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Computation of Power Generation of Green Power Unit based on Probability Distribution Parameter

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Abstract: ***Today's power systems era is speedily going towards natural sources of power. The power system is also in the mode of decentralization. Decentralize means to split a large power system into small, safe and smart power grid or to create microgrid. This decentralization required separate control of each part of the power system. It can reduce the complexity of the large power system; provide efficient and economical installation and easy operation. To keep our globe healthy; green sources of electrical energy like solar, wind tidal, biomass are the best option for the power sector. Integrating green power sources in a decentralized power system needs better planning and upgraded technology. To deal with uncertainties of Green power sources, the first step is to estimate output power. In this paper output power with the uncertain nature of sources is estimated and analyzed to integrating green power sources. For it, the statistic model of solar and wind power generation has been discussed. Probable distribution of wind speed and solar irradiation is found using available mean data. Output power Generation of wind and solar sources are estimated based on the probability distribution curve and power equation. It has analyzed for different value of shape parameter Here mean wind speed and mean solar irradiation data of one town of Gujarat state, India has been collected for the planning of microgrid.***

Keywords: ***Wind speed,Solar irradiation, Weibull probability distribution, Beta Distribution, Green power output generation***

I. INTRODUCTION

Green power generation is the best way for electrical power world to minimize pollution of the globe and to give room to our next generation for a better life. The most feasible and economical substitute for renewable power generation sources is wind power and solar power generation. The output of green power sources is intermittent and uncertain as it depends on the weather statistics. It is also categorized under non- dispatchable generation. For planning small and smart distribution system say microgrid with renewable sources, desire accurate estimate of power generation must be necessary. These non-dispatchable sources have considerable effects on power grid operation, management, cost, stability, reliability and power quality etc. Estimation of wind power generation and solar power generation by different methods had been done for different areas as per researchers' location. Many different approaches for accurate output power estimation have been used in case of wind power as well as solar power generation. The power generation of green power unit is computed from the unit's specification or generation chart given by manufacturer. But probability of that power generation depends on historical data of natural resources. This data collection is carried out for two purposes. (1) Long term planning of power system operation,(2) Short term planning of power system. If there is a need to integrate new green power possible generating unit in an existing system, long-term planning is essential. Long-term planning means to collect past data of long period and estimate output power generation from a few months to an entire year. This long-term planning is useful in optimal placement of renewable distributed generators in a microgrid. On another hand to analyze the impact of an existing green power generator, short-term estimation is necessary which may 24-hours ahead. This short-term planning is helpful in decision formation like unit commitment, trading of power and energy dispatch.

To integrate or analyze green power generator, historical-metrological data of natural sources are required. It has been referred that statistic model such as probability distribution, autoregressive model, time series model and artificial intelligence like neural network model had been applied for managing nature of green power sources.

To place and determine a size of single renewable DG unit with optimal power factor, the author has used Weibull distribution function and beta probability density function for wind and solar power generation respectively.[1] A Beta, Weibull, and normal probability distribution functions have been used for modeling uncertainty of wind turbine and the solar module in[2][3]. For the middle term and Long-term power system analysis author in [4] has used discrete probability time series model of the hourly mean value of solar irradiance and beta distribution and computed output power generation. The wind speed and hourly solar irradiance data have been modeled by Beta and Weibull probability density functions for optimal allocation of renewable DG in [5].

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Artificial neural network (ANN) has been viewed as a convenient method to forecast the power output of the renewable generating unit. Wind velocity and solar radiations have been forecasted using time series and feed-forward neural network (FNN) techniques.

Calculation of wind power generation has been done using piecewise function which can be fit the relationship between wind power output and velocity of wind for optimal sizing of energy storage in microgrid [6]. ANN-based approach for forecasting the power output of the PV system at 24-hour-ahead has been proposed in [7].

The wind speed time series and the corresponding probability distribution function of three different wind speed regimes has been considered for wind power distributed generator in [8].The wind power estimation for unit commitment is proposed in [9]. To estimate solar power generation and wind power generation, different models with power output equation have been reviewed and listed in [10] .

