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Decentralized Electrical Power System in Pakistan

Waqas Ahmad*[1], Awais Ahmad[1], Afraz Ahmad[1], Kamran Khan[1]
[1]Renewable Energy Engineering, University of Engineering and Technology, Peshawar, Center for Advance Studies in Energy (CAS-E)
wahmad2@asu.edu*[1]

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Abstract— Due to the rapid increase in energy demand throughout the world, the electrical distribution system is changing swiftly. An efficient and ecofriendly power system is the need of today's technology dependent era. To achieve this, losses and carbon emissions of the system needs to be accounted for. Distributed Generation (DG) is one of the quickest solutions to this hasty growth of energy demand by providing quality and reliable power solutions.

Micro generation is gaining more and more popularity in rural electrification due to its simplicity and easy installation. Power delivery to remote population of a country has always been a challenge. Because of difficult terrain and long distances, extending central grid to distant areas with less energy requirement is not an efficient approach. For these reasons rural inhabitants of Pakistan are facing power shortages and detachment.

This paper puts forward an approach to demonstrate the principles and operations of an off-grid solar power system for a government school situated at a remote village of Kam Shalman, Landi Kotal, in the province of KP. Far from the national grid and situated in a rough steep terrain, the place is never been provided with electrical power from the grid. RETScreen by Natural Resources Canada is used for simulation purposes. Weather data of the site illustrates solar photovoltaic (PV) a seemly option of powering the school. Aim of this work is to promote indigenous resources powered off-grid power generation, dodging costly and complex grid extensions. Results and outcomes are established on actual measurements to assess socio-economic impacts of small scale distributed power generation on rural life.

Keywords— Distributed generation, electrical system, RETScreen, solar photovoltaic and rural electrification.

I. Introduction

High transmission losses, distribution losses, unreliable power and limited resources are some factors, which are prompting energy sector to come up with better strategies for serving the load growth. For these reasons, the energy planners are motivated to evaluate technically as well as economically feasible alternatives like distributed generation. Above and beyond, the current developments in DG technology and the use of renewable energies (RE) have made DG a striking alternative for the energy developers [1]. RE based power generation is gaining more and more popularity in energy sector. With 178GW of capacity addition in the year 2017, RE based power generation is accountable for more than 66% of the global electrical power growth [2]. RE capacity is expected to increase by more than 1TW in the years 2018 to 2023.

China is leading the world in adopting renewable technology since the last few years. The installed renewable energy capacity of the country has reached 728 GW, by the end of 2018 [3]. Solar DG in China has increased by a factor of 3.5 in the year 2017 and reached 19.4 GW [4]. Figure 1.1 illustrates solar PV growth worldwide.

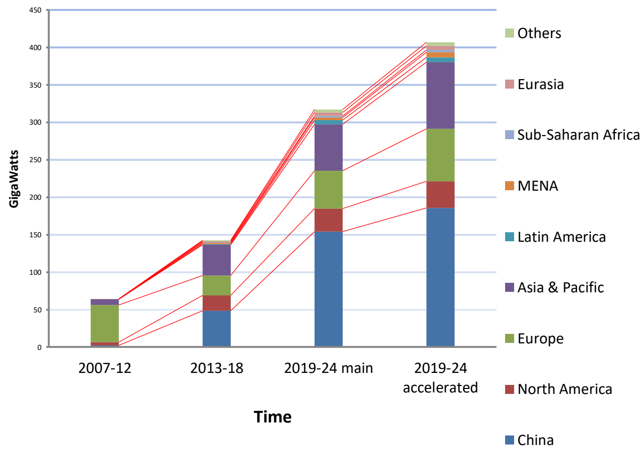

Figure 1. Countries leading in Solar Power

Pakistan has 471kwh of per capita electricity generation which is very low if compared to the global average of 3127kwh [5]. This country needs to fight alongside the rest of the world, and that will only be possible if solid action is taken today. Regardless of having such a descent sum of renewable resources, Pakistan is still struggling generating sufficient electrical power. Moreover, the energy mix is mostly fossil fuel dependent.

