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Calculation of power generation by rooftop wind turbine an experimental study

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Abstract

Background/Objectives: This article outlines the analysis of the power load data as well as the effect of various atmospheric parameters on the power generation.
Methods/Statistical analysis: A yearlong (2013) daily data was measured for a small scale wind turbine. The following criteria had been taken into consideration for the assessment - calculation of daily power generation, plotting graphs of power generation versus wind speed, temperature, air density and energy per swept area. Following this, a meticulous analysis of all the components was also gauged.
Findings: The power generation is proportional to the wind velocity, temperature and air density. The wind velocity and swept area is more profound effect on the power generation. The small scale is more useful in places such as Resorts, hotels, monuments and areas that demand pollution free atmosphere.

Keywords: Renewable energy; Wind power generation; turbine; atmospheric parameters

1. Introduction

In contemporary years, the wind energy technology becomes the only apt resolution to the speedy and effluence free production of energy also it is a promising alternative to the conventional energy system. Where one-third of the world's people have been living deficient of electricity, wind energy systems seem to have been making a momentous role in everyday life to develop countries [1,2]. Small to medium-scale wind energy generation procedures are most aptly favored in the Universities, peripheral and environmentally sensitive areas such as World Heritage locations and national parks [3]. As compared to other mainstream accommodations, the visitors to the Heritage centers and other such sectors have great expectations about the 'environmentally friendly' energy source and are cognizant of its greenhouse gas (GHG) emissions [4]. The exhaustion of fossil fuels as well as the gradual upcoming realization about environmental degradation has given precedence to the utilization of conventional and renewable alternative energy sources which are solar, wind and solar-hydrogen energy [5]. Furthermore, the noteworthy here is the fact that, in growth with other kinds of generating plants, the so-called "energy payback time" is less for wind energy, as it varies from a few months to one year at most, as it relies on the size of the wind turbine. While a machine has functioned for this period, it has fabricated enough energy to produce another wind turbine akin to it [6]. The wind energy potential is colossal to serve the world's electricity needs. Roughly about every country has establishes with regular wind speeds of more than 5 m/s measured at a height of 10 m, which are passable for growth [7]. Yet, as the cost of investment and maintenance is considered the power generation by small wind turbine will not diminish much pollution [8], and small businesses are the opinion of expensive [9]. Many a times like accommodation are in remote this type of standalone power generation is useful [10] and have proven that diesel gen-sets are more proficient and more reliable to maneuver [11]. Many installations of small scale power generations are made in Greece for the accommodation of tourists' which have been successful and economically viable [12]. In the Russian part Alaska is suffering from power supply, since long time due to the system short comings. There is frequent power failure in the system. The Alaska-sponsored PCE (power cost equalization) arranges subsidies for development energy for urban areas and supported for wind, renewable energy projects [13]. At different wind

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speeds and load the wind turbines are tested for Dynamic performance investigation of Wind Turbine (WT) implementing Permanent Magnet Synchronous Generator (PMSG) using active and reactive power. The detail data are validated using Mat lab/Simulink software [14]. The reason behind the development of renewable energy is due to the global pressure towards the development towards clean energy [15]. India is in need of huge amount of energy, development in the renewable energy is essential [16].

1.1. Importance of wind turbine as alternate sources of energy

Wind gets its movement as an upshot of its energy. Whichever device is proficient of slowing down the mass of moving air can haul out part of the energy and thus this energy can be toggled into useful work. Following aspects direct the output of wind energy converter: The wind speed, cross-section of the windswept by rotor, conversion efficiently of rotor and generator transmission system. By arresting and averting the channel of air through the rotor hypothetically it is feasible to get 100% efficiency. However in reality, a rotor is proficient to slow down the air column merely to one third of its free velocity. A competent wind generator is capable to switch maximum up to 60% of the accessible energy in wind into mechanical energy. Additionally, owing to the losses incurred in the generator or pump the whole efficiency of the power generation can go down to, say, 35% [17].

1.2. Wind turbine technology

The progress of a general probabilistic model of an autonomous wind energy alteration system is elucidated. It consisted of a compilation of several wind turbines attached to load and battery storage and to appraise the energy acquired from or injected to the grid in the case of grid-connected systems [18]. The advancement of the technology of wind turbines and a variety of parameters related to the wind energy conversions are evaluated [19]. It has been examined the study and development of technology of wind turbines and its effect on the cost of wind energy systems. In addition to this, the gap amid the theoretical research and practical implementation had been scrutinized and the setbacks connected with this have been summarized as well [20].

1.3. Wake effect

The wake effect necessitates the study about the different models like dynamic inflow, Coleman's model and Yaw Dyn's model. These models offer the knowledge about the exact calculation of both magnitude and location of thrust on the disk of rotor [21]. Intended for the horizontal axis, wind turbine numerical technique calculation is used to analyze the wake structure [22]. A numerical model is illustrated to uncover the flow field in wind turbine wake [23]. Vindeby off shore wind farms have been assessed with single, double and quintuple wake cases [24]. Six wake models are used to calculate the presentation of wind farm as a result of wake amid that; one is aero elastic model [25].

1.4. Design

There are fairly a few features of the techniques recently used for the design calculation of wind turbine production and loading. Diverse types of examinations and techniques for the design of wind turbine systems have been examined in this writing in a widespread method. A small capacity stand-alone of 5 KW pilot plants is constructed and tested for severe cold conditions [26]. Hybrid wind-solar pilot plant design is tested for optimization of wind power [27]. All over the world, the design wind loads are considered on the basis of load owing to the force of the wind imminent on the wind turbine structure [28].

