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A approachable model of Wind power generation in Bhubaneswar, Odisha, India

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Abstract: This paper describes an analytical method of power generation from Wind energy in a specific location. The specific location is chosen as Bhubaneswar, Odisha, India. This paper also includes wind speed analysis, power and energy calculation, Probability Density function, Rate of return etc. over a period of time and conditions affecting it. The different parameters necessary for wind generation are studied and compared.

Keywords: Wind energy, wind speed analysis, Probability Density function, Rate of return.

I. INTRODUCTION

Wind energy is the kinetic energy associated with movement of large masses of air. It is the result of temperature, density, and pressure difference due to uneven heating of the atmosphere by the sun. It is estimated that 1% of the solar radiation is converted to kinetic energy of the atmosphere. Thus, wind energy is an indirect form of solar energy. It is a renewable, widely available and distributed, eco-friendly, free from GHG emissions and can be used as an alternative to fossil fuel. Wind energy capacity has expanded rapidly to 336GW in June,2014 and wind production is 4% of total worldwide electricity usage.

In India, As of 31st March 2014, the Installed capacity is 21136.3MW mainly across Tamil Nadu (7,253MW), Gujurat(3,093MW), Maharastra(2,976MW), Karnataka(2,113MW),Rajasthan(2,355MW), P(386MW), Andhra Pradesh(435MW), Kerela(35.1MW), Odisha(2MW), West Bengal(1.1MW) and others (3.2MW). Additionally, 6,000MW is planned in 2014. Wind energy contributes 8.5% of India's total Installed Capacity and generates 1.6% of total.

TABLE I
WIND POWER SCENARIO

COUNTRY	NEW CAPACITY (MW)	WIND POWER TOTAL CAPACITY(MW)	% WORLD TOTAL
CHINA	16,088	91,412	28.7
US	1,084	61,091	19.2
GERMANY	3,238	34,250	10.8
SPAIN	175	22,959	7.2
INDIA	1,729	20,150	6.3
UK	1,883	10,531	3.3
ITALY	444	8,552	2.7
FRANCE	631	8,254	2.6
CANADA	1,599	7,803	2.5
DENMARK	657	4,772	1.5
REST OF WORLD	7,761	48,332	15.2
TOTAL	35,289MW	3,18,105MW	100%

(Fig. Wind power scenario of the World)

In India, As of 31st March 2014, the Installed capacity is 21136.3MW mainly across Tamil Nadu (7,253MW), Gujurat(3,093MW), Maharastra(2,976MW), Karnataka(2,113MW), Rajasthan(2,355MW), MP(386MW), Andhra Pradesh(435MW), Kerela(35.1MW), Odisha(2MW), West Bengal(1.1MW) and others (3.2MW). Additionally, 6,000MW is planned in 2014. Wind energy contributes 8.5% of India's total Installed Capacity and generates 1.6% of total.

Odisha being a coastal state has higher potential for wind energy nearly 1600MW but it is producing 2MW. It may be due to higher thermal reserve and is a power surplus state. Hence, a model is proposed suitable for Odisha.

II. LITERATURE SURVEY

A. NATURE OF WIND

It is required to understand the nature of winds to predict performance of wind turbine and proper design of supporting structure. For power generation, the speed required is between 5-25m/sec for 70-80% of time.

BEAUFORT NUMBER: This scale provides a wind speed classification(0-12).

VARIABILITY: It is classified into Spatial and Temporal variation.

SPATIAL: It includes climatic regions, physical geography, type of vegetations etc.

TEMPORAL: It includes geographical variation, long term wind speed variation, annual and seasonal variations and synoptic & diurnal variation, turbulence and extreme wind speeds.

SOLIDITY: It is the ratio of the projected area of the rotor blades on the rotor plane to the swept area of the rotor.

REYNOLD'S NUMBER: It indicates the nature of flow around a body. It is the ratio between Inertia force and Viscous force. Laminar flow occurs when Reynold's no is low and viscous force are dominant and is characterised by smooth, constant and fluid motion. Turbulent flow occurs when Inertia force is dominant. In this case, eddies are formed.

B. CLASSIFICATION OF WIND TURBINES

Wind turbines are classified into two categories according to the orientation of the axis of rotation w.r.t the direction of wind i.e Vertical axis wind turbine(VAWT) & Horizontal axis wind turbine(HAWT).In VAWT, the axis of rotation of wind turbine is perpendicular to the wind. They are used in small scale installations. In HAWT, the

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axis of rotation of these turbines is parallel to the wind. These are the modern and mostly used. They are mounted on towers so to raise the wind turbine above the ground for stronger winds in order to harness more energy.

C. TYPES OF ROTORS

D. UPWIND AND DOWNWIND M/C

UPWIND M/C: In this case, rotor is located in-front of the tower. It produces higher power as it eliminates tower shadow on blades and results in lower noise, lower blade fatigue and smoother power output.

DOWNWIND M/C: The rotor is located behind the tower. It allows use of free yaw system

E. ENERGY ESTIMATION & POWER OUTPUT FROM WIND

The Power estimated is the kinetic energy in per unit time and is given by **Po=0.5*p*A*(uo^3)** where Po=Power available in wind per unit area, p=density of the air, A=area and uo=Speed of free wind in unperturbed state considering no turbulence. The power output of wind turbine is given by **Po=0.5*p*A*(uo^3)*Cp**, where Cp= power coefficient.

F. POWER COEFFICIENT(Cp)

The power captured by the wind depends on the upstream and downstream velocity of air, rotational speed of turbine and blade pitch. The theoretical maximum value of Cp is 16/27(0.593) called the Betz limit given by a German physicist Albert Betz. It is a function of tip speed ratio and blade pitch angle which depends on type and operating condition of the turbine. This relationship is usually provided by the turbine manufacturer in the form of a set of non dimensional curves.

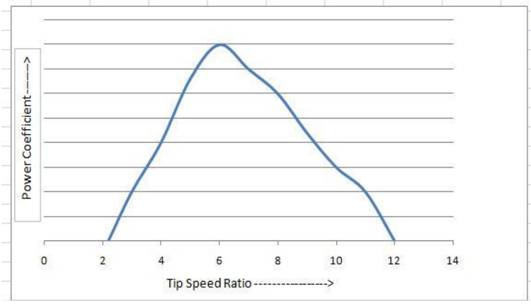
G. TIP SPEED RATIO

It is defined as the ratio between speed of the tip of the rotor blade to the speed of incoming air.

$$TSR=R*w/uo$$

where, w=turbine speed in rad/sec and R=radius of blade.

The variation of Cp with TSR is shown as:



H. GENERATORS USED FOR WIND ENERGY EXTRACTION SYSTEM

Squirrel Cage Induction Generator(SCIG): It is preferred in distributed generation as it has the ability to auto start and no need for synchronisation. It is mechanically simple, highly efficient and requires low maintenance.

Permanent Magnet Synchronous Generator(PMSG): When PMSG machines are used, the wind generator doesn't need to supply excitation system and are connected to grid and are widely used in variable speed wind generators for their high efficiency and higher generated power to weight ratio than induction generators. They have a loss free rotor and the power losses are mainly related to the stator windings and the stator core.

