IJCTA, 9(21), 2016, pp. 155-161

An Analysis for Repowering Prospects of Jamgodarani Wind Farm using WASP

Manoj Verma* Siraj Ahmed J.L.Bhagoria*****

Abstract : Wind turbine technology and design has greatly improved in recent years with the development of megawatt class turbines. The aim of repowering is to generate the highest possible constant output power under all types of wind conditions in India. Re-powering in wind energy means replacement of installed old wind turbines of lower capacity by modern turbines of higher capacity normally in lesser numbers. This study depicts cost/production viewpoints of the repowering procedure for the wind farms. Repowering can produce significantly more power with less number of turbines. This procedure was the consequence of a developing interest for renewable energies, encouraged by the availability of wind energy in many region of India. The wind farms concentrated on in this work were situated up before 1998 and they had out of date apparatus with low power. The study/simulation in this paper shows strong evidences that repowering is a productive attempt for such old wind farms by using Wind Atlas Analysis and Application Program (WAsP). Wind energy has found favor due to benefits of relativity less installation time, environment friendliness and cost competitiveness. In this paper a detailed study of various performance indices necessary to determine the reliability and performance of a particular wind farm for repowering is studied. To carry-out the study an old wind farm located at Jamgodrani, Madhya Pradesh, India is selected to implement repowering. The wind farm was commissioned in 1990 with a capacity of approximately 13.05 MW, which consists of 58 wind turbines of 225 kW capacity each.

Keywords : Wind Farm Repowering, Renewable Energy, Annual Energy Production, WAsP.

1. INTRODUCTION

Each time when the wind energy is produced. It saves a considerable amount of CO2 outflows which may discharged to the environment if the same power is generated by coal, fuel, or regular gas power stations. Amid the recent years, the developments in technology have changed the ways and opened new areas of development. Repowering permits increment of the total available power of the wind farms, in light of the fact that the proficiency of new wind turbines is greater. Repowering a wind farm involves location mapping with new installation its establishments with the point of augmenting its administration life and/or expanding its power, execution or accessibility and expanding, altering and/or upgrading the hardware for ideal limit or effectiveness. Repowering a wind farm entails revamping its installations with the aim of extending its service life or increasing its power, performance or availability and increasing, modifying and/or updating the equipment for optimum capacity or efficiency.[1][3]

Repowering Advantages

Given the constant advances made in wind and generator technology, it is now possible for the same site to have a much higher energy production with new machines [8]. They are quieter, their efficiency is higher (2 or 3

* Department of Mechanical Engineering Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India E-mail: manojverma.nitb@gmail.com,

** Department of Mechanical Engineering Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India E-mail: siraj.ahmed@yahoo.com,

*** Department of Mechanical Engineering Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India E-mail: palak_bh@rediffmail.com

MW), and their start-up speed (winds of 2.5-3 m/s) are much lower when compared with older turbines (0.1-0.65 MW, with start-up wind speed of 5 m/s). Moreover, higher hubs on the new machines make it easier to exploit the wind at great heights. For this reason, repowering a wind farm leads to a noticeable increase in farm production, although the number of generators installed is reduced [6][8].

The challenges for re-powering are many and some are identified as [2] [12][14]

- Turbine ownership: Issue of ownership is to be resolved in cases where more number of turbines are replaced by few and one to one replacement is not possible.
- Land ownership: Multiple ownership of wind farm land is to be resolved.
- Power purchase agreement: PPA might have been signed for long duration and before end of that period re-powering may pose difficulties.
- Electricity evacuation: The grid is designed to handle current power supply but enhanced power output due to re-powering may require modification or replacement of equipments and systems.
- Additional cost: The decommissioning cost of existing turbine is to be estimated.
- Disposal of existing turbines: Many options are to be analysed like scrap value, buy-back by manufacturer, relocation etc.