In this paper, simple steps are presented for estimation of yearly average wind power and solar power generation. Probability of power generation is analyzed for diverse value of shape parameter. To estimating energy generation of green power sources throughout the year, hourly average wind power and solar power has been integrated. Here Weibull probability distribution functions and beta distribution function have been used to calculate probable wind power and solar power generation respectively. Analysis of natural power generation has done on basis of weather data collected from [11][12],[13].Theses weather data are of one town of Gujarat State near gulf of khambhat

II. PROBABLE POWER GENERATION OF GREEN POWER UNIT

A. Wind power generation

Electrical power in the packet of mass 'm' air moving per area A in time 't' with velocity ' v' and air density 'ρ' is given by

$$p_{wind} = \frac{1}{2}\frac{m}{t}v^2 \qquad (1)$$

where m= ρAv;

This cubic relation is not enough for wind energy generated at any location for the given wind turbine. Electrical energy captured in wind depends on turbine characteristics, topography, obstructions, and surface roughness, the velocity of wind, timing, and predictability. Wind potential in any region can be evaluated by wind speed probability. It is viewed that uncertainty of wind speed follows Weibull probability distribution. The expression of Weibull probability distribution function for wind speed "v" is given as

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left(-\frac{v}{c}\right)^{k} \qquad (2)$$

'*k*" and 'c' are the parameter of Weibull distribution. '*k*' is the shape factor and 'c' is scale factor. The scale factor for probability distribution function is considered using expression

$c = \frac{v_m}{gamma\left(1+\frac{1}{k}\right)}$, where "$v_m$" is mean wind speed.

It has been studied that most of research articles had assumed rayliegh distribution for wind speed probability in case of optimal placement of distributed generator. In this Rayleigh distribution value of k=2. It shows that the author has considered the location with fair wind blows during a specific small period. k =2 indicates the standard deviation of wind speed fluctuation is 52% of mean wind speed, while k=3 shows that location has good steady wind speed for most of the period. Only after knowing wind power potential which is followed by Weibull probability distribution, mean power generation and energy output for the given wind turbine are possible to calculate. The mean wind speed is not enough to know wind potential, standard deviation of wind speed must required. By studied historical data of wind speed, it is seen that standard deviation and fraction of hourly mean - μ with respect to standard deviation- σ of sample data has varied per every time span. It has been referred that for any site mainly mean wind speed is available. So, in this paper analysis is done only on the basis of diverse value shape parameter and mean wind speed.

Probable average wind power with variable wind speed around mean speed can be calculated using the following equation

$$P_{wg}(v) = \int p_w(v_m) * f(v_m)dv \qquad (3)$$

Here $f(v_m)$ is Weibull distribution of mean wind speed.

$p_w(v_m)$: mean wind power output generation. It is obtained by "(3)"

$$p_w(v_m) = \begin{cases} p_s, & v_s \le v_m \le v_o \\ p_s\frac{v_m - v_i}{v_s - v_i}, & v_i \le v_m \le v_s \\ 0, & v_m \le v_i \ , \ v_m \ge v_o \end{cases} \qquad (4)$$

Ps: specified rated wind power generation at specified rated wind speed.

vi : cut-in wind speed;

vs : specified rated wind speed,

vo : cut off wind speed

The following steps have been developed for estimation of daily power generation of wind unit. The daily wind energy generation for the specified period (monthly, quarterly, seasonal) is computed on the basis of probability of hourly mean wind speed for the specific time period.

- Read hourly mean wind speed- μ for a specified period.

- Calculate scale parameter " c" for various value of "k"
- Obtain weibull probability distribution with help of "(2)"
- Calculate probable production of hourly wind power with that steady wind speed and variable wind speed using "(3) and "(4)"

Estimate energy generation per year .with help of equation: $E_{wg} = \int_{t=t1}^{t2} p_{wg}\, dt$

Estimated wind power potential in Gujarat is 35071MW at 80 mt from sea level [14]. The installed capacity of wind power in Gujarat is 4227.31MW up to 2016. In the [11] resources of wind power assessment in Gujarat has been given. WLF model has been used to determine the potential of wind in different five stations. Wind speed map of Gujarat for every month has been given in this paper. Near the bay of Khambhat, average wind speed of 6 to 7 m/s per year [11], Map of available wind speed of every month shows that good wind speed is available during period April, May, and June. For the Detail analysis of wind power potential, mean wind speed at seashore near Khambhat has taken from the [13]. The data collected for every three months. Weibull PDF and the probable wind power generation have been estimated using "(2), "(3) and"(4)" which is shown in in section 3,.

