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Solar Irradiance & On Grid Solar Power Systems with Net Metering in Pakistan

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ABSTRACT

This paper presents a case study of solar irradiance and scope of on-grid solar power systems with net-metering in Pakistan. Detailed analysis of solar irradiance in Pakistan is being carried out by developing the dedicated solar excel sheets. The need of on grid solar power systems for the present energy crisis in developing countries like Pakistan is also discussed. It also presents the inclination of many countries especially USA and Europe towards it. Identification of barriers for implementing on grid net metered solar power systems in Pakistan along with solutions of these barriers is carried out.

1. Introduction

Pakistan is one of those countries around the world having maximum solar irradiance throughout the year. The solar energy needs to be exploited on very large scales in order to overcome the severe energy shortfall. This paper establishes the fact that solar irradiance in most cities of Pakistan ranges between 5 to 7 kWh/m^2 per day. In this research, dedicated excel sheets have been designed that gives the solar irradiance anywhere on the globe by just entering latitude, longitude and altitude of a particular location. In order to exploit this energy, large scale solar power plants need to be installed. But conventional solar power systems make use of batteries to store the excessive power, which makes the system expensive, less reliable and requires maintenance on a large scale. Batteries also reduce the overall efficiency and redundancy of the system. So the modern techniques are being employed in solar power systems to get rid of the batteries and feeding the excessive power to the grid directly. This makes use of the sophisticated techniques for synchronization between solar power system and the grid.

In order to promote the concept of distributed generation using renewable energy sources for the customers, an innovative approach of "net-metering" is employed. This helps to enhance the power production at commercial level, thus decreasing the net load on national grid. Net-metering allows two-way power flow between the utility and distributed generators (solar power plants). Two way power flow helps the distributed generators (DGs) to feed the surplus power to the grid (preferably during the day when sunlight is abundant) and get the required power from the grid (mostly at night) so it prevents wastage of electrical power. To implement this technique, smart energy meters are used that measure amount of power fed to the grid and also the amount consumed by DG. Fig. 1 is showing that how net metering is employed on the currently functional conventional system.

Since the conventional sources of energy (fossil fuels) are depleting rapidly, so it is necessary to rely on renewable energy sources as well. Developing countries like Pakistan also are facing substantial energy shortage should shift its maximum load to solar plants as it has one of the highest solar irradiance in the world. The effective way of using solar energy without use of batteries is "Net Metering".

2. Solar Irradiance in Pakistan

Pakistan is situated in a very favorable location as far as solar radiation is concerned with peak solar hours. In many parts of the country the sun shines for 7 to 8 hours daily and solar energy is available for approximately 2300–2700 hour per annum and there is sun shine for more than 300 days in a year [1]. Pakistan has Solar Irradiance of 2400 kWh/m^2 per year on average [2]. US National Renewable Energy Laboratory developed solar maps of Pakistan which indicates that many regions of the country are blessed with higher solar irradiance averaging from 5-7 kWh/m^2 per day [3].

Fig. 2 clearly shows that average solar irradiance in Pakistan is about 4.5-5 kWh/m^2 per day and the irradiance of South-Western part goes as high as 6.5-7 kWh/m^2 per day.

Data of Solar Irradiance for various cities of Pakistan is shown in table 1.