1.5. Loads

A wind turbine should be examined for gravitational loads, aerodynamic loads, operational loads and inertia loads that it will encounter during its design life as part of the design process. Investigators had created a variety of mathematical models for the estimation of structural loads and material stresses. Few mathematical models are briefly discussed here. Cluster examination method was applied in 2002 to come across the local wind patterns for modeling renewable energy systems, which sturdily depended on the load of the wind [29]. A probabilistic technique was applied to resolve the intense response of pitch regulated wind turbine caused by wind speed gusts. To design the consistent and optimized wind turbine, the extreme loading was considered [30]. Angular velocity was studied in

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case of small wind turbine, which helped to design stronger wind turbine than the traditional one [31]. Wind turbine working in wind farm's effects and conclusions were drawn from the structural loads [32]. Gust's Model explains design of wind turbines especially for pattern of wind loads and the origin of wind loads [33]. A different method is applied for mutually loading in operating as well as in rest condition [34].

1.6. Blade

In 1984 the progress of special purpose aero foil for (Horizontal Axis Wind Turbine) HAWT started. New aero foils were developed as per the demands of wind turbine. This was resulted in a superior effectiveness of energy capture. The diverse methods that had been created by many researchers for design, testing, fatigue strength and examinations of wind turbine blades have been reviewed. As the airfoils were concerned, the earlier ones were of low lift-to-drag ratio with moderate power coefficient, whereas modern airfoils had higher lift-to-drag ratio and increased power coefficient of about 0.5 and it increased the efficiency to about 20% [35]. National Renewable Energy Laboratory (NREL) conducted single axis fatigue test and two-axis fatigue on wind turbine blades. This test concluded that the damage was observed in the single-axis test [36]. Carbon fiber coated wind turbine blades were more cost-effective. Fatigue strength for the stud joint boosted by 20% when a restricted number of carbon fiber layers were applied. Thus, the total costs of the turbine can be decreased by 4–5% [37]. With the use of computer software, blades fatigue strength built up in the blade can be analyzed. This test revealed that the ultimate load bearing capacity of blade is 2.8 times the required strength [38]. To design the composite blades in the beginning stage, the automated technique was developed. This technique permitted arbitrary specification of the chord, twist, and aero foil geometry along the blade and an arbitrary number of shear webs [39]. On seven aero foils, aero acoustic tests were conducted. When the Aero acoustic tests of seven aero foils in wind tunnel had been performed, the test revealed that the trailing edge noise was in the central of tunnel flow and the leading edge noise was central in turbulent flow [40]. Acoustic emission monitoring test was conducted on small wind turbine blades. The test disclosed an audible cracking sound from the blade and spotted the damage area of failure [41]. The drag in the blade depended on the tapering and twisting of the blades. The augment in the drag would lead to the tip effect [42]. The design of wind turbine blade and their tower is correlated using finite element analysis [43]. The blade designs have been assessed on the basis of power performance, weight, static strength in flap-wise bending, fatigue life in edgewise bending, and tip deflection under design loads [44]. The damage analysis of wind turbine blades needs a detailed description of the fatigue load spectra and the fatigue behavior of blade material [45]. On the wind turbine all the tests are conducted at significant position such as static and dynamic fatigue tests, the failure wind speed is 130 m/s and safest is75 m/s [46]. The power pulsation occurs due to the effect of wind shear, turbulence intensity, wind speed, rotor position and tower oscillation. This pulsation is periodic [47]. Recent blades made from carbon or glass-carbon hybrids are not only lighter and good in performance but also low in installation cost [48]. The three-bladed rotor has a steady motion and is visually the most suitable one [49].

1.7. Gearbox

Compact spur gear sets are preferred for minimizing the gear size in the wind turbine. A Range of dynamic rating factors were examined and evaluated for this purpose. The results concluded that, if the bending stress exceeds the normal value of fatigue strength; the gear tooth had every chance of failure [50]. In Ramco Wind power Farm, it had been observed that, the gearboxes habitually break down after 23000/30000 hours of operations. To reduce the crash of gear box a scientific approach is developed [51].

1.8. Generator

For converting mechanical energy into electrical power the electrical system of the wind turbine contains all components. A concise review of the generator has been dealt here.

Self-exited induction generators are preferred for wind power generation because it delivers the demand load [52]. For residential electricity the computer based simulation models are used to design the parameters like inverter and storage components to fix up the wind-energy conversion system [53]. In the wind generator the broken bars can be observed due to the startup current transient [54]. Variety of stator faults are observed with their reasons, detection parameters/ techniques, and the trends in the technology [55]. Fluctuation of voltage in case of induction

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type wind generator in even speed generator is observed ranging from (2.5% - 9.5%) and in case of uneven speed generators from (6% – 12%).

1.9. Transformer

In the power system, transformer is a combined part. In the wind power projects, the transformer is used to interlink the turbine generator and the utility grid. The exercise of high-efficiency transformers is made up of amorphous metal to cut electrical losses. The transformer can be improved in a number of ways for instance, size of a transformer being fixed in the network and also a change in the way they are loaded can really boost savings. It is roughly estimated that about 50% of the transformers are at utmost effectiveness [56].

