A Review: Dealing with Electricity Crisis by Using Solar Pond and Parabolic Trough Collector Technologies for the Khuzdar Region of Pakistan

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Summary
World is facing difficulties dealing with energy crisis due to the depletion of fossil fuels and other constraints like cost. In the current scenario, globally power generation is necessary for industrial and economic development, so efforts are required to be made to find out the ways to replace fossil fuels with more environmental-friendly alternatives. One of the better options is to use renewable energy sources. This research work addresses the electricity shortage problem of Pakistan with a specific focus on use of solar energy with the help of solar pond and parabolic trough for the generation of electricity. A review has been presented on the recent works on application of solar pond and parabolic trough technology in this area. Besides that, potential use of these technologies in Khuzdar region, a remote area of Pakistan has been described. Review shows that remote areas of Balochistan province especially Khuzdar region is very much feasible to use solar energy as replacement of conventional power generation resources with a focus on solar pond and parabolic trough collector technologies of renewable energy. Future work also mentions potential use of Artificial Intelligence based techniques to be used for solving problems related with electricity generation.

Key words:
power generation, renewable energy, Khuzdar, solar pond, parabolic trough collector, fuzzy logic

1. Introduction

Renewable energy (RE) applications is an area of research which is gaining appreciation throughout the world. Electrical power systems are crucial for economic development of any country. Now a day's most countries are interested in power generation from Renewable Energy Sources. Alternative energy sources provide an environmental friendly way for electricity generation. Earth temperature would keep on increasing if traditional sources are continued in energy sector which can catastrophically damage the environment and can cause hazards. Solar technology can be used for electricity generation in multiple ways. One way is Photovoltaic (PV) cell where solar energy is directly converted to electricity through photovoltaic process. Other method is using Solar thermal technology where solar is used as heating source and a receiver is used to capture the concentrated sunlight [1]. Solar Pond and Parabolic Trough Collector (PTC) are related with solar thermal technology.

In this work, we have reviewed that use of solar energy especially application of solar pond and PTC which has substantial scope for power generation in remote areas of Pakistan. Example of Khuzdar region of Balochistan province of Pakistan has been used as a case study. Discussion has been provided to show that solar thermal technology e.g solar pond and PTC can provide long term solution of electricity generation fulfilling the required demand.

In this work, Section II describes the solar potential of Pakistan in general, followed by Sections III and IV which describe Solar Pond technology and PTC applications in electricity generation. Section-V reviews the solar technology application for power generation in Balochistan province with a focus on Khuzdar region. Finally, section VI provides conclusion and future work.

2. Solar Potential Of Pakistan

Solar energy has high potential as a RE source throughout the world including Pakistan. In a review by authors in [4], it was found that trend of using solar energy as renewable energy resource is on the rise around the world and more and more countries are making efforts to use this as an alternative to conventional energy resources which is healthier in terms of environment as well. The solar power development based on research is shown in Fig. 1

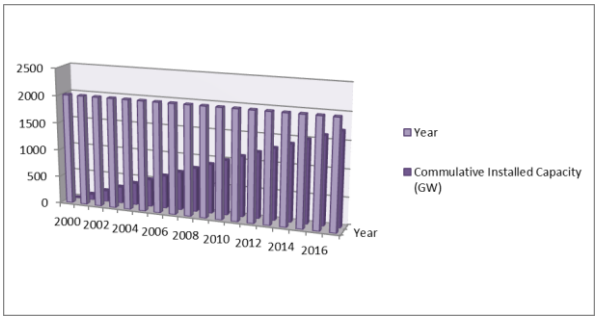

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Fig. 1 Chart representing year wise solar development [2]

In [1], authors have looked at trends for application of renewable energy sources as potential solution for power crisis in Pakistan. Power sector of Pakistan heavily relies on conventional resources including thermal, hydal and nuclear. Out of these, main contributor is thermal power. Supply of fossil fuel is dependent on import. Increased prices of fossil fuels in international market as well as variance of price cause cost of electricity to become higher. Although energy produced by fossil fuel is appreciable but it also causes harmful emissions and considered dangerous for environment. An alternate energy resource to cater with the requirement is a must. Renewable energy provides a viable option to deal with the electricity problem of Pakistan. Out of many other renewable energy options available, it is estimated that around 2900GW solar potential is available in Pakistan. It is also estimated that solar irradiance of the country is 2200 KWh/m2. In Pakistan, five places including