B. Solar power generation calculation:

India is one of the richest countries in case of solar energy. Now a day's converting electrical energy from solar energy is easy with advanced technology. PV module is the one device which can do this energy conversion. The output power of the PV module depends on its specification, installation, location and weather condition. Solar power generation can be estimated for given solar PV array by solar irradiation forecasting or by solar irradiation probability distribution using physical measurement and statistics of historical data. Insolation strikes on the collector of PV array are the function of latitude, longitude, azimuth, tilt angle, single axis, and 2-axis tracking system. In the United States, National Renewable Energy Laboratory (NREL) has established the National Solar Radiation Data Base for 239 sites. In Russia World, Radiation Data Center is measured solar radiation of hundreds of other sites in the world. Insolation in "KW/m2" per hours of the full sun of any place in the world can be known From [12]. Insolation in "KW/m2" -hours of full sun is defined as solar irradiation.

Solar PV array output power can be estimated using many methods for solar irradiation probability and many types of equations given in [10]. Here Beta probability distribution function (pdf) has been used to obtain the probability distribution of solar irradiation. In case of beta probability distribution, many researchers has assumed value of distribution parameters basis on study of historical data. But It has been studied through historical data of the site that these parameters were variable from morning to evening period. It is not advisable to take constant value of parameters for through the period. The Beta probability density function is given by "(6)".

$$F(s)=\begin{cases}\left\{\dfrac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}s^{(\alpha-1)}(1-s)^{(\beta-1)}, if\, 0\le s\le 1, \alpha,\beta>0\right. \\ 0, otherwise\end{cases} \tag{5}$$

Where,

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

Beta distribution parameters α and β are calculated using average value - μ and standard deviation of hourly solar irradiation data The mean solar power generation for the given PV module can be calculated by the equation:

$$P_{sg}(S)=\int p_s(s_m T_A)*f(s_m)ds \tag{6}$$

s_m : Mean solar irradiation,

$f(s_m)$: Probability distribution of s_m .

$$p_s(s_m,T_A)=s_m/s_{rated} * p_{rated} * \eta_{rated} * \eta_t \tag{7}$$

Here

T_A: Ambient temperature,

P_{rated}: rated power of given solar module.

η_{rated} : Efficiency of the solar power module,

η_t: efficiency of solar module related to solar cell temperature and ambient temperature.

Estimation of solar power generation has been computed using the following steps.

- Read average hourly ambient temp of the site for the specified period. (monthly, seasonal or as per available data)
- Read average hourly irradiance of the site for that period
- Calculates mean μ and standard deviation σ
- Calculate Alpha and beta to determine the potential of solar irradiation
- Obtain Beta probability distribution.
- Calculate probable power Generation using " (6)"

Estimate energy generation per year using equation: $E_{sg} = \int_{t=t1}^{t2} p_{sg}\, dt$

Here Solar irradiation for the town Khambhat, Gujarat has been obtained from the [12].On this site latitude and longitude of town, Khambhat is required to fill and optimum solar irradiation for single axis and two-axis tracking system can be obtained. The past temperature data from [13] and irradiation data have been utilized to obtain beta pdf and solar power generation.

III. RESULT AND DISCUSSION

A. Wind power generation:

For long-term planning of power grid with renewable power generation, estimation of yearly power generation is required. Here It has been done using simple steps given in section 2. The wind speed data for the site has been taken from [13].

The flow of wind is not fair for a long period as seen from collected data. To examine proper wind potential, the probability distribution has obtained for three different value of K= 1.2, 1.6 and 2 as per steps mentioned in section 2.1. The mean wind speed of each quarter (three months per year) has been considered.. This Quarterly mean wind speed has been calculated after studied Gujarat map which shows wind speed per quarter.[11].On the website[12] speed per three hours is given.

