Chapter 3

Solar Power Generation Unit Model

3.1 Introduction

The sun has been producing energy for billions of years and is the ultimate source of all energy sources. India is one of the wealthiest countries in terms of solar energy. Individuals have utilized the sun's beams for thousands of years for warmth and to dry various items in India and worldwide. Over time, individuals created advances to gather sun-oriented vitality for warmth and change it into power. Sun-powered era advances have experienced strong vitality showcase development within the past few years, with a comparing increment in nearby network penetration rates. As in the case of wind, the sun-based energy sources at the ground level are exceedingly variable due to cloud cover changeability, barometrical vaporized levels, and by implication and to a lesser degree, partaking gasses within the climate. The inborn inconstancy of solar power generation poses issues related to the power grid's economic, reliability and stability. As a result, accurate estimate frameworks are required for numerous time horizons that are related to the regulation, dispatching, planning, and placement of solar-based power resources. Solar energy in the form of solar radiation is much higher than people are using in everyday life. Solar energy usage devices such as solar ovens, Solar thermal collectors, concentrating collectors, and the photovoltaic system can capture solar radiation and convert it into useful energy like heat and electricity. The concentrating solar collector used in a thermal power station is concentrated direct solar radiation for energy conversion. The Photovoltaic system receives global solar radiation, which includes diffuses (scattered) and direct solar radiation with an optimum angle for specific azimuth. The utilization of solar energy, especially for electricity production using Photovoltaic, has been expanded all our the world.

3.2 Solar Photovoltaic System

The configuration of the Solar Photovoltaic (PV) system for a large amount of power generation in the power grid is in array form. The array is formed by a series-parallel connection of solar PV modules. The PV module is assembled by a series connection of PV cells. The solar cell is defined nonmechanical device which transforms solar isolation into electrical potential difference by the solar cell (PV cell). It is a semiconductor device such as PN Junction diode. When the sunlight hits on solar PV semiconductor cell, it may be partly reflected or partly absorbed by the cell. The absorbed photon of sunlight is the actual source of electricity. The type of PV cell material and technology of cell formation determines the efficiency at which electrical power production from solar energy. According to technology from the mid-1980s, the productivity of PV modules was 10% per dollar. It will be increased to 15% by 2015, and it is currently approaching 20% (`https//www.nrel.gov/index.html`). PV cells produce direct current power. Because consumers use alternating current (AC), the DC power generated by the solar panel is used first to charge the batteries, and the stored DC electricity is converted to alternating current (AC) by the invertor. When PV modules are directly facing the sun, they will produce a massive amount of electricity. The 180-degree and 360-degree rating tracking systems are commonly used in grid-connected networks to obtain direct sun rays, which results in increased electricity production. The output power generation of a specified PV system arranged with advanced tracking technology is affected by the area of a solar array, solar irradiation, and ambient temperature. Solar power system production of fixed size PV arrays can be modeled by solar irradiance forecasting or statistical analysis of solar radiation as per physical parameters such as latitude, altitude, seasonal variation, and daily variation. The forecasting of solar irradiation and solar irradiation analysis is the primary part of integrating solar energy sources such as PV systems in the distributed power network. The authors in [68] and [70] have reviewed different solar forecasting method. The solar irradiation analysis was carried out to find out the probability distributions that best fit the data of a given month of the year for the site Kumasi –Ghana.[69].