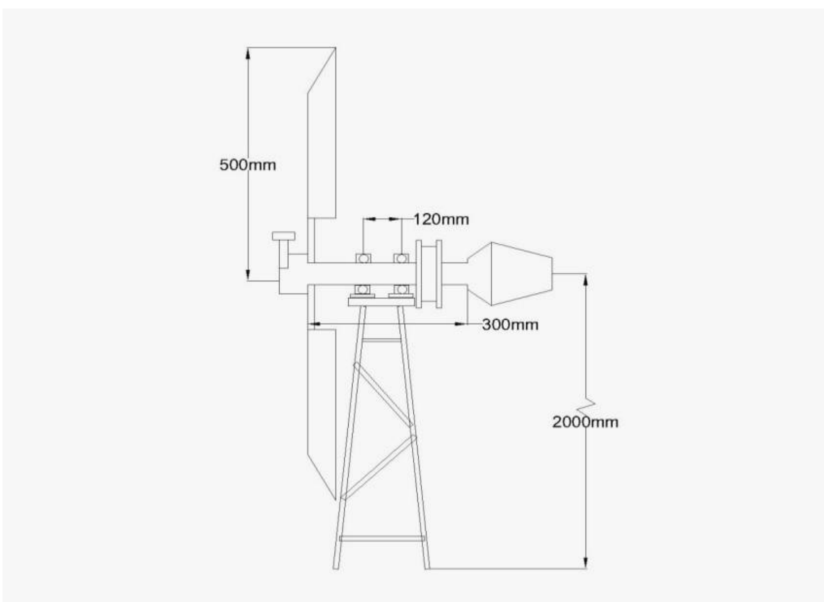
2. Case study

In this work we have selected the site on the roof of Dr Babasaheb Ambedkar Technological University, Lonere, Taluka Mangaon, and District Raigad. with wide variation of wind speed (from 3 – 8 m/s), longitude and latitude of the site is (18.1684° N, 73.3356°E) and The University is located at Lonere, the place in the ranges of Western Ghat, at the foot of Raigad fort. Here the wind is less because it is surrounded by the mountains on all sides.

3. Methodology

The average temperature of the site is 35 °C in summer and 20 °C in winter which is at a mean sea level (MSL) of 12 m. The average total rain fall during monsoon (June – September) is 1424 mm. The average percentage of humidity is 78 %, pressure 1013 mb, cloud cover 6%, visibility 10 km.The setup is as shown in figure 1 and their details are in table 1.

Figure 1. Sketch of roof top wind turbine installed on university roof



The data pertaining to various parameters and power generated found the particular turbine was measured and calculated for one complete year (January – December 2013). Parameters like average temperature, average velocity and average density were calculated along with rpm of impeller. From this the average energy sample calculations for the month of January are shown below. Also since power generation depends on factors like wind speed, air temperature and air density, so effect of these on power generation were plotted (figures 2 - 7). The monthly average values are shown in Table 2.

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Table 1. Specifications of wind turbine

Turbine Detail: Rotor diameter: 1.0 m, Hub diameter: 200 mm, Effective diameter of blade: 800 mm, Radius blade: 500 mm, Sweptarea:3.14 m^2
Generator: Generator Type: 1 Speed generator, water cooled, Rated power :1650 KW, Synchronous Speed:1200rpm, Apparent Power:1808KVA, Rated current:1740A,
Rotor: Number of blades:3 pcs equally spaced of 1.0 m diameter.
Blades: Type: GI sheet, material of 2 mm thickness: Type of rotor air brake: full blade, Ball bearing, Twist: 20^{o}, Standard color: red.
Hub: Type: Spherical, Material: cast iron, 200 mm diameter.
Tower: Type: steel truss of height 3.0 m above ground level.
Foundation: Type: Pad / Pedestal, Material: Steel truss, grouted on slab with bolt.

Figure 2. Effect of Wind speed on Power Generation for (a) January, (b) February, (c) March, (d) April, (e) May, (f) June, (g) July, (h) August

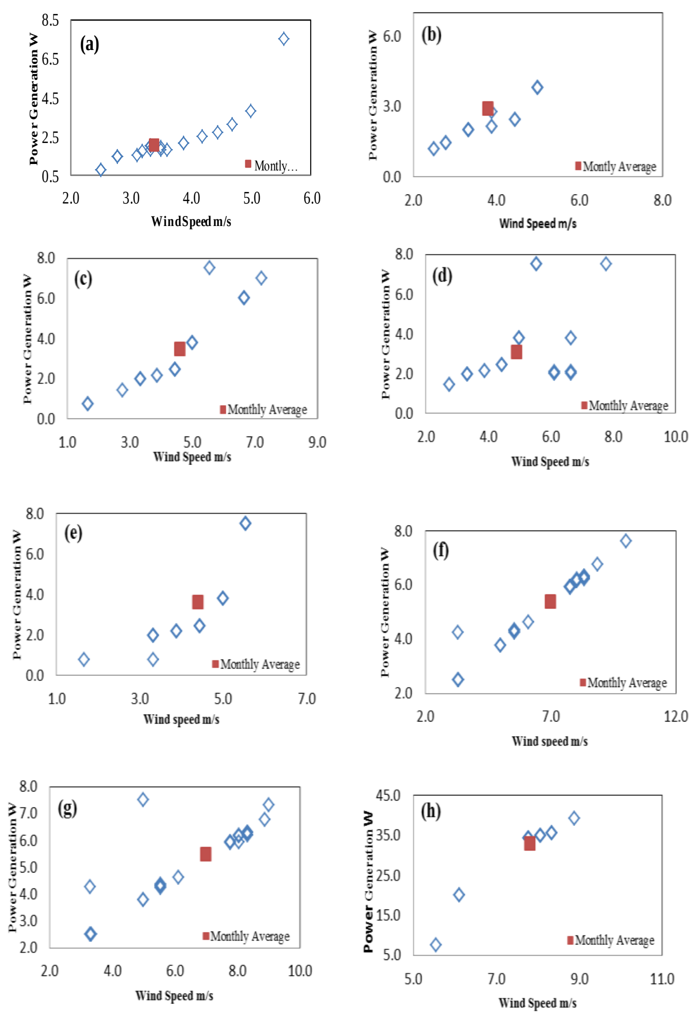

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Table 2. Monthly average speed, temperature, air density and power generation for the year 2013