The rest of the paper is organized as follows

- Detailed methodology and existing wind farm parameters are compared with proposed wind farm parameters in Section II.
- Techno-economic analysis is carried out to generate the highest possible constant level of power output under all types of wind conditions in India in Section III.
- To determine the re-powering potential of an existing wind farm site different technical aspects are to be considered like wind resource of the site in terms of speed frequency distribution curve of past several years, Waybill parameters, wind power density, turbulence intensity, power law index, wind rose, prevailing wind direction and other characteristics in Section IV.
- Experimental results are presented and concluding remarks are given in section V.

2. METHODOLOGY AND COMPARISON OF EXISTING WIND FARM WITH PROPOSED WINDFARM

2.1. Methodology

1. Selection of the research site
2. Compilation of the wind data from National Institute of Wind Energy from Chennai, Tamilnadu
3. Extrapolation of data at different heights to optimize the results [15]
4. Replacement of existing wind turbines with new modern wind turbines
5. Analysis of site (Jamgodrani Hills) by meteorological data
6. Illustrate wind rose pattern of the research site using Wind Atlas Analysis and Application Program (WAsP)
7. Evaluate and analyze technical data of research site with economical study [16]
8. Compare current technical data with modern wind turbines data to enhance the efficiency and net increase power generation through repowering

2.2. Physical Characteristics

The Jamgodrani wind farm is located in district Dewas of state Madhya Pradesh in India. The Date of Commencement of site was March, 1992. The geographical coordinates of the farm is longitude (E) of 76º 9'5

6.5" and latitude (N) of 22º 59' 9"at an altitude of 580 m from the sea level. The mean annual wind speed at mast height of 20 meter is 5 m/s, power law index is 0.19, mean annual wind power density is 130 W/*m*2 and wind power density at 50 *m* is 222 W/*m*2. The factors which may impact the characteristics of wind are urban cities Indore and Ujjain which are closest to the farm and the Kshipra River. The farm covers an approximately 12000 square meters of area which have non-uniform surfaces, containing number of small water pools, farm lands and some manmade developments as shown in figure 1[3].

2.3. Electrical Characteristics

The present structure of the wind farm consists of 58 number of turbines, with a rated capacity of 225 kW. In the proposed repowering approach the old 225 kW turbines are replaced with 7 number of turbines with a rated capacity of 2 MW machines. The detailed specifications of existing and proposed turbines are presented in Table 1.

Table 1. Specifications of existing and proposed turbines

Name	***Parameters***	
Make	NEPC India	Vestas
Model	WGL	WGL
Rating	225 kW	2.00 MW
Rotor Diameter	29.8 Meters	80 Meters
Hub Height	30 Meters	80 Meters
Number of Blades	3	3
Generator Type	Asynchronous	Asynchronous
Voltage	415 Volts	415 Volts
Wind Cut-In Speed	4 m/s	4 m/s
Wind Cut-Out Speed	25 m/s	25 m/s
Wind Rated Speed	15 m/s	15 m/s

Fig. 1. Wind farm at Jamgodrani Hills

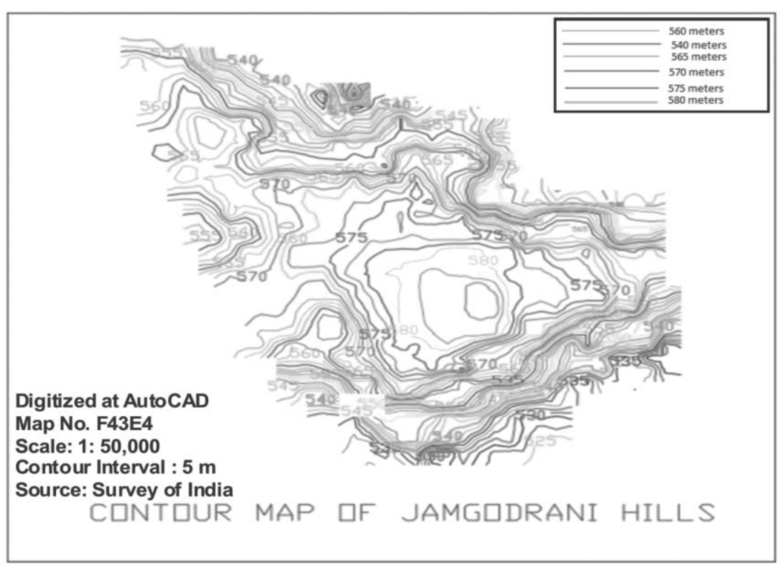

Fig. 2. Contour Map of Jamgodarani Hills (Digitized at AutoCAD Design Software)