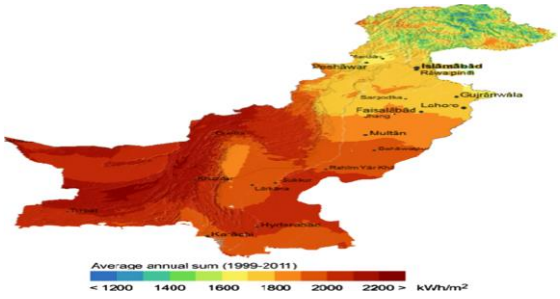

Fig. 2 Pakistan Direct Solar Radiation Map [1]

Karachi, Lahore, Multan, Peshawar, and Quetta have facility to record this data. Other places have to rely on associated empirical data to be used as reference. A map of direct solar radiation of Pakistan is shown in Fig 2.
In [3], authors have conducted SWOT (Strength, Weakness, Opportunities, Threat) analysis of current status along with future road map of Renewable energy sector in Pakistan. They have described that load shedding in Pakistan has risen on average upto 18 hours a day. It was described that wind and solar renewable energy methods can be very helpful in fulfilling the electricity demand of the country. It is estimated that 25 million people in Pakistan have no access to electricity. 6500 MW shortfall of electricity was recorded in 2017. In the SWOT analysis, authors analysed that one of the strengths of the solar energy potential of Pakistan is availability of highly accurate solar maps. Other factors included reduction in environmental pollution and strong public acceptance of solar energy across Pakistan. Now we discuss solar pond and parabolic trough collector technologies with aspect of power generation.

3. Solar Pond

Solar Pond is used for collection and preservation in terms of storage of solar energy (heat). Different types of solar pond exists, examples include salt gradient solar ponds, partitioned solar ponds, membrane stratified solar ponds and others. A typical salt gradient solar pond is shown in Fig 3. It can be seen that its structure consists of three layers namely upper convective zone (UCZ), non-convective zone (NCZ) and lower convective zone (LCZ). UCZ is considered a zone of constant temperature and salinity whereas NCZ zone serves as an insulating layer. LCZ is of high temperature and used as storage layer for energy/heat etc. [4].

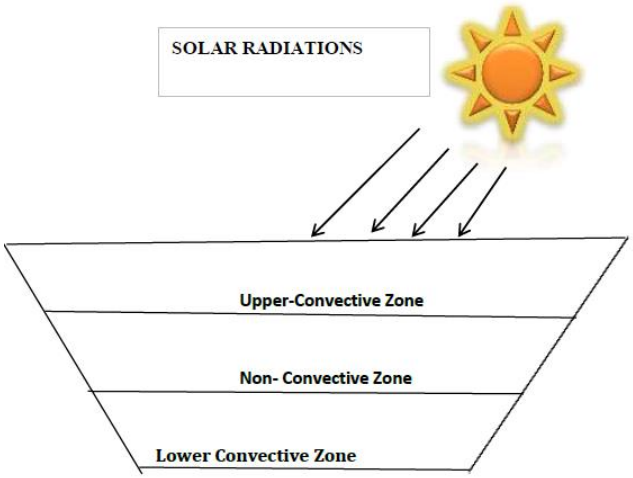

Fig. 3 Structure of Salinity Gradient Solar Pond [4]

Solar ponds are used to preserve solar energy which can be used for electricity generation in conjunction with steam, thermo electric generators (TEG). In solar pond, high temperature is maintained in the lower region and salt water is used to prevent it from convection that is why the term solar gradient pond is also used. A variety of solar ponds in size ranging from few hundred to thousand square meters have been constructed globally in last few decades.
Authors in [5] have investigated that Solar energy resources have high potential to meet the energy demands of the world upto 100%. One of the requirements of making effective use of solar energy, storage mechanism is required especially when weather is rainy or cloudy. Solar pond is helpful in these conditions because it has own energy storage. This might be sufficient for low energy requirements of heating and cooling of buildings. Authors performed thermal analysis of a salt gradient solar pond with heat extraction from lower convective zone. They recommended solar pond of 1.5m but also suggested that if quality is compromised than smaller ponds can also show good results. They

concluded that solar pond are sufficient to meet the energy requirements of a small building or house.

4. Parabolic Trough Collector

A parabolic trough collector (PTC) is described as a linear concentrating system. Long mirrors/ silver coatings with parabolic structure mirrors are generally used for construction of PTC. It also has a receiver tube placed along the focal axis of the parabola. In this way, DNI is able to be concentrated onto the receiver tube absorbing the solar energy by the HTF. Common PTCs can achieve concentration ratios of 50, whereas HTF temperature can reach up to 400℃. Parabolic troughs can be placed in solar field with various arrangement and architecture. and architecture [6]. An example of PTC is shown in Fig 4. PTC can be helpful in electricity generation.