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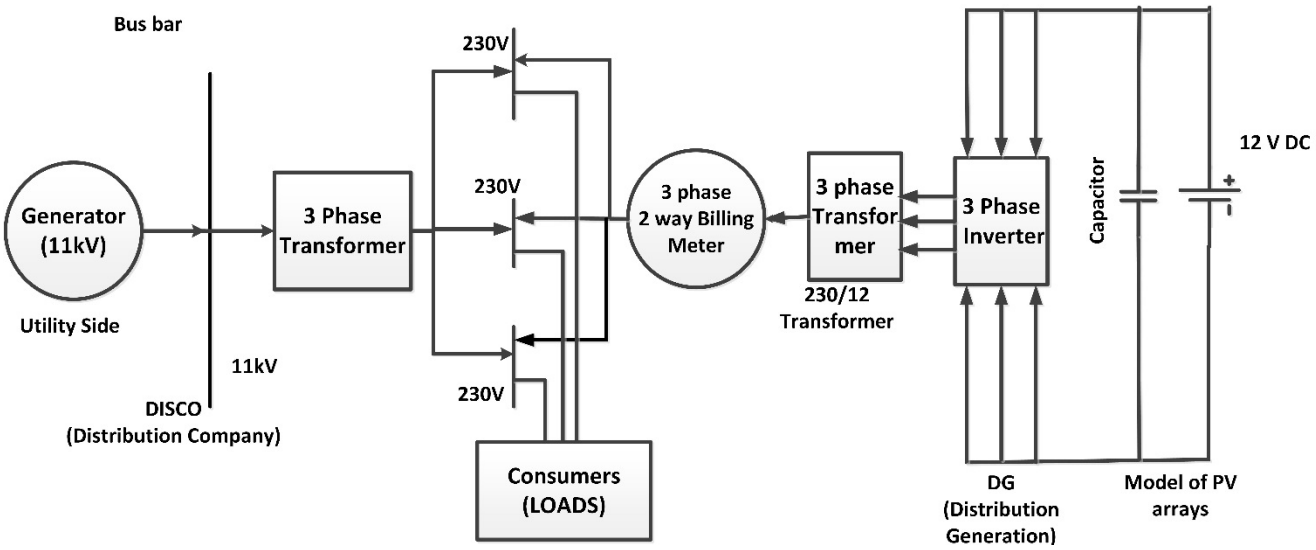

Figure 1: Schematics of two way net metering

Table 1: Annual solar irradiance in various cities of Pakistan

City	Solar Irradiance (kWh/m^2)
Lahore	1806
Bahawalpur	1981
Karachi	2168
Mardan	2143
Chiniot	1820
Faisalabad	1816
Multan	1961
Quetta	2287
Islamabad	2135
Gujrat	1854

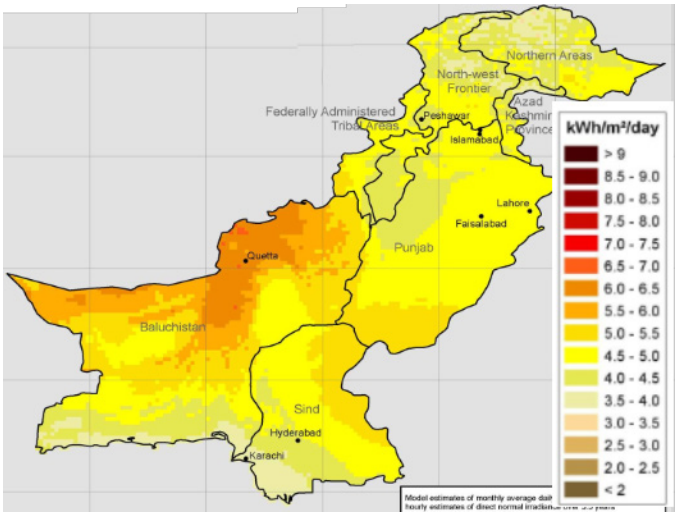

Figure 2: Solar irradiance map of Pakistan

Values from Table 1 show that various cities of Pakistan have high irradiance throughout the year. If the solar energy in these cities is utilized effectively, then the short fall of electricity will not be a problem anymore. When solar irradiance is sufficiently high, then it can be used to solve large scale energy crisis. The excess power produced is fed to the grid using net metering, thereby reducing load on national grid considerably.

In this research, excel sheets have been designed that give us the solar irradiance of any location after every 15 minutes throughout the year. The inputs to that excel sheet are latitude, longitude and altitude of some location. The sheet computes intensity for every 15 minutes and then we can get irradiance of a day, month or year as per requirement.

Table 2 shows the inputs provided to the excel sheet for the computation of solar irradiance. All the inputs i.e., latitude, longitude and altitude for any location are easily available.

Table 2: Data input for excel sheet to get solar irradiance

Location	Mardan (Pakistan)
Latitude	34.198°
Longitude	72.04°
Standard longitude	60
Altitude (m)	286
Degrees to radians	0.017453293

The daily solar irradiance curves for Mardan for three random days (Fig.3, 4 and 5) show compliance with the annual solar irradiance graph. The graph for annual solar irradiance is discussed in results and discussion chapter.