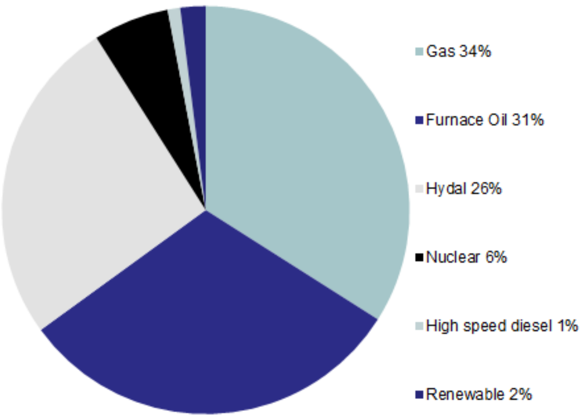

Figure 2. Energy Mix of Pakistan

Conventional centrallized electrical power generation is associated with some complications and problems which can be avoided using decentralized system.

A. *Access to Electricity*

Being a developing country, reliable electricity is the need of time to encourage industrial growth. By 2018, 71.09% of the total population of Pakistan had access to electricity [6]. In this modern age of electricity dependent life almost 29% of the population is not connected to the national grid, most of which is rural and remote inhabitants.

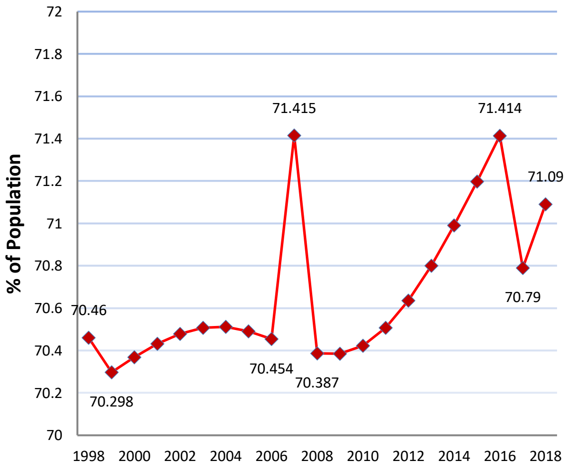

Figure 3. Access to electricity

B. *Transmission Losses*

Significant amount of energy is lost if the system uses long and aged transmission lines. Though power sector of our country has developed with time but still a good portion of the generated power is lost in the form of transmission and distribution losses [7] that are demonstrated in the following figure.

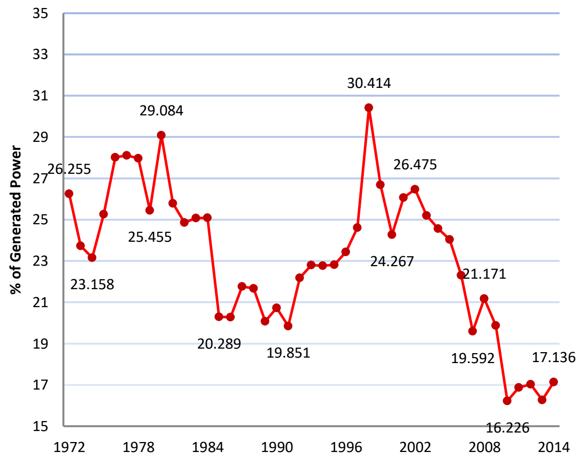

Figure 4. T&D losses

C. *Carbon Emissions*

Environmental pollution is big concern on recently. Nations throught the globe are taking serious action to deal with this issue. According to the 2016 Paris Climate Accords, actions must be taken against emissions of harmful gases to the atmosphere. Pakistan's energy mix is immensely fossil fuel reliant resulting in the increase of carbon discharges. These emissions are growing with time unless bold steps are taken by energy planners.