Doubly fed Induction Generator(DFIG): Wound rotor induction generators(WRIG) are provided with three phase windings on the stator and on the rotor. The stator is directly connected to the grid while the rotor winding is connected via slip rings to the grid through a converter-inverter combination. WRIG provides constant (regulated) voltage and frequency in the stator terminals. The rotor is supplied through a static power converter at a variable voltage and a variable frequency as per the speed variation.

I. WIND SPEED PREDICTION AND FORECASTING

STATISTICAL METHODS

Persistent Forecast:

$$\hat{Y}_k = Y(k-1)$$

nth Order Autoregressive model:

$$\hat{Y}_k = \Sigma\, a_i Y(k-i);\ i=1,...n$$

nth Order Autoregressive mth order Moving Average model:(ARMA(n,m))

$$\hat{Y}_k = \Sigma\, a_i Y(k-i) + \Sigma b_j\, e(k-j);\ i=1,...n; j=1,...m$$
$$\text{where, } e_k = \hat{Y}_k = Y(k)$$

ARMAX model:

In addition to ARMA model, an exogenous variable 'X' is included which influences **Ý**.

Model parameters ai & bj can be estimated in various ways like Method of Recursive Least Squares(RLS).

METEOROLOGICAL METHODS

It uses detailed analysis and modelling of the atmosphere.

J. WIND VELOCITY DISTRIBUTION

The wind regime is influenced by regional and local effects and depends on seasonal and short-time variations. Wind velocity varies with height above ground and influenced by surface roughness. Assuming stable conditions, the dependence of velocity 'V' on height 'Z' is given as

$$V2(Z2) = V1 * \{\ln(Z2/Z0)/\ln(Z1/Z0)\}$$

where Z0= Roughness length;

Z0=0.03m for farmland

=0.1m for scattered shrubs & trees

=0.5-1.6m for forests.

This equation can be used when calculating the reference energy used in the project stage.

WEIBULL DISTRIBUTION:

It includes probability density function(PDF) which is defined by

$$f(x;\lambda,K) = K/\lambda * (x/\lambda)^{\wedge}\{e^{\wedge}((-x/\lambda)^{\wedge}K)\};\ x>=0$$
$$=0;\ x<0$$

The PDF of a continuous random variable is a function that describes the relative likelihood for this random

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variable to take on a given value. The probability of a random variable falling within a particular range of values is given by the integral of this variable density over that range.

$Pr[a<X<b]= \int_a f(x).dx \;;a<x<b=F(x);$

λ, K=Parameters which affects the distribution.
K=Shape Parameters which affects the shape of distribution rather than simply shifting it.
λ= Scale Parameters which stretches or shrinks the distribution.
K=1(Weibull Distribution);K=2(Rayleigh Distribution)
RAYLEIGH DISTRIBUTION:
It represents wind speed distribution .

$$f(x; \lambda, K) = 2/ \lambda*(x/ \lambda)^{e^((-x/ \lambda)^2)}; \; x>=0$$
$$=0; \; x<0$$

Wind Speed distribution improves estimation of Wind Power Potential.

III. SYSTEM CONFIGURATION

LOCATION: BHUBANESWAR,ODISHA,INDIA
ELEVATION:46m
LATITUDE: 20.2 deg ; LONGITUDE: 85.8 deg
AREA =5026 m2

A. NATURE OF WIND

The wind speed of Bhubaneswar for the year of 2014 varies from 0.278 to 13.07m/sec. Its Beaufort No varies from 0 to 6 which indicates calm to strong wind.

B. TYPE OF TURBINE USED

A HAWT is considered having 3 blades rotor. An upwind machine is considered as it produces higher power as it eliminates tower shadow on blades and results in lower noise, lower blade fatigue and smoother power output.

C. ENERGY ESTIMATION & POWER OUTPUT FROM WIND

Yearly data of wind speed is taken for 2013 and its power output and energy is calculated.

MONTH	DAY	WIND SPEED	PRESSURE	TEMP	TEMP	DENSITY	POWER /AREA	POWER	ENERGY
		(m/sec)	(Pa)	(°C)	(°K)	(ρ)	(Watt/m2)	(KW)	(KWh)
JAN									
	1	1.112	101.309	23	374.309	1.193	0.819896	4.1207975	98.899139
	2	1.946	101.2075	24	374.2075	1.187	4.3749477	21.988487	527.72369
	3	1.668	101.238	26	374.238	1.180	2.7374653	13.7585	330.20401
	4	1.788	101.3	23.33	374.3	1.191	3.4042737	17.10988	410.63712
	5	0.894	101.475	23.33	374.475	1.193	0.4262693	2.1424297	51.418314
	6	1.668	101.514	23	374.514	1.195	2.7727485	13.935834	334.46001
	7	1.668	101.4107	24	374.4107	1.190	2.7606006	13.874779	332.99469
	8	1.946	101.425	21	374.425	1.202	4.4290879	22.260596	534.2543
	9	1.39	101.463	19	374.463	1.211	1.6257635	8.1710871	196.10609
	10	0.894	101.337	20.556	374.337	1.203	0.4297123	2.1597338	51.833612
	11	1.39	101.271	20	374.271	1.204	1.6171488	8.1277899	195.06696
	12	1.39	101.51228	20	374.51228	1.207	1.6210017	8.1471545	195.53171
	13	1.112	101.664	20	374.664	1.209	0.8311933	4.1775776	100.26186
	14	0.834	101.625	23	374.625	1.196	0.3469725	1.743884	41.853216
	15	0.894	101.638	23.889	374.638	1.193	0.4261502	2.1418308	51.403938
	16	0.834	101.563	24	374.563	1.192	0.3455933	1.736952	41.686848
	17	0.834	101.538	24	374.538	1.191	0.3455082	1.7365244	41.676586
	18	1.112	101.712	24	374.712	1.193	0.820386	4.1232598	98.958235
	19	0.834	101.775	24	374.775	1.194	0.3463147	1.7405777	41.773864
	20	1.112	101.737	22	374.737	1.202	0.8261509	4.1522344	99.653626
	21	1.668	101.638	22	374.638	1.200	2.785546	14.000154	336.00371
	22	1.39	101.663	21	374.663	1.205	1.6178867	8.1314984	195.15596
	23	0.834	101.675	20	374.675	1.209	0.3506976	1.7626062	42.30255
	24	1.39	101.65	22	374.65	1.201	1.6121961	8.1028978	194.46955
	25	1.39	101.588	20	374.588	1.208	1.6222108	8.1532317	195.67756
	26	1.668	101.5	20	374.5	1.207	2.8007521	14.07658	337.83792
	27	1.112	101.557	21	374.557	1.204	0.8274943	4.1589863	99.81567
	28	1.668	101.633	20	374.633	1.209	2.804422	14.095025	338.2806
	29	1.112	101.5	20	374.5	1.207	0.8298525	4.1708385	100.10012
	30	0.834	101.6	22	374.6	1.200	0.3480631	1.749365	41.98476
	31	0.834	101.6	22	374.6	1.200	0.3480631	1.749365	41.98476
FEB									
	1	0.834	101.63	23	374.63	1.196	0.3469896	1.7439698	41.855275
	2	1.112	101.55	22	374.55	1.199	0.8246324	4.1446023	99.470456
	3	1.39	101.44	24	374.44	1.190	1.5980314	8.0317056	192.76094
	4	0.834	101.59	24	374.59	1.192	0.3456852	1.7374138	41.69793
	5	0.834	101.65	25	374.65	1.189	0.3447286	1.7326062	41.582549
	6	0.834	101.5	25	374.5	1.187	0.34422	1.7300495	41.521187
	7	0.556	101.24	26	374.24	1.180	0.1013896	0.5095842	12.23002
	8	1.668	101.3	24	374.3	1.188	2.7575871	13.859633	332.63119
	9	1.668	101.39	24	374.39	1.189	2.7600371	13.871946	332.92672
	10	1.79	101.41	23.33	374.41	1.192	3.4194193	17.186002	412.46404
	11	0.834	101.39	23	374.39	1.193	0.3461702	1.7398514	41.756433
	12	0.834	101.39	22	374.39	1.198	0.3473437	1.7457492	41.897981
	13	0.834	101.26	24	374.26	1.188	0.3445623	1.73177	41.562481
	14	1.34	101.28	25	374.28	1.184	1.4246557	7.1603197	171.84767
	15	1.668	101.24	26	374.24	1.180	2.7375193	13.758772	330.21053
	16	1.668	101.14	25	374.14	1.183	2.7439926	13.791307	330.99136
	17	1.668	101	23	374	1.189	2.7587091	13.865272	332.76653
	18	1.668	101.21	24	374.21	1.187	2.7551371	13.847319	332.33566
	19	1.39	101.38	22	374.38	1.197	1.6079139	8.0813751	193.953
	20	1.39	101.38	24	374.38	1.189	1.5970862	8.026955	192.64692
	21	1.112	101.41	24	374.41	1.190	0.8179501	4.1110171	98.664411
	22	0.834	101.53	24	374.53	1.191	0.345481	1.7363876	41.673303
	23	1.668	101.45	25	374.45	1.186	2.7524031	13.833578	332.00587
	24	1.39	101.4	26	374.4	1.182	1.5867163	7.974836	191.39606
	25	1.668	101.43	26	374.43	1.182	2.7426569	13.784594	330.83025
	26	1.112	101.43	26	374.43	1.182	0.8126391	4.084324	98.023777
	27	1.112	101.3	26	374.3	1.180	0.8115975	4.0790893	97.898143
	28	1.112	101.12	28	374.12	1.171	0.8047723	4.0447857	97.074857
MAR									
	1	1.39	101.24	27	374.24	1.176	1.5789319	7.9357116	190.45708
	2	1.67	101.37	26	374.37	1.181	2.7509062	13.826054	331.82531

