International Journal of Electrical Engineering and Ethics- Volume 7, Issue 1, 2024

RESEARCH ARTICLE OPEN ACCESS

Photovoltaic Energy System; Current Technology, Profitability & Prospects

Talha Farooq[1], Boker Agili[2], Miao He[3]

[1,2,3](Department of Electrical and Computer Engineering, Texas Tech University, Lubbock, TX 79409

Email: talha4034@gmail.com[1], boker.agili@ttu.edu[2] , miao.he@ttu.edu[3])

Abstract:

Increasing energy demand of the world can only be fulfilled using the renewable energy resources which will decrease the dependability on the conventional and non-renewable energy resources. Energy produces in one hour by the largest carbon free available energy source, Sunlight, is more than the complete year energy consumption of the planet and still only a small proportion of the earth energy consumption come from sunlight (David Barlev, 2011) . Being a cost-efficient solution, Photovoltaic is also environment friendly. This study includes different types of solar power system, photovoltaic energy systems, current technologies, profitability, and prospects. On the other hand, the only challenge that can flush PV technology is the energy storage capability, which we will address in the future.

Keywords — Hybrid renewable energy resources (HRES), Renewable Energy, Photovoltaic System, Solar Energy system

I. INTRODUCTION

Energy crisis has become the most emerging issue in this world due to exponentially increasing human population and shrinking the fossil fuels sources which has been the main source of the energy for many decades, which urged researchers to look for the alternative clean energy resource like Microgrid using Hybrid renewable energy resources (HRES) (Sarvar Hussain Nengroo, 2019) . Different countries have set their targets to move towards the renewable energy sources, like developing country Pakistan has aim to increase the share of 30% of their electricity demand from renewable energy resources by 2030 (magazine, 2019).

Fossil fuels are major cause of Global warming, but using renewable energy resources is able to minimize Greenhouse gasses emission which are the major sources of Global warming. By means of PV systems at small level decrease the dependability on the National grid and reduce monthly electricity bill. Sunlight is not a reliable energy resource as there are some following challenges associated with this.

- It is affected by the environmental conditions, for instance cloudy weather.
- Unavailability in the nighttime.

These challenges can be overcome by installing energy storage systems.

II. PHOTOVOLTAIC ENERGY SYSTEMS AND CURRENT TECHNOLOGIES

A. Photovoltaic Energy Systems

Photovoltaic cells are electronic devices which convert direct sunlight into electrical energy. PV cells take the sunlight and convert that into energy which can be used in household, industrial and commercial.

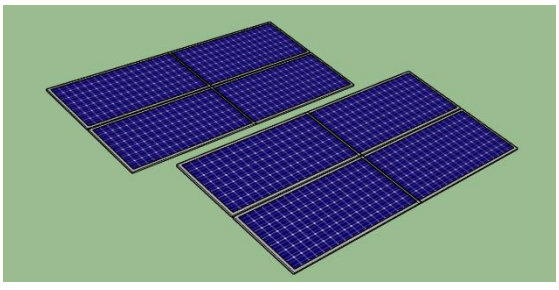

Figure 1. Solar panels

These solar panels include many small PV cells which are attached on a panels & there are different components involve in harvesting the energy in direct current (DC) form, DC received from the PV Cells convert into Alternating current by using inverters then it would be able to use in different applications. Following is the block diagram to describe the working process of solar energy systems.

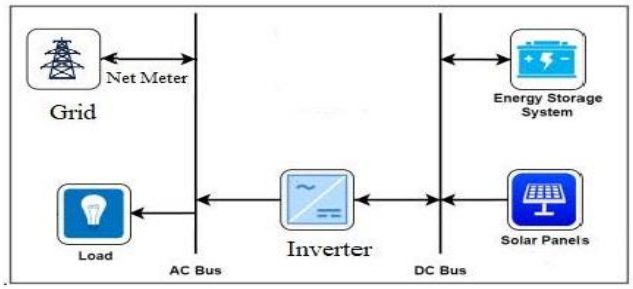

Figure 2. Grid interfaced Solar Energy systems

Figure 2 shows microgrid, designed in Homer pro software using the Photovoltaic Solar Panels and it's connected to the utility grid. Potential of Solar power vary area to area, as it depends on the Global Horizontal Irradiance (GHI), Production of KWH/KW is different for the different locations. Output power of solar depends on the irradiance of the sun. Following are the GHI data for Sindh, Pakistan.

