel allows obtaining the maximum electrical output to cover the electrical needs over the year. Taking into account the labour cost and work required for cleaning the RIPVT system because of the dust accumulation due to the tropical Saharan wind, the tilt inclination angle of PV panel between 10° to 20° facing South orientation is recommended for better amount of energy production of PV project in the city of Douala, Cameroon. The cost of electricity loss due to 20° tilt inclination angle facing the South orientation is compensated with the labour cost and work required for cleaning the RIPVT system of the horizontal roof.

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