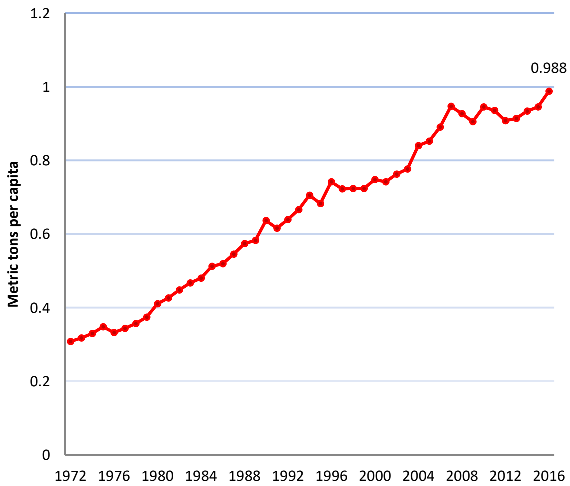

Figure 5. Carbon Emissions

D. *Solar Energy Potential*

The geographical location of Pakistan makes it one of the highest solar irradiance receiving zones [8]. According to [9], Pakistan is the sixth most solar abundant country in the world. Quetta, the capital city of Balochistan province receives the highest number of irradiance which is 7-7.5 kWh/m2/day in the case of direct normal radiation for concentrated solar power [10]. These values differ with location throughout the country with the annual average of 5kWh/m2/day. Until recently, this energy source was not exploited properly, but these days besides large power plants, solar energy is used for various purposes such as, water pumping, water heating, and powering telecommunication towers. Pakistan's total solar PV install capacity is 1568MW by end 2018, making 12% of the total renewable installed capacity [9]. Figure 6 represents the growth in cumulative solar capacity.

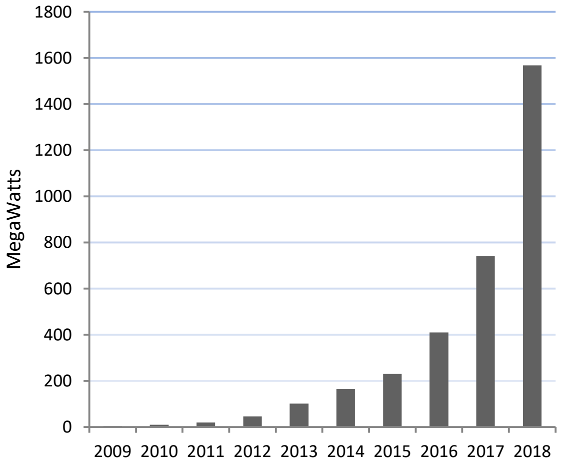

Figure 6. Cumulative Solar Capacity of Pakistan

Disruption of utilities is a common trend in most parts of the country out of which rural population is affected the most [11]. The rural areas being far away from big power stations result in high transmission losses. Also the existing transmission lines have aged and need to be replaced. Replacing existing transmission line and connecting these far away and mostly mountainous regions to the national grid is far more expensive than the power sector can afford. Accordingly, renewable distributed power generation can be used to power rural populations with large renewable resources, such as solar, hydro, wind and biomass.

II. Methodology

Based on solar electrification of a school this paper set forth an approach to motivate the use of distributed power generation driven by indigenous resources (renewable or traditional).

For this purpose, a government school was selected for electrification through solar photovoltaic. Location of this research study is Kam Shalman, Landi Kotal, which is about 40 km from Peshawar city with the coordinates 34.1 latitude, 71.1 longitudes.

A. Load Assessment of the Facilty

The building is two stories with eight large halls, four offices, six washrooms and two corridors. The total proposed load of the building along with details is illustrated in the table.

TABLE I. Load Assessment

Ground Floor		
Size	***Current Load***	***Replacement***
Halls - 4	Fan = 6 per hall = 24 total Tube light = 6 per hall = 24	Remains the same
Rooms - 4	Fan = 1 Tube light = 1	Replace with 25 Watt LEDs
Washroom		
Washrooms - 3	Tube light = 3 Exhaust = 2	Replace with 25 Watt LEDs
Corridor		
Waranda on ground floor	Tube light = 6	Replace with 25 Watt LEDs
Stairs ground to first floor		
Stairs	Tube light = 1	Replace with 25 Watt LEDs
First Floor		
Halls - 4	Fan = 6 per hall = 24 total Tube light = 6 per hall = 24	Remains the same
Washrooms		
Washrooms - 3	Tube light = 3 Exhaust = 2	Replace with 25 Watt LEDs
Corridor		
Waranda on ground floor	Tube light = 6	Replace with 25 Watt LEDs
Top Floor		
Roof	Tube light = 4	Replace with 25 Watt LEDs
Building exterior		
Street lights	None at present	10 LEDs with pole
External lights	Tube light = 8	Replace with 25 Watt LEDs
Future load		
Computer labs	None at present	50 computers
Load calculation	Fan taken as = 120 W (Total fans = 64) LED = 25 w (total LEDs = 160) Exhaust = 50 W (Total exhaust = 10) Total computers = 50 Street Lights = 10 LEDs with poles	
Total load	**Around: 22.3 Kw**	

