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The Solar Energy Potential In Gujarat – A Case Study

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Abstract: ***An accurate knowledge of the solar radiation distribution at a particular geographical location is of vital importance for the development of many solar energy devices and for estimates of their performance. In this paper, the measured data of global solar radiation on a horizontal surface and number of Bright Sunshine Hours (BHS) for Gujarat was analyzed. The solar energy potential (BHS) of several locations in Gujarat is received by compiling data from Agricultural Universities of Gujarat and its Agricultural science centre (krishi vigyan Kendra). The locations are Amreli, Anand, Rajkot, SK Nagar, Navsari, Vadodara, Junagadh, Godhra, for the period of five years(2009-2013). The results are all shown in graphical forms. The calculated shape and scale parameter of these locations with the help of Weibull distribution. Weibull Probability density function (PDF) and Weibull Cumulative density function (CDF) are also calculated. Regression constants for the first order Angstrom-type correlations for Gujarat was calculated and developed using the method of regression analysis. Corelation-coefficient (R^2) range between from 0.9821 to 0.9887.so all locations are best goodness of fit for installed new solar projects i.e. solar power plant, solar roof top, solar design etc.***

Keywords: ***Global solar radiation, Angstrom-type correlations, regression analysis. Corelation-coefficient (R^2), Weibull distribution, Bright sunshine hours (BHS)***

I. INTRODUCTION

Solar radiation has been identified as the largest renewable resource on earth. The energy source is more evenly distributed in the Sunbelt of the World than wind or biomass, allowing for more site locations. The maximum intensity of solar radiation at the earth's surface is about 1.2 kW/ m^2 but it is encountered only near the equator on clear days at noon. Under these ideal conditions the total energy received is from 6-8 kWh/m^2 per day. Solar energy is not available continuously because of the day/night cycle and cloud cover. Its intensity varies according to season, geographical location, and position of the collector .Studies on solar radiation have become an important issue for renewable energy issues stemming from oil crises, global warming and other environmental problems, thus increasing the need of reliable measurements of surface solar radiation. An estimate of the global solar radiation was then obtained through the well-known Angstrom–Prescott equation Although pyranometers are nowadays available to directly measure the global solar radiation, the sunshine duration is still an essential climatologically parameter that is still monitored in many meteorological stations. Proposed first theoretical model for estimating global solar radiation based on sunshine duration. Angstrom-type model make it possible to calculate monthly average of the daily global solar radiation on a horizontal surface from monthly average daily total insolation on an extraterrestrial horizontal surface. for estimating the global solar radiation based on longitude, latitude and routinely available meteorological parameter observed usefulness of these meteorological parameters for global solar radiation (GSR) estimation review of some literature reviews reveals that mostly the efforts are to develop an estimation model for a single location or a group of locations for a small region.

II. STUDY AREA

Gujarat is a state in the western part of India. Geographically, Gujarat has the following coordinates: 20° 6' N to 24° 42' N (north latitude) and 68° 10'E to 74° 28'E (east longitude). The boundaries of Gujarat are surrounded by the Arabian Sea in the West, Arabian Sea as well as the Pakistani province of Sindh to the west. Rajasthan in the North East, Madhya Pradesh in the East and Maharashtra in the South East. It shares a common border with Pakistan on the Northern side. It has an area of 196,204 km^2 with a coastline of 1,600 km with the longest coast line.(Govt. of Gujarat, 2014). The population of Gujarat State was 60,383,628 according to the 2011 census data. Gujarat is counted among the fastest growing Indian states in terms of economy. The following locations are selected for the research work for solar radiation and bright sunshine hours analysis. The detail coordinates are as follows.

Sir No.	Name of Location	Name of region	Latitude ^{0}N	Longitude ^{0}E	Elevation (m)
1	Amreli	Saurashtra	23.16	71.15	73
2	Anand	Central Gujarat	22.32	73.00	197
3	Rajkot	Saurashtra	22.18	70.56	58
4	S.K.Nagar	North Gujarat	24.12	72.28	201
8	Navsari	South Gujarat	21.07	73.4	222
7	Vadodara	Central Gujarat	22.00	73.16	197
2	Junagadh	Saurashtra	21.31	70.36	55
6	Godhra	Central Gujarat	23.56	69.5	29

Table 1

The data were collected from the various agricultural Universities and its Agricultural Science centres for detail analysis.