3. Trend of On Grid Solar Power Systems with Net Metering around the world

Solar energy technologies experienced the second highest annual growth rate of 28% among Renewable Energy Technologies (RETs) after wind energy during last decade [3]. According to the

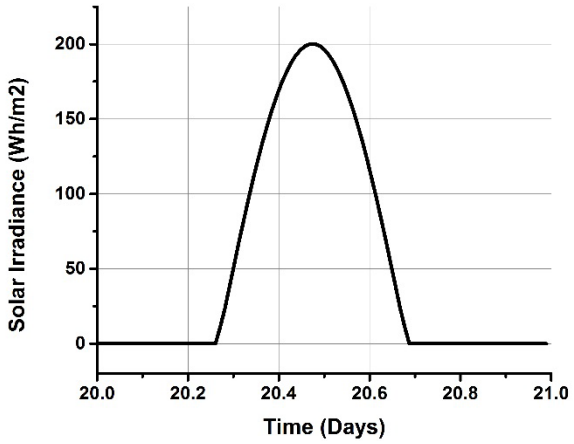

Figure 3: Graphical representation of solar irradiance of a day (21st, January) in Mardan

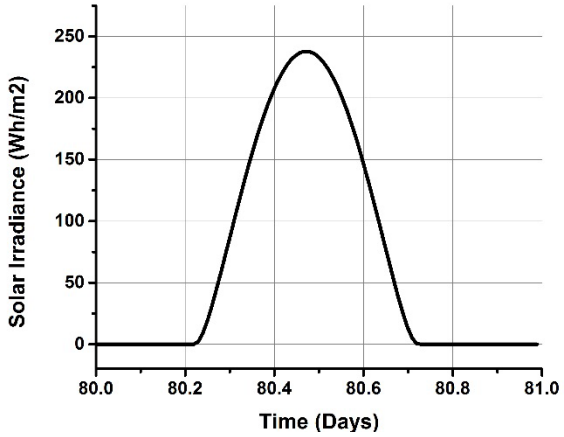

Figure 4: Graphical representation of Solar Irradiance of a day (March 21) in Mardan

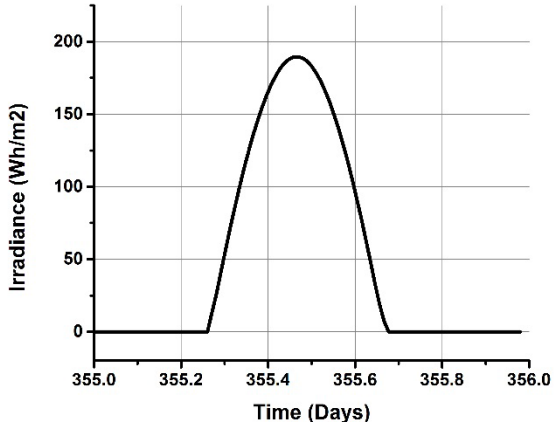

Figure 5: Graphical representation of Solar Irradiance of a day (December 21) in Mardan

European Photovoltaic Industry Association,[4] solar photovoltaic power increased by 16 GW in 2010 around the world, approximately doubled the increase seen in 2009. Also there is a growing interest for electricity generation from solar thermal energy and in 2008 over 6 GW of solar thermal based projects has been announced by various countries [5]. Many countries around the world are meeting their major electricity demand by the use of Solar Energy. Percentage of electricity produced by Solar Energy in different countries is shown below:

Table 3: Percentage of electricity produced by solar energy

Countries	%age of electricity produced by solar energy
Germany	21.58%
Italy	10.43%
China	15.10%
USA	10.33%
Japan	13.16%
Spain	12.00%
Austria	1.80%
India	1.67%

On Grid Solar Power Systems along with Net Metering is very common in the world especially in USA and Europe. Many states of USA and many countries of Europe like Austria, Belgium, France, Germany and Denmark etc. (Table 4). are successfully converting their solar energy into electrical energy and feeding surplus energy into the grid.

Many countries already producing electricity from solar energy have shifted their off-grid solar systems to on-grid solar systems using net metering [6].

Table 4: Percentage of solar power systems

Countries	% of on-grid	Yearly Solar irradiance
Germany	73%	1146.1
Italy (Genova)	78%	1400.38
China (Beijing)	70%	1561.89
USA (Orlando)	78%	1678.08
Japan (Tokyo)	63%	1371.18
Spain (Almeria)	15%	1827.73
Austria	90%	1115.08
India (Delhi)	23%	1823.47

Table 4 show the solar irradiance in many countries around the world and the corresponding exploitation of solar energy by using Net Metering. [7]