Keeping this load in view a 25KW system was proposed for the facility.

B. Simulation Software

Renewable energy and Energy efficiency Technology screening software (RETScreen) is used for system simulations. The latest version RETScreen Expert is user friendly and one of the most fitting simulation software for evaluating renewable energy technology projects. Weather data collected on the site is used for various locations across the globe while for the rest of the sites satellite data is used.

Figure 7. RETScreen Software

C. Weather Data

This site is blessed with an adequate solar irradiance throughout the year. Weather data of the location is illustrated as under.

TABLE II. WEATHER DATA OF THE SITE

Month	*Daily Irradiance-Horizontal*	*Daily Irradiance-35° Tilt*	*Earth Temperature*	*Wind Speed*	*Air Temperature*
Unit	*kWh/m2/day*	*kWh/m2/day*	*°C*	*m/s*	*°C*
Jan	3.08	4.79	7.4	1.7	11.2
Feb	4.03	5.47	9.9	1.9	12.9
Mar	4.99	5.78	1.58	1.9	17.4
Apr	6.11	6.19	22.4	2	23.2
May	7.15	6.53	29.9	2.2	28.6
Jun	7.24	6.3	35.5	2.2	33.1
Jul	6.55	5.84	35.5	2.4	32.3
Aug	5.98	5.78	32.9	2.2	30.7
Sep	5.43	5.96	28.9	1.8	28.9
Oct	4.55	5.92	21.6	1.7	23.7
Nov	3.73	5.79	14.5	1.7	17.6
Dec	3.02	5.02	9.1	1.7	12.5
Average	5.16	5.78	22	1.9	22.7

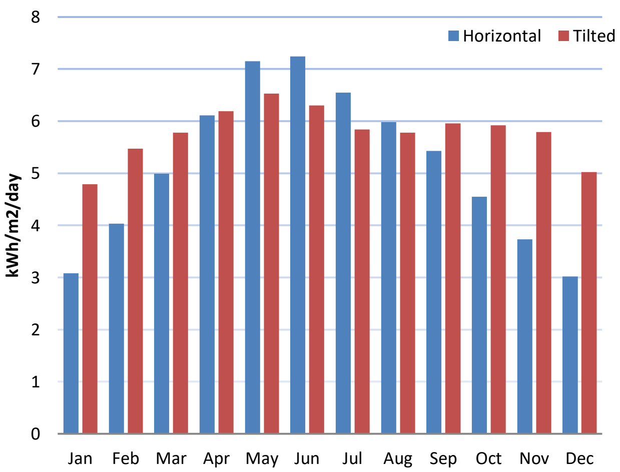

Figure 8. Daily Irridiance

III. RESULITS

Energy delivered to load by any PV system is dependent on the value of solar radiation at that specific site as current production is directly proportional to incoming photons, which results in high power in case of high solar irradiance. Therefore, energy production may vary for different locations. Table III and figure 8 compares the monthly electrical energy production and the average irradiance for that month, which indicates that, higher the value of radiation higher will be energy collection.