III. MATERIALS AND METHODS

(1)Method of Estimating of Global Solar radiation base on BHS (Measured):

In this present study, data of the monthly mean of daily global solar radiation and sunshine duration from Agricultural universities of study locations were collected and utilized. The data obtained cover a period of five years (2009-2013). The first correlation proposed for estimating the monthly average daily global radiation is based on the method of Angstrom-Prescott type regression equation-related monthly average daily radiation to clear day radiation in a given location and average fraction of possible sunshine hours is given by,

$$\frac{H}{Ho} = a + b\frac{S}{So} \quad (1)$$

where H is the monthly average daily global radiation on a horizontal surface (Kwh/m²/day), H_o the monthly average daily extraterrestrial radiation on a horizontal surface (Kwh/m²/day), S the monthly average daily hours of bright sunshine, S_o the monthly average day length, and "a" and "b" values are known as Angstrom constants and they are empirical. The monthly average daily extraterrestrial radiation on a horizontal surface (H_o) can be computed from the following equation (2).

$$Ho = (24/\pi)I_{sc}[1+0.033\cos(360n/365)]x[\cos\phi\cos\delta\sin\omega+(2\pi\omega/360)\sin\phi\sin\delta] \quad (2)$$

Where I_{sc} is the solar constant (=1367 W/m^2), ϕ the latitude of the site, δ the solar declination,

ω the mean sunrise hour angle for the given month, and n the number of days of the year starting from the first of January. The solar declination (δ) and the mean sunrise hour angle (ω) can be calculated by the following equations (3) and (4) respectively in equation (2):

$$\delta = 23.45\sin[360\,x(284 + n/365)] \quad (3)$$

$$\omega = \cos^{-1}(-\tan\phi\tan\delta) \quad (4)$$

For a given month, the maximum possible sunshine duration (monthly average day length (S_o) can be computed by using the following equation (5).

$$S_o = 2/15\,\omega \quad (5)$$

IV. WEIBULL DISTRIBUTION

(1)Frequency Distribution of Solar radiation:

The Weibull distribution has been found to fit a wide collection of recorded radiation data**.** In this paper, the Weibull method is used. The Probability density function of the Weibull distribution is given by,

$$f = (k/c)(r/c)^{k-1}\exp(-(r/c)^k) \quad (6)$$

Where r is the solar radiation, k is a shape parameter, and c is a scale parameter determined from the data. These parameters allow the calculation of the expected monthly and annual, solar power density per unit area in a given area. The corresponding cumulative probability function of the Weibull distribution is given by:

$$f(v) = 1-\exp(-(r/c)^k) \quad (7)$$

For this present work, the scale and shape parameters were estimated using standard deviation method (SDM).

Determine the k and c from the following equation:

$$k=(\sigma/r_{mean})^{-1.086} \quad c = r_{rmean}/\Gamma(1+1/k) \quad (8)$$

where k = shape parameter, c = scale parameter(m/s), r ( ) = Gamma Function, σ = standard deviation,

r_{rmean}= solar radiation(Mean)

V. GRAPHICAL REPRESENTATION

From the recorded data, the graphical representation of selected locations are as under

Fig. Period (Month 2009-2013) verses Measured and calculated mean (solar radiation)

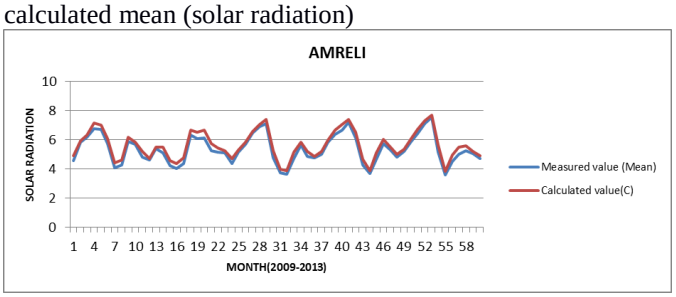

Figure 1

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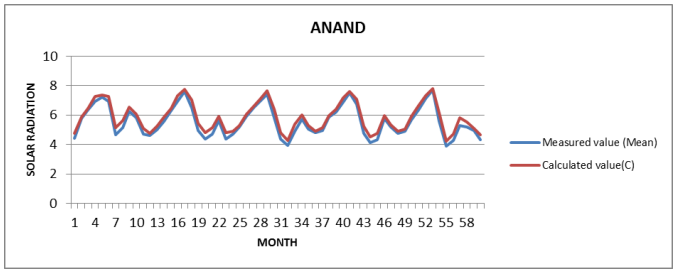