Mean wind speed per three hours slot per day per quarter has been calculated using collected data. Weibull pdf for three discrete value of " k" for each quarter has obtained as shown in figure.1, figure.2, "figure.3,. By examining these graphs it is clear that maximum steady wind speed for the site is 12m/sec with minimum probability throughout the year. It is concluded that for this site, wind potential to generate power is only between 3m/s to 10 m/s with considerable probability. Scale parameter "c" has been calculated at quarterly mean wind speed. Probable power generation with different wind value of shape parameter k=1.2/ 1.6 /2 has been integrated with variable wind speed 3m/s to 10 m/s about mean speed using "(3)". The probable power generation at variable with wind speed within 3m/s to 8 m/s around mean wind speed has been shown in figure 4 for k= 1.2, 1.6 and 2. This is probable power generation is calculated based on the distribution parameters is also tabular in Table I. Power generation graph for each quarter has been shown in figure.5 to figure.8. The graph shows for the quarter Sept to Dec is with respect to k=1.2.and for Jan to March with k=1.6 It has been taken as considering low wind potential in that period. For the period April to June power generation has been estimated by considering good potential k=2. The approximate average energy unit generated per day has been computed for three discrete value of k for the Khambhat site. It is shown in Table II.

Here wind turbine of the following specification has been chosen for estimation of annual power generation as a sample. Rated power: 1000KW, cut in speed 3.5 m/s, rated speed =12m/s and cut out speed 20 m/s, Assume: windmill blades move as-per wind direction.

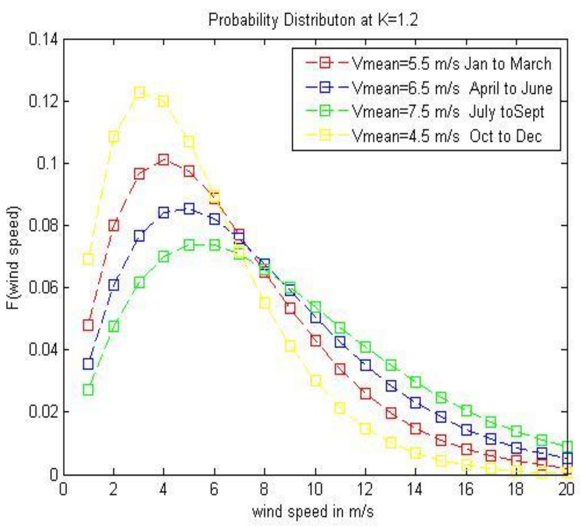

Fig. 1. Weibull Probability distribution at k=1.2

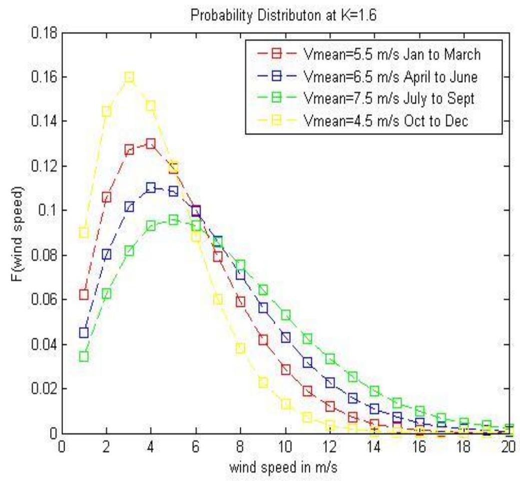

Fig. 2.: Weibull Probability distribution k=1.6

Table. I Probable power generation at variable wind speed around mean speed

Mean wind speed-m/s	Power in KW (K=1.2)	Power in KW (K=1.6)	Power in KW (K=2)
5.5	100	108	129
6.5	173	197	209
7.5	222	250	312
4.5	50	52	54

B. Solar power generation:

Solar power generation for the same site has been analyzed using steps given in section 2.2. For analysis power generation possibility, beta probability distribution has been obtained for the different values of parameter α and β. Past two years data of the site Khambhat town has been collected from [12]. Using hourly solar irradiation, the value of α and β per hour per one quarter has been calculated as per "(5)".With the different value of α and β per hour, hourly probability distribution per one quarter has been obtained. Here we have shown only two graphs; one for the period 9 am to 10 am in figure:.9 and second for the period 3 pm to 4 pm in figure.10. By examining PDF graph, the probability of solar irradiation (≥ 0.5) is good for the quarter Jan to March, April to June and September to December. During the quarter of July to August, the probability of solar irradiation (≥ 0.5) is low compared to the other three quarters. It is nearer to 0.16 throughout the day. It is clearly seen in figure:.9 and figure.10. Power generation for all four quarters has been calculated as per "(6)".Solar power generation per hour per quarter considering probable solar radiation and variation in ambient temperature is shown in figure.11. From this graph probable unit generated per day per quarter using solar module has been computed for the Khambhat site. It is shown in Table II. During the period April to May, cell temperature is higher due to higher ambient temperature; efficiency of the solar module is reduced. power generation of the solar cell is low even though the good probability of solar irradiation. Here for estimation purpose solar module of 1000 KW and efficiency of 0.83 has been considered. temperature efficiency as per ambient temp has been taken from the data base in [12].