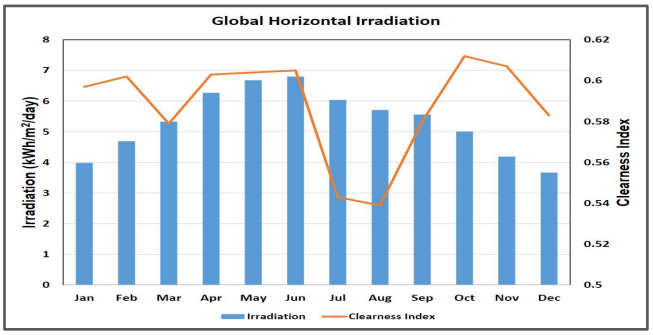

Figure 3. Global Horizontal Irradiance Sindh, Pakistan

There are the following types of solar energy systems which are getting popularity in the world.

1. **Grid-Tied Solar systems:** Grid tied solar system is connected to the home/load and with the traditional grid. It takes energy from both grid and solar to fulfill the load demand. If, Solar is producing more energy than the load then it starts to export energy to the utility grid and owner can make money by exporting this energy, this is called the Net Metering. This is the most common solar system.

2. **Off-Grid Solar systems:** Off-grid solar systems is independent of the traditional utility grid which also has energy storage systems, which makes it popular for the remote areas which are not having the utility grid systems.

3. **Hybrid Solar systems:** Hybrid solar systems is like grid-connected solar systems which has the storage systems, though battery storage is somewhat costly, but it can be paid off as electricity bills get decrease.

B. Current Technologies

Different countries and companies worldwide are manufacturing the PV cells using an extensive range of PV materials according to their availability which have variable efficiencies. Cost differs according to the location, size of the system and project to project. Silicon is the most frequently used material in manufacturing the PV materials (Mehreen Gul, 2016).

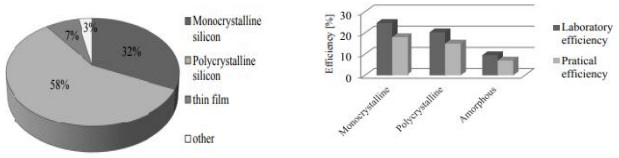

Figure 4. Global solar production by using different silicon materials and efficiency (L.A. Dobrzański, 2012)

1. **Monocrystalline Silicon Solar Cells:** First generation of PV Panels had been made using crystalline structure of silicon. Monocrystalline silicon is used mostly in manufacturing of the PV Modules because of its high efficiency. Generally, the companies in China and Germany are manufacturing the PV Modules having the efficiency from 16.0% to 16.9%, but the solar leading company of the United States of America, SunPower Corporation-2015 manufactured the PV modules with higher efficacies, for instance from 20.0% to 20.9%

which is also tested by the National Renewable Energy Laboratory (NREL) (Mehreen Gul, 2016).

Monocrystalline solar modules are manufactured by using a single silicon crystal.

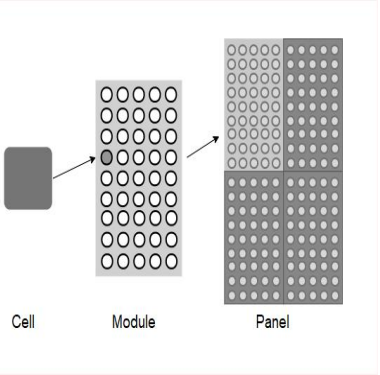

Figure 5. Monocrystalline Solar panel manufacturing (L.A. Dobrzański, 2012)

Figure 6. Monocrystalline Solar panel (Plante, 2014)

2. **Polycrystalline Silicon Solar Cells:** Manufacturing of the Polycrystalline solar module are less expensive as compared to monocrystalline but they are less efficient, despite of this reality, they have good market and get the preference on all other types of modules. Efficiency range of the polycrystalline is 15.0% to 16.9% for different companies and a company from Taiwan, Neo Solar Power corporation(T10) has the highest efficiency 16.9% which is about 4% less to Monocrystalline modules (Mehreen Gul, 2016).