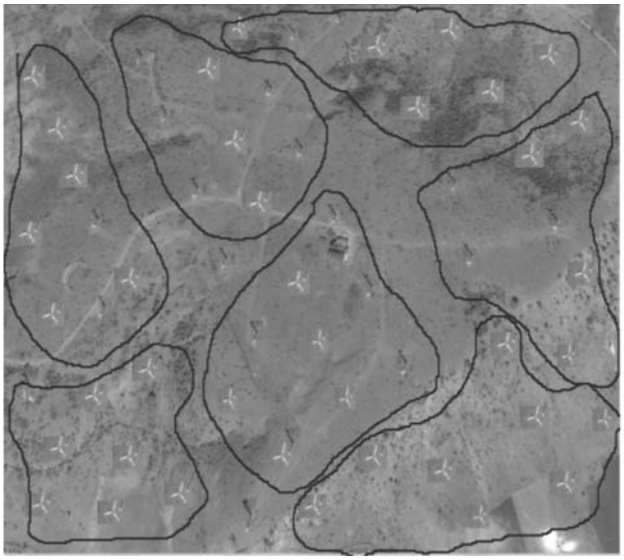

Fig. 3. Wind farm at Jamgodrani Hills (Google Earth Image)

Fig. 4. Proposed wind farm layout of site (Google Earth Image)

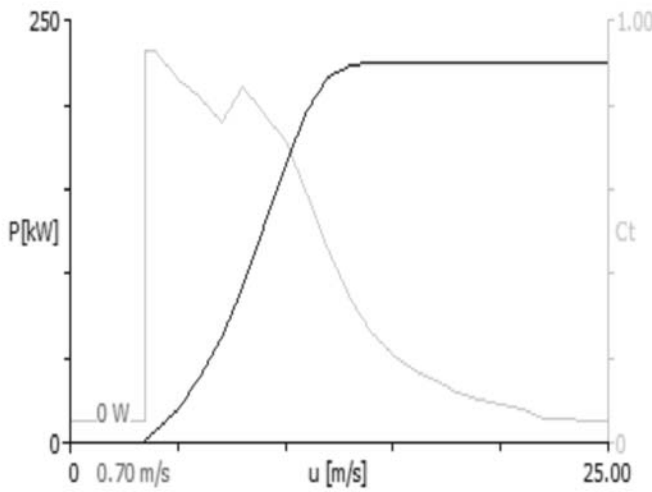

Fig. 5. Power Curve for existing 225 kW Turbine

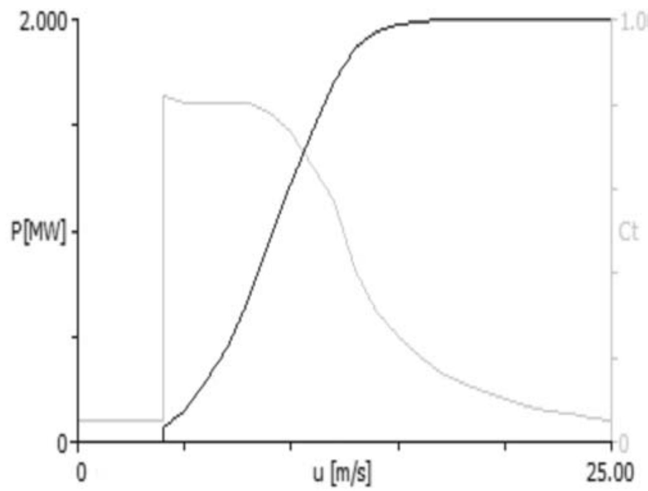

Fig. 6. Power Curve for proposed 2 MW Turbine.