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	3	1.11	101.34	26	374.34	1.181	0.807545	4.0587214	97.40
	4	1.67	101.43	26	374.43	1.182	2.7525344	13.834238	332.0
	5	1.39	101.46	27	374.46	1.178	1.582363	7.9529563	190.8
	6	1.39	101.43	28	374.43	1.174	1.5766396	7.9241908	190.1
	7	2.22	101.37	28	374.37	1.173	6.4193341	32.263573	774.3
	8	1.95	101.31	28	374.31	1.173	4.3478821	21.852456	524.4
	9	2.22	101.11	28	374.11	1.170	6.4028694	32.180822	772.3
	10	2.5	100.99	30	373.99	1.161	9.0728531	45.600159	1094.
	11	3.34	101.01	30	374.01	1.162	21.639601	108.76064	2610.
	12	3.61	100.95	30	373.95	1.161	27.306963	137.2448	3293.
	13	1.95	101.01	30	374.01	1.162	4.3063932	21.643932	519.4
	14	2.22	101.14	30	374.14	1.163	6.3624935	31.977892	767.4
	15	1.39	101.24	30	374.24	1.164	1.5632989	7.8571402	188.5
	16	1.34	101.34	28.89	374.34	1.170	1.4071315	7.0722428	169.7
	17	1.67	101.26	29	374.26	1.168	2.7206239	13.673855	328.1
	18	1.39	100.99	28	373.99	1.169	1.5698002	7.8898159	189.3
	19	2.22	100.95	30	373.95	1.161	6.350541	31.917819	766.0
	20	1.67	100.96	30	373.96	1.161	2.7036112	13.58835	326.1
	21	2.69	100.84	30	373.84	1.160	11.285873	56.722797	1361.
	22	4.03	100.67	31.11	373.67	1.153	37.746146	189.71213	4553.
	23	3.61	100.86	31	373.86	1.156	27.192873	136.67138	3280.
	24	3.34	100.95	30	373.95	1.161	21.626747	108.69603	2608.
	25	3.06	100.69	32	373.69	1.150	16.479305	82.824986	1987.
	26	2.22	100.59	32	373.59	1.149	6.2863998	31.595446	758.29069
	27	1.95	100.73	31	373.73	1.155	4.2803294	21.512936	516.31045
	28	1.95	100.81	32	373.81	1.152	4.2696838	21.459431	515.02634
	29	1.95	100.91	30	373.91	1.160	4.3021299	21.622505	518.94012
	30	3.06	100.66	32	373.66	1.150	16.474395	82.800309	1987.2074
	31	3.34	100.7	32	373.7	1.150	21.431726	107.71585	2585.1805
APR									
	1	2.78	100.84	32	373.84	1.152	12.375293	62.198223	1492.7574
	2	2.5	100.85	31	373.85	1.156	9.030472	45.387152	1089.2917
	3	3.61	100.85	32	373.85	1.152	27.101029	136.20977	3269.0345
	4	2.5	100.49	33	373.49	1.144	8.9394243	44.929547	1078.3091
	5	1.95	100.48	34	373.48	1.140	4.2279826	21.249841	509.99617
	6	2.24	100.57	33.33	373.57	1.144	6.4285212	32.309748	775.43394
	7	3.34	100.05	34	373.05	1.136	21.154669	106.32336	2551.7607
	8	3.13	100.6	33.33	373.6	1.144	17.544038	88.176337	2116.2321
	9	13.07	100.69	33	373.69	1.147	1279.911	6432.8329	154387.99
	10	4.73	100.61	33	373.61	1.146	60.616555	304.65881	7311.8114
	11	4.17	100.63	33	373.63	1.146	41.543427	208.79726	5011.1343
	12	4.73	100.76	32	373.76	1.151	60.905968	306.11339	7346.7215
	13	4.45	100.86	32	373.86	1.152	50.767674	255.15833	6123.7999
	14	3.06	100.86	31	373.86	1.156	16.561427	83.237735	1997.7056
	15	3.34	100.69	31	373.69	1.154	21.500089	108.05945	2593.4268
	16	8.34	100.28	32	373.28	1.146	332.27736	1670.026	40080.624
	17	3.61	100.24	32	373.24	1.145	26.937106	135.38589	3249.2614
	18	4.73	100.33	33	373.33	1.142	60.447858	303.81093	7291.4624
	19	4.47	100.57	31.11	373.57	1.152	51.45747	258.62524	6207.0058
	20	2.78	100.84	26	373.84	1.175	12.623627	63.446348	1522.7123
	21	1.95	100.94	27	373.94	1.172	4.346443	21.845222	524.28534
	22	1.39	100.99	27	373.99	1.173	1.5750329	7.9161153	189.98677
	23	2.22	101.05	30	374.05	1.162	6.3568318	31.949437	766.78648
	24	1.95	101.03	31	374.03	1.158	4.2930773	21.577007	517.84816
	25	3.06	100.95	32	373.95	1.153	16.521857	83.038856	1992.9325
	26	2.78	100.88	32	373.88	1.152	12.380202	62.222895	1493.3495
	27	3.89	100.69	32	373.69	1.150	33.855046	170.15546	4083.7311
	28	5.01	100.49	34	373.49	1.141	71.710996	360.41947	8650.0672
	29	5.56	100.56	34	373.56	1.141	98.084272	492.97155	11831.317
	30	5.01	100.51	34	373.51	1.141	71.725269	360.4912	8651.7888
MAY									
	1	5.004	100.36	34	373.36	1.139	71.361224	358.66151	8607.8762
	2	5.282	100.18	34	373.18	1.137	83.777221	421.06431	10105.544
	3	6.116	100.14	34	373.14	1.137	130.00491	653.40467	15681.712
	4	7.23	100.25	34	373.25	1.138	215.00522	1080.6162	25934.79
	5	7.51	100.48	33	373.48	1.144	242.30709	1217.8354	29228.05
	6	7.51	100.44	34	373.44	1.140	241.42167	1213.3853	29121.247
	7	5.84	100.43	30	373.43	1.155	115.01315	578.05607	13873.346
	8	6.39	100.28	32	373.28	1.146	149.45318	751.1517	18027.641