3.2.1 Photovoltaic Generation Modelling

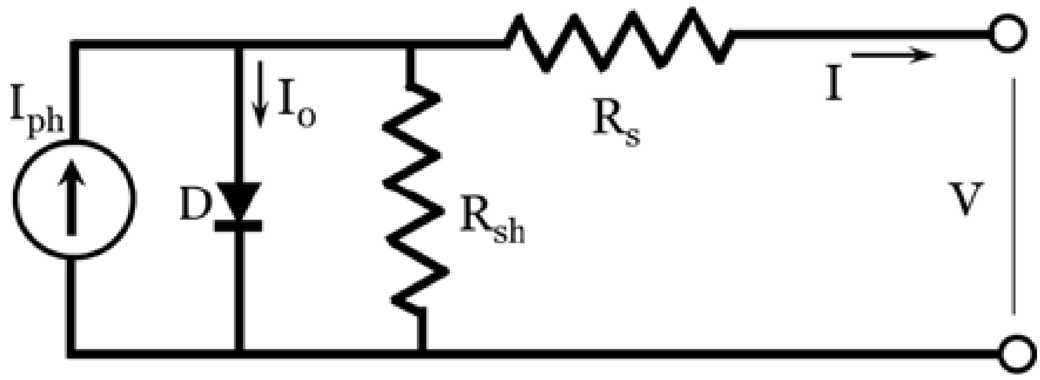

Figure 3.1: Model circuit of solar cell

The Single diode circuit is the most common model of PV cell, as shown in Fig: 3.1[81]. The output current-I_o of a solar cell is equal to the addition of Photo current-I_{ph} and saturation current- I_s, which depend on the temperature of the site, cell temperature, and solar insolation.The value of Photo current-I_{ph}. The cell's output voltage is V. The power output from the PV cell is a product of output voltage and current. The power generation of PV system is modeled by considering the effect of solar irradiation and cell temperature. In [81] the mathematic model of the output current of cell and maximum output power of PV module has been mentioned, and the power generation from the arrays has been given as per the equation below:

$$P_{s_{array}}(r) = N_s N_p P_M \tag{3.1}$$

Where,N_s =numbers of series module ,N_p = numbers of parallel modules, P_M = output of PV module. In the paper [82],the author has used the model of solar power system is as;

$$P_{s_{array}}(r) = \frac{r}{1000}\eta_{pv} P_{srated} \tag{3.2}$$

The r is solar radiation, η_{pv} efficiency of the solar module with a convertor, and P_{srated} is the rated capacity of a solar array. Here power output of the solar array is considered directly proportional to the solar radiation that falls on the solar module. In the article [83], the power output of PV array mentioned, in which PV output power generation model has been shown considering clearness index (K_t). The clearness index is defined as the ratio of irradiance on the ground surface to the total extraterrestrial irradiance.It is expressed as(3.3).

$$P_{s_{array}}(r) = \eta_{pv} A_c I_\beta = \eta_{pv} A_c (T k_t - T'(k_t)^2), \tag{3.3}$$

Where T and T' are parameters related to the location and inclination of the PV system. The detailed modeling of the power probability density parameters, single solar cell voltage, and solar cell current has been presented in this paper, obtained through circuit analysis. Another model of power generation of PV system consisting of m- numbers of parallel modules and n- numbers cell per module is given by (3.4).

$$P_{s_{array}}(r) = V_{array} I_{array} = mnVI \tag{3.4}$$

The output power of the solar system can be predicated using solar radiation-r and cell temperature-T_c forecasting model as P_{pv} =forecast (r, T_c). The various solar forecasting methods have been described in [68]. The prime model of solar power generation has been used in [47][53] [60] [63] [84] is

$$P_O = N * FF * V_y * I_y \tag{3.5}$$

Where,

$FF = \frac{V_{Mpp} * I_{Mpp}}{V_{oc} * I_{sc}}$,$V_y = V_{oc} - k_v - T_{c_y}$,

$I_y = s\left[I_{sc} + k_i \times \left(T_{c_y} - 1\right)\right]$,

$T_{c_y} = T_A + s\frac{(N_{0T} - 20)}{0.8}$

N is the number of modules; T_{c_y} and T_A are cell and ambient temperatures respectively. $(\cdot C)$; K_i and K_v are current and voltage temperature coefficients respectively; N_{0T} is the nominal operating temperature of cell in $(\cdot C)$; FF is Fill Factor; V_{oc} and I_{sc} are the open-circuit voltage in volts and short circuit current in ampere respectively; V_{Mpp} and I_{Mpp} are respectively the voltage and current at maximum power point.

It is very clear from the above solar power generation model that an adequate estimation of the output power of the solar system is required to analyze the potential of solar energy for a specific location. The paramount importance in assessing solar potential is the knowledge of solar irradiation. The analysis of the solar irradiation data helps to evaluate available solar power resources, economic viability, and long-term performance of the power system. The sunlight (solar radiation) falling on the solar module is subjected to the daily, monthly and seasonal variation. The accurate measurement of variable solar radiation in the time phase is impossible for all periods. The statical analysis, which is based on the frequency distribution of historical data, can be helpful in determining solar potential. In most of the literature related to power grid planning has employed beta probability density function for statical analysis of the solar radiation [53] [47] [60] [63] [68][84].