3. TECHNICAL ANALYSIS

Currently 58 turbines of 225 kW is installed on the Jamgodarani project which give the total capacity of 13.05 MW. Now to get the same capacity we needed the 13.05/2?7turbines of 2 MW [13][7]. The analysis shows that the repowering can increase the capacity utilization factor from 12.26 % to 22.61 % hence about 10% boost could be achieved [9][10].

Energy Production Analysis

The theoretical maximum annual energy production in given by

$$AEP_{max} = \frac{(R \times N \times 24 \times 365)}{1000} \text{kWhr} \qquad ...(1)$$

While the actual annual energy production is given by

$$AEP = \left(\sum_{m \in M} W(m) \times P(m) \right) \times \frac{N \times 24 \times 365}{1000} \text{kWhr} \qquad ...(2)$$

Where,

R = Rating of turbine. P = Power Curve of Turbine.

N = Number of turbines. M = Values of discrete wind speeds at which and are calculated.

W = Weibull Distribution.

	BEFORE REPOWERING	
(*a*)	Annual Energy Production (AEP)	114.186 GWhr per year
(*b*)	The actual Annual Energy Output is	14.003 GWhr per year
(*c*)	Capacity Utilization Factor (CUF) [$c = b/a$]	12.26 %
	AFTER REPOWERING	
(*a*)	Annual Energy Production (AEP)	122.6400 GWhr per year
(*b*)	The actual Annual Energy Output is	27.727 GWhr per year
(*c*)	Capacity Utilization Factor (CUF) [$c = b/a$]	22.61 %

4. ECONOMIC ANALYSIS AND DATA INTERPRETATION THROUGH WASP

Considering the tariff of 4.35 INR per units with no escalation for 25 years the repowered wind farm can be recovered within

$$\frac{1050000000}{2771640} = 8.7 \text{ years} \qquad \text{...(3)}$$

The payback period/ recovery can be further decreased by considering the reselling of old turbines, finance rate and the government subsidies.

Data Interpretation Through WAsP

In 1987 the Wind Energy and Atmospheric Physics Department at Risø National Laboratory introduced Wind Atlas Analysis and Application Program (WAsP) - a powerful tool for wind data analysis, wind atlas generation, wind climate estimation and siting of wind turbines. WAsP (Version 8.0) is a complete software package for map editing and wind resource assessment. Working with wind resource assessment and WAsP in practice, however, requires other software as well [11]. Key features of WAsP as follows:

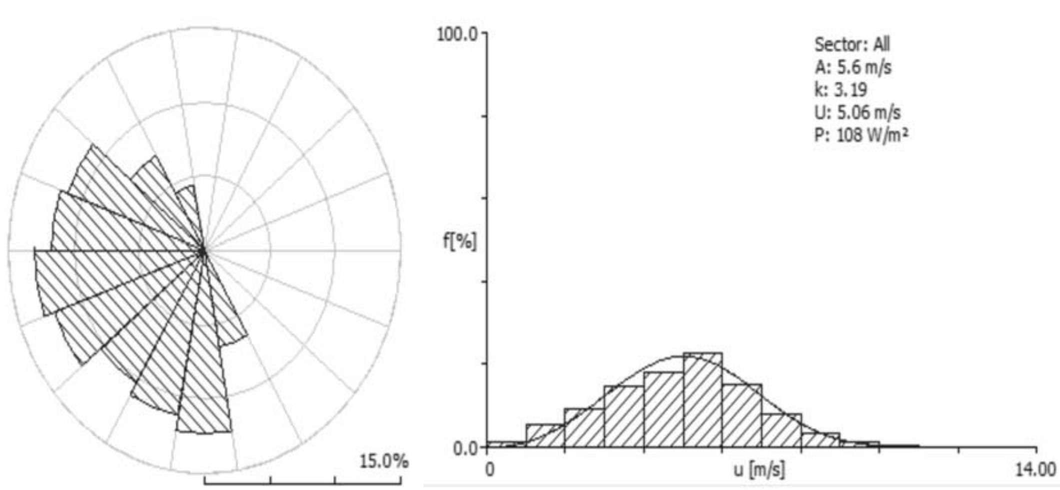

Fig. 7. Wind rose distribution and Probability Distribution Function (PDF) at 20 meter height in WAsP software