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	9	6.116	100.26	34	373.26	1.138	130.1607	654.18766	15700.504
	10	6.116	100.23	34	373.23	1.138	130.12175	653.99191	15695.806
	11	5.282	100.11	34	373.11	1.136	83.718682	420.7701	10098.482
	12	5.282	100.36	32	373.36	1.147	84.478095	424.58691	10190.086
	13	2.224	100.39	28	373.39	1.162	6.3917005	32.124687	770.99248
	14	1.34	100.23	31.11	373.23	1.148	1.3815593	6.9437171	166.64921
	15	1.67	100.1	30	373.1	1.151	2.6805812	13.472601	323.34243
	16	2.5	100.1	31	373.1	1.147	8.9633143	45.049618	1081.1908
	17	4.73	100.26	32	373.26	1.145	60.603735	304.59437	7310.2649
	18	6.39	100.3	34	373.3	1.138	148.50916	746.40703	17913.769
	19	6.116	100.19	33	373.19	1.141	130.49488	655.86729	15740.815
	20	5.84	100.05	35	373.05	1.132	112.71794	566.52034	13596.488
	21	6.39	100.14	33	373.14	1.140	148.75681	747.6517	17943.641
	22	3.58	99.99	35	372.99	1.131	25.950339	130.4264	3130.2337
	23	4.45	99.93	34	372.93	1.134	49.971876	251.15865	6027.8076
	24	4.45	99.89	34	372.89	1.134	49.951873	251.05811	6025.3947
	25	2.78	99.85	35	372.85	1.130	12.134443	60.987711	1463.7051
	26	2.22	100	32	373	1.142	6.2495276	31.410126	753.84302
	27	0.834	100.13	28	373.13	1.159	0.3361894	1.6896878	40.552507
	28	1.34	100.06	31.11	373.06	1.146	1.379216	6.9319398	166.36656
	29	2.5	99.98	27	372.98	1.161	9.0719367	45.595554	1094.2933
	30	3.06	99.76	30	372.76	1.147	16.434867	82.601643	1982.4394
	31	2.78	100	29	373	1.154	12.394116	62.292826	1495.0278
JUNE									
	1	4.45	100.31	31	373.31	1.150	50.656921	254.60168	6110.4404
	2	3.06	100.28	30	373.28	1.153	16.520534	83.032204	1992.7729
	3	2.78	100.24	32	373.24	1.145	12.30166	61.828142	1483.8754
	4	1.95	100.31	31	373.31	1.150	4.2624823	21.423236	514.15766
	5	2.5	100.26	32	373.26	1.145	8.9482064	44.973686	1079.3685
	6	2.78	100.18	32	373.18	1.144	12.294297	61.791134	1482.9872
	7	2.22	100.11	32	373.11	1.144	6.2564021	31.444677	754.67225
	8	2.5	100.03	29	373.03	1.154	9.0163645	45.316248	1087.5899
	9	1.95	99.93	31	372.93	1.145	4.2463349	21.342079	512.2099
	10	2.22	99.89	30	372.89	1.149	6.2838588	31.582674	757.98418
	11	0.834	99.91	30	372.91	1.149	0.3332365	1.6748467	40.196322
	12	2.22	99.53	26	372.53	1.160	6.344974	31.889839	765.35614
	13	3.06	99.39	26	372.39	1.158	16.592961	83.396221	2001.5093
	14	2.22	99.48	28	372.48	1.152	6.2996484	31.662033	759.88879
	15	3.34	99.81	28	372.81	1.155	21.524599	108.18263	2596.3832
	16	3.133	100.09	30	373.09	1.151	17.697721	88.948748	2134.7699
	17	3.06	100.13	30	373.13	1.151	16.495822	82.908004	1989.7921
	18	2.24	100	31.67	373	1.144	6.4269137	32.301668	775.24004
	19	1.95	99.91	30	372.91	1.149	4.2594966	21.40823	513.79751
	20	2.22	99.95	28	372.95	1.157	6.3294115	31.811622	763.47894
	21	2.5	99.9	26	372.9	1.164	9.0949943	45.711442	1097.0746
	22	1.95	99.75	28	372.75	1.155	4.2809322	21.515965	516.38317
	23	1.95	99.55	28	372.55	1.152	4.2723489	21.472825	515.34781
	24	3.06	99.3	28	372.3	1.149	16.467783	82.767078	1986.4099
	25	5.37	99.89	28.88	372.89	1.153	89.268582	448.66389	10767.933
	26	5.29	100.02	31	373.02	1.146	84.853232	426.47235	10235.336
	27	4.17	100.03	30	373.03	1.150	41.704595	209.6073	5030.5751
	28	3.06	100.01	30	373.01	1.150	16.476053	82.808643	1987.4074
	29	2.5	100.06	28	373.06	1.158	9.0490323	45.480436	1091.5305
	30	2.78	100.01	28	373.01	1.158	12.436536	62.506029	1500.1447
JULY									
	1	2.22	99.84	28	372.84	1.156	6.3224457	31.776612	762.63869
	2	0.556	99.83	26	372.83	1.163	0.0999775	0.502487	12.059689
	3	3.06	99.94	29	372.94	1.153	16.519039	83.024692	1992.5926
	4	2.69	99.89	30	372.89	1.149	11.17955	56.18842	1348.5221
	5	1.11	100.05	30	373.05	1.151	0.7867405	3.9541578	94.899786
	6	1.39	100.28	30	373.28	1.153	1.548475	7.7826355	186.78325
	7	2.24	100.29	30	373.29	1.153	6.4810768	32.573892	781.7734
	8	1.34	100.12	28.88	373.12	1.156	1.3902375	6.9873337	167.69601
	9	1.11	99.89	30	372.89	1.149	0.7854823	3.9478343	94.748023
	10	1.69	99.7	30	372.7	1.146	2.7669464	13.906673	333.76015
	11	1.95	99.6	28	372.6	1.153	4.2744947	21.48361	515.60665
	12	3.34	99.89	28	372.89	1.156	21.541851	108.26935	2598.4643
	13	3.89	100.01	28	373.01	1.158	34.073272	171.25227	4110.0544
	14	2.22	99.9	28	372.9	1.156	6.3262452	31.795709	763.09701
	15	1.39	99.85	28	372.85	1.156	1.5520799	7.8007537	187.21809
	16	1.95	99.79	26	372.79	1.163	4.3112954	21.66857	520.04569
	17	2.22	99.81	28	372.81	1.155	6.3205459	31.767064	762.40953
	18	1.39	99.67	28	372.67	1.154	1.549282	7.7866913	186.88059
	19	0.834	99.58	27	372.58	1.157	0.3354572	1.6860079	40.46419
	20	1.11	99.74	27	372.74	1.158	0.7921459	3.9813251	95.551801
	21	1.39	99.53	27	372.53	1.156	1.5522628	7.801673	187.24015
	22	2.5	99.38	28	372.38	1.150	8.9875357	45.171355	1084.1125
	23	1.95	99.51	27	372.51	1.156	4.2848677	21.535745	516.85788
	24	1.95	99.7	26	372.7	1.162	4.307407	21.649028	519.57666
	25	2.5	99.62	27	372.62	1.157	9.0392712	45.431377	1090.353
	26	4.45	99.64	26	372.64	1.161	51.160016	257.13024	6171.1258
	27	4.73	100	28	373	1.158	61.249851	307.84175	7388.202
	28	3.61	100.19	28	373.19	1.160	27.281459	137.11661	3290.7987
	29	1.95	99.87	28	372.87	1.156	4.2860822	21.541849	517.00438
	30	3.06	99.41	26	372.41	1.158	16.5963	83.413003	2001.9121
	31	3.06	99.43	27	372.43	1.155	16.544307	83.151685	1995.6404
AUG									
	1	3.34	99.73	28	372.73	1.154	21.507346	108.09592	2594.3022
	2	2.22	100.07	30	373.07	1.151	6.2951822	31.639586	759.35005
	3	2.24	100.16	30	373.16	1.152	6.4726757	32.531668	780.76004
	4	1.79	100.09	30	373.09	1.151	3.300618	16.588906	398.13374
	5	1.11	100.06	30	373.06	1.151	0.7868191	3.954553	94.909272