3.3 Beta probability distribution

The random nature of solar irradiation is modeled in this study using the Beta probability density function in two ways. In a first way, hourly beta pdf for each season were obtained, and probable power was computed based on that probability ranging from zero to maximum irradiation. In a second way, probable power generation has been integrated for four states around the mean solar radiation -s_m. The solar radiation beta pdf can be described as follows:

$$F_b(s) = \begin{cases} \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta))} s^{(\alpha-1)} \left(1-s\right)^{(\beta-1)}, & \text{if } 0 \leq s \leq 1, \alpha, \beta > 0 \\ 0, & otherwise \end{cases} \tag{3.6}$$

Where, $F_b(s)$ is the Beta distribution function of random variable of solar irradiance s (kW/m^2), $\alpha \geq 0$ and $\beta \geq 0$ are parameters of beta distribution; These parameters are computed using mean (μ) and variance(σ) of time series historical data of solar irradiance as per equation: 3.7. The $F_b(s)$ is 0 outside the interval[0,1].

$$\beta = (1-\mu)\left(\frac{\mu\,(1+\mu)}{\sigma^2} - 1\right); \quad \alpha = \frac{\mu * \beta}{1-\mu} \tag{3.7}$$

The probability can be determined based on beta parameters. When the $\alpha - a$ and $\beta - b$ parameters are equal, and more than one, the shape of beta pdf will be bell shape, so normal distribution of solar radiation is possible with a mean value of 0.5. The area under the curve will depend on the variance. When the α parameter is less than the β parameter, the pdf curve will be left from the normal distribution, and it shows that the solar irradiation is lesser than 0.5. The beta pdf curve of the site having high solar irradiation will be right-skewed, which means the α parameter is higher than the β parameter. The Fig:(3.2) shows beta pdf for three discrete value of beta pdf parameters.