Month	speed m/s	Temperature °C	Air Density (kg/m^3)	RPM of Impeller	Voltage	Current ampere	Power watt
January	3.4	26.5	1.46000	37	1.68	1.16	2.0
February	3.8	35.7	2.11000	43	1.83	1.37	2.9
March	4.6	30.5	1.52000	65	2.65	2.08	3.5
April	4.9	29.0	1.43000	71	2.9	2.31	3.1
May	4.4	30.9	1.51000	54	2.03	1.62	3.6
June	7.0	23.6	1.09000	116	5.22	4.12	5.4
July	7.0	23.6	1.10000	134	6.19	4.9	5.5
August	7.8	25.5	1.15000	137	6.41	5.07	33.0
September	4.5	24.8	1.33000	54	2.01	1.67	3.6
October	4.7	25.8	1.18000	55	1.93	1.65	3.3
November	4.7	25.6	1.18000	50	1.83	1.58	2.9
December	5.3	24.6	1.23000	74	2.54	2.15	5.7

Figure 3. Effect of Wind speed on Power Generation for (i) September, (j) October, (k) November, (l) December

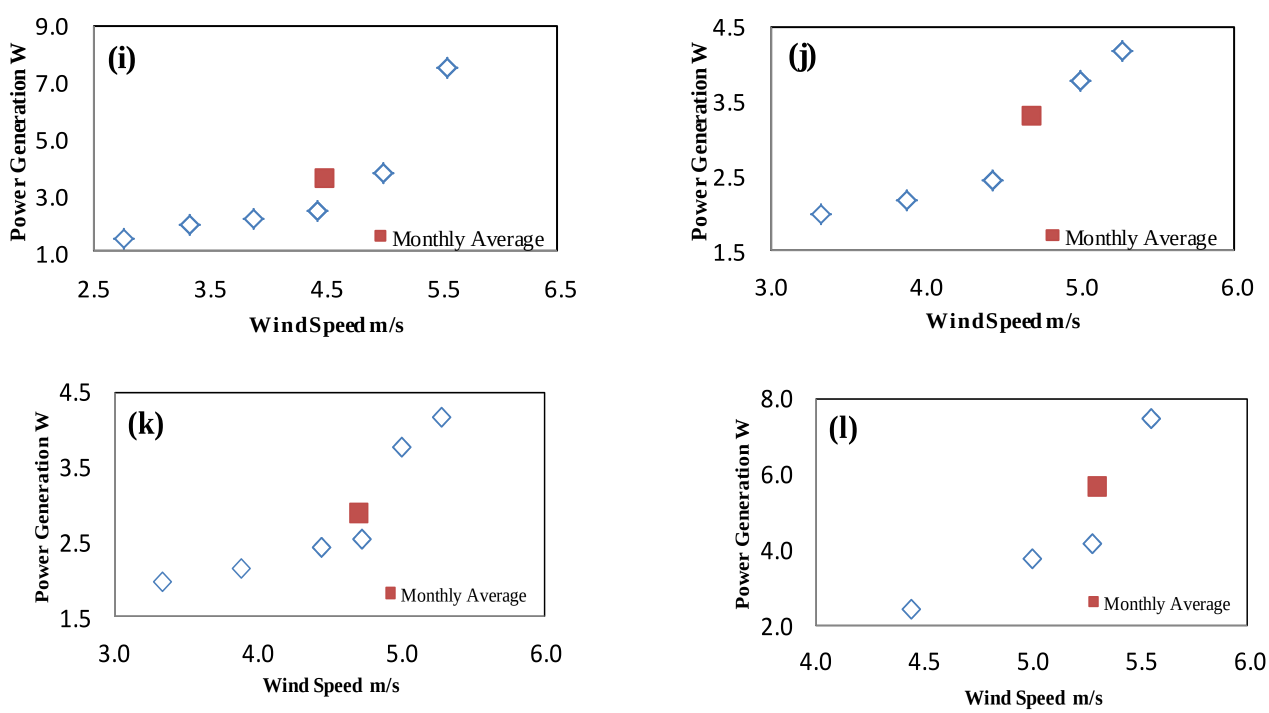

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Figure 4. Effect of Temperature on Power Generation for (a) January, (b) February, (c) March, (d) April

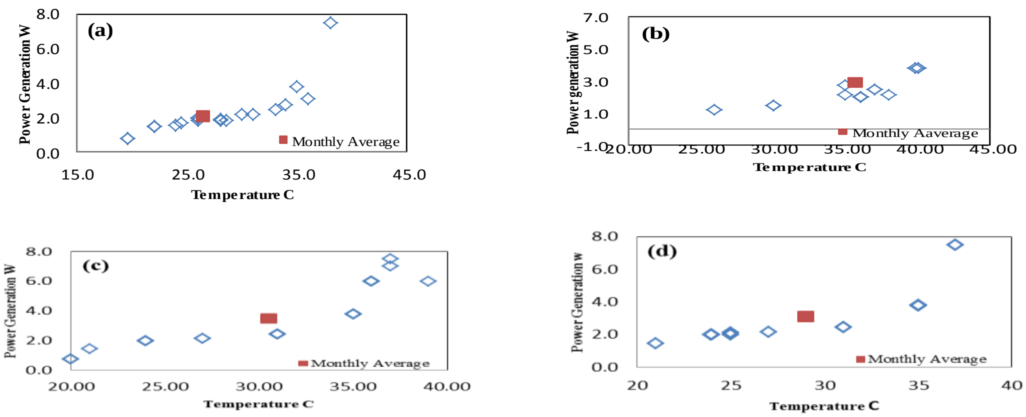

Figure 5. Effect of Temperature on Power Generation for (e) May, (f) June, (g) July, (h) August, (i) September, (j) October, (k) November, (l) December