- **Analysis**

  Time-series of wind speed and direction – > observed wind climate (OWC)
- **Application**

  Predicted wind climate + power curve – > annual energy production (AEP) of wind turbine
- **Wind farm production**

  Gross annual energy productions + wake losses – > net AEP

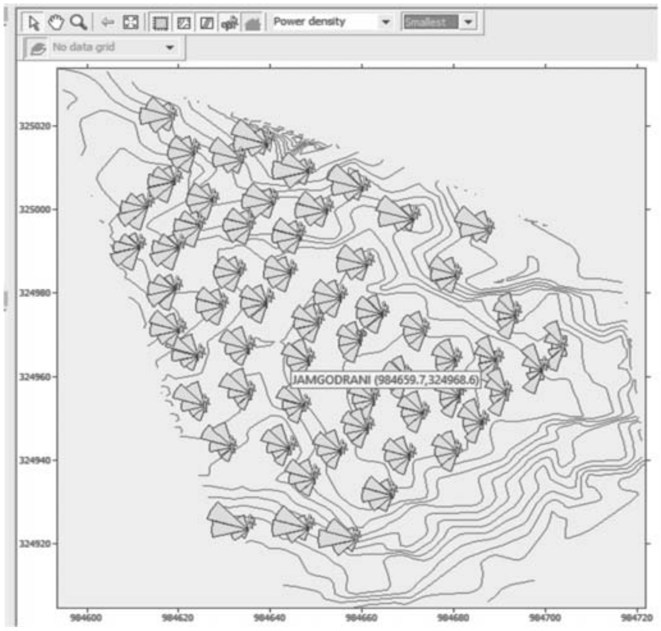

Fig. 8. Power density at site through WAsP software

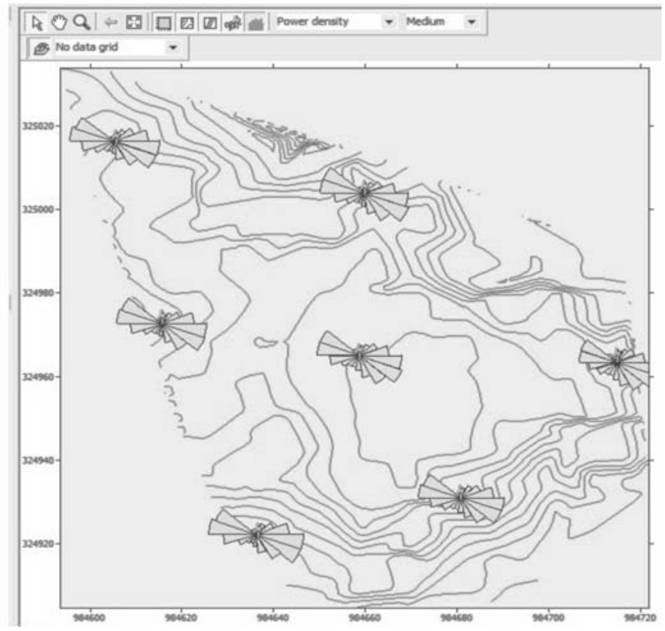

Fig.9. Power density at proposed site through WAsP software

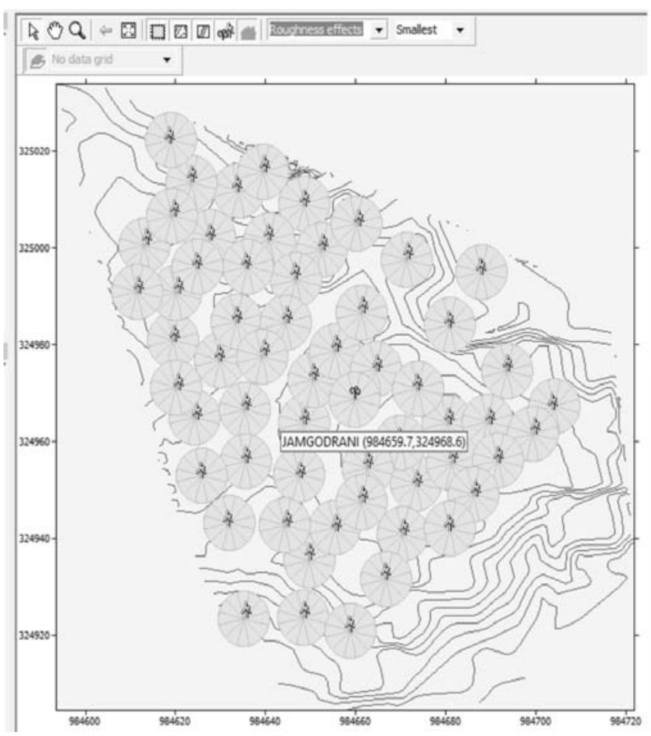

Fig. 10. Roughness effect in site through WAsP software

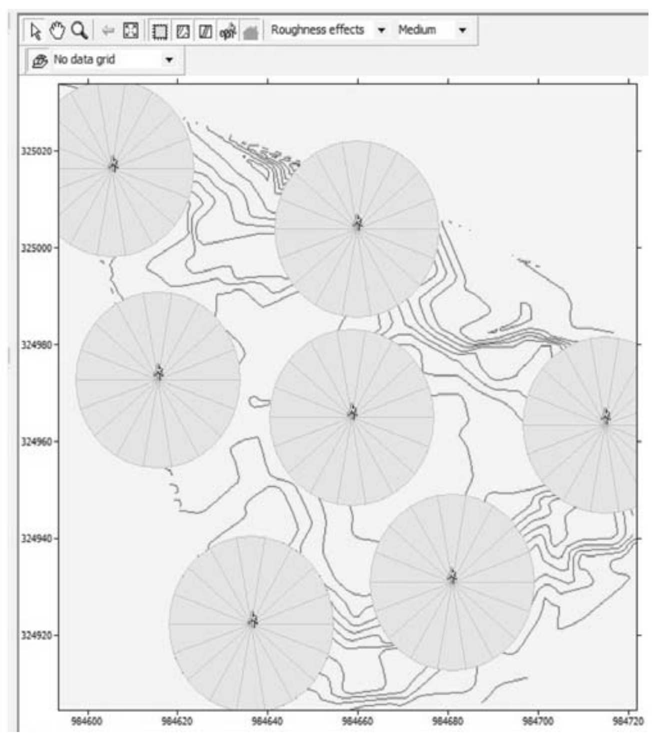

Fig. 11. Roughness effect in proposed site through WAsP software

Environmental Analysis

The repowering causes a significant reduction in the total number of wind generators from 58 to 7, which are also located at much greater heights. This greatly reduces the visual and acoustic impact.[4][5]

5. CONCLUSION

This paper presented the repowering aspects both financial and electrical of Jamgodarani wind farm. The paper pointed out a number of advantages, including technical analysis through Wind Atlas Analysis and Application Program (WAsP), economical analysis through calculations and environmental analysis, which shows that the repowering of considered farm could increase its annual energy production by 10% (from 12.26 % to 22.61 %) while using only 7 turbines instead of 58 turbines presently in used which also reduces the environmental impact. Considering the economic aspects, the calculation shows that the repowering cost can be recovered within 8 years and 7 months , while we did not considered the scrap cost of old systems. Furthermore the financing of repowering and government subsidies could also reduce the cost burden of repowering. Overall it can be said that these are strong evidences that repowering is a profitable investment in electrical, economic and environmental aspects.

