

An Overview of the Solar Cell Technology and its Future Challenges

P. Karuppusamy

Professor, Department of EEE, Shree Venkateshwara Hi-Tech Engineering College, Erode, India

E-mail: pkarrupusamypd@gmail.com

Abstract

Despite the fact that the electronics of the solar cell are progressing, the material and manufacturing aspects of the solar cells are seeing a significant increase. Maximum power point tracking methods based on artificial intelligence are the future of solar-based circuits. First- and second-generation solar cells are reviewed in this article by looking at the materials on which these technologies are built. Solar panel technologies are also examined from the manufacturing perspective. Furthermore, this article describes the efficiencies and limits of several newer solar cell technologies in the current and future. There has been much advancement in solar cell technology over the last several decades. Incredibly, they are more efficient than conventional solar cells. Moreover, this study analyses the performance and problems of various kinds and generations of solar cells.

Keywords: Solar energy, electricity, energy crisis, power tower, artificial intelligence, Photovoltaic Module

1. Introduction

Economic growth and development depend heavily on the availability of energy. A rising population and developing economy need the usage of renewable energy sources, which are less harmful to the environment than their conventional equivalents. In the present state of affairs, solar energy offers the best alternative. Effort has been made to develop solar technology to its fullest extent. It is during this procedure that problems such as decreased silicon cell performance, increased processing costs, lack of adequate infrastructure, and shortage of qualified workers are brought to light [1-2]. Research in this area has laid the groundwork for the development of newer technologies. Modern man needs energy in addition to food, clothing, and shelter. Many industries saw a rise in energy consumption

after the industrial revolution. Steam and electricity powered the industrialisation in many developed countries. Fossil fuels have been utilized widely over the globe for a long time, resulting in improved quality of life and environmental damage. All industrialized and emerging nations realize the need for alternate energy sources, however fossil fuel supplies are rapidly decreasing [3-6]. Various powers such as nuclear and several thermal station powers are some of the alternative energy sources that may be used to generate electricity for both commercial and non-commercial uses. The sun's energy is limitless, ecologically friendly, and easily accessible in almost any corner of the earth with a suitable climate. Aside from these challenges, the gathering and storage of solar energy necessitates considerable upfront expenditure because of its scalability and fluctuation in energy supply. The future trends solar cell has been shown in figure 1.