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	6	1.95	100.18	28	373.18	1.160	4.2993864	21.608716	518.60918
	7	3.06	100.29	28	373.29	1.161	16.631963	83.592248	2006.214
	8	1.95	100.18	28	373.18	1.160	4.2993864	21.608716	518.60918
	9	0.834	100.21	30	373.21	1.152	0.3342371	1.6798758	40.31702
	10	1.39	100.26	30	373.26	1.153	1.5481662	7.7810833	186.746
	11	1.11	100.39	27	373.39	1.166	0.7973082	4.0072711	96.174507
	12	1.39	100.27	29	373.27	1.157	1.5534475	7.8076271	187.38305
	13	1.39	100.2	28	373.2	1.160	1.5575204	7.8280974	187.87434
	14	1.39	100.2	29	373.2	1.156	1.552363	7.8021765	187.25224
	15	1.67	100.23	30	373.23	1.153	2.6840625	13.490098	323.76235
	16	1.95	100.08	30	373.08	1.151	4.2667442	21.444657	514.67176
	17	1.79	100.02	30	373.02	1.150	3.2983096	16.577304	397.8553
	18	1.39	99.99	28	372.99	1.157	1.5542561	7.8116912	187.48059
	19	3.13	99.79	27.78	372.79	1.156	17.723896	89.0803	2137.9272
	20	3.33	99.61	27	372.61	1.157	21.360061	107.35567	2576.536
	21	2.5	99.68	28	372.68	1.154	9.0146666	45.307714	1087.3851
	22	2.5	99.92	32	372.92	1.141	8.9178614	44.821172	1075.7081
	23	1.39	100.09	31	373.09	1.147	1.5404571	7.7423375	185.8161
	24	1.67	100.19	30	373.19	1.152	2.6829913	13.484714	323.63315
	25	2.22	100.14	30	373.14	1.152	6.2995857	31.661718	759.88123
	26	1.39	100.11	30	373.11	1.151	1.54585	7.7694419	186.46661
	27	1.39	100.18	28	373.18	1.160	1.5572095	7.8265349	187.83684
	28	5.28	100.41	26	373.41	1.170	86.118341	432.83078	10387.939
	29	1.67	100.53	28	373.53	1.164	2.7099839	13.620379	326.8891
	30	2.78	100.49	29	373.49	1.159	12.454847	62.598061	1502.3535
	31	2.5	100.42	30	373.42	1.155	9.0216448	45.342787	1088.2269
SEPT									
	1	2.24	100.43	30.56	373.43	1.153	6.4781512	32.559188	781.42051
	2	1.11	100.5	30	373.5	1.156	0.7902791	3.9719426	95.326622
	3	2.5	100.5	28	373.5	1.163	9.0888241	45.68043	1096.3303
	4	2.22	100.44	30	373.44	1.155	6.3184581	31.75657	762.15768
	5	1.95	100.24	32	373.24	1.145	4.2455422	21.338095	512.11428
	6	1.67	100.47	30	373.47	1.155	2.6904895	13.5224	324.5376
	7	1.39	100.62	29	373.62	1.161	1.5588699	7.8348802	188.03713
	8	1.39	100.68	27	373.68	1.169	1.5701981	7.8918159	189.40358
	9	0.834	100.75	28	373.75	1.166	0.338271	1.7001502	40.803606
	10	1.11	100.61	28	373.61	1.165	0.7964008	4.0027105	96.065052
	11	1.11	100.61	30	373.61	1.157	0.791144	3.97629	95.43096
	12	1.67	100.74	30	373.74	1.158	2.6977198	13.55874	325.40975
	13	1.67	100.7	30	373.7	1.158	2.6966486	13.553356	325.28055
	14	1.67	100.4	30	373.4	1.155	2.6886149	13.512979	324.31149
	15	0.834	100.23	30	373.23	1.153	0.3343038	1.6802111	40.325066
	16	0.834	100.21	28	373.21	1.160	0.336458	1.6910378	40.584907
	17	1.67	100.16	28	373.16	1.159	2.7000098	13.570249	325.68598
	18	1.39	100.11	27	373.11	1.163	1.5613085	7.8471364	188.33127
	19	2.22	99.94	28	372.94	1.157	6.3287783	31.80844	763.40255
	20	2.22	100.03	27	373.03	1.162	6.3555925	31.943208	766.63699
	21	1.67	100.12	28	373.12	1.159	2.6989315	13.56483	325.55592
	22	1.95	100.16	28	373.16	1.159	4.298528	21.604402	518.50564
	23	1.11	100.25	28	373.25	1.160	0.7935512	3.9883881	95.721315
	24	1.39	100.43	30	373.43	1.155	1.5507913	7.7942768	187.06264
	25	1.67	100.63	30	373.63	1.157	2.6947741	13.543935	325.05443
	26	1.67	100.7	30	373.7	1.158	2.6966486	13.553356	325.28055
	27	1.39	100.64	28	373.64	1.165	1.5643598	7.8624722	188.69933
	28	1.39	100.47	27	373.47	1.167	1.566923	7.875355	189.00852
	29	1.34	100.12	26.67	373.12	1.164	1.4004902	7.0388638	168.93273
	30	0.56	100.07	28	373.07	1.158	0.1017161	0.511225	12.2694
OCT									
	1	1.11	100.29	26	373.29	1.169	0.7991779	4.0166683	96.40004
	2	1.11	100.63	27	373.63	1.169	0.7992143	4.0168512	96.404429
	3	1.95	100.76	28	373.76	1.166	4.324278	21.733821	521.61171
	4	2.5	100.71	28	373.71	1.166	9.1078157	45.775882	1098.6212
	5	2.22	100.61	30	373.61	1.157	6.3291524	31.81032	763.44768
	6	1.95	100.64	30	373.64	1.157	4.2906189	21.564651	517.55161
	7	0.834	100.76	30	373.76	1.159	0.3360716	1.6890958	40.538298
	8	1.39	100.85	28	373.85	1.167	1.567624	7.8788784	189.09308
	9	1.39	100.85	28	373.85	1.167	1.567624	7.8788784	189.09308
	10	1.67	100.9	28	373.9	1.168	2.719958	13.670509	328.09221
	11	3.06	100.61	27	373.61	1.169	16.740649	84.1385	2019.324
	12	6.67	99.59	24	372.59	1.168	173.35042	871.2592	20910.221
	13	8.9	99.87	26	372.87	1.164	410.22487	2061.7902	49482.965
	14	3.89	100.46	29	373.46	1.159	34.113254	171.45321	4114.8771
	15	0.834	100.8	28	373.8	1.167	0.3384389	1.700994	40.823856
	16	0.834	100.8	28	373.8	1.167	0.3384389	1.700994	40.823856
	17	0.56	100.94	28	373.94	1.168	0.1026004	0.5156695	12.376069
	18	0.834	101	28	374	1.169	0.3391104	1.704369	40.904856
	19	0.834	101.05	28	374.05	1.170	0.3392783	1.7052127	40.925106
	20	0.834	100.98	29	373.98	1.165	0.3379206	1.698389	40.761336
	21	1.39	100.88	27	373.88	1.172	1.5733173	7.9074929	189.77983
	22	2.22	100.99	24	373.99	1.185	6.4814019	32.575526	781.81263
	23	3.06	101.07	24	374.07	1.186	16.987059	85.37696	2049.047
	24	2.22	101	25	374	1.181	6.4602919	32.469427	779.26625
	25	2.22	100.87	24	373.87	1.183	6.4737005	32.536819	780.88365
	26	1.11	100.9	25	373.9	1.180	0.8067369	4.0546599	97.311837
	27	1.67	100.95	23	373.95	1.188	2.7672738	13.908318	333.79964
	28	1.39	100.95	26	373.95	1.176	1.5796746	7.9394447	190.54667
	29	1.11	101.19	26	374.19	1.179	0.8063497	4.0527138	97.265131
	30	6.12	101.33	28	374.33	1.173	134.43549	675.67275	16216.146
	31	1.39	101.41	24	374.41	1.190	1.5975588	8.0293303	192.70393
NOV									
	1	1.11	101.4	26	374.4	1.182	0.8080232	4.0611244	97.466986
	2	0.56	101.36	26	374.36	1.181	0.1037164	0.5212788	12.510692