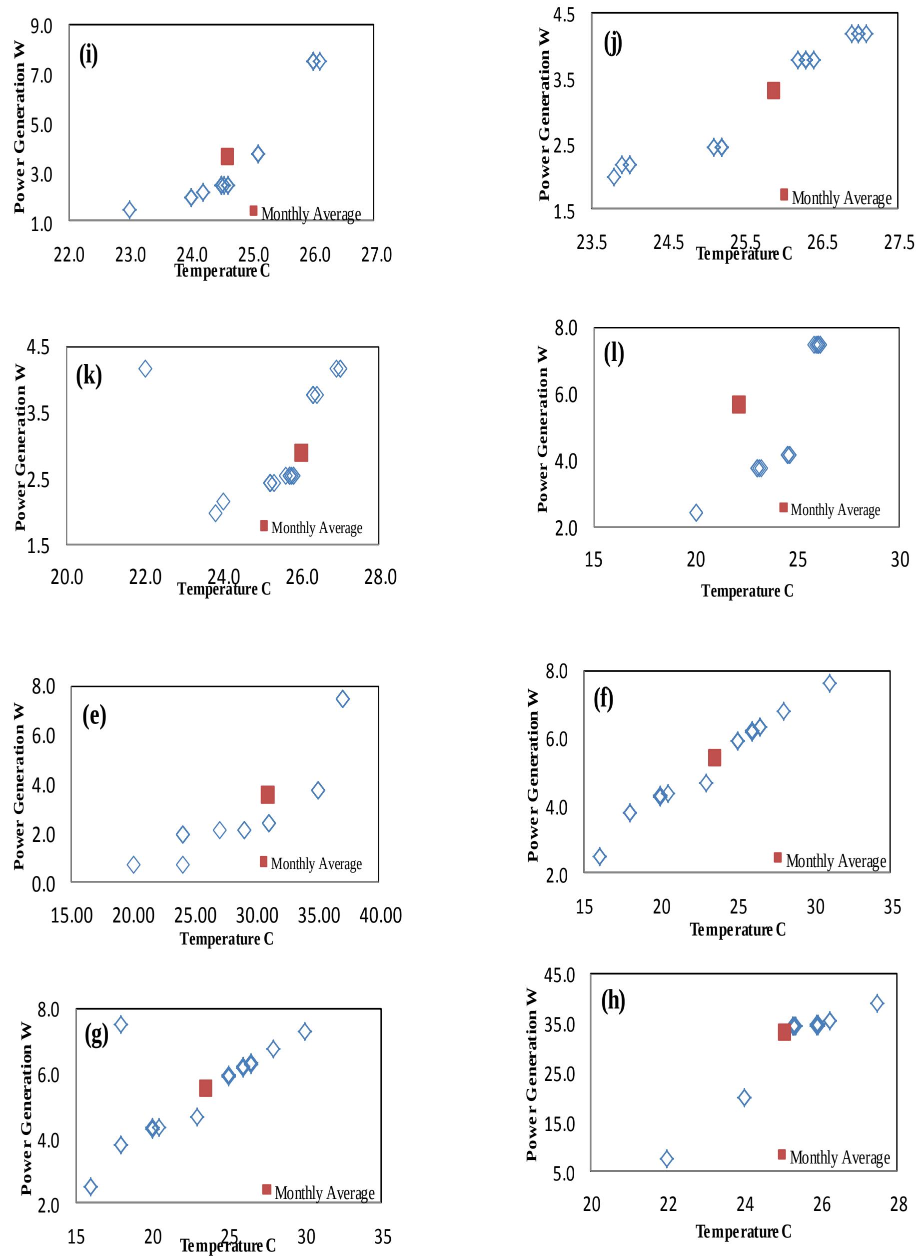

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Figure 6. Effect of Air Density on Power Generation for (a) January, (b) February, (c) March, (d) April, (e) May, (f) June, (g) July, (h) August