IV. CONCLUSION

In this paper, probable power generation of one town with past wind speed and solar irradiation data has been calculated. This gives us an idea about the possibility of renewable energy generation capacity in a particular area. This calculation method and graphical representation can use to plan autonomous microgrid of that area or to install green sources in the existing small distribution system of the area. Here for Khambhat town power generation by wind is higher during quarter April to May. Very low power generation during the period October to December. While solar power generation is higher in month January to March.

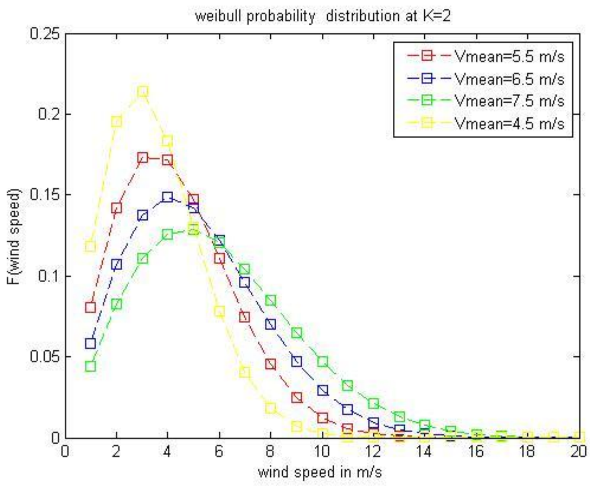

Fig. 3.: Weibull Probability distribution k=2

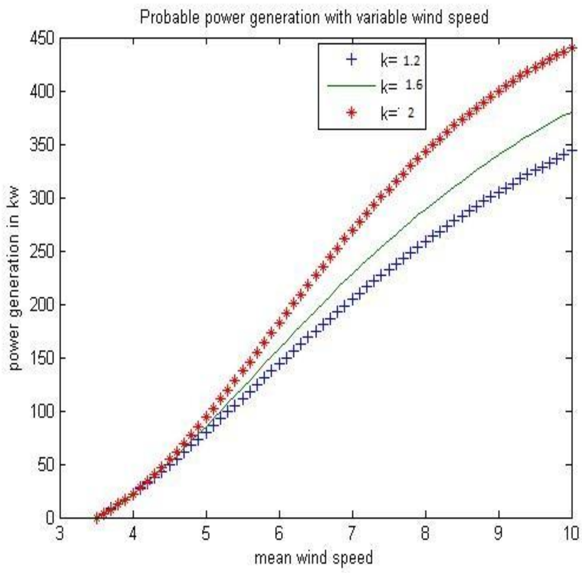

Fig. 4.probable power generation with variable wind speed

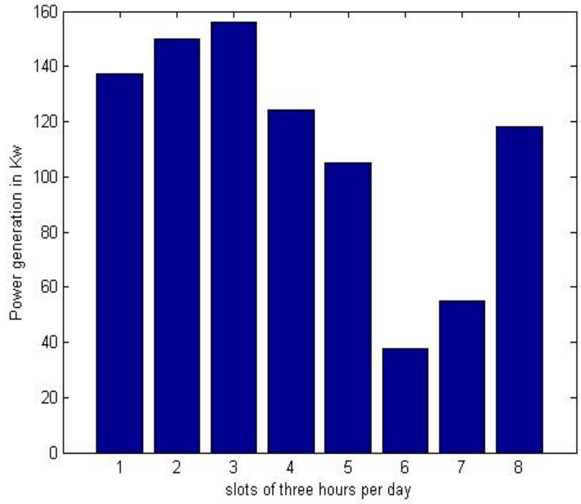

Fig. 5.: probable power generation for the quarter Jan to March

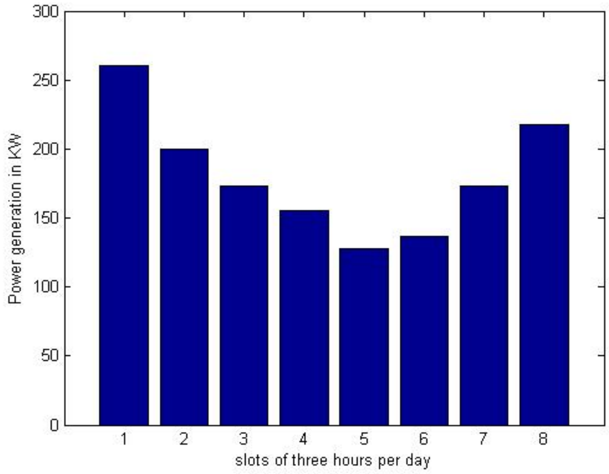

Fig 6: probable power generation for the quarter April to June

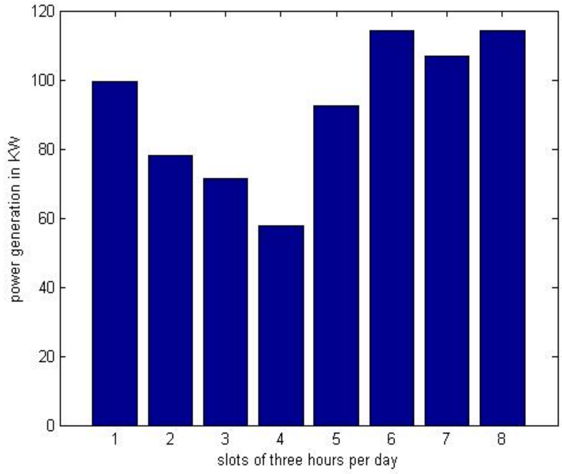

Fig 7: probable power generation for the quarter July to September

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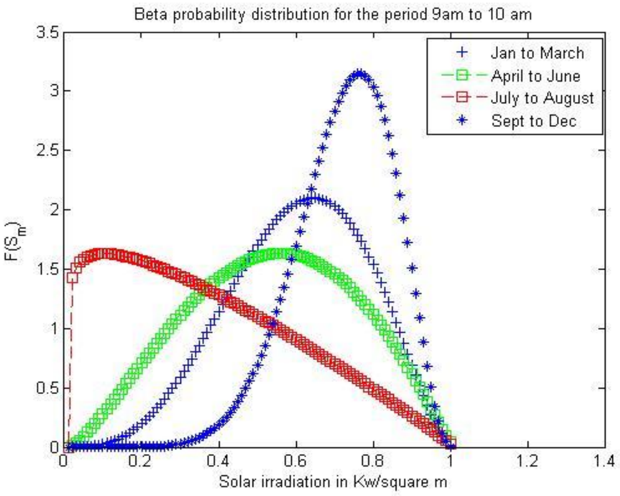