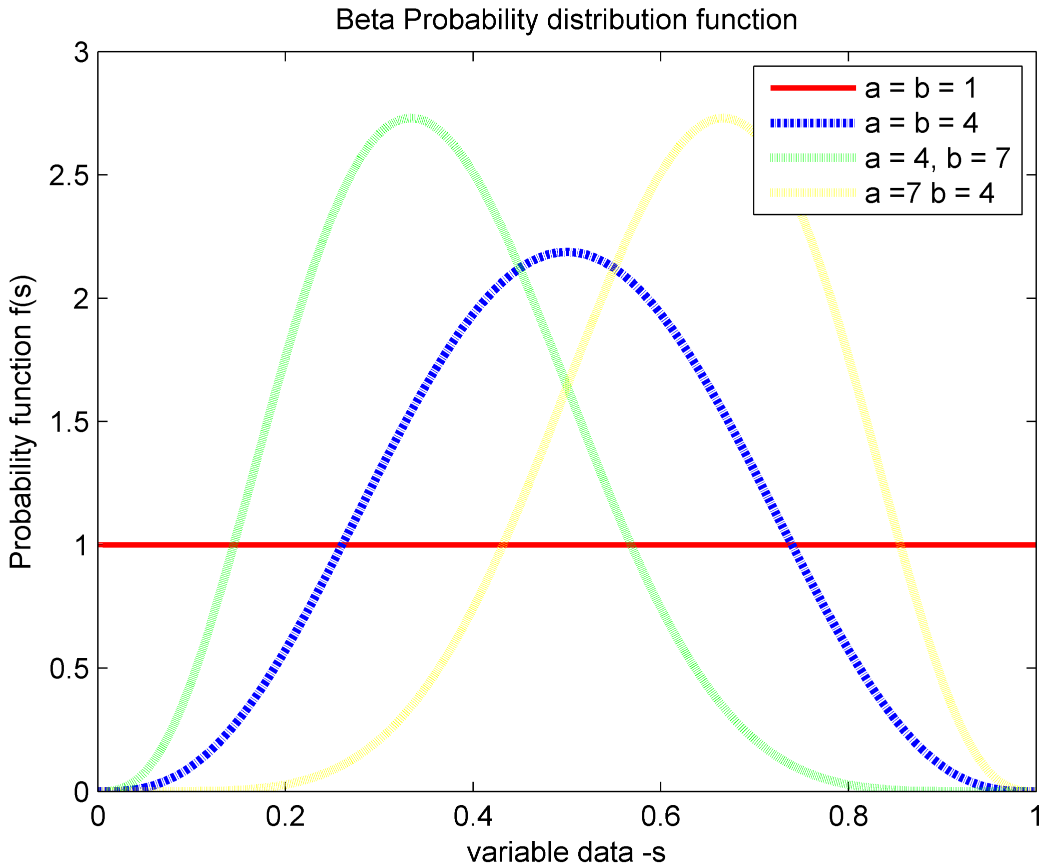

Figure 3.2: Beta probability distribution at discrete value of parameters

3.4 Solar Irradiation Modelling and Analysis

3.4.1 Data sources

Solar power analysis can be performed after modeling of the random nature of solar resources. The time series daily solar irradiation data for the last three years are collected from the site (`http://niwe.res.in`) for this study. The solar radiation data are available for only the period between 6:30 am to 6:30 pm at an interval of one hour. The dual-axis tracking system-mounted solar panel is assumed to be in a position that is optimally irradiating. The data have been collected by adjusting the solar panel at the optimum angle. Here the selected site is as same as given in chapter: 2. For the purposes of analysis, a year is divided into four seasons. The solar power potential analysis for each season has been done using hourly data because solar radiation in the morning and evening is lower than solar radiation in the noon. So, based on the beta pdf of each hour per day/season, one-day generated energy has been computed.

3.4.2 Solar Power Probability by Beta pdf

The following steps have been executed to obtain a Beta pdf for each slot/day/quarter and analyze the potential of the site for power generation. The Matlab platform has been used to carry out this task. Here the one slot is for one hour.

- Load the solar irradiation data sheet in which each slot/day/quarter has been recorded
- The beta shape parameters and scale parameters have been computed using the equation:(3.7).
- The beta probability distribution has been obtained through Matlab code.
- Solar potential has been analysed on the basis of Beta pdf.
- The hourly power production has been calculated as expression (3.8); In this work, the power generation model has been developed from (3.5). The solar irradiation-s has been replaced by solar hourly average mean radiation for the specific period. The module current -I_Y and cell temperatures are modeled as;

  $I_y(s) = s_m \left[I_{sc} + k_i \times \left(T_{c_y} - 1\right)\right]$

  $T_{c_y} = T_A + s_m \frac{(N_{0T} - 20)}{0.8}$

  $$P_O(s_m) = N * FF * V_y * I_y(s_m) \tag{3.8}$$

- The probable power power production per one hour at mean solar irradiation has been computed by:

  $$p_{sg} = p_{s_{avg}}(s_m) \int_0^{s_m} f_b(s)\, ds \tag{3.9}$$

- The estimation of energy generation per day has been done by expression

$$E_{sg} = \sum_{i}^{h} p_{wg_i} \tag{3.10}$$

where, h = no of hours per day in which period the solar irradiation is available

3.5 Result Analysis

The solar irradiation data for the selected location have been stored in the excel sheet from the site [`https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html`. This data has been analyzed, and the probability of solar radiation has been computed using equation: (3.6) using the Matlab coding. The hourly probable power has been calculated through equation:(3.9). Each season's calculated hourly mean, standard deviation, and variance are tabulated in Table: 3.1 to 3.4. The beta pdf parameters and probability of solar radiation per hour have been obtained and used to estimate solar energy per day per season.

