Appraisal of Climatic Conditions for Potential Solar Energy Applications in Nawabshah and Quetta Cities

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Submission date: 15-Nov-2018 02:06PM (UTC+0500)
Submission ID: 1039508560
File name: Manuscript.docx (291.54K)
Word count: 2760
Character count: 16029

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***Abstract*—This study was conducted to appraise climatic conditions for potential applications of solar energy units in Nawabshah and Quetta cities. For that, twenty two monthly average yearly data of insolation on horizontal surface, at various slopes on titled surface, air temperature, earth skin temperature was acquired from NASA. The data was evaluated through Statistical Package for the Social Sciences software. It was found from comparative analysis that Quetta city receives 6% more insolation on horizontal surface, 9% more insolation at optimum slope than Nawabshah city. Quetta acquires 6 % more minimum radiation at the slope of 0°, and 9% more maximum radiation at the optimum slope than Nawabshah. Moreover, Quetta has 72% less minimum temperature and 36% less maximum temperature than Nawabshah. Quetta also has 46% less average temperature and 38% less earth skin temperature than Nawabshah. It is discovered from the study that Quetta is more promising place for installation of solar energy applications as compared to Nawabshah city as it receives more solar radiations and less air temperature.**

Keywords-air temperature; insolation; solar systems; climatic conditions

I. INTRODUCTION

The climatic conditions have prominent effects on any existence on the earth. Climate change severely influence the weather patterns of various countries by reducing precipitation or increasing temperatures which results in lower water availability in all for every sector [1]. It is an exciting challenge to ascertain the causes of climate variations with the logical certainty needed for environmental policy making. A rise of 0.6-1.0°C in average temperature in coastal areas of Pakistan has been reported since early 1900s [2]. It is important to mention here that Pakistan also experiencing rise of total change of temperature around 0.47°C during 1960-2010 [1].

Power sector is more susceptible to extreme weather condition, predominantly electricity supply and demand [3]. Currently Pakistan is confronting stern energy crisis and power failures [4]. The level of electricity dearth has jumped up to about 5000 MW, which is being compensated by increasing load shedding from 8 to 14 hours per day. Industrial development has also been slow down and thus it has negative impact on economy of the country [3]. It is also observed that 16% of total country population lives in rural a area which is directly connected with grid-connected electricity, compared to remaining 85% of the urban population [3]. The conditions are most horrible in remote rural areas where they have no any easily accessible commercial energy. The provision of energy amenities needs to be extended to the distant areas to raise their living standard. Alternative methods of providing energy at their homes must be arranged to supply uninterrupted power to the rural community to overcome energy crisis in Pakistan [4, 5]. This goal can be achieved by utilizing solar energy which can drive out this challenge precisely. Since the solar energy is wholly dependent on the climate conditions of the area and there are many climatic zone in Pakistan to difference in physical [4, 6, 7]. The variety of climatic zones has profound effect on the availability of solar energy. Climatic divisions of Pakistan include highland, lowland, coastal and arid climate. Even a division of climatic zones does not indicate accurately the same conditions throughout the zone as there are unlimited variants in rainfall, temperature, humidity etc. in the similar climatic zones [8, 9].

Nawabshah is located almost at the geographical center of Sindh province of Pakistan. The climate of Nawabshah is hot to exceptionally hot during the summers and cold and foggy during the winters [10]. The highest temperatures in the city are typically climbing to above 50°C from May to August. On 26th May 2010, the air temperature reached up to 52°C, which was the highest temperature ever recorded in Nawabshah. On 7th January 2011, the temperatures in the city dropped to 4°C. On the other hand, the Quetta is the capital of Balochistan province bordering along Afghanistan [11]. The climate of the capital city is dry and arid, and temperature variations significantly between winter and summer months. It is hot in summers and mild to extreme cold in winter [12]. The highest temperature observed is around 42°C and lowest temperature noted is -18.3°C [1]. To analyze the link between electricity consumption and climatic variables requires appropriateness of climate for any particular application. Thus this work is an attempt to compare the weather variability on solar energy applications of Nawabshah and Quetta cities.