Globally, solar technologies share a growth of 18% in renewables energy generation. Many other countries rely on solar energy to meet their energy demands tremendously. Undoubtedly Germany, USA, Austria, Italy and China are the biggest players in this market. Other than these, some countries like Greece and Brazil are now exploiting high solar irradiance in the various cities. For example, The NEB (Brazilian Northeastern region) has the largest solar energy resource in Brazil, presenting an average global radiation of approximately 5.9 kWh/m^2 per day according to the Brazilian Atlas of Solar Energy [8, 9]. Greece has a strong potential of solar electricity generation, especially during cloudless summer days. For example, a typical crystalline silicon PV system established in an urban residential area in Greece can produce annually between 1100 and 1330 kWh/m^2 peak [10, 11]. Lebanon also has very high solar irradiance throughout the year. On

average, Lebanon has solar irradiance of 5.28 kilo watt hour per square meter per day and an annual irradiance of 1928.7 kilo watt hour per square meter [12].

4. Identification of barriers and solution for implementation of grid solar systems in Pakistan

The exploitation of Solar Energy along with Net Metering is one of the main solutions of electricity crisis in Pakistan but still it is not being harvested at a large scale. Pakistan is moving towards RETs at a snail's pace. There are many barriers in the way of tapping solar energy with net metering. Stated below are those barriers and their possible solutions [13, 14];

4.1. Discouragement by Utility

The unwelcoming approach of utility (WAPDA) in Pakistan is a major setback to the promotion and installation of net-metered solar power systems. This is due to the fact that if the Distributed Generators (DGs) offset their electricity usage from utility by sufficient production of electricity from solar panels, then utility would have no usage based revenue. If DG is producing more electricity than required and feeding excess to Grid, then it will not be willing to pay utility rather expect utility to pay it. As a matter of fact, DG uses Utility's transmission lines for the purpose of feeding power to the grid or getting power from the grid during night [15].

So DG and utility should come in an agreement where DG will pay utility a fixed amount for the maintenance of transmission line and grid irrespective of its own production. In this way, Utility will not be in deficit anymore and will encourage its users to adopt net-metered solar power systems.

4.2. Lack of local production of equipment & technical staff

The back bone of net-metered solar power systems is comprised of solar panels, Grid-Tied Inverter (GTI) and two way energy meters. Unfortunately, none of this equipment is locally produced in Pakistan. Thus, we have to import them which increases the net cost of the system exponentially. Likewise, there is no dedicated staff for the installation and maintenance of such systems. This causes the plants to be unsustainable.

The possible solution to this problem is the development of local industries for the production of above stated equipment. This will help lower the net cost of the system. Users will not have to pay any additional charges that incurred in the import of equipment. Moreover, the local engineers should be trained to install and maintain such systems in order to ensure sustainability of the system [16].

4.3. Lack of awareness

In Pakistan, there is an extreme crisis of awareness in all people, from policy makers to the public, from technical staff in the Utility to the consumers. To implement a grid connected system with net metering, DG is responsible for extra cost associated with the installation and protection. Due to lack of awareness, DG does not feel safe investing that huge amount of money. He does not actually believe in the pay-backs associated with the system. The people in rural areas do not have access to electricity. They do not know the natural resources available to them. They have adapted themselves to live without the basic need of life, i.e., electricity [17].

To handle this problem, awareness campaigns must be carried out. The technical staff in the utility must be given special training courses about the on grid net metering system. Moreover, awareness has to spread in the public regarding the reliability, sustainability and pay back associated with such a system. Factors like green energy and independent generation should be exploited. Lastly, the rural population should be taught that they should not rely on the far off grid stations for power. They should generate power of their own in order to meet their energy demands. Media can play an important role towards general acceptance of Renewable Energy Technology (RET) and confidence building of people. Once people are convinced about the advantages associated with this, only then such a system will be able to thrive in Pakistan [18]-[22].