6. REFERENCES

1. Ahmed Siraj. Wind Energy: Theory And Practice (Third Edition) 2015.ISBN-978-81-203-5163-9. PHI Publication.
2. B.S. Nivedh, R.P. Kumudini Devi, E. Sreevalsan. "Repowering of Wind Farms - A Case Study". Wind Engineering; 37(2): 137-150, 2013.
3. Eric Lantz, Michael Leventhal, Ian Baring-Gould. "Wind Power Project Repowering: Financial Feasibility, Decision Drivers, and Supply Chain Effect". National Renewable Energy Laboratory; NREL/TP-6A20-60535, USA 2013.
4. Indhumathy.D, Seshaiah.C.V, Sukkiramathi.K. "Estimation of Weibull Parameters for Wind speed calculation at Kanyakumari in India" International Journal of Innovative Research in Science, Engineering and Technology; 3 (1) : 8340-8345, 2014.
5. J.V. Seguro, T.W. Lambert. "Modern estimation of the parameters of the Weibull wind speed distribution for wind energy analysis" Journal of Wind Engineering and Industrial Aerodynamics; 85: 75-84, 2000.
6. Laura Castro-Santos, Almudena Filgueira Vizoso, Eugenio Muñoz Camacho, Luigi Piegiari. "General Economic Analysis about the Wind Farms Repowering in Spain". Journal of Energy and Power Engineering; 6: 1158-1162, 2012.
7. Mohit Goyal. "Repowering-Next big thing in India". Renewable and Sustainable Energy Reviews; 14: 1400-1409, 2010.
8. Nilesh Diwakar, Subramanyam Ganesan, Siraj Ahmed, V.K. Sethi. "Prediction of wind power potential by wind speed probability distribution in a hilly terrain near Bhopal, Madhya Pradesh". International Journal on Emerging Technologies; 1(1): 80-86, 2010.
9. Rohit Verma. "Repowering Potential of Wind Farm in India". International Journal of Enhanced Research in Science Technology & Engineering ; 2 (12): 132-138, 2013.
10. Sachin Kumar, Priyanka Pandey. "Survey and Performance Evaluation of Jamgodrani Hills and Nagda Hill Wind Farm in Madhya Pradesh, India - A Case Study". 4th International Conference on Advances in Energy Research. Energy Procedia 2014; 54: 97 - 104.
11. Said Diafa, Gilles Notton, Djamila Diaf. "Technical and economic assessment of wind farm power generation at Adrar in Southern Algeria" Energy Procedia; 42: 53 - 62, 2013.
12. Ahmed Siraj, "Remote sensing application in Wind energy", ministry of New and renewable Energy Government of India, Renewable Energy Akshay Urja, Vol. 7, Issue 5, pp: 16-19, 2015.
13. B.R. Karthikeya, Prabal S. Negi, N. Srikanth., "Wind resource assessment for urban renewable energy application in Singapore" Renewable Energy, vol. 87, pp- 403-414, 2016.
14. Andrade CF, Neto HFM, Rocha PAC, Silva MEV, "An efficiency comparison of numerical methods for determining Weibull parameters for wind energy applications: a new approach applied to the northeast region of Brazil, Energy Conversion and Management, vol. 86, pp-01-8, 2014.
15. Kumer VM, Reuder J " A comparison of LiDAR and radiosonde wind measurements. Energy Procedia, vol. 53, pp- 214-20, 2014.
16. Lee Kuk Jong, Yook Daesik, Lee Jai Kun, Yun Jong-Il, Beeley A.Philip, "Weibull parameter calculation and estimation of directional and seasonal wind speeds for the return period: A case study in the Barakah NPP area, Annals of Nuclear Energy, vol. 80, pp- 62-69, 2015.