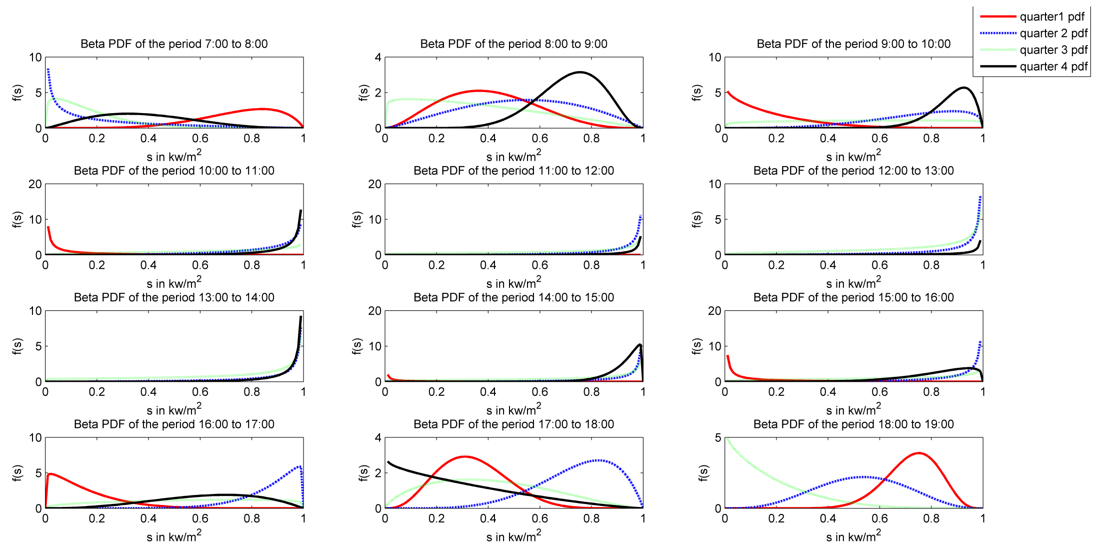

Figure 3.3: Hourly Beta probability distribution

Based on careful examination of the quarterly solar irradiation statistics and hourly beta pdf shown in the Table:3.1 to 3.4 and Fig: 3.3 for the selected location, it is determined that the variation in the shape of the pdf from quarter to quarter and hour to hour is very large. As a result, the probability of hourly average solar generation will vary

Table 3.1: Solar statistics for the quarter Jan to march

slot no	slot time	s_m	s_{sd}	σ	α	β
1	00 to 1:00	0	0	0	-	-
2	1:00 to 2:00	0	0	0	-	-
3	2:00 to 3:00	0	0	0	-	-
4	3:00 to 4:00	0	0	0	-	-
5	4:00 to 5:00	0	0	0	-	-
6	6:00 to 7:00	0	0	0	-	-
7	7:00 to 8:00	0.25461	0.15180	0.02304	1.8421	5.3929
8	8:00 to 9:00	0.59647	0.17374	0.03018	4.1594	2.8140
9	9:00 to 10:00	0.8273	0.15046	0.02263	4.3917	0.9161
10	10:00 to 11:00	0.94577	0.1235	0.0152	2.2311	0.1279
11	11:00 to 12:00	0.974343	0.1563	0.02445	0.0218	0.0006
12	12:00 to 13:00	0.99522	0.11486	0.01319	-0.6365	-0.0031
13	13:00 to 14:00	0.9943	0.09042	0.00817	-0.3069	-0.0018
14	14:00 to 15:00	0.9884	0.06300	0.0039	1.8508	0.0216
15	15:00 to 16:00	0.93931	0.1391	0.0193	1.8264	0.1180
16	16:00 to 17:00	0.8512	0.1225	0.01501	6.3288	1.1062
17	17:00 to 18:00	0.65881	0.13140	0.01726	7.9172	4.001
18	18:00 to 19:00	0.27596	0.10109	0.01022	5.1190	13.437
19	19:00 to 20:00	0	0	0	-	-
20	20:00 to 21:00	0	0	0	-	-
21	21:00 to 22:00	0	0	0	-	-
22	22:00 to 23:00	0	0	0	-	-
24	23:00 to 24:00	0	0	0	-	-

from hour to hour and quarter to quarter. This result demonstrates that modeling of the uncertain nature of solar irradiation and estimation of solar power should necessitate detailed analysis for any location. When determining the size and allocation of solar panels, the assumption of beta parameters may lead to an increase in error in power estimation. Minimizing the error in solar power prediction is one of the most important factors that

Table 3.2: Solar statistics for the quarter April to June

slot no	slot time	(s_m)kw/m^2	s_{sd}	var	α	β
1	0.00 to 1:00	0	0	0	NA	NA
2	1:00 to 2:00	0	0	0	NA	NA
3	2:00 to 3:00	0	0	0	NA	NA
4	3:00 to 4:00	0	0	0	NA	NA
5	4:00 to 5:00	0	0	0	NA	NA
6	5:00 to 6:00	0	0	0	NA	NA
7	6:00 to 7:00	0.071	0.006	0	NA	NA
8	7:00 to 8:00	0.1803	0.2113	0.0446	0.4167	1.8939
9	8:00 to 9:00	0.5280	0.2153	0.0464	2.3099	2.0651
10	9:00 to 10:00	0.7357	0.1775	0.0315	3.8026	1.3661
11	10:00 to 11:00	0.8544	0.1614	0.0260	3.2273	0.5499
12	11.00 to 12:00	0.9236	0.1251	0.0156	3.2458	0.2689
13	12.00 to 13:00	0.9384	0.1327	0.0176	2.1408	0.1406
14	13:00 to 14:00	0.9470	0.1239	0.0153	2.1509	0.1204
15	14:00 to 15:00	0.9431	0.1201	0.0144	2.5673	0.1549
16	15:00 to 16:00	0.9245	0.1202	0.0144	3.544	0.2893
17	16:00 to 17:00	0.8737	0.1069	0.0114	7.5676	1.0937
18	17:00 to 18:00	0.7411	0.1490	0.0222	5.665	1.9793
19	18:00 to 19:00	0.5280	0.1656	0.0274	4.2684	3.815
20	19:00 to 20:00	0	0	0	NA	NA
21	20:00 to 21:00	0	0	0	NA	NA
22	21:00 to 22:00	0	0	0	NA	NA
23	22:00 to 23:00	0	0	0	NA	NA
24	23.00 to 24:00	0	0	0	NA	NA