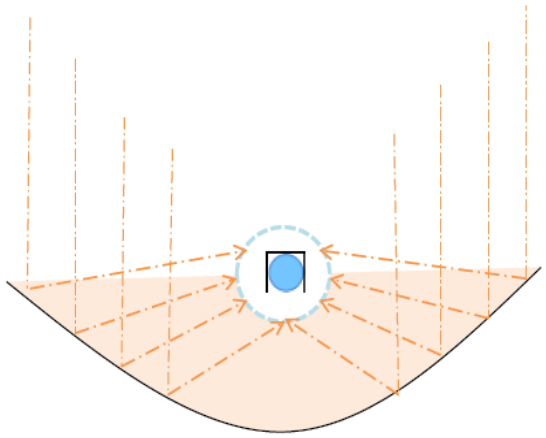

Fig. 4 Example of Parabolic Trough/Dish Collector [6]

In [7], authors have described the design of a 100MW CSP using PTC technology with 6 hours thermal energy storage. They argued that performance of Photovoltaic is inferior when compared with CSP. System Advisor Model (SAM) was used for simulation. The results indicated that proposed system was able to 244,688,560 KWh of electricity. Authors concluded that results were appreciable and further work is required to be done in this regard with CSP to become a key factor in electricity generation through solar energy.

Authors in [8] have discussed Concentrated Solar Power (CSP) as a popular renewable energy option. Parabolic Trough configuration of CSP has been used for 50MWe PT plant of Abu Dhabi UAE. The aim was to look at the performance in terms of improvement in energy and being economical. System Advisor software model was used to carry out the simulation work. Results indicated that utilization of CSP technology in conjunction with appropriately selected technology could be beneficial in reducing cost of energy as well as limiting environmental pollution.

In [9], authors have looked at the performance with economic analysis of Concentrated Solar Power (CSP) generation in Pakistan. The results indicated that Quetta region of Balochistan Province was among areas found suitable for CSP based projects. Use of Parabolic Trough was also among the suggested one method for development projects related with CSP.

In [10], it was argued that Parabolic trough solar collector is considered a technology working on medium temperature range which can be efficiently used as RE option to deal with the energy crisis of Pakistan. The authors performed a detailed study with comprehensive analysis with integration of Combined Cooling and Power Plant (CCP) operated by Parabolic Trough Solar Collectors (PTSC). Data of Quetta and Lahore city of Pakistan was used and analysis of results was presented and discussed.

In [7], authors have reported the effects of solar radiations and weather conditions based on data collected from five major cites of Pakistan using PTC. Matlab software was used to carry out analysis. It was analysed that although Pakistan has diversified weather, still availability of solar beam radiations intensity of these cities is high. June-July have maximum radiation while December and February have the least values. It was concluded that PTCs have strong feasibility to be used in diversified climatic conditions of Pakistan. Parabolic collectors gets heat from the incident solar radiations. The obtained heat is transferred to the Heat Recipient Fluid (HRF). It is then circulated through a centrally heat pipe of the collector. This heat can be used for a variety of applications including power generations, and other high temperature applications. Parabolic troughs are very reliable, and efficient solar thermal collectors and that is why more researchers are inclined towards use of PTC.

Authors in [11] performed a study where they investigated the performance of PV, PTC and wind power plants with 10MWe capacities for the data taken from the City of Multan Pakistan. In terms of electrical energy generation, they found that PTC took the lead over other systems with 7.5h storage with 45.96% capacity factor. In terms of PTC, authors concluded that it was a viable option for non-sunny days however the cost would be higher as compared to PV system.

5. Discussion On Solar Potential Of Khuzdar

Khuzdar is considered of significant importance in Balochistan province after Quetta. Balochistan is the largest province of Pakistan area wise where 77% of population reside in rural areas. It is estimated that 90% villages do not have proper electricity. Demographic nature of the province

makes it hard to provide electricity at all places. Solar energy provides a solution to provide electricity in far flung areas of Balochistan Solar potential of Balochistan province is very high. 40% of the province land area has solar insolation of 6kwh/m2. Even remaining province receives direct solar radiation of 4.5kwh/m2. It leads to power generation possibility of around 1.2 Million MW. Developing large scale solar projects require more investment, however, their maintenance cost is low. For Balochistan, mini projects can be initiated. As Balochistan is the hub of activities for the CPEC, with the co-operation of Chinese Government, more mega solar projects with a specific focus on Balochistan can be started thus providing better facilities especially for the rural areas of Balochistan [7].

Authors in [12], have explored renewable energy resources in Pakistan. They analysed that along with other areas, Balochistan province has maximum solar energy generation potential in Pakistan. They concluded that at least 10% of energy demand can easily be achieved through use of RE with solar providing a viable option.

