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Conversion of Solar Energy into Electrical Energy Using Photovoltaic Technology: A Review

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ABSTRACT
Photovoltaic (PV) technology has emerged as a useful source for converting solar energy into electrical energy and using this energy for meeting the electricity needs of villages, hospitals, offices and houses. Solar energy can play a major role in reducing environmental pollution by reducing the dependency on fossil fuel to fulfill the increasing global demand for energy in near future. Till now, photovoltaic technology is the best way to convert solar energy into electrical energy but still it is more expensive than the traditional sources. The development in solar PV technology is growing very fast in recent years due to technological improvement, cost reductions in materials and government support for renewable energy based electricity production. The purpose of this paper is to review the photovoltaic technology, its applications and problems associated with this technology.
Key words: *renewable energy, photovoltaic technology, solar energy*

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INTRODUCTION

Solar energy can be converted into electrical energy using an electronic device called "solar cell" and the physical phenomenon with which this conversion takes place is known as photovoltaic effect. In the name photovoltaic the term *photo* is taken from the Greek word *phos*, which means "light," and term *volt* is a measure of electricity named for Alessandro Volta (1745-1827), a pioneer in the development of electricity. In this way Photovoltaic means light–electricity[1]. Photovoltaic is a fast growing market and steady progress in photovoltaic energy technologies, are opening up new opportunities for utilization of solar energy to overcome increased global demand for energy. The Compound Annual Growth Rate (CAGR) of PV installations was 40% between 2010 to 2016.Concerning PV module production in 2016, China&Taiwan hold the leadwith a share of 68%, followed by Rest of Asia-Pacific & Central Asia(ROAP/CA) with 14%. Europe contributed with a share of 4% (was 5% in2015); USA/CAN contributed 6%[2].

PV power is the cheapest form of electricity which is generated by the interaction of the bundles of radiant energy coming from sun, known as photons with the semiconductor materials in the PV cells. These photons may be reflected, absorbed, or transmitted by the PV cell. The absorbed photons generate electricity by transferring their energy to electrons in the atoms of the PV cell made up of a semiconductor material. After receiving the energy from photons, the electrons in the atoms of the semiconductor material become able to escape from their normal positions. After leaving from their positions, they start flowing to become a part of current in the electrical circuit causing the formation of holes in the atomic structure of the cell to allow other electrons to move. A built-in electric field in PV cell provides the voltage needed to drive the current through the circuit. The amount of electricity produced by a PV cell depends on its size, its conversion efficiency, and the intensity of the light source. The

conversion efficiency of a PV cell may be defined as the proportion of radiant energy converted by a cell into electrical energy, relative to the amount of radiant energy that is striking the PV cell [1][3].
The PV cell can produce about 0.5 volts of electricity, so a number of small PV cells are connected and assembled together to form a PV module that absorbs the solar radiation and generates usable electrical energy. The PV modules also known as solar panels generate direct current electricity which is converted into alternating current with the help of an inverter to make it usable to fulfill the household energy needs or to feed the electrical grid. A PV module is the smallest PV component sold commercially, and can range in power output from about 10 watts to 300 watts. Two or more PV modules can be assembled together as a pre-wired, field installableunit to form a PV array[1].

APPLICATIONS

Solar photovoltaic energy can be used in water-pumping systems for automatic and drip irrigation of agriculture land.
Building-integrated photovoltaic (BIPV) systems can be used on roof, sides and glass of a building with the advantage of cost and appearance as the photovoltaic material can substitute the conventional materials and secondly the BIPV installations are architecturally more appealing than roof mounted PV structures.
Solar energy can be economically used for Reverse Osmosis desalination plant.
Solar energy technology can be used in automotive sectors to produce the solar powered or hybrid vehicles. These vehicles can play an important role to save the nonrenewable sources such as petrol, diesel etc.
Photovoltaic solar panels are used in the spacecrafts operating in the inner solar system to generate electricity from sunlight. PV technology is also used to generate energy for the functioning of man made satellites in space.
Solar photovoltaic (PV) technology can be used cost effectively in Solar Home Systems (SHS) to substitute kerosene and dry cell batteries to reduce GHG emissions and thus make a significant contribution to climate protection.
Lighting of streets, gardens, small calculators, wrist watches and street signals.Power provision for houses, factories and warehouses far from the grid or where power is unreliable.

PROBLEMS RELATED TO PHOTOVOLTAIC TECHNOLOGY

The energy produced by PV systems depends upon sunlight so these systems cannot operate all the time because of their dependency on sunlight.
PV systems are not well suited for energy-intensive uses such as heating due to loss of energy during the conversion of radiant energy into electricity and then again converting this electric energy into heat.
Grid-connected PV systems are becoming useful and more economical in rural area, but the installation cost of these systems are still high.
Installation of photovoltaic panels in urban area also faces problems due to the requirement of large amounts of land or space for utility or large scale power generation.
The manufacturing process which are used to make photovoltaic panels and other parts of PV system can have harmful effects on the environment.