II. MATERIALS AND METHODS

The comparison of Nawabshah (26.3°N and 68.4°E), Sindh and Quetta (30.1°N and 67.0°E), Balochistan weather parameters was made to realize their influence on solar energy application [10,12,13]. The meteorological data of both locations were acquired from NASA and Solar Energy [14]. The methodology adopted for the data comparison is given in Table 1. The appraisal was made with the help of SPSS software.

TABLE I. ADOPTED METHODOLOGY FOR ACQUISITION OF SATELLITE DATA [10,15]

Effect	*Range*
Type of database	NASA SSE 6
Level	Global
Data inputs	GEWEX/SRB, 3 + ISCCP Satellite, Clouds + NCAR, Reanalysis
Length of data	1983–2005
Time resolution	3-h
Spatial resolution	1 arc-degree x 1 arc-degree
Insolation	Satellite model
Diffuse part of radiation	Diffuse Radiation Model
Tilted surface (diffuse model)	RetScreen Model

III. RESULTS AND DISCUSSIONS

The annual monthly average insolation on horizontal and tilted surfaces is shown in Figure 1. In Nawabshah, the monthly average yearly insolation on horizontal surface was found 5.24kWh/m^2/d [16] and in Quetta it was 5.57kWh/m^2/d. The maximum value of insolation in Nawabshah was recorded in May with 6.42kWh/m^2/d and minimum in December with 3.75kWh/m^2/d, whereas, in Quetta the maximum insolation was noted in June with 7.6kWh/m^2/d and minimum in December with 3.3kWh/m^2/d. Similarly, monthly average minimum yearly insolation on tilted surface at Nawabshah was noted as 4.68kWh/m^2/d and in Quetta 4.97kWh/m^2/d. The maximum value of insolation in Nawabshah was recorded in May with 5.97kWh/m^2/d and minimum in December with 3.34kWh/m^2/d, while, the maximum insolation in Quetta was noted in June with 6.82kWh/m^2/d and minimum in December with 2.66kWh/m^2/d. It is found that both monthly averaged and minimum insolation on a horizontal and tilted surface was 6% more in Quetta than that of Nawabshah.

Monthly mean insolation on tilted surface at different slopes for Nawabshah is shown in Figure 2. The monthly average yearly isolation was found maximum at the optimum slope with 5.87kWh/m^2/d and minimum with 5.18kWh/m^2/d at 0° slope. The maximum amount of insolation was noted in May with 6.39kWh/m^2/d at optimum slope and minimum 3.66kWh/m^2/d in December at 0° slope. Since, at the slope of ±15°of the latitude, the insolation was in between maximum and minimum values.

Average monthly radiation on tilted surface at different slopes for Quetta is shown in Figure 3. The monthly average yearly isolation was found maximum at the optimum slope with 6.38kWh/m^2/d and minimum with 5.51kWh/m^2/d at 0° slope. The maximum amount of insolation was noted in June with 7.56kWh/m^2/d at optimum slope and minimum 3.25kWh/m^2/d in December at 0° slope. Since, at the slope of ±15° of the latitude of the location, the insolation was in between maximum and minimum values at all slopes.

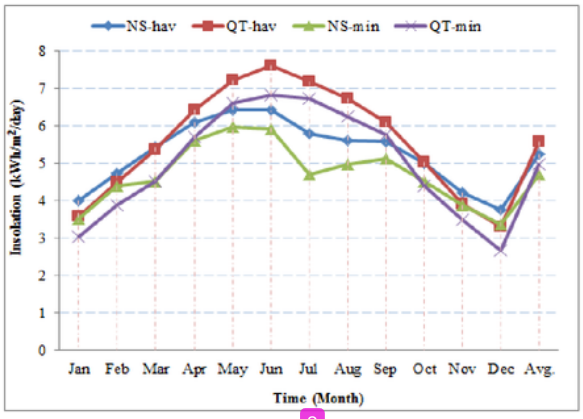

Fig. 1. Monthly averaged insolation on a horizontal surface and minimum on tilted surface.