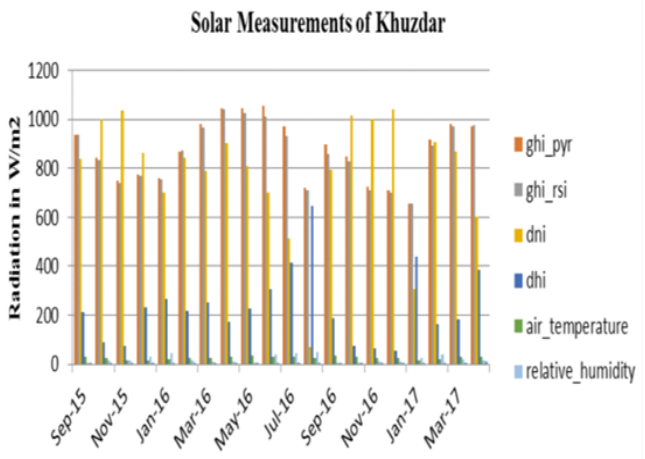

Fig. 5 World Bank Solar Measurements of Khuzdar [1][13]

In [14] , results of solar potential of Balochistan province have been reported. The parameters used were global horizontal radiance (GHI), direct normal irradiance (DNI), diffuse horizontal irradiance (DHI), air temperature and relative humidity. Results from Khuzdar area of Balochistan are presented in Fig. 5. It can be clearly seen that all parameters indicate the high potential of Khuzdar region of Balochistan making it strongly feasible to use solar renewable energy source for practical applications for socio economic development. The priority should be electricity generation.

In [15], authors while investigating solar potential of Pakistan found that Sindh, Balochistan and southern parts of Punjab have maximum solar potential in Pakistan. The global insulation of Balochistan is 19-20MJ/m2 per day with average mean sunshine duration of 8-8.5h. Such values indicate that Balochistan is highly feasible for solar energy applications. Furthermore, one of the weather stations in Pakistan is located in Balochistan University of Engineering and Technology Khuzdar providing round the clock updated data of the region. It can be very helpful in initiating solar energy projects including electricity generation because of availability of authenticated data from weather station of Khuzdar. Authors also investigated the barriers found in promotion of solar energy application in Pakistan. One of the major obstacle was unawareness of people regarding solar energy products in rural areas. As mentioned before, majority of persons live in rural areas in Balochistan. With awareness campaign, utility of solar energy in power generation could be high with the co-operation of local community. Government of Pakistan has initiated solar energy electricity program for rural areas of Pakistan. Reportedly 400 villages of Balochistan are initially part of the project. There is need to increase the number to overcome the electricity crisis in Balochistan. Authors concluded that solar energy can solve the energy problem of Pakistan as it is cheaper than wind, economical and has less maintenance cost as well.

Literature review reveals that Balochistan province in general and Khuzdar region specifically can be one of the ideal places in Pakistan to invest on solar energy projects especially in electricity generation. It has also been shown in this research that numerous researchers have highlighted significance of using solar energy for power generation in Pakistan. Another importance aspect is that use of solar energy would provide environment friendly option as compared to conventional power generation sources.

We have also shown that Solar Pond and PTC technology provide a viable option to be used for electricity generation. For Khuzdar region, where solar parameters as shown in Fig 5 are high, Government should be encouraged to invest on projects with Solar Pond and PTC technology in Khuzdar region. Although initial investments would be on higher side, but once installed, cost of electricity would reduce and also maintenance cost would also be significantly low. The ultimate beneficiaries would be underprivileged people living in remote areas of Balochistan in general and Khuzdar specifically with cost effectiveness in terms of long term initial investment resulting into sustainable growth of inhabitants. In the next stage of this work, experiments based on empirical data of Khuzdar would be performed and investigation would be done to deal with any complexities found using intelligent methods of Artificial Intelligence.

6. Conclusion And Future Work

In this work, we have performed a review on the potential use of solar renewable energy source for power generation

for Khuzdar region of Balochistan Province of Pakistan with solar pond and PTC technologies. It has been analysed that Khuzdar region due to its demography is best suited to initiate solar energy projects for electricity generation especially for remote areas of the region and beyond with environmental pollution free environment. In future, we would be investigating hybrid approaches of these two technologies. We also aim at using fuzzy logic to identify vagueness found in various solar energy technologies related to electricity generation. One of the examples of using fuzzy logic in solar technology can be found in [16] ,where authors have used fuzzy set theory for evaluation of solar electric power technologies. We would also be investigating other Artificial Intelligence based techniques including deep learning methods, Artificial Neural Networks etc., in conjunction with solar pond and PTC technologies to find intelligent solutions in power generation with a specific focus on Khuzdar region of Pakistan.

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