IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 4 ISSUE : 11 Print / Issue Publication Date: 10-May-2020

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2020.v04i11.075

Indexed In

Google Scholar · Open Access · doi · Crossref

WWW.IJEAST.COM

editor@ijeast.com

International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 4, Issue 11, ISSN No. 2455-2143, Pages 421-423
Published Online March 2020 in IJEAST (http://www.ijeast.com)

MODELLING OF RENEWABLE ENERGY SOURCES IN DISTRIBUTION SYSTEM PLANNING

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Abstract: Now a days the renewable energy generation integration to the grid is more important in power systems. The fluctuations in output power of photovoltaic and wind turbines are to be modelled for effective planning in distribution systems. In this paper the mathematical modeling of renewable energy sources and load model are presented. The output of the photovoltaic and wind turbine can be effectively used for distribution system planning.

Keywords: Renewable energy sources, Solar, Wind, Biomass, probability density functions, Load model.

I. INTRODUCTION

The government, utilities and consumers in power grid has been taken keen interest for the employment of renewable energy resources. This is because it will provide so many benefits to the grid, the environment, consumers and utilities. Because of the fluctuation in the output power of wind turbines and photovoltaic modules, the degree of uncertainty from the generation side is increasing. Due to major fluctuations and availability it should be properly modeled. Therefore, the random variations in wind speed or solar irradiance can be represented in equations. The behavior of wind speed and solar irradiance is modelled using proper density functions. In addition to that the output power from wind turbines and photovoltaic modules are also calculated in this paper. Then renewable DG units (i.e. wind, solar PV and biomass) generation characteristics are presented.

II. RENEWABLE GENERATION MODELLING

Renewable energy sources are generally classified into two categories with their capability of delivering energy is concerned. Solar, wind and biomass renewable energy sources are considered in this paper. If the DG output is controlled with the rate of fuel consumption simultaneously, the DG units are considered to be dispatchable DG unit. Biomass and small hydro power plants are examples of dispatchable DG unit. If DG unit is totally depending in weather condition (e.g., wind speed and solar irradiance) and it is not automatically controlled then it is called non-dispatchable DG unit. Solar PV and wind turbines are examples of such DG units.

A. Dispatchable Generation

Biomass

Biomass raw materials are used to produce biogas which runs the gas turbines. Synchronous machines are considered as gas turbines which can dispatch load demand curve accordingly.

B. Non-dispatchable Generation

Solar Irradiance

The amount of energy that earth receives from sun varies between locations. This solar irradiance probabilistic nature can be expressed in Beta Probability Density Function (PDF). Many PV studies Atwa et al. (2010,2011) have employed this model. Teng et al. (2013), Soroudi et al. (2012), Dheeraj et al. (2013) presented the solar irradiance PDF over each one-hour period is expressed as

$$f_b(s) = \begin{cases} \dfrac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \times S^{(\alpha-1)} \times (1-S)^{(\beta-1)} & 0 \le S \le 1, \alpha, \beta \ge 0 \\ 0 & \text{Otherwise} \end{cases}$$

Where s is the solar irradiance random variable (kW/m2). fb(s) is the function of beta distribution s. α and β are fb(s) parameters, which are obtained from the mean(μ) and standard deviation (σ) of s

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

$$\alpha = \frac{\mu \times \beta}{1-\mu}$$

The PV module output power at solar irradiance s can be expressed as

$$PV_{out}(s) = N \times FF \times V_N \times I_N$$

$$FF = \frac{V_{MPP} \times I_{MPP}}{V_{OC} \times I_{SC}}$$
$$V_N = V_{oc} - K_v \times T_{cell}$$
$$I_N = s[I_{sc} + K_i \times (T_{cell} - 25)]$$
$$T_{cell} = T_{amb} + s\left(\frac{NOT - 20}{0.8}\right)$$

Here N is the module number. The cell and ambient temperature (0C) are Tcell and Tamb respectively.

The current and voltage temperature coefficients (A/0C and V/0C) are Ki and Kv respectively.

NOT is the nominal operating temperature of cell in 0C. FF is the fill factor. The output date of Solar PV module is shown in Table 1. The output of Solar PV module is shown in Figure 1.

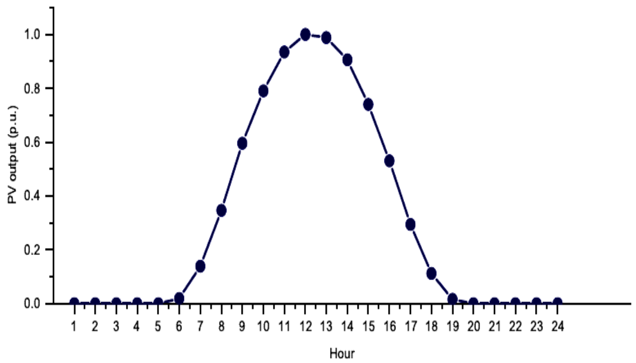

Figure 1. PV solar output

Wind Speed

At any location the wind turbine uncertainties mainly due to wind speed variation and density of air. Haque et al. (2014) presented Weibull PDF is used in this paper for the probabilistic nature of the wind speed. The PDF for wind speed v for each one hour is

$$fw(v) = \frac{k}{v}\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right] 0 \le v \le \infty$$

where fw(v) is the Weibull distribution function of v, v is the random variable of wind speed (m/s); k=2 is the shape index, c ≈ 128vm is the Rayleigh scale index. The wind turbine power output is given by

$$Pwo(v) = \begin{cases} 0 & 0 \le v \le v_{ci} \\ k_0 + k_1 \times v + k_2 \times v^2 + k_3 \times v^3 & v_{ci} \le v \le v_r \\ P_{rated} & v_r \le v \le v_{co} \\ 0 & v_{co} \le v \end{cases}$$

where v_{ci}, v_r, and v_{co} are cut in, rated and cut out speed of the wind turbine, respectively; P_{rated} is the rating of wind turbine; k0,k1,k2 and k3 are the coefficients calculated using any standard curve fitting technique such as 'Polyfit' routine in Matlab .The output of wind turbine is shown in figure 2.