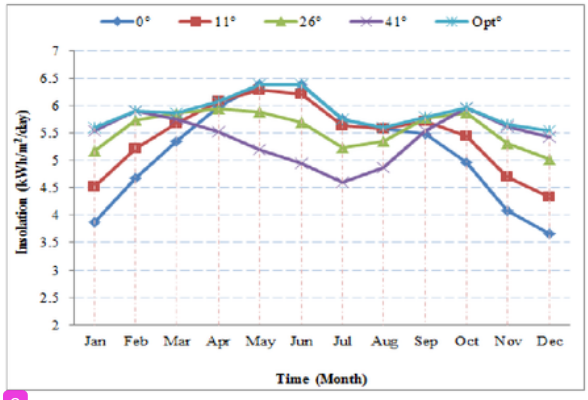

Fig. 2. Monthly average insolation on tilted surface at different slopes at Nawabshah.

Average monthly radiation incident on an equator-pointed tilted surface at optimum slopes for both locations is given in Figure 4. The annual monthly average insolation was found maximum at the optimum slope with 6.38kWh/m^2/d for Quetta and 5.87kWh/m^2/d for Nawabshah. The minimum insolation was noted as 5.33kWh/m^2/d in December and maximum in June with 7.56kWh/m^2/d for Quetta. Similarly, the minimum insolation was noted as 5.54kWh/m^2/d in December and maximum in May with 6.39kWh/m^2/d for Nawabshah. Since Quetta receives approximately 9% more annual monthly average solar radiations than Nawabshah at optimum slope.

In order to consider only worst and best situations at optimum slopes for both locations, the monthly minimum average and maximum average radiations were analyzed as illustrated in Figure 5. The monthly average minimum yearly mean was found 5.17kWh/m^2/d for Nawabshah and 5.54kWh/m^2/d for Quetta, whereas, monthly average maximum yearly mean was found 6.7kWh/m^2/d for Nawabshah and 7.38kWh/m^2/d for Quetta. It was found that Quetta receives 7% more minimum radiation and 10% more maximum radiation than that of Nawabshah.

The monthly average yearly mean insolation on all slopes for both locations is illustrated in Figure 6. It was found that both locations receives minimum amount of insolation at 0° slope and maximum at optimum slope. The minimum and maximum insolation at Nawabshah was noted as 5.18kWh/m^2/d and 5.87kWh/m^2/d, and for Quetta 5.51kWh/m^2/d and 6.38kWh/m^2/d respectively. It was found that Quetta receives 6% more minimum radiation at the slope of 0°, and 9% more maximum radiation at optimum slope than that of Nawabshah.

Previously from the study, it was found that both locations could get maximum insolation at optimum slope. Therefore, optimum slope was determined. The monthly average and yearly optimum slopes of both locations are depicted in Figure 7.

It was found that optimum slope of both locations are almost 2° less than that of their respective latitudes. For example, Nawabshah is located on 26.24° N latitude, its optimum average slope for solar system installations would be at 24.7°, and Quetta is located on 30.25°N, its optimum slope would be at 38.3°. However, maximum slope of 53° was determined for Nawabshah in December, and 57° of December for Quetta. Similarly, 0° was required for Nawabshah from the month of May up to July, whereas, for 0° slope from June to July is best for Quetta.

Temperature is an important parameter for installation of solar systems after solar radiations, as it has negative relationship with the power output or efficiency of solar photovoltaic systems. Therefore, monthly minimum and maximum average temperature of both locations are analyzed and illustrated in Figure 8. The monthly average minimum yearly mean was found 20.7°C for Nawabshah and 12°C for Quetta, whereas, monthly average maximum yearly mean was 32.6°C for Nawabshah and 23.9°C for Quetta.

Monthly average air and earth skin temperature of both locations are illustrated in Figure 9. The monthly average yearly mean air temperature was found 26.3°C for Nawabshah and 18.0°C for Quetta, whereas, monthly average yearly mean earth skin temperature was 29.7°C for Nawabshah and 21.5°C for Quetta.