LITRATURE REVIEW

Ubertini and Desideri [4] presented the power plant performances measured during the year. The climate in the area has been simulated and the system behavior under these conditions is predicted. The experimental data is also used to validate a predicting numerical model for photovoltaic plants performance.
Poponi [5] assessed the prospects for diffusion of photovoltaic (PV) technology for electricity generation in grid-connected systems. The methodology of experience curves is used to predict what would be the different levels of cumulative world PV shipments required to reach the calculated break-even prices of PV systems, assuming different trends in the relationship between price and the increase in cumulative shipments and also analyzes the niche markets or applications that seem promising for the diffusion of photovoltaic in the next few years.
Li et al [6] investigated the operational performance and efficiency characteristic of a small PV system installed at the City University of Hong Kong by systematically recorded and analyzed solar data and power generated in different months to assess and size PV systems.
Li and Lam [7] presents a numerical approach to calculate the solar radiation on sloped planes by integrating the measured sky radiance distributions. The environmental benefits in terms of greenhouse gases reductions and cost implications were also considered.

Saly et al [8] monitored a small PV system and investigated its long term behavior for three years. They checked the changes in PV module properties and evaluated the ageing process using the polarization index dependence and changing current measured and compared on aged and non-aged modules.
Aoun et al [9] assessed the suitability of a mono-crystalline photovoltaic module for use in different weather and sky conditions in desert climate in the region of Adrar, Algeria. They found that photovoltaic energy production is directly proportional to irradiation, and the module produced 83% more energy in July than November and at the same time module had approximately 10.8% and 10.5% higher efficiency and performance ratio values in December than July, respectively. Thus the photovoltaic energy provided during warmer weather conditions is higher than in colder conditions, and the maximum efficiency and performance ratios were observed during weather with low irradiation levels and ambient temperatures.
Lima et al [10] presented the performance analysis of a photovoltaic system for one year. They presented the data of annual energy yield, average daily reference, array and final yields of the system.
Krawczynski et al [11] presents an initial analysis of an ongoing project on large scale PV systems of different module technologies installed in different type of climates. Appropriate performance indicators are discussed and applied to the measurements of two sites.
Rehman et al [12] utilized monthly average daily global solar radiation and sunshine duration data to study the distribution of radiation and sunshine duration over Saudi Arabia. The analysis also includes the renewable energy production and economical evaluation of a 5MW installed capacity photovoltaic based grid connected power plant for electricity generation. The economical indicators like internal rate of return, the simple payback period, the years to positive cash flows, the net present value, the annual life cycle savings, the profitability index and the cost of renewable energy production are also considered for comparison of two sites. It was found that on an average an approximate quantity of 8182 ton of green house gases can be avoided entering into the local atmosphere each year.
Stoppato [13] presented the results of a life cycle assessment (LCA) of the electric generation by means of photovoltaic panels. The energy payback time (EPBT) and the potential for CO_2 mitigation have been evaluated, considering different geographic collocations of the photovoltaic plant with different values of solar radiation, latitude, altitude and national energetic mix for electricity production.
Ali et al [14] presented the Life Cycle Assessment (LCA) study of Keshavpuram solar power plant (1MW) situated in north Delhi having 5571 solar power panels made up of mono crystalline. LCA study is used to calculate the energy consumption in manufacturing, installation, transportation of solar PV systems.
Candelise et al[15] described the causes of, recent changes in PV costs and prices at module and system level, and found that both module and system costs and price trends have reflected multiple overlapping forces. They found that forecasting methods like experience curves and engineering assessments have limited ability to capture key learning effects behind recent PV cost and price trends. Production scale effects, industrial re-organization and shakeouts, international trade practices and national market dynamics are likely to remain prominent aspect of technology learning effects in the foreseeable future.
Sampedro and Gonzalez [16] calculated the Spanish photovoltaic (PV) learning curve over the period 2001–12 by using cost data from the PV sector itself and determines the accuracy of the obtained progress ratio by using both the coefficient of determination R^2 and also the error σ_{PR}, which is directly determined from fitting the data.
Berrada and Loudiyi [17] proposed a method to identify the optimum daily operational strategy of a storage system. They also proposed a method to optimize the size of the storage system with respect to the net present cost (NPC), while meeting the service requirement
Fanney et al [18] presents the effect of elevated cell temperature on the panel's performance for different cell technologies. Comparisons are made between the electrical performance of the insulated and non-insulated panels for each of four cell technologies.
Nangare and Utture [19] discussed the various methods used to manufacture PV solar panels. To make the solar panels cost effective different printing processes such as screen printing, offset web press type method to put material onto foil and inkjet printing are used in place of traditional ones that are often placed on rooftops. All the printing methods are discussed along with traditional method of manufacturing PV solar panels.
Seung-HoYoo and Eun-TackLee [20] gives one year analysis of the system performance, evaluation of the system efficiency and the power output of a building-integrated photovoltaic system (BIPV) in the Samsung Institute of Engineering & Construction Technology (SIECT) in Korea, taking into account the weather conditions.
Vincenzo et al [21] presents a combined study of building energy consumption and the electricity production from a PV system integrated into a shading device for different surrounding building configurations and tilt angles.