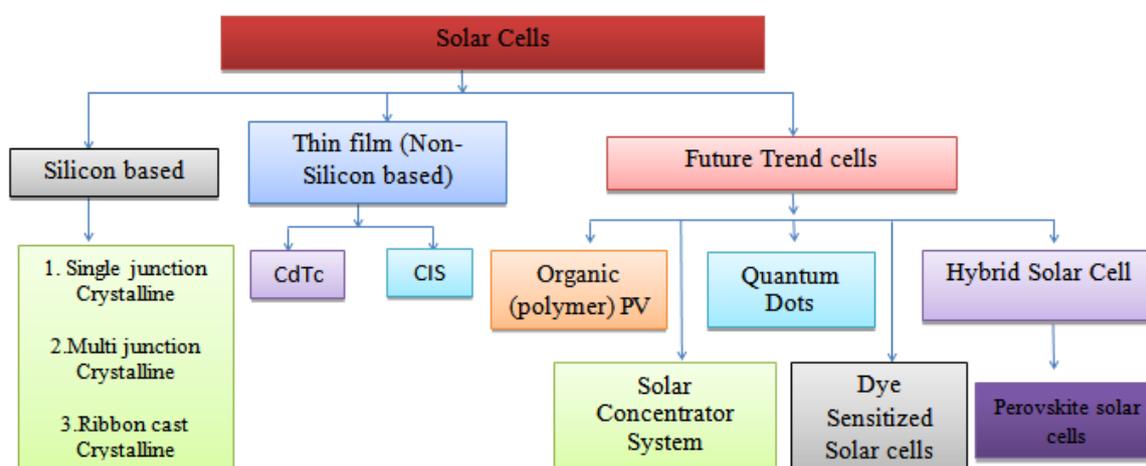


Figure 1. Classification of Solar cells

Solar energy is now used for just 0.3 percent of the total energy needed to generate electricity; many power renewables make up to just about 5% to 10%. When using fossil fuels, the environment is being polluted since their supplies are finite and they emit large amounts of CO₂. For example, for every tonne of coal burnt, one tonne of carbon dioxide is emitted into the atmosphere. As a result of the emission of carbon dioxide, global warming, the greenhouse effect, climate change and loss of the ozone layer have all been caused. In order to have a future that is both clean and sustainable, humans must develop new sources of energy. In terms of alternative renewable energy sources, solar energy is the best because of its sheer size, ubiquitous availability, adaptability, and environmental friendliness. Since solar energy may be utilized to create heat and power, it has a wide range of applications in numerous industrial sectors, as has been previously mentioned. In addition to room heating, solar thermal energy is employed in chemical and food processing, as well as in the textile

sector [7 -10]. Telecommunications, transportation, water heating, and water purification are just a few of the many uses for solar energy's power. An in-depth examination of the solar energy system is provided in this review study, which examines every feasible technique for generating power from the sun. All the technical, economic, and environmental issues related with solar technology are addressed in this article. For this technology to progress, this document provides a list of the most crucial research paths.

2. Technological System

2.1 PV cells generation –Stage 1

First-generation cells with an efficiency of 25 percent have been attained by using mono crystalline silicon (Si p–n) junctions.

2.2 PV cells generation – Stage 2

PV cells are made on thin films and it is used to generate power. Because they consume less silicon, they are cheaper than the previous generation. As a result of this, they have a much lesser market share.

Thin Film Solar Cells: With less reliance on silicon wafers as raw material, technology has helped in bringing about lower price solar cells. Thin-film modules also have the benefit of being able to be produced in large scales and placed on curved surfaces using appropriate substrates. Thin-film solar cells, on the other hand, have lower efficiency than wafer-based ones.

2.3 PV cells generation – Stage 3

Improved efficiency and environmental friendliness may be achieved by using third-generation PV cells. Cheapness is a big perk for these cells. A reduction in power consumption of 50-80% is anticipated as compared with the current generation. Using quantum wells and quantum dot nanostructures, these devices can enhance absorption, carrier production, and separation in a way that no other technology can. Spin technology may be used to apply solutions containing quantum dots on a film. Third-generation solar cells include organic and dye-sensitized (DS) varieties [11 – 13]. To put it another way, DS cells work the reverse way of LEDs. It is attached with semiconductor devices, where light is absorbed. At the contact, photo induced electrons from the paint enter the solid's conduction band and promote charge separation. The anode acts as a charge collector for the electrons,

which are subsequently distributed in the conduction band. These types of cells are more efficient than previous generation cells.

3. Solar Cells Classification

3.1 Crystalline Silicon Solar Cells

Because silicon is plentiful and non-toxic, single crystal and multi-crystalline semiconductors are quite popular. Although their efficiency is lower, multi-crystalline silicon is utilized for commercial modules because of the rising output of solar PV cells that are available at a lesser cost [14].

3.2 Multi-junction Solar Cells

Composite semiconductors, which include diverse groupings of components with considerably higher efficiency, provide the basis for these devices. However, the cost of producing them is prohibitive.

3.3 Future Solar Cells

3.3.1 Perovskites

This series of perovskite-like compounds is made up of calcium titanate, which is similar in crystal structure to the mineral perovskite (CaTiO_3). The perovskite solar cells are constructed on the basis of organometallic halides. The efficiency in single-junction topologies is reported to be 25.5%, and in silicon-based tandem cells to be 29.1%.

3.3.2 Polymer Solar Cell

It is possible to make organic or polymer solar cells out of thin film by using organic semiconductors. Using a solution-based processing method, this form of cell may be advantageous since it is flexible, light, and economical. However, the efficiency of these cells is subpar. Because of this, organic solar cells have been tested in a variety of architectural and material configurations [15 – 17].

3.3.3 Dye Sensitised Solar Cells

Anode, sensitizer, electrolyte, and counter electrode make up the cell. Metal-organic and organic sensitizers are also available. This can be created by printing based process that improves efficiency.