Fig 8: A beta probability distribution for the morning period

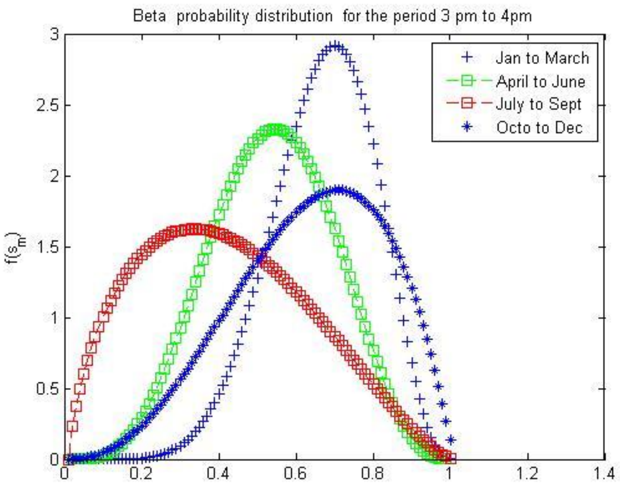

Fig 9 A beta probability distribution for the evening period

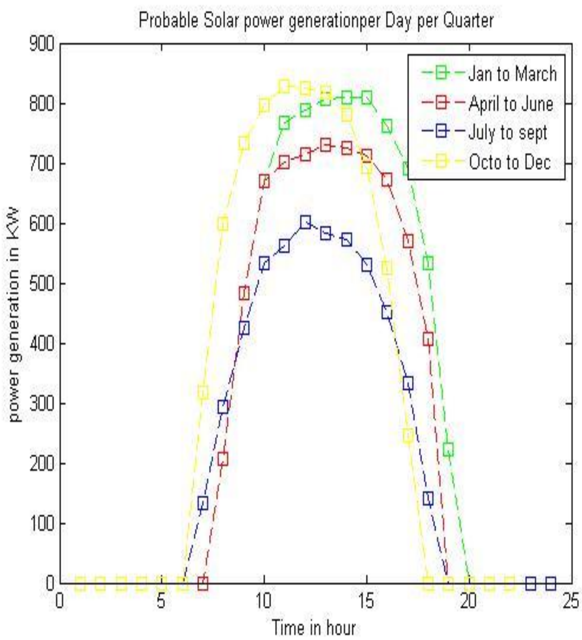

Fig 10: Probable solar power generation of the year.

Table II: Probable Energy Generation per day

Type of Energy	Probable Energy Generated(kwh)/day/Quarter			
	January to March	*April to June*	*July to September*	*October to December*
Wind energy (k=2)	7056	11560	5875	2734
Wind energ (k=1.6)	6152	8574	4765	2250
Wind energ (k=1.2)	4325	6985	2198	1276
Solar energy (Alpha and beta parameters vary hour to hour)	7548	6591.9	5154	7159

REFERENCES

1. D. Q. Hung and E. Engineering, “Smart Integration of Distributed Renewable Generation and Battery Energy Storage,” 2014.
2. A. Soroudi, M. Aien, and M. Ehsan, “A Probabilistic Modeling of Photo Voltaic Modules and Wind Power Generation Impact on Distribution Networks,” 2011.
3. Z. Liu, F. Wen, Y. Xue, J. Xin, and G. Ledwich, “Optimal siting and sizing of distributed generators considering plug-in electric vehicles,” Dianli Xitong Zidonghua/Automation Electr. Power Syst., vol. 35, no. 18, pp. 2541–2551, 2011.
4. Y. Lv, L. Guan, Z. Tang, and Q. Zhao, “A Probability Model of PV for the Middle-term to Long-term Power System Analysis and Its Application,” Energy Procedia, vol. 103, no. April, pp. 28–33, 2016.
5. Y. M. Atwa, E. F. El-Saadany, M. M. A. Salama, and R. Seethapathy, “Optimal Renewable Resources Mix for Distribution System Energy Loss Minimization,” Power Syst. IEEE Trans., vol. 25, no. 1, pp. 360–370, 2010.
6. D. W. Gao, “Sizing of Energy Storage Systems for Microgrids,” Energy Storage Sustain. Microgrid, vol. 3, no. 1, pp. 125–142, 2015.
7. M. Ding, L. Wang, and R. Bi, "An ANN-based approach for forecasting the power output of a photovoltaic system," Procedia Environ. Sci., vol. 11, no. PART C, pp. 1308–1315, 2011.
8. A. Hadian, M. R. Haghifam, J. Zohrevand, and E. Akhavan-Rezai, “Probabilistic approach for renewable DG placement in distribution systems with uncertain and time varying loads,” 2009 IEEE Power Energy Soc. Gen. Meet. PES ’09, pp. 1–8, 2009.
9. A. Botterud et al., “Demand Dispatch and Probabilistic Wind Power Forecasting in Unit Commitment and Economic Dispatch: A Case Study of Illinois,” IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 250–261, Jan. 2013.
10.] P. A. Upadhyay and S. K. Joshi, “Models and methods for integrating green power distributed generators in microgrid,” in 2017 52nd International Universities Power Engineering Conference (UPEC), 2017, pp. 1–6.
11. C. Draxl, A. Purkayastha, and Z. P. Nrel, “Wind Resource Assessment of Gujarat (India),” no. July, 2014.
12. “http://re.jrc.ec.europa.eu/.” .
13. “www.worldweatheronline.com/lang/en-in/khambhat- weather- history /gujarat/ in. aspx.” .
14. http://niwe.res.in/

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