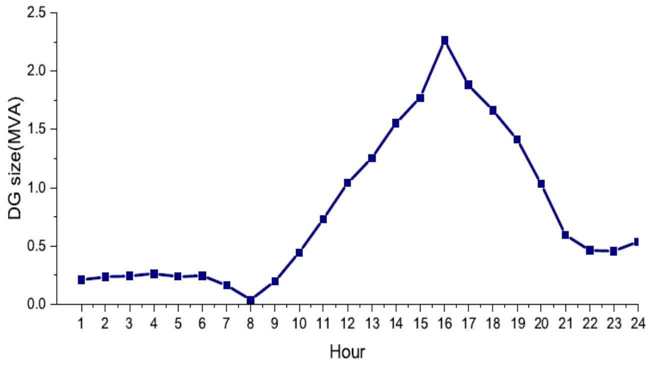

Figure 2. Wind turbine output

C. Load Modelling

The load model which is dependent on time and voltage is defined as time varying load model or voltage dependent time varying load model. At time varying period t, the voltage dependent load model can be expressed as

$$Pj(t) = Poj(t) * Vj^{nk}(t)$$
$$Qj(t) = Qoj(t) * Vj^{nl}(t)$$

Where the active and reactive power injecting at bus j are Pj and Qj are respectively.

At nominal voltage, the active and reactive load at bus j are Poj and Qoj respectively. The nominal voltage at bus j is Vj, np and nq are load constants as given in Table 2.

Table 2. Load constants

Type of Load	nk	Nl
Constant	0	0
Industrial	0.18	6
Residential	0.92	4.04
Commercial	1.51	3.40

The distribution system is assumed to follow load curve of IEEE-RTS system presented in Hung et al. (2010), S.G asper (1995) as shown in Figure 3. The ratio of area under the load curve in p.u to the total duration gives the load factor (LF) or the average load level, which is as follows.

$$CF = \sum_{t=1}^{24} \frac{p.u\ demand(t)}{24}$$

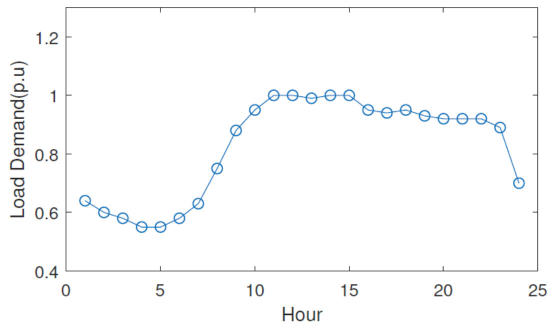

Figure 3: Normalized daily load demand curve

III. CONCLUSIONS

In this paper the models of the renewable resources that have been used in distribution system planning is modelled using MATLAB. It outlined the preparation and analysis of large amounts of historical data to be suitably utilized in planning problems. The probability density functions that have used to model the behavior of wind speed and solar irradiance are discussed.

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Table 1. PV Solar irradiance data

Hour	μ (kW/m²)	σ (kW/m²)	β	α	α+ β	Γ (α+ β)	Γ(α)	Γ(β)
6	0.017112049	0.039434305	10.01796677	0.174412	10.1923793	560705.5027	5.305653	377868.3644
7	0.045940476	0.036324663	33.78953483	1.627055	35.4165898	1.29389E+39	0.896847	4.14955E+36
8	0.16005348	0.085789514	20.34982889	3.8777	24.2275293	5.30807E+22	5.156635	3.44951E+17
9	0.287745098	0.149028537	11.17097258	4.512981	15.6839532	5.51676E+11	11.84358	5432343.74
10	0.396595238	0.211538287	6.865360649	4.512343	11.3777038	8880663.452	11.83307	560.3166835
11	0.471276427	0.260417651	4.877049771	4.347146	9.22419581	65346.12899	9.434613	19.97665779
12	0.51680178	0.29173004	3.967374012	4.243281	8.21065528	7728.68259	8.211723	5.759950687
13	0.513857278	0.287326456	4.094643249	4.328075	8.4227184	11954.80439	9.195225	6.765948881
14	0.467431447	0.262911085	4.752291249	4.171051	8.92334184	34229.78943	7.468588	16.6413826
15	0.384812716	0.2125964	6.638118675	4.152284	10.7904029	2221285.299	7.288453	369.3596033
16	0.268176498	0.142420168	11.53871952	4.22836	15.7670798	6.9182E+11	8.051459	13058204.12
17	0.144005848	0.079600439	21.4000641	3.600182	25.0002457	6.20936E+23	3.71779	8.17733E+18
18	0.038166981	0.031880458	36.53595075	1.449801	37.9857522	1.30711E+43	0.885663	7.02804E+40
19	0.012310606	0.031787494	11.1938179	0.13952	11.3333382	7988979.823	6.712871	5734441.477

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