Figure 2

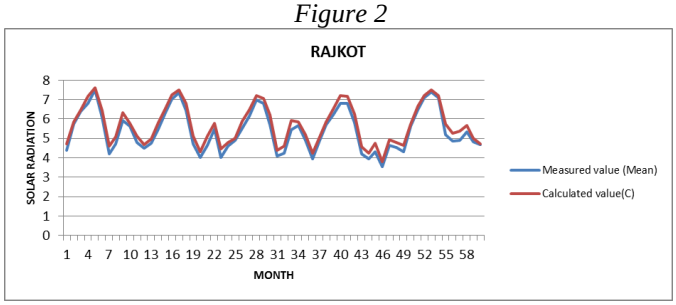


Figure 3

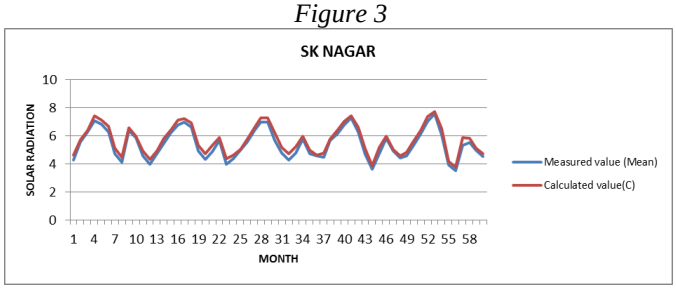


Figure 4

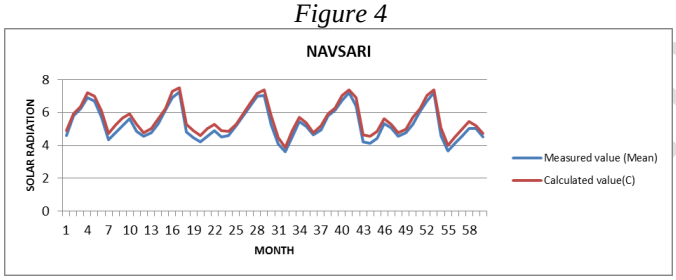
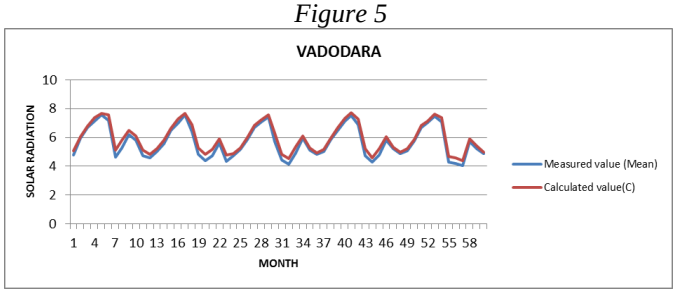


Figure 5



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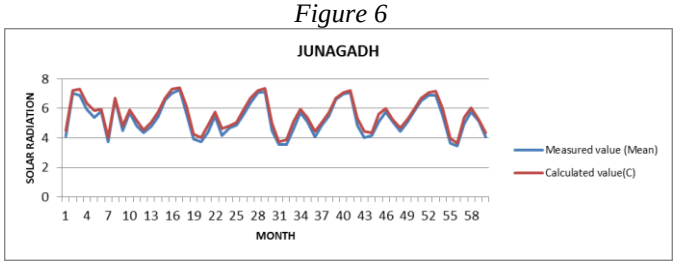

Figure 7

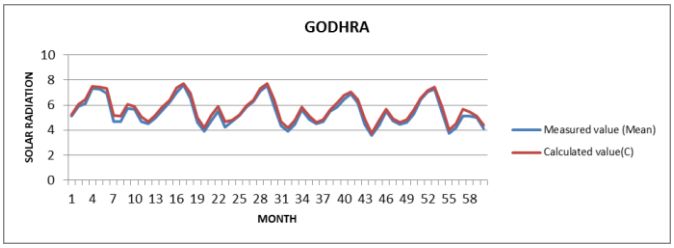

Figure 8

From the graphical representation the measured value (Mean) and Calculated value(c-scale parameter of Weibull distribution).The statistical analysis of solar radiation data are as under:

VI. STATISTICAL ANALYSIS

After Statistical Analysis(correlation coefficient R^2 test) the data of selected locations are as under:

Location	Correlation coefficient (R^2)
Amreli	0.984438
Anand	0.982052
Rajkot	0.986263
SK Nagar	0.986599
Navsari	0.98503
Vadodara	0.983461
Junagadh	0.988658
Godhra	0.985721

Table 2

VII. CONCLUSION

From this study, it is concluded the solar radiation is higher of these locations, so it is widely useful for power generation from solar energy in Gujarat. The range from 2 kwh/m^2/day to 8 kwh/m^2/day. It is the best for installed new solar power projects. It is also favorable for domestic purpose. New projects related to solar energy decrease the crisis of energy demand and also indirectly to solve the problem of Global warming. The temperatures of Gujarat increase day by day so the development of renewable energy source i.e. solar energy is imperative necessary.

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