TABLE III. ENERGY PRODUCTION

Month	*Daily tilted angle irradiance (kWh/m2/day)*	*Electricity Production (kWh)*
January	4.79	3,103.25
February	5.47	3,163.26
March	5.78	3,631.84
April	6.19	3,665.19
May	6.53	3,895.70
June	6.30	3,585.95
July	5.84	3,463.05
August	5.78	3,442.09
September	5.96	3,440.24
October	5.92	3,604.17
November	5.79	3,503.20
December	5.02	3,225.39

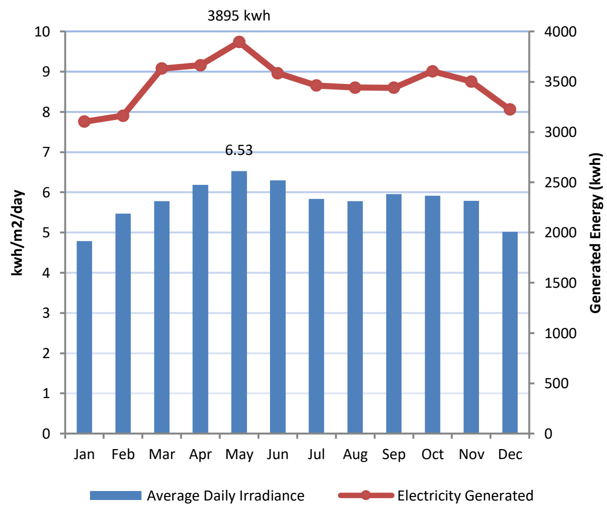

Figure 9. Energy production

A. *Fiscal Assessment*

Financial viability of a project is assessed to see wether a project is financially feasible or not. Inclusive overview of the project feasibility is presented, showing that the proposed system will recover its initial value in less than five years.

TABLE IV. FISCAL ASSESSMENT

Financial viability	
Pre-Tax IRR- Equity	20.4 %
Pre-Tax MIRR- Equity	11.9 %
Pre-Tax IRR- assets	20.4 %
Pre-Tax MIRR- assets	11.9 %
Simple Payback	4.9 yr
Equity Payback	4.8 yr
Net Present Value (NPV)	58,964 $
Annual Life cycle Savings	2,359 $/yr
Benefit-Cost (B-C) ratio	4.5
Debt Service Coverage	No debt

B. *Emission Assessment*

As discussed in the introduction part of this paper most of the nation's energy is from fossil fuels resulting in the release of harful gases like carbon dioxide to our environment. Switching to green energy like photovoltaic can help in managing the increase in this factor. Results show 19.5 tones of CO_2 reduction for the system annually.

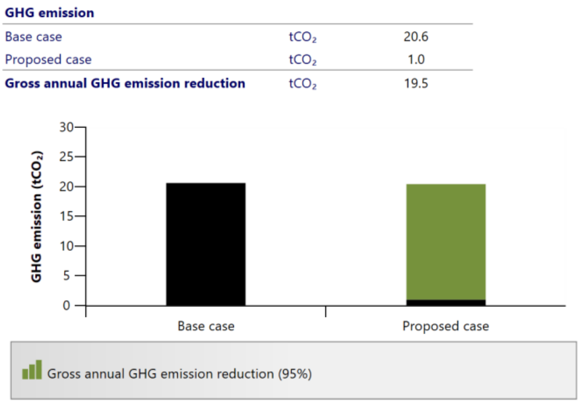

Figure 10. GHG emission

CONCLUSION

Being a developing and economically struggling nation, it is not viable to develop and construct bulky transmission lines and power plants. Moreover, the increase in small scale DG can result in competition among the power producers, which can lead to affordable energy tariff and better services.

A small photovoltrtaic system is installed and examined in this paper to illustrate the importance as well as need of distributed generation to our power sector. Energy demand is increasing with each passing day and DG can be a solution to this quick growth and will provide better quality and reliable power solution. In addition, The rural life style is critically affected by the lack of electricity. DG, powered by region specific renewable resources is a good option to power remote population as the struggling financial situation of the power company and the geographical barriers does not allow otherwise.

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Waqas Ahmad (DOB Mar Ist 1995) belongs to Thana Malakand. He has secured Bachelor of Electrical Engineering (Power) from University of Engineering & Technology Peshawar, Pakistan in 2017. Master of Renewable Energy Engineering from Center for Advance Studies in Energy (CAS-E) UET Peshawar, Pakistan in 2021. Energy research training from Arizona state university Arizona, US.

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