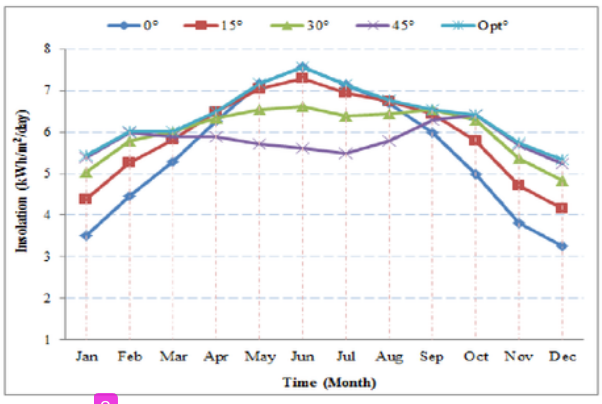

Fig. 3. Monthly average insolation on tilted surface at different slopes at Quetta.

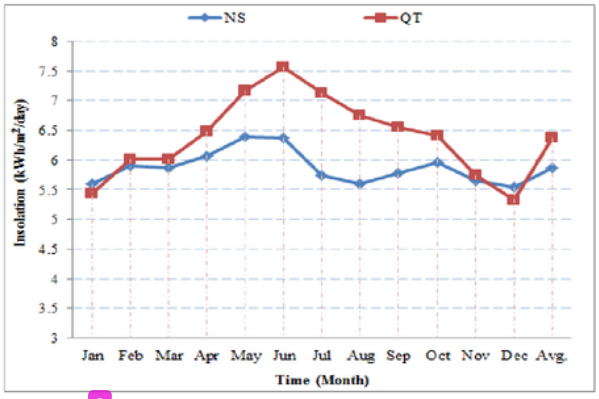

Fig. 4. Monthly average insolation on an equator-pointed tilted surface at optimum slope.

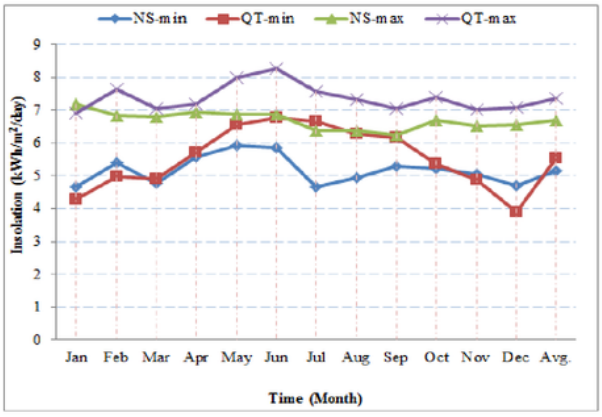

Fig. 5. Monthly averaged minimum and maximum insolation on tilted surface

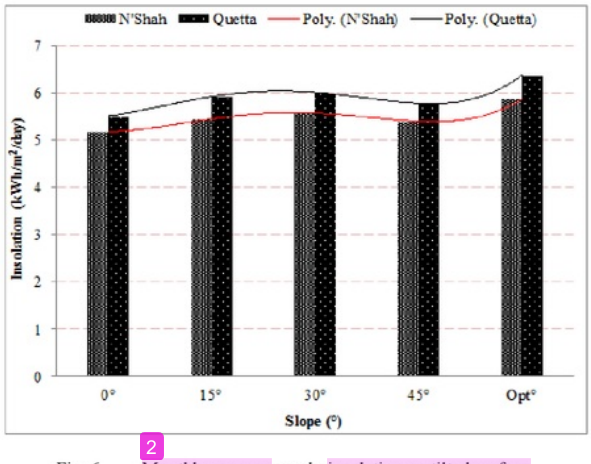

Fig. 6. Monthly average yearly insolation on tilted surface.

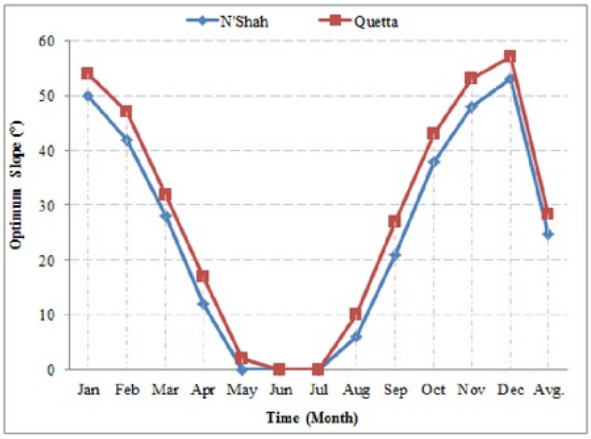

Fig. 7. Monthly average optimum slope for solar system mountings.