influence the best location for solar panels in the distribution network. To reduce the error in calculating probable solar power, state-wise probability of solar power using best fitted hourly beta pdf of solar radiation is being considered. As a result, the solar power generation model (3.9) has been formulated with four states. The proposed solar model

Table 3.3: Solar statistics for the quarter July to Sept

slot no	slot time	(s_m)kw/m^2	s_{sd}	var	α	β
1	0.00 to 1:00	0	0	0	NA	NA
2	1:00 to 2:00	0	0	0	NA	NA
3	2:00 to 3:00	0	0	0	NA	NA
4	3:00 to 4:00	0	0	0	NA	NA
5	4:00 to 5:00	0	0	0	NA	NA
6	5:00 to 6:00	0	0	0	NA	NA
7	6:00 to 7:00	0.0182	0.0250	0.0003	NA	NA
8	7:00 to 8:00	0.1641	0.1281	0.0164	1.2078	6.1528
9	8:00 to 9:00	0.3584	0.2378	0.0566	1.0987	1.9667
10	9:00 to 10:00	0.5227	0.2793	0.0780	1.1489	1.049
11	10:00 to 11:00	0.6529	0.2647	0.0700	1.4594	0.776
12	11.00 to 12:00	0.6878	0.2828	0.0800	1.159	0.5261
13	12.00 to 13:00	0.7364	0.2659	0.0707	1.2847	0.4599
14	13:00 to 14:00	0.7141	0.2902	0.0842	1.0175	0.4074
15	14:00 to 15:00	0.7022	0.2852	0.0813	1.1035	0.468
16	15:00 to 16:00	0.6499	0.2784	0.0775	1.2573	0.6772
17	16:00 to 17:00	0.5537	0.2635	0.0694	1.4176	1.1427
18	17:00 to 18:00	0.4079	0.2147	0.0461	1.7287	2.5097
19	18:00 to 19:00	0.1739	0.1493	0.0223	0.9464	4.4955
20	19:00 to 20:00	0	0	0	NA	NA
21	20:00 to 21:00	0	0	0	NA	NA
22	21:00 to 22:00	0	0	0	NA	NA
23	22:00 to 23:00	0	0	0	NA	NA
24	23.00 to 24:00	0	0	0	NA	NA

is presented as;

$$p_{sg} = \sum_{i}^{st} p_{sg}(s_{mst}) \int_{s_1}^{s_2} f(s)\, ds; \quad s_1 \geq 0 and s_2 \leq 1 \tag{3.11}$$

where, s_1 and s_2 is lower limit and upper limit of solar irradiation state respectively. s_{mst}

Table 3.4: Solar statistics for the quarter October to December

slot no	slot time	(s_m)kw/m^2	s_{sd}	var	α	β
1	0.00 to 1:00	0	0	0	NA	NA
2	1:00 to 2:00	0	0	0	NA	NA
3	2:00 to 3:00	0	0	0	NA	NA
4	3:00 to 4:00	0	0	0	NA	NA
5	4:00 to 5:00	0	0	0	NA	NA
6	5:00 to 6:00	0	0	0	NA	NA
7	6:00 to 7:00	0.0032	0.0090	0.0008	NA	NA
8	7:00 to 8:00	0.3779	0.0325	0.0164	2.3532	3.8747
9	8:00 to 9:00	0.7138	0.0154	0.0566	8.7419	3.5051
10	9:00 to 10:00	0.8736	0.0064	0.0780	14.2364	2.059
11	10:00 to 11:00	0.9487	0.0076	0.0700	5.157	0.2788
12	11.00 to 12:00	0.9838	0.0032	0.0800	3.9756	0.0653
13	12.00 to 13:00	0.9815	0.0082	0.0707	1.206	0.0228
14	13:00 to 14:00	0.9730	0.0043	0.0842	4.9858	0.1385
15	14:00 to 15:00	0.9283	0.0039	0.0813	14.7394	1.1386
16	15:00 to 16:00	0.8251	0.0171	0.0775	6.1538	1.3045
17	16:00 to17:00	0.6258	0.0366	0.0694	3.3775	2.0195
18	17:00 to 18:00	0.2915	0.0485	0.0461	0.9504	2.3095
19	18:00 to 19:00	0.1739	0.1493	0.0223	0.9464	4.4955
20	19:00 to 20:00	0	0	0	NA	NA
21	20:00 to 21:00	0	0	0	NA	NA
22	21:00 to 22:00	0	0	0	NA	NA
23	22:00 to 23:00	0	0	0	NA	NA
24	23.00 to 24:00	0	0	0	NA	NA

is average solar irradiation of the state;