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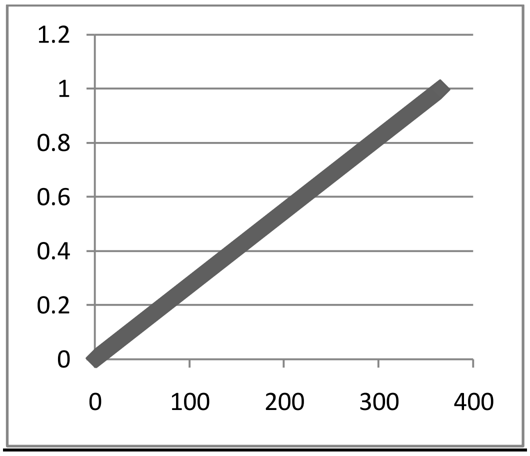
	3	0.834	101.47	25	374.47	1.186	0.3441182	1.7295381	41.508915
	4	0.834	101.59	24	374.59	1.192	0.3456852	1.7374138	41.69793
	5	1.11	101.59	24	374.59	1.192	0.8149886	4.0961329	98.30719
	6	1.11	101.54	25	374.54	1.187	0.811854	4.0803782	97.929078
	7	1.11	101.4	24	374.4	1.190	0.8134644	4.0884721	98.123329
	8	1.11	101.3	24	374.3	1.188	0.8126622	4.08444	98.026561
	9	1.11	101.26	24	374.26	1.188	0.8123413	4.0828272	97.987853
	10	1.11	101.23	24	374.23	1.188	0.8121006	4.0816176	97.958823
	11	1.67	101.11	24	374.11	1.186	2.7623276	13.883458	333.203
	12	1.34	101.21	22.78	374.21	1.192	1.4343566	7.2090761	173.01783
	13	1.67	101.21	23	374.21	1.191	2.774401	13.94414	334.65935
	14	1.39	101.3	22	374.3	1.196	1.606645	8.074998	193.79995
	15	1.11	101.34	22	374.34	1.197	0.8184948	4.1137549	98.730118
	16	1.11	101.43	22	374.43	1.198	0.8192217	4.1174083	98.8178
	17	1.67	101.4	24	374.4	1.190	2.7702504	13.923279	334.15868
	18	1.39	101.43	24	374.43	1.190	1.5978738	8.0309139	192.74193
	19	1.95	101.38	22	374.38	1.197	4.4393789	22.312318	535.49564
	20	1.79	101.21	23.33	374.21	1.190	3.4126756	17.152107	411.65058
	21	2.22	101.14	22	374.14	1.195	6.5350357	32.845089	788.28215
	22	1.95	101.31	25	374.31	1.185	4.3916528	22.072447	529.73872
	23	0.278	101.34	25	374.34	1.185	0.0127288	0.0639749	1.5353976
	24	1.11	101.26	26	374.26	1.180	0.8069075	4.0555173	97.332416
	25	1.39	101.08	24	374.08	1.186	1.5923601	8.003202	192.07685