Tianze et al [22] gave the analysis of the design of PV system software and hardware, economic benefit, and basic ideas and steps of the installation and the connection of the system and elaborated on the information acquisition, the software and hardware design, the evaluation and optimization of the system. They showed the analysis and prospect of the application of photovoltaic technology in outer space, solar lamps, freeways and communications.
Reges et al [23] presents a prototype of an automated irrigation system for later installation on the field. After the prototype development, they analyzed the use of a previously built photovoltaic microgeneration, in order to insert the electricity generated in the automated irrigation system. The photovoltaic microgeneration has an installed capacity of 2.76 kWp and a battery bank with 24 V. The integration of photovoltaic solar energy in the automated irrigation system represented a good application for family farming, minimizing water waste, besides representing the use of a renewable energy source.
Balamurugan and Manoharan [24] proposed a Solar Electric Powered Hybrid Vehicle (SEPHV) system which solves the major problems of fuel and pollution. The proposed topology has the most feasible solar/electric power generation system mounted on the vehicle to charge the battery during all durations by multi charging from both solar and electric power. The household electric supply of 230V is reduced with a step-down transformer to 48V and then it is converted to the DC with a rectifying unit to charge the battery. Two solar panels each with a rating of 230watts are attached to the top of the Vehicle to grab the solar energy and is controlled with a help of charge controller.
Nader et al [25] designed and built a solar race car for the world solar challenge. Three main goals were targeted for the competition: lightweight, aerodynamics, and efficiency. The car speed initially was tested at 70 km/hr and expected to double for the world solar challenge race with traveling distance of about 3000 km. The body and chassis of the car were manufactured from fiber glass and aerospace aluminum material. Moreover, a system AC motors were designed, manufactured and assembled accompanied by gearbox, steering, axle, bearings, suspension system. Semi flexible solar panels were installed with power trackers and instrumentation. One driver was accommodated with a car net weight of 300 Kg.
Bilton and Dubowsky [26] presented a computer-based modular design method that can enable non-experts to configure Photovoltaic Reverse Osmosis (PVRO) system for their community from an inventory of modular components. The method employed fundamental engineering principles to reduce the number of possible configurations and optimization methods to configure a system. Example cases for a range of communities demonstrate the power of this approach.
Amy M. Biltona, Leah C. Kelleyb and Steven Dubowsky [27] presented a research program that is focused on improving the feasibility of Photovoltaic Reverse Osmosis(PVRO) systems. For this purpose a methodology to evaluate the economic feasibility was developed and the results, reviewed here, showed that the economic feasibility is a strong function of location and increasing the efficiency of PVRO systems can extend their feasibility to currently marginal or unfeasible locations. The focus of this research program was the development of smart control algorithms to increase system efficiency and improve feasibility. They also presented PVRO system models which have been developed to evaluate the smart control algorithms. These models were verified using an experimental system.

FUTURE SCOPE

Solar energy is a continually and abundantly available source of energy which can be used to fulfill our future energy needs, and photovoltaic technology is one of the best technologies available till date to convert solar energy into useful energy form. In recent years, a significant improvement in performance of this technology has been achieved but still a great scope of improvement is there with respect to increase the overall efficiency, device design, material selection and consumption, reliability and production technologies which are used during the manufacturing of various parts of PV system.

CONCLUSION

A review of various solar photovoltaic technologies along with their application and limitations is presented. The papers having major topics regarding PV systems like analysis of small scale and large scale grid connected photovoltaic systems in different climates, numerical approach to calculate solar radiation, environmental benefits in terms of green house gases, life cycle assessment, energy payback time, economical evaluation, calculation of break even prices, numerical model for PV plant performance, method to optimize the size of the storage system, changes in PV costs and prices and performance of building integrated PV systems are discussed. This paper can be useful for the manufactures of solar PV system, students and researchers.

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