Polycrystalline solar modules manufactured by using multiple silicon crystals fragments.

Figure 7. Polycrystalline silicon solar module (M. Stupca, 2007)

Figure .8 Polycrystalline Solar panel (Abdil KARAKAN1, 2022)

3. **Thin Film Silicon Solar Cells:** Alternative technology to for the solar cells manufacturing which uses a small portion of silicon or it can also be manufactured without the silicon, and its efficiency is about the 10.7% (Yamamoto, 2001).

4. **Maximum Power Point Tracking:** An electronic DC-DC converter which help to make a match between the output power from solar and utility grid or energy storage systems. By using the automatic control algorithms which adjust the interfaces of solar power to and harvest the highest power from the solar system, it has become the major component in designing of the PV systems and evaluating the performance it (Xiao, 2012).

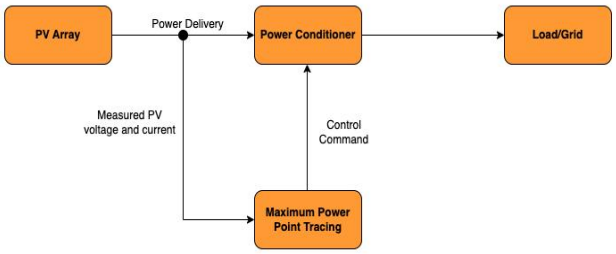

Figure 9. Block diagram to show the operation of MPPT (Xiao, 2012)

5. **Inverter:** Conversion DC to AC power is done by the using an electronic device, called the Inverter. It is the major component for the interconnection of solar power to power sector. Nowadays, Inverters are coming with the MPPT which make it suitable for the wider DC voltage input. Several companies are manufacturing the numerous types of inverters which have Small KVA ratings to higher KVA (Kumar, 2018).

6. **Net Meter:** Net meter is two-way metering device use for monitoring the electrical energy export and import in between the electricity utility grid and Electrical power generating systems. In the Solar power systems if the generation is greater than the household load it starts to export to the utility grid and owner can make a handsome amount (Kumar, 2018).

III. PROFITABILITY

Environment friendly and financial benefits make to move towards the installation of solar energy systems. But mostly it gets the priority because of the financial profits over the environmental arguments. First consideration is payback period of the capital cost of the installation the PV Energy systems. Assessment of the returns of the PV power is done based on the payback period of the cost, although received power is clean energy. Installation cost of the PV power systems depends on multiple factors, for instance project location, client power needs and choosing the equipment and material-as different types of the PV cells has been discussed above etc., (Kessler1, 2017).

Gradually decreasing the prices over about last 50 years of PV silicon cells have been urged society to transfer towards the PV power systems. Cost of the overall Solar power has been decreased over the last some decades. The following figure shows some statics of the prices of PV Silicon cell from 1977 to 2020.

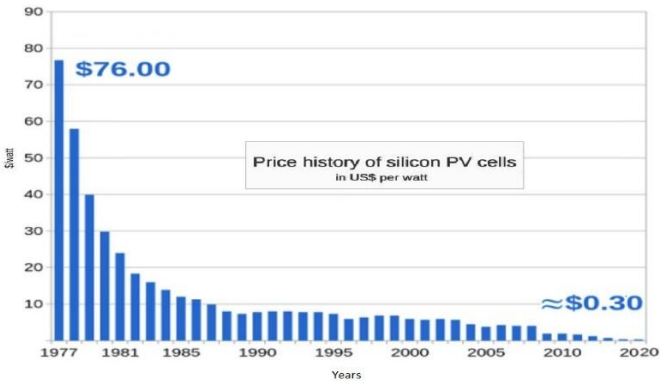

Figure 10. Price history of the PV silicon cell in USD/watt (Mohamed Ibrahim A. Arafa, 2019)

Calculation of the payback period is done by the following formula.