	18	0.834	101.26	22	374.26	1.196	0.3468983	1.7435108	41.84426
	19	1.11	101.31	22	374.31	1.197	0.8182525	4.1125371	98.70089
	20	1.39	101.46	23	374.46	1.194	1.6037463	8.0604287	193.45029
	21	1.11	101.58	22	374.58	1.200	0.8204332	4.1234974	98.963937
	22	1.11	101.73	22	374.73	1.202	0.8216447	4.1295864	99.110074
	23	0.834	101.76	22	374.76	1.202	0.3486112	1.7521199	42.050878
	24	1.34	101.78	21.11	374.78	1.206	1.450625	7.2908413	174.98019
	25	0.834	101.78	23	374.78	1.198	0.3475017	1.7465438	41.917051
	26	0.834	101.68	22	374.68	1.201	0.3483371	1.7507425	42.017819
	27	0.9	101.61	21.67	374.61	1.201	0.4379416	2.2010943	52.826263
	28	0.834	101.58	22	374.58	1.200	0.3479946	1.7490206	41.976496
	29	0.834	101.55	22	374.55	1.199	0.3478918	1.7485041	41.964098
	30	1.67	101.7	22	374.7	1.201	2.7972833	14.059146	337.4195
	31	1.39	101.76	22	374.76	1.202	1.6139408	8.1116663	194.67999

D. RESULTS OBTAINED:

Graph between Speed(m/sec) & Probability, F(U):

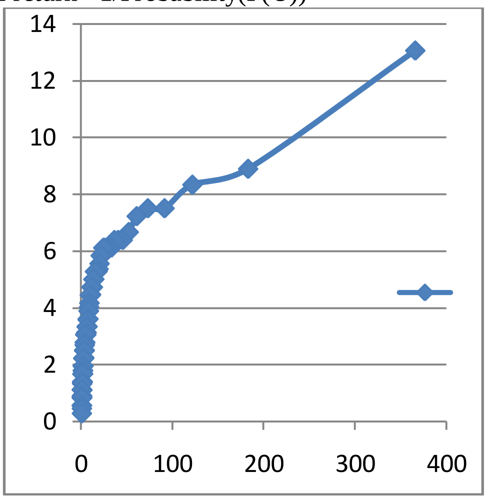
It includes in Y-axis the daily speed in descending order and in X-axis the probability obtained from equation F(U)= speed/(N+1), where N=No. of days. For yearly calculation, N=365.



Graph between Speed(m/sec) & Rate of return:

It includes in Y-axis the daily speed in descending order and in X-axis the rate of return.

Rate of return= 1/Probability(F(U))



Histogram & Approximate graph between Freq. & Energy for 1 year:

Wind velocity are assigned to 'k' equally distribution classes of width Δv=1m/sec with centre values of vi(i=1...k).

hi= Relative frequency of wind velocity in the period under consideration and is equal to

hi= ti/T; T=365 days

The graph includes 'hi' in X-axis & speed(m/sec) in Y-axis.

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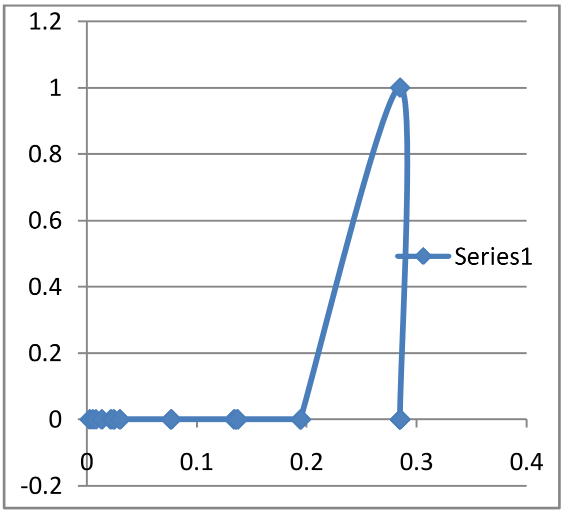


E. DIFFERENT PARAMETERS CALCULATION:

The average wind speed & average power from the yearly data of 2013 is obtained as 2.197m/sec & 6.617KW respectively.

TABLE II
RELATION BETWEEN ROTOR DIAMETER, ROTOR SPEED & RATED POWER

SL.NO	FEATURES	SMALL		MEDIUM			LARGE			VERY LARGE		
1	RATED POWER(KW)	10	25	50	100	150	250	500	1000	2000	3000	4000
2	ROTOR DIAMETER(m)	6.4	10	14	20	25	32	49	64	90	110	130
3	ROTOR SPEED(RPM)	200	150	100	67	55	43	29	19	15	13	11

In order to get suitable rotor speed in Bhubaneswar whose average wind speed is 2.197m/sec, the rotor diameter is considered to be 6.4m which comes in the range of small wind turbine. Hence, the rated power we can get is 10KW.
The maximum torque developed on any ideal turbine would occur if maximum circumferential force acts on the tip of blade with radius R.

Tm= (Po*R)/ uo

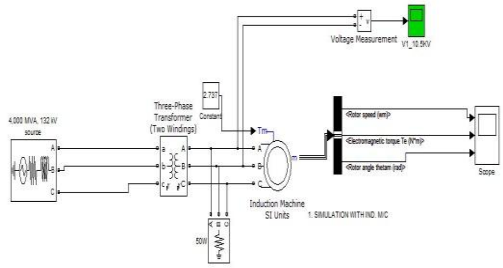
I
n this case, Tm= (6.617*6.4)/2.197= 19.276Nm.
Practical Observations indicates Tip Speed ratio, TSR= (4∏/n), where n =No. of blades.
For a 3-bladed turbine, TSR=(4*3.14/3) =4.186.
For a practical machine where circumferential force is not concentrated at the tip but spread through the length of the blade, less shaft torque will be produced which is given by

Tsh=CT*Tm

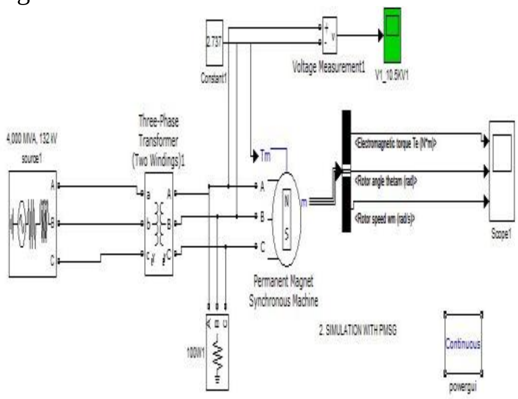
where CT=Torque Coefficient & is gievn by
CT=Cp/TSR. Maximum CT=Cpmax/TSR
= 0.593/4.186= 0.142
Hence, Tsh= 0.142*19.276= 2.737Nm

This can be used as an input to various types of generators simulation to get the desired output parameters like voltages & current.