The four solar irradiation states for estimation of solar power generation unit are shown in Table:(3.5). The probability of solar irradiation greater than the mean value for each hour per quarter has been obtained. It shows the good potential of solar energy for most of the

Table 3.5: Solar irradiation state

state	s_1	s_2
1	$s_m - 2(s_{sd})$	$s_m - (s_{sd})$
2	$s_m - (s_{sd})$	s_m
3	s_m	$s_m + (s_{sd})$
4	$s_m + (s_{sd})$	$s_m + 2(s_{sd})$

period. During the period July to Sept low potential for solar energy. It is because of a cloudy day in that period. The amount of probable power generation has been obtained for the system of 100 KW. The technical specifications of the solar power system are given here as:

- maximum power point voltage $V_{mpp} = 31$ V;
- maximum power point current$I_{mpp} = 8.08$ amp;
- open circuit voltage $V_{oc} = 37.6$ V;
- short circuit current I_{sc} =8.78 amp;
- voltage coefficient $k_v = 0.04$;
- current coefficient $k_i = 0.012$;
- normal operating cell temperature $N_{ot} = 45.7$;
- no of modules $N = 400$
- system technical losses= 28

The system technical losses do not account for irradiation losses, temperature losses, or solar forecasting errors. System technical losses include inverter losses, dust losses, DC cable losses, and array mismatch losses. The system is assumed to have an optimal tracking angle and is adjustable in the direction of maximum irradiation. The expected solar power generation graph for all quarters is depicted in Fig: 3.4. The comparison of estimated energy generated per day evaluated according to the equation: (3.10) and energy generated using a state-wise probability of solar irradiation computed using the equation: (3.11) is presented in Table:3.6.