3.3.4 Quantum Dots

In order to minimize the cost per watt ratio of solar power, Quantum Dot (QD) solar cells have tailored band gaps that fit the spectral distribution of the sun spectrum [18].

Nanocrystals, on the other hand, are made up of a significantly different set of materials than quantum dots.

4. Various Challenges

4.1 Future Challenges

1. Renewable energy policy should specifically address financing costs to reduce the hurdles to the expansion of renewable energy investments, not simply for cost-effective deployment options but for decarbonizing power production.
2. Instead of cutting down on renewable energy, the current infrastructure should be upgraded and a high-voltage system, or "super grid" should be constructed.
3. Solar power production may benefit from improved weather predictions. It is possible to boost the system's overall dependability by using big data and artificial intelligence in the forecasting process. For this reason, greater renewable generation and reserve forecasts are beneficial.
4. The negative social consequences that might occur during the design and construction phases of solar PV projects must be detected, analyzed, and rectified well in advance if the rise of solar PV electricity is to accelerate in the future decades.
5. For future urban planning, new structures may include PV systems into their construction to maximize the installation area. PV panels, which must be oriented correctly to capture as much sunlight as possible, have a significant challenge in cities due to a lack of available space.
6. Policy must be made more effective. As long as energy is linked and coordinated with the rest of the economy, the energy transition will provide the greatest possible systemic benefit. Renewable energy generation, consumption, and application must be the primary goal of such initiatives.
7. Industrial policy, labor market and social policy, education and skills programs, and finance policy are all parts of the enabling framework.

4.2 Challenges in Solar vehicle

Solar-powered automobiles are the subject of extensive study in an effort to reduce the environmental effect of transportation while also providing a viable alternative to fossil fuels. Solar-assisted cars have a promising future, partly due to the rising fossil fuel prices and technological advancements in photovoltaic (PV) cells. In contrast, an 8m² wide solar car may produce higher power consumption; hence, a solar vehicle can only generate horsepower during noon. Fossil fuels, on the other hand, have become more controversial due to their environmental repercussions and high prices. The poor efficiency, narrow speed range, and expensive starting cost of the solar vehicle are preventing it from reaching its full potential [19].

4.3 Solar energy in space

Satellite power stations may be built using solar energy. These satellite power plants may use PV and other solar technologies to convert solar energy into electricity. The satellite has a microwave generator and antenna that can transform this power into a microwave beam. The electricity generated by this satellite system may be distributed to any location on the planet.

4.4 Environmental challenges

Solar energy systems have a major benefit that they are ecologically benign. In comparison to typical fossil fuel-powered systems, solar energy is a significantly superior option. The usage of household solar water heating systems reduces greenhouse gas emissions by as much as 80% compared to more conventional ways.

4.5 Economic challenges

Solar energy's future is predicated on a variety of factors, including its affordability, environmental effect, and rate of technical progress. In order to consume the solar power, there are many storage devices through reliable energy sources available. For example, greenhouse gas emissions are reduced by 40% when solar space heating is employed instead of a standard electric power plant system [20 -23].

5. Conclusion

To make the cell seem like conventional glass, organic absorber components may be replaced with the ones that absorb solar radiation in a wavelength that is not visible to the

human eye. However, the cells' efficiency is limited in this location. Brittle translucent electrodes containing rare elements like indium are utilized to capture the charge from these cells. Solar photovoltaics are always being improved to gather the most energy from the sun. Commercialization of the technique depends heavily on the choice of materials and the layout of the final product. Also, photovoltaic roofs and canopies are all examples of the exciting new applications.

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Author's biography

P. Karuppusamy is working as a Professor and Head in the Department of Electrical and Electronics Engineering at Shree Venkateshwara Hi-Tech Engineering College, Erode, India. In 2017, he completed doctorate in Anna University, Chennai, and in 2007, he completed his postgraduate Power Electronics and Drives in Government College of Technology, Coimbatore, India. He has more than 12 years of teaching experience. He has published more than 60 papers in national and international journals and conferences. He has acted as Conference Chair in IEEE and Springer international conferences and Guest Editor in reputed journals. His research area includes modeling of PV arrays and adaptive neuro-fuzzy model for grid connected photovoltaic systems with multilevel inverter.