F. SIMULATION WITH DIFFERENT GENERATORS:



(Fig.1. SIMULATION WITH IND. GENERATOR)

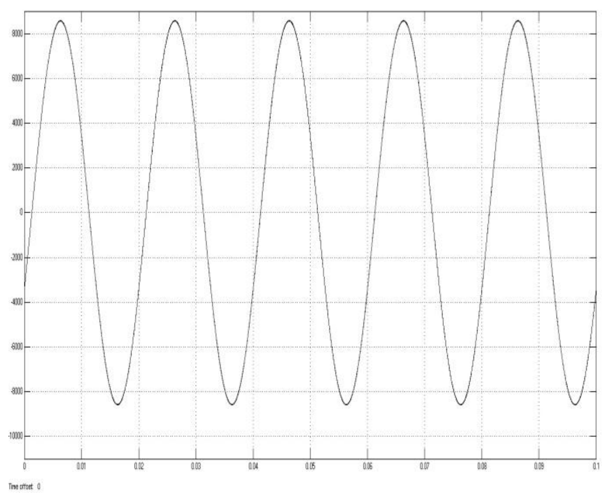


(Fig.2. SIMULATION WITH SYN. GENERATOR)

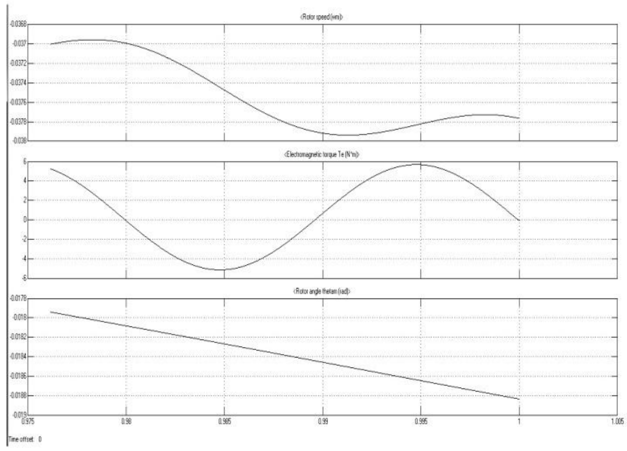
G. RESULTS OBTAINED WITH DIFFERENT GENERATORS:

The result includes the Voltage generated & Other parameters like electromagnetic torque(Nm), rotor speed(rad/sec), rotor angle(rad).

SIMULATION WITH IND. GENERATOR

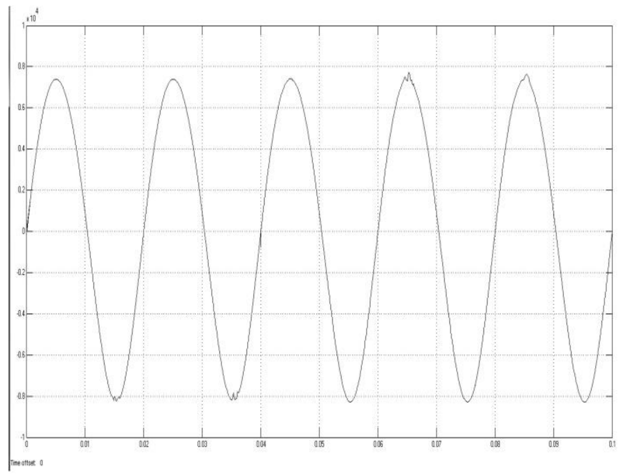


(Fig.3. Obtained Voltage)

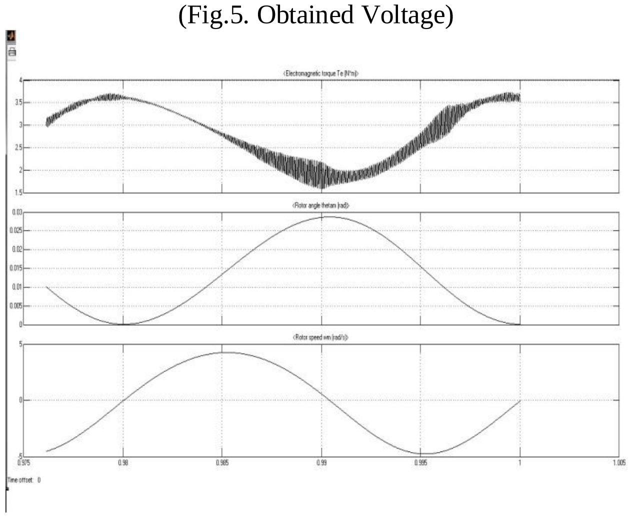


(Fig.4. Other Parameters)

SIMULATION WITH SYN. GENERATOR



(Fig.5. Obtained Voltage)



(Fig.6. Other Parameters)

IV. WIND ENERGY AND THE ENVIRONMENT

A. POSITIVE BENIFITS OF WIND ENERGY

It doesn't involves combustion or nuclear reaction, it is pollution free. It is renewable and plentiful. It can be installed in remote areas, in mountains and coastal regions. It omits the release of GHG associated with fossil fuels. The general equation for estimating the reduction in emitted gas is:

Gas emission reduction(in tonnes)= A*0.8*h*KG

where A=rated capacity of development in KW, h=No. of operational hrs per year=8760hrs, KG=specific gas constant.

A=10KW;

CO_2 emission reduction(in tonnes)=
10*0.8*8760*862/1000000= 60.4

SO_2 emission reduction(in tonnes)=
10*0.8*8760*9.9/1000000= 0.693

NO_2 emission reduction(in tonnes)=
10*0.8*8760*2.8125/1000000= 0.0197

B. NEGATIVE IMPACTS OF WIND ENERGY

NOISE:

The moving parts in wind turbine creates noise. Well developed technology and well designed wind turbines are generally quiet in operation compared to noise of road traffic, trains, aircrafts etc.

TABLE III
DIFF. SOURCES & THEIR NOISE LEVELS IN DB

SOURCE/ACTIVITY	INDICATIVE NOISE LEVELdB(A)
Threshold of hearing	0
Rural night time background	20-40
Wind farm at 300m	35-45
Car at 40mph at 100m	55
Busy general office	60
Truck at 30mph at 100m	65
Pneumatic drill at 7m	95
Jet air craft at 200m	105
Threshold of pain	140

There are two potential sources of noise related to wind turbines; the turbine blades passing through the air as the hub rotates and the gearbox and the generator. Noise from the blades is minimised by careful attention to the design and manufacturer of the blades. The noise from the gearbox and generator is controlled using the sound insulation and isolation materials.

OTHER FACTORS

Other factors which are associated with wind energy are Bird kill, Visual impacts, Shadow flicker & communication interference.

A number of national wind energy associations have established detailed best practiced guidelines for development of wind farms including visual impacts.

V. CONCLUSION

In this paper, a detailed analysis of wind energy parameters at a specified location are presented and different constraints affecting it are figured. Then, an yearly data in that location is obtained and various calculations are done. Then, it is simulated & results are studied. Its affect on the environment is also taken into account.

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