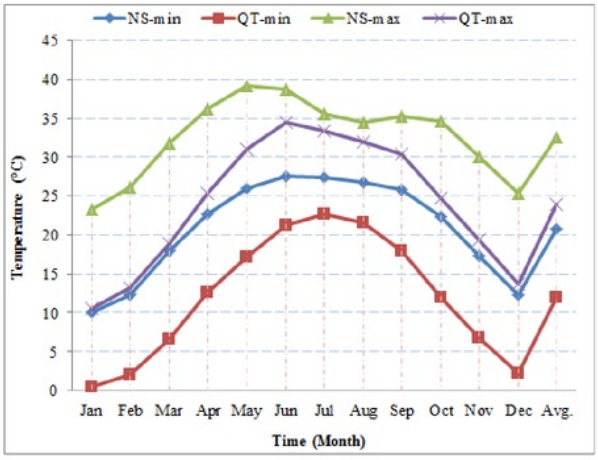

Fig. 8. Monthly average minimum and maximum air temperature

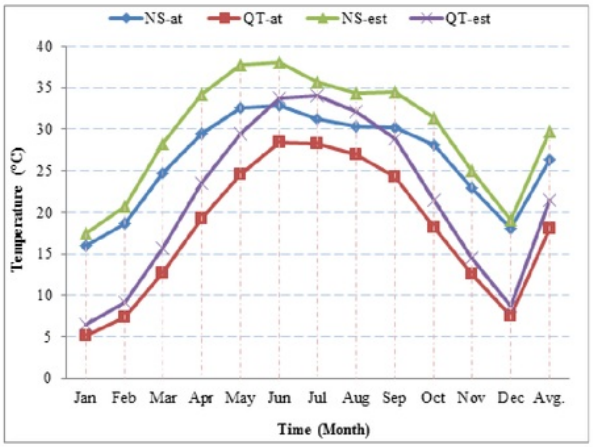

Fig. 9. Monthly average air and earth skin temperature

It was found that Quetta has 46% less average temperature and 38% less earth skin temperature than that of Nawabshah. Not only air temperature of Quetta is colder than that of Nawabshah but also earth skin temperature as well.

It is revealed from the study that Quetta is more favorable place for installation of solar systems that that of Nawabshah as it receives more solar radiations and less air temperature. Both above conditions are making Quetta more appropriate place than that of Nawabshah.

IV. CONCLUSIONS

In Nawabshah, the monthly average yearly insolation on horizontal surface was found 5.24kWh/m^2/d and in Quetta it was 5.57kWh/m^2/d. The monthly average yearly insolation was found maximum at the optimum slope for both locations with 5.87kWh/m^2/d for Nawabshah and 6.38kWh/m^2/d for Quetta, whereas, minimum insolation was 5.18kWh/m^2/d and 5.51kWh/m^2/d for Nawabshah and Quetta respectively at 0° slope. It was found that optimum slope of both locations are almost 2° less than that of their respective latitudes. However, maximum slope of 53° was determined for Nawabshah in December and 57° in December for Quetta. Similarly, 0° was required for Nawabshah from the month of May up to July, whereas, for 0° slope from June to July is best for Quetta. The hottest month at Nawabshah was observed to be May with 39.2°C and coldest month January with 23.3° C, whereas, hottest month at Quetta was observed to be June with 34.4°C and coldest month January with 10.5° C. It is found that Quetta receives 6% more insolation on horizontal surface, 9% more insolation at optimum slope than Nawabshah. Quetta also gets 6 % more minimum radiation at the slope of 0°, and 9% more maximum radiation at the optimum slope than Nawabshah. Moreover, Quetta has 72% less minimum temperature and 36% less maximum temperature than Nawabshah. Quetta also has 46% less average temperature and 38% less earth skin temperature than Nawabshah. It is revealed from the study that Quetta is more promising place for installation of solar systems that that of Nawabshah as it receives more solar radiations and less air temperature. Both above conditions are making Quetta more appropriate place than Nawabshah.

ACKNOWLEDGMENT

The authors are thankful to the authorities of Meteorological Department of Karachi and NASA for providing the data.

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