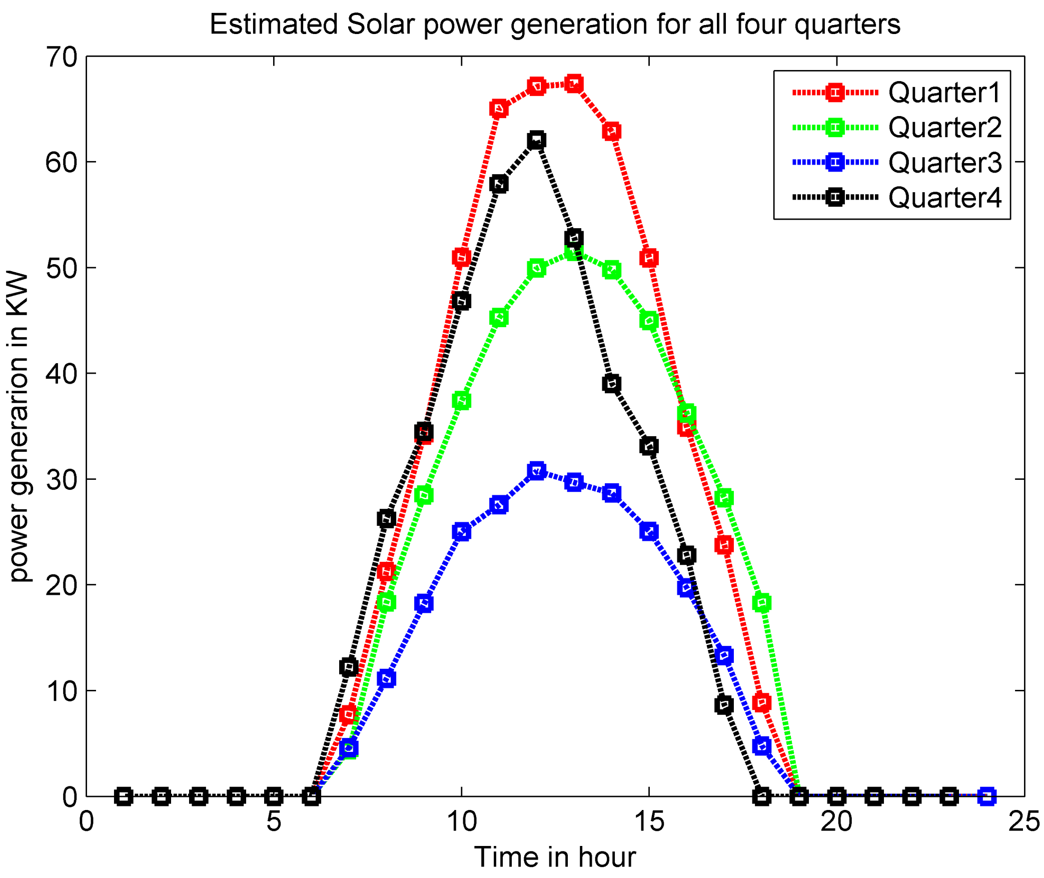

Figure 3.4: Probable Solar Power Generation of each Quarter

3.6 Conclusion

The entire world is attempting to harness free and clean energy for electrical energy generation. Solar power is one of the best natural sources for it. There are numerous methods, models, and algorithms available in research articles that have been proven and claimed to be optimal for installing and operating an electrical power grid with a solar power unit. In this study, the solar power generation model has been developed after a thorough examination of the solar radiation at the chosen location-Town, Cambay, the nearby seashore of Gujarat state. The beta pdf for each sky clear hour has been obtained to know the potential of solar irradiation. For each hour, the solar probability varies significantly from quarter to quarter. Because of this, it is preferable to estimate solar power generation on an hourly basis rather than an assumption of beta pdf parameters. As a result, the probable solar power has been calculated in two ways. For power estimation at the preliminary level, hourly mean solar radiation has been taken into account. To model uncertain solar power production, the four states of hourly solar irradiation have been proposed. The energy generated per day per quarter has been computed considering hourly mean solar radiation and state-wise solar radiation. When the state-by-state probability is considered, the average unit generated per hour during quarters 1 and 2 is 25% higher. During the third quarter, the energy produced per hour is less than that produced by the primary method. The estimation of hourly average energy generated achieved during the fourth quarter by preliminary and state by state methods is the same. The result of the estimation has been compared with the power production tools, which are readily available on the site(`https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html`). The technical specification chosen for this study has been entered in the readily available tools for solar power calculation. The result obtained is almost identical to the methodology proposed here. It is concluded that the assessment of solar power potential using beta pdf is a simple and reliable method. So many researchers have used this for integrating solar power generation systems into the power grid. However, a majority of them have assumed beta parameter values for modeling solar irradiation. It may produce an optimistic result, but it is not close to the actual result. In this study, four states of solar radiation have been proposed, but more states can be considered for greater accuracy. It has the potential to speed up the computation procedure. Further study has been carried out on the basis of this model.

Table 3.6: Comparison of hourly Estimated Solar power Generation for all Quarters with mean solar radiation and state wise solar radiation

Time	Jan to March		April to June		July to Sept		Octo to Dec	
slot	p_{sg} at S_m	p_{sg} at state wiseS_m	p_{sg} at S_m	p_{sg} at state wiseS_m	p_{sg} at S_m	p_{sg} at state wiseS_m	p_{sg} at S_m	p_{sg} at state wiseS_m
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	7.71	15.4	18.36	27.55	11.15	7.57	26.27	22.17
9	34.14	54.82	28.49	42.61	18.23	13.45	34.50	36.08
10	50.98	63.19	37.44	50.76	25.03	13.38	46.83	44.63
11	65.03	66.86	45.27	56.99	27.59	11.79	57.92	46.26
12	67.12	68.21	49.95	59.57	30.78	0.00	62.07	47.85
13	67.39	68.19	51.51	59.87	29.69	0.00	52.80	46.21
14	62.90	66.78	49.81	58.70	28.67	9.42	39.03	46.78
15	50.89	62.92	44.98	55.53	25.06	13.64	33.15	44.38
16	34.91	59.28	36.23	49.98	19.71	13.14	22.79	38.34
17	23.77	44.06	28.22	41.80	13.29	7.90	8.61	26.32
18	8.84	17.62	18.32	26.27	4.77	2.97	0.00	10.31
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$E_{sg_{ave}/day}$	494.92	627.61	412.96	536.81	238.58	95.95	396.18	419.05
$E_{sg_{ave}/hour}$	41.24	52.30	34.41	44.73	19.88	8.00	33.01	34.92