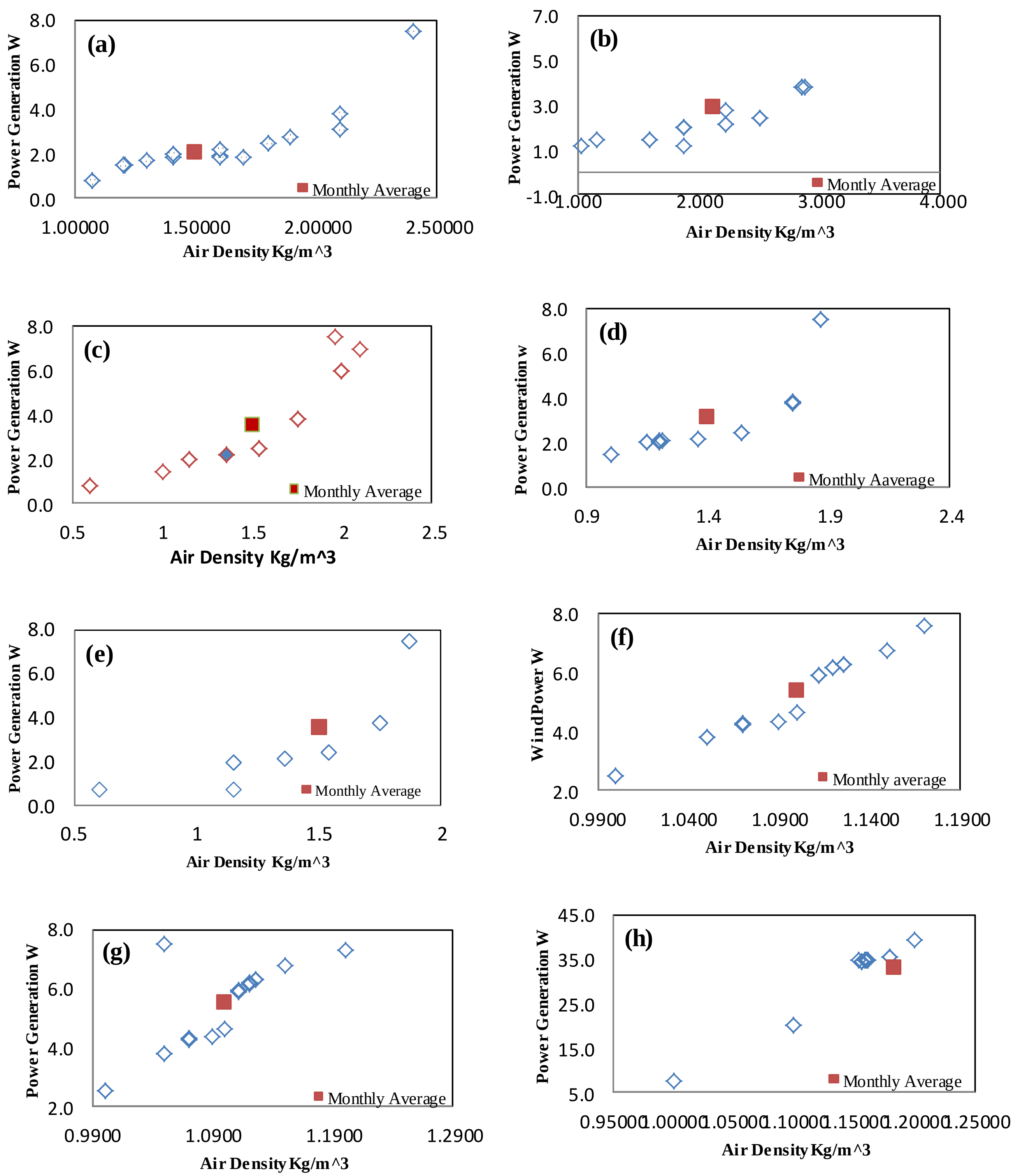

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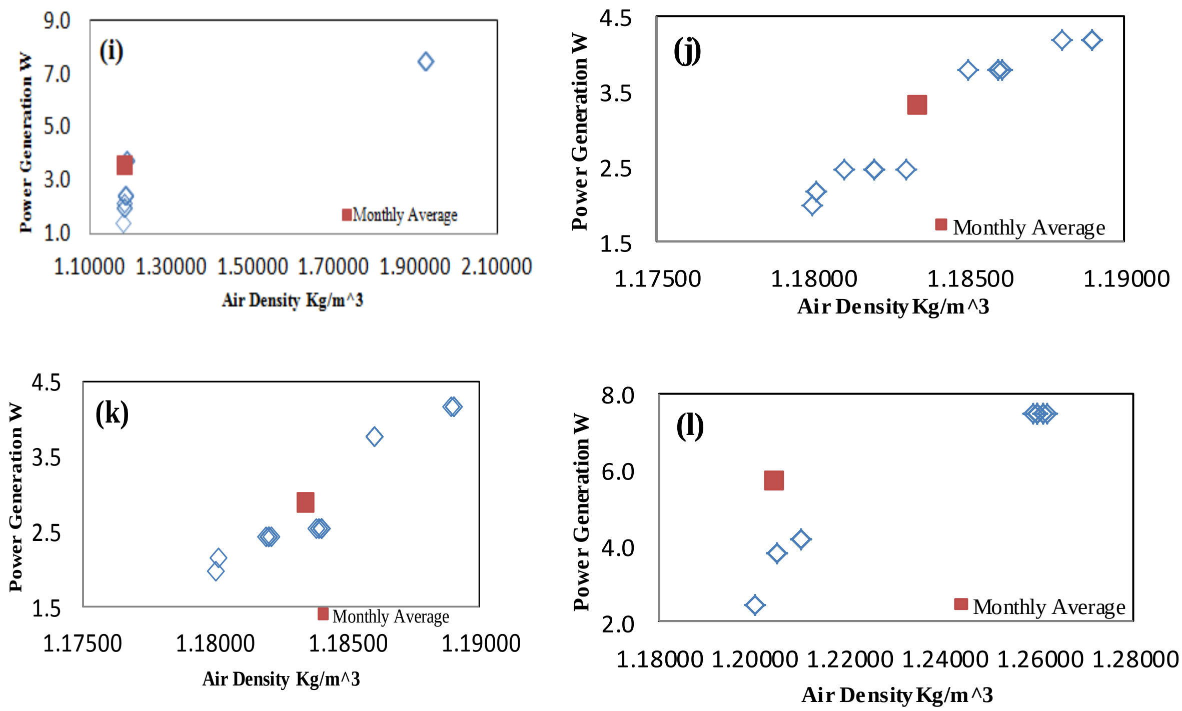
Figure 7. Effect of Air Density on Power Generation for (i) September, (j) October, (k) November, (l) December



4. Results and discussion

The power generation for the entire year 2013 was monitored with special emphasis given to understanding and interpretation of the effect of various parameters on power generation (Fig. 1 to 6). Three such factors have been identified, namely wind speed (m/s), temperature of air (ºC) and density of air (Kg/m^3). The natural variation of these parameters has been recorded, plotted and analyzed for one entire year 2013. The following can be observed:

1. When wind speeds are larger, large power generation is doable. This is palpable especially in the months of June, July and August. Very low power generations have been observed in September and November where wind speeds are quite low. According to Betz's law, the power generation is proportional to 3rdpower of wind speed. For this reason in comparison with any other parameter effect of wind speed will preponderate the power generation.
2. In the month of June-August, it is observed that air density is comparatively large with the corresponding augment in power generation. Air density is also large in September-December, but the wind speed is low and hence the power generation values are low.
3. The observance of effect of temperature on power generation emphasized that on dry days (non-monsoon period) higher temperature caused more power generation. However since the variation of temperature throughout the year is only marginal (20 ºC to 39 ºC) no profound effect was noted. In countries with severe winters, temperatures become very vital parameters. It is also evident that in tropical countries like India, in parts of the Western Ghat of Maharashtra, where the climate is more hot than cold throughout the year, the upshot of temperature is not seen much.
4. The Betz's equation P = 1/2 ρAV^3Cp Watts indicates that wind velocity will have most profound effect on power generation, since the velocity has an index of 3 (V^3).This has also reflected in this work to be factual.