4.4. Financial Barrier

Right now, the equipment associated with on grid net metering system costs too much to be used by a common man in Pakistan. The equipment that is imported costs sky high. Obviously installing the local industries in Pakistan will be a long term solution to this problem. But development of industries takes

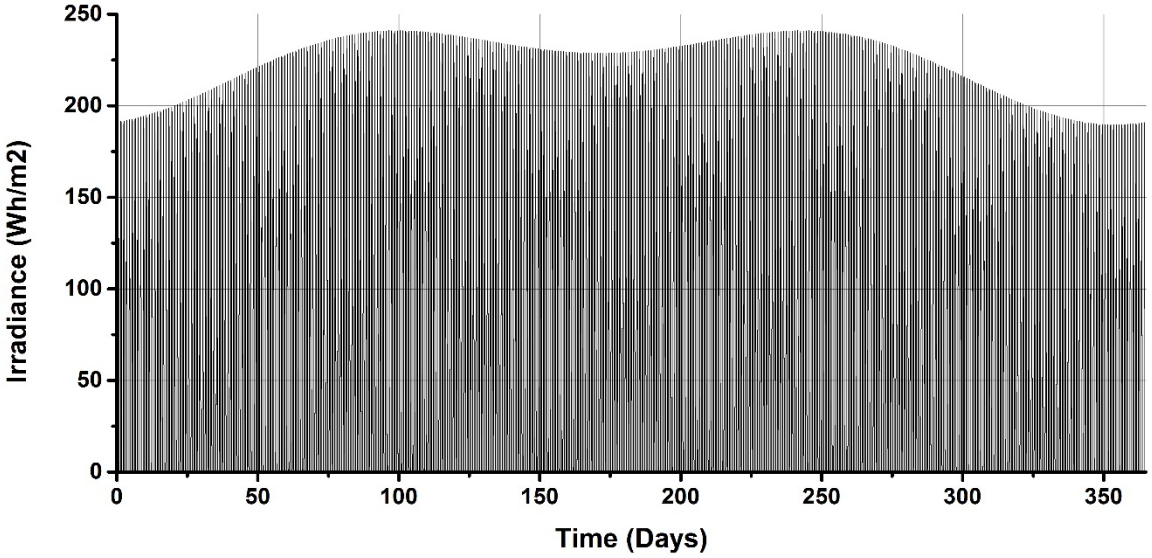

Figure 6: Graphical representation of Annual Solar Irradiance in Mardan (in 2012)

ample amount of time. So the short term solution to this problem is that government steps in and subsidizes the import of equipment needed to install on grid net metering systems in order to encourage the users to adopt this. This way cost of the system incurred to users will be quite less and they will be encouraged to install them.

5. On-going research on Net-metered Solar Power Systems

On Grid solar power systems with net-metering have high initial cost due to Solar Panels, protection system, grid-tied inverters and smart meters. Research is being carried out to reduce the cost of individual components so that cost of the system can be reduced. Moreover sustainability of the system is also a problem. Solar panels have to be replaced after every 20-25 years whereas life of a conventional system is along as 40 years. So intensive research is being conducted throughout the world to optimize between the reliability and cost of the system. When a Distributed Generation is installed on already existing conventional system, then a threat is posed to stability of the system if already installed transmission lines are unable to cope up with the additional power flow. So researchers are looking ways to increase the transmission capacity and system stability efficiently and prevent cascading disturbances.

Innovative solutions involving power electronics with both HVDC and FACTS solutions have the potential to cope with these challenges. They provide the necessary features to avoid technical problems in heavily loaded AC systems; they increase the transmission capacity and system stability very efficiently and assist in preventing cascading disturbances [23].

Net-metering is the technique of grid connection that will be practiced in the near future in Pakistan. Pakistan is at the verge of adopting net metering systems on large scales. The utility in Pakistan i.e., WAPDA (Water and Power Development Authority) and NEPRA (National Electric Power Regulatory Authority) have come up with the set of guidelines that helps to establish the agreement between utility and the customer for net-metering.

6. Results and Conclusion

Pakistan is facing an acute shortage of electricity despite the fact it has one of the highest solar irradiance in the world. In this research, the yearly solar irradiance of a city of Pakistan i.e., Mardan was plotted. Fig. 6 is showing irradiance of Mardan city for a complete year. So it is observed that it has high solar irradiance and variation of irradiance is small throughout the year. The data points of solar irradiance were obtained after every fifteen minutes by the excel sheet and then plotted against time. Using the same techniques, a complete day irradiance is also observed and discussed already in fig. 3, 4 and 5.

Fig. 6 is drawn for one complete year just to observe the variation in irradiance throughout the year. High solar irradiance throughout the year except December and January when winter causes high humidity and foggy weather.

Solar power systems with net metering are used world widely for the production because of many advantages like clean energy, substantial reduction in bills and elimination of batteries from the system. All these points are discussed in previous sections. There are certain barriers in implementing on grid solar power systems with net-metering. But certainly these problems can be solved by awareness, technical expertise and with the upgrade of infrastructure.

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