Payback period = ((Csystem) / (Qyear) (PR) (P) (Celec) … (Kessler1, 2017)

Csystem is showed the initial capital cost of the system, Qyear is the GHI for the project location, PR is the performance ration of DC to AC conversion, Power of the total solar panels is P and Celec is electricity cost avoided by the production local systems. Payback period of the system is about 1.9 to 2.6 years (Kessler1, 2017).

A. *300 KW PV power system Payback*

Following calculation shows that the payback period of the 300KW system in Punjab, Pakistan is about the 2.42 Years.

System Size – DC Power	300 KW
System Type	Grid-Tied
Capital Cost	25,800,000 PKR
Electricity company tariff	24.5 PKR, 3% Increment every year
System Life	25 Years
Note: 1 USD = 187.76 PKR	

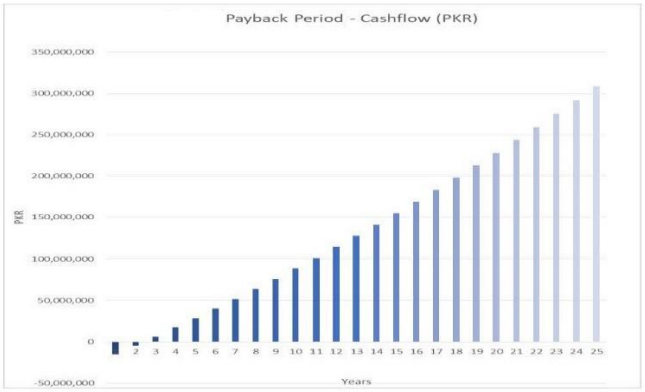

Figure 11. Payback period of 300 KW Solar power systems Punjab, Pakistan

B. *Profit comparison of Solar Power vs Utility Grid power*

Increasing utility grid tariff has increased the household expenses, which has become major concern of the people. Installing the solar makes able to overcome these expenditures. Following table shows the consumption of electrical energy of a household for a complete year in Lahore, Punjab, Pakistan which has been offered 20 KW grid-tied solar power systems solution. Helioscope (Solar calculation and designing software) is used to get the yearly energy production for the required site.

Utility grid Tariff = 23.5 PKR

S.No	Month	Monthly total Units Consumed (KWh)	Share from Monthly 20KW Solar Production Kwh
1	AUG	4978	2378
2	SEP	2831	2341
3	OCT	871	2332
4	NOV	944	1966
5	DEC	1739	1774
6	JAN	3328	1878
7	FEB	1128	2060
8	MAR	953	2670
9	APR	1694	2621
10	MAY	3144	2760
11	JUN	3775	2380
12	JUL	3978	2135

Table 1. Monthly consumption of a residence site and 20KW Solar production for the location

A comparison of the prices, share of utility grid electricity bills and power from the solar energy systems is shown below in figure 12. In December, as load is less so there is no share from utility grid, most of the portion is from the solar.

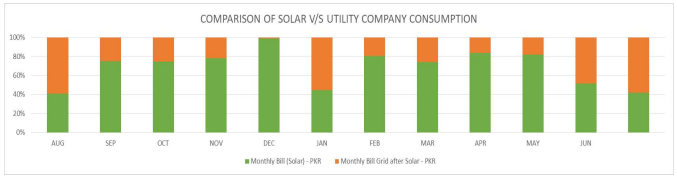

Figure 12. Comparison of price share of electricity from solar and utility company

IV. PROSPECTS

Consumption of fossil fuels led to serious environmental and atmospheric problems which made researchers think about the alternative clean energy resource. Among all the renewable energy resources, for instance wind, geothermal, wave and Hydro etc., Solar power is the most promising and freely available resource. Because of the abundant availability of the sunlight, cost effectiveness and efficiency, it is predicted that Solar energy is going to play its significant role in meeting the energy needs of the globe in future (Şen, 2004).