5. Conclusion

The performance and economic viability of a stand-alone wind turbine has been investigated using a small scale rooftop model. The case studies demonstrated that RES is technically feasible and economically viable for small scale

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pollution free energy generation. These small scale installations can be utilized for small bulbs, fans etc. in class rooms, canteens. Another important observation made is with extensive analysis on the year-long data by using the power curve is the effect of wind speed on power generation was remarkable than other parameters although effect of other parameters will be there. However, while designing the wind turbine the parameters like wind speed, temperature and air density must be taken into account.

6. References

1. A. Demirbas. Biomass and the other renewable and sustainable energy options for Turkey in the twenty-first century. *Energy Sources*. 2001; 23, 177-187.
2. A. J. Cavallo, M. J. Grubb. Renewable energy sources for fuels and electricity. London: Earthscan Publications Ltd; 1993.
3. A. N. Celik. A simplified model for estimating the monthly performance of autonomous wind energy systems with battery storage. *Renew Energy*. 2003; 28, 561-572
4. Renewable Energy Resources: Opportunities and Constraints 1990—2020, study performed and published by the World Energy Council, London, UK, 1993.
5. P. Gipe. Wind Energy Comes of Age, Wiley, New York, NY, 1995.
6. C. Casale, E. Sesto. Wind power systems for power utility grid connection, *Advances in Solar Energy*. vol. 9, in: K.W. Bo¨ er (Ed.), American Solar Energy Society, Boulder, CO, USA, 1994.
7. E. Sesto, D.F. Ancona. Present and prospective role of wind energy in electricity supply, in: Proc. Of New Electricity 21, OECD Publications, Paris, France, 1995.
8. Marco Raugei, Silvia Bargigli, Sergio Ulgiati. Life cycle assessment and energy pay-back time of advanced photovoltaic modules: CdTe and CIS compared to poly-Si, Energy. 2007; 32, 1310-1318.
9. B.Viswanathan. An introduction to energy sources. National center for catalysis research department of chemistry Indian institute of technology, madras, 2006.
10. A Survey of Long-Term Energy Resources, Nanophysics of Solar and Renewable Energy, Wiley publication, 2012.
11. G.D. Rai. Non-Conventional energy sources, Khanna Publishers, 2011.
12. Prasad N S. Assessment of wind turbine for a site other than power. *Windpro Journal*. 2005; 87, 235.
13. Bruce Wright, Brian Hirsch, John Lyons, A better use of wind energy in Alaska and applicability for Russian villages. *Indian Journal of Energy*. 2012; 1(1), 20-22.
14. Maziar Izadbakhsh, Alireza Rezvani, Majid Gandomkar, Sohrab Mirsaeidi. Dynamic Analysis of PMSG Wind Turbine under Variable Wind Speeds and Load Conditions in the Grid Connected Mode. *Indian Journal of Science and Technology*. 2015; 8(14), 1-7.
15. M. Amulya Gupta, Clean energy: sources, technology, economics and relevance, *Indian Journal of Energy*. 2014; 3(1), 154-158.
16. M. Amulya Gupta, Energy from waste: Intriguing necessity in Indian sub-continent. *Indian Journal of Energy*. 2015; 4(1), 1-3.
17. K.A. Kocak. Method for determination of wind speed persistence and its applications. *Energy*. 2002; 27(10), 967-973.
18. M.J. Lambert, M.H. Ogle, B.W. Smith. Investigation of wind-induced fatigue in tall guyed steel masts. *Journal of Wind Engineering and Industrial Aerodynamics*. 1988; 30, 55-65.
19. M.C. Torre, P. Poggi, A. Louche. Markovian model for studying wind speed time series in Corsica. *International Journal* of *Energy* and Environmental Engineering. 2001; 3(2), 311-319.
20. R.K. Panda, T.K. Sarkar, A.K. Bhattacharya. Stochastic study of wind energy potential of India. *Energy*. 1990; 15, 92-130.
21. K. Chaney, Jr. A.J. Eggers, P.J. Moriarty, W.E. Holley. Skewed wake induction effects on thrust distribution on small wind turbine rotors. *Journal Solar Energy Engineering*. 2001; 123, 290-295.
22. A. Zerovos, S. Huberson, A. Hemon. Three-dimensional free wake calculation of wind turbine wakes. *Journal of Wind Engineering and Industrial Aerodynamics*. 1988; 27, 65-76.

ISSN (Online) : 2278-9278
ISSN (Print) : 2278-926x

23. J.F. Ainslie. Calculating the flow field in the wake of wind turbines. *Journal of Wind Engineering and Industrial Aerodynamics*. 1988; 27, 213-224.
24. W. Schlez, A. Umana, Barthelmie, Larsen, Rados, Lange, Schepers, Hegberg. Improvement of wake model with offshore wind farms. *Wind Engineering*. 2001; 25(5), 281-287.
25. L. Solero, F. Caricchi, F. Crescimbini, M. Falchetta. Direct-drive wind generator pilot plant for stand-alone units in extremely cold climates. International Journal *of* Energy *and Environmental Engineering*. 2001; 3(2), 326-332.
26. R. Chedid, S. Rahman. Unit sizing and control of hybrid wind solar power systems. IEEE Trans Energy Conversion 1997; 12(1), 79-85.
27. S. P. Singh. Comparative study of wind load in Indian standard with that of other countries. IE(I) J-AR1994; 74, 514.
28. V.M. Gomez-Munoz, M.A. Porta-Gandara. Local wind patterns for modeling renewable energy systems by means of cluster analysis techniques. *Renewable Energy*. 2002; 25, 171-182.
29. W. Bierbooms. Modelling of guests for determination of extreme loads of pitch regulated wind turbines. *Wind Engineering*. 2004; 28(3), 291-303.
30. L.M. Fitzwater, S.R. Winterstein. Predicting design wind turbine loads from limited data: comparing random process and random peak models. Proceedings of 2001 ASME wind energy symposium, 39th AIAA aero. *Science meeting*. 2001. 355-364.
31. J.A. Dahlberg, M. Poppen, S.E. Thor. Load/fatigue effects on a wind turbine generator in a wind farm. *Journal of Wind Engineering and Industrial Aerodynamics*. 1992; 39, 199-209.
32. F.J. Verheij. Development of a gust model for the design of large wind turbines. *Journal of Wind Engineering and Industrial Aerodynamics*. 1988; 27, 89-102.
33. L.M. Fitzwater, A.C. Cornell. Predicting the long-term distribution of extreme loads from limited duration data: comparing full integration and approximate methods. *Journal of Solar Energy Engineering*. 2002; 124, 378-386.
34. A.K. Dutta, R.D. Dutta, N.P. Morey, A. Basu. Modern technological developments in wind power generation. Proceedings of the national conference on wind energy commercialization, Maulana Azad College of Technology, Bhopal, India, 1999; 28-38.
35. S. Larwood, W. Musial. Comprehensive testing of Nedwind 12-meter wind turbine blades at NREL. Presented at the 19th American Society of Mechanical Engineers (ASME) wind energy symposium, Reno, NV, January 10-13, 2000, Conference paper, NREL/CP-500-27497, 2000.
36. P.A. Joosse, D.R.V. Van Delft, X. ChrKensche, D. Soendergaard, R.M. Van den Berg, F. Hagg. Cost effective large blade components by using carbon fibers. *Journal of Solar Energy Engineering*. 2002; 124, 412-418.
37. D.R.V. Van Delft, J.L. Van Leeuwen, C. Noordhoek, P. Stolle. Fatigue testing of a full scale steel rotor blade of the WPS-30 wind turbine. *Journal of Wind Engineering and Industrial Aerodynamics*. 1998; 27, 1-13.
38. G.S. Bir. Computerized method for preliminary structural design of composite wind turbine blades. *Journal of Solar Energy Engineering*. 2001; 123, 372-381.
39. P. Migliore, S. Oerlemans. Wind tunnel aeroaccoustic tests of six airfoils for use on small wind turbines. *Journal of Solar Energy Engineering* (special issue on wind energy). 2004; 126, 974-984.
40. P.A. Joosse, M.J. Blanch, A.G. Dutton, et al. Acoustic emission monitoring of small wind turbine blades. *Journal of Solar Energy Engineering*. 2002; 124, 446-454.
41. M.A. Rumsey, W. Musial. Application of acoustic emission nondestructive testing during wind turbine bladetests. *Journal of Solar Energy Engineering*. 2001; 123, 270.
42. S. Malayappan, M. Sivakumar, I. Neethimanickam, G. Venkatachalam. Design of wind turbine blade and ananalysis of wind turbine tower using finite element analysis. *Windpro Journal.* 2003; (68), 31-9.
43. D.A. Griffin, M.D. Zuteck. Scaling of composite wind turbine blades for rotors of 80 to 120 meter diameter. *Journal of Solar Energy Engineering*. 2001; 123, 310-317.
44. H.J. Sutherland, J.F. Mandell. Effect of mean stress on the damage of wind turbine blade. *Journal of Solar Energy Engineering*. 2004; 126, 1041-1049.
45. J. Ir, F.G. Th. The features which make the wind Holec wind turbine WPS 30-3 unique in the world. *Journal of Wind Engineering and Industrial Aerodynamics*. 1988; 27, 15-25.

ISSN (Online) : 2278-9278
ISSN (Print) : 2278-926x

46. T. Thiringer, J-A. Dahlberg. Periodic pulsation from a three-bladed wind turbine. IEEE Trans Energy Conversion 2001; 16(2), 128-133.
47. O'Dell K. Improved blade designs and manufacturing process reduce the cost of wind energy. *Journal of Solar Energy Engineering*. 2001; 123, 268.
48. James and James. Renewable energy world. Technology update, wind power. United Kingdom: (Science Publishers) Ltd. 1999; 2(1), 45-49.
49. P-H. Lin, H.H. Lin, F.B. Oswald, D.P. Townsend. Using dynamic analysis for compact gear design. *Journal of Mechanical Design.* 2002; 124, 91-96.
50. A.S. Sivakumar. Wind power-a user's experience. *Windpro Journal*. 2003; 63, 32.
51. A.K. Vasudevan, K. Sadananda, G. Glinka. Critical parameters for fatigue damage. *International Journal of Fatigue.* 2001; 23, 39-53.
52. S.C. Tripathy. Performance of wind turbine driven self-excited induction generator. IE(I) J-EL. 1994; 75, 115-128.
53. B.N. Haack. Economic analysis of small wind-energy conversion systems. *Applied Energy*. 1982; 11, 51-60.
54. H. Douglas, P. Pillay, A.K. Ziarani. Broken rotor bar detection in induction machines with transient operatingspeeds. IEEE Trans Energy Convers. 2005; 20(1), 135-141.
55. A. Siddique, G.S. Yadava, B. Singh. A review of stator fault monitoring techniques of induction motors. IEEE Trans Energy Conversion 2005; 20(1), 106-113.
56. G.R. Bhawatikar, W.Z. Gandhare. Energy conversion in grid connected wind power projects. *Windpro Journal* 2003; 43, 8.

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