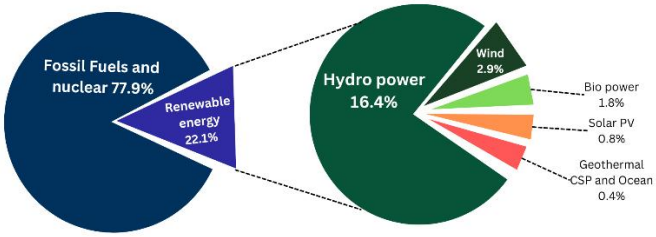

Figure 13. World Electricity production (Kannan, 2016)

Global Electricity production has been shown in figure 13 by showing the portion of different of energy resources including the fossil fuels and renewable energy resources (22.1%).

The following figure is showing the solar electrical power production in Billion Kilowatt hours and after 2000 it's gradually increasing.

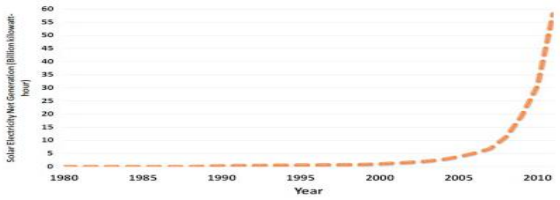

Figure 13. Solar electricity production of the world
(Kannan, 2016)

V. CONCLUSION

This project shows a comprehensive analysis of Photovoltaic Energy systems, current technologies, profitability, and prospects. It has been discussed and presented that PV is the most abundant available renewable energy sources which is not only environmentally friendly but also it is cost effective solutions to deal with the present energy crisis of the planet. Statics shows that solar is most adopting solution in the present era.

Although solar is not a reliable source because of its unavailability in the nighttime and it is affected by the weather condition but are still couple of solutions which can be adopted to resolve this issue for instance energy storage systems.

References

Abdil KARAKAN1, Y. O. (2022). Solar Energy Experiment Set Design and Application Consisting of Monocrystalline and Polycrystalline. 6th International Conference on Engineering Technology and Applied Sciences (ICETAS) . Tirana/Albania.

David Barlev, R. V. (2011). Innovation in concentrated solar power. Solar Energy Materials and Solar Cells, 2703-2725.

Kannan, N. (2016). Solar energy for future world: - A review. Renewable and Sustainable Energy Reviews, 1092-1105.

Kessler1, W. (2017). Comparing energy payback and simple payback period for solar photovoltaic systems. International Conference on Advances in Energy Systems and Environmental Engineering (ASEE17).

Kumar, N. M. (2018). On-Grid Solar Photovoltaic System: Components, Design Considerations, and Case Study. IEEE. Chennai, India.

L.A. Dobrzański, A. D. (2012). Monocrystalline silicon solar cells applied in photovoltaic system. Journal of Achievements in materials and manufacturing Engineering.

M. Stupca, M. A. (2007). Enhancement of polycrystalline silicon solar cells using ultrathin films of silicon nanoparticle. Applied Physics Letters.

magazine, R. e. (2019). Pakistan to set 30 percent plus 30 percent Renewable Energy Target by 2030.

Mehreen Gul, Y. K. (2016). Review on recent trend of solar photovoltaic technology. Energy Exploration & Exploitation, 485–526.

Mohamed Ibrahim A. Arafa, E.-S. S. (2019). A different vision for uninterruptible load using hybrid solar-grid energy. International Journal of Power Electronics and Drive System (IJPEDS), 381~387.

Plante, R. H. (2014). Solar Energy, Photovoltaics, and Domestic Hot Water.

Sarvar Hussain Nengroo, M. U. (2019). An Optimized Methodology for a Hybrid Photo-Voltaic and Energy Storage System Connected to a Low-Voltage Grid.

Şen, Z. (2004). Solar energy in progress and future research trends. Progress in Energy and Combustion Science, 367-416.

Xiao, W. (2012). Overview of maximum power point tracking technologies for photovoltaic power systems. IECON 2011 - 37th Annual Conference of the IEEE Industrial Electronics Society. Melbourne, VIC, Australia: IEEE.

Yamamoto, K. (2001). Cost effective and high-performance thin film Si solar cell towards the 21st century. Solar Energy Materials and Solar Cells, 117-125.