Performance evaluation of a 2 MW wind power project

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Abstract

This work is the analysis of the energy generation of a 2 MW wind power project installed at Motha, District Amaravati, in the state of Maharashtra. The various availabilities of the wind power project were studied for the efficient energy production of the project. It was observed that 92.72 percent of the system was available for energy generation throughout the year. The energy generation data with the various shutdowns of the system was studied. The energy generation of the system was studied in terms of the plant load factor or the capacity factor. Capacity factor was observed to be 21.16 percent with the total energy generation unit being 3.73 MWh.

Keywords: shutdown, power coefficient, system availability, rating power, performance

Introduction

The wind, one of the renewable energy sources is a free, clean and inexhaustible energy source. It has served human kind well in many countries by propelling ships and driving wind turbines to grind grain and pump water. The day of cheap and plentiful petroleum was drawing to an end and people began to realize that the world's oil supplies would not last forever and that remaining supplies should be conserved for petroleum industries. Wind power has attracted great attention worldwide due to its techno-commercial viability and environmental friendly nature. Therefore, it is popularly known as 'Green Power' (UN 1997).

Wind energy development has been thriving both in India and around the world. This reflects not only the declining cost of the resource and the improved performance of wind power plants, but also a growing awareness among utilities and other potential customers that this renewable energy technology offers many benefits for the economy and the environment.

Wind energy helps our economy in other ways. For communities and states in which wind power facilities are located, wind power plants create jobs, generate income and support economic development. Several studies have established that wind energy produces more jobs per capital invested or per kilowatt-hour generated than most conventional resources. Out of the various renewable energy sources wind is the only renewable energy source that has reached commercial viability for large grid connection requirements.

A Demonstration Wind Power Project of 2 a MW capacity was made functioning on 17 June 2003 at Motha, Dist. Amaravati in the state of Maharashtra. In Vidarbha, there are a good number of wind sites and the study was made on the performance and techno-economic feasibility aspects of such a power project, and will be valuable for future installations of wind farms in Vidarbha (MEDA 2001).

Project background

The site is on the top of the Satpuda (Seven Hills) range and is approximately 35 km north of the town, Paratwada, in the district of Amaravati. The wind power project at Motha is spread over 53 ha of land, and the site is approximately 5 km away from Chikhaldara (a popular hill station in Western Vidarbha). The wind project is situated on a relatively flat plain, and treeless, and that is well exposed to the prevailing westerly wind for rain and other winds in the winter and summer seasons. Two small commercial wind energy conversion systems (WECS) (SUZLON 1000, make – Suzlon Energy Ltd., Pune) of a capacity of 1 MW generation are each installed at Motha, Taluka- Chikhaldara, Dist. Amaravati through the Maharashtra Energy

Development Agency, Pune by the Ministry of Non-conventional Energy Sources, New Delhi.

The Ministry of Power, GoI, New Delhi, laid down the foundation stone for this wind power plant on March 14, 2003, and it was commissioned by the hands of the Chief Engineer, MSEB Amaravati Division, on 17 June 2003 (MEDA 2002).

Methodology

Data collection and theory for analysis

The wind energy generation data of the 2 MW wind power project was collected from the project site, Motha, with the help of the Maharashtra Energy Development Agency (MEDA), and Suzlon, Pune, for the performance analysis of the system, in 2003-2004.

The collected data of the system was analysed for the various parameters and for evaluating the performance of the system. These parameters are as follows:

Wind system energy productivity

During the year, there are times when the wind does not blow or blows at speeds below the cut-in wind speed of the turbine. Obviously, wind systems do not produce energy during all of the 8 760 hours in a year. Even when a wind system does produce energy, it does not always do so at its full rated power.

Capacity factor/ plant load factor

The capacity factor (CF) is a parameter often used to describe the energy production performance of a wind turbine. The capacity factor is a measure of the annual energy production. It is defined as the ratio of the (actual or estimated) energy produced to the energy production that would result from operation at full rated power for an energy hour of the year (Anon 1997).

CF = Energy production ÷ (Power rating x 8760 x 100

Wind system reliability

A commonly used operational measure of wind turbine and wind farm reliability is the availability. The value for a wind farm for a given period may be built up from the daily values of availability for each wind turbine. However, in general, for a specified period (e.g. a day, week, month, year), availability is defined as the ratio of hours that the wind system was able to generate power to the number of hours in the time period (NWCC 1997, Iniyan *et al* 1996, 2003).

Machine availability (%) = Hours of wind turbine capable of operation ÷ Grid available hours in period

Another more difficult-to-determine and possibly more ambiguous definition is the ratio of grid hours available of wind turbine to the number of hours in a period (NWCC 1997).

Grid availability (%) = Grid available in period ÷ Hours in period

System Availability (%) = Machine availability x Grid availability

No matter how defined, a perfect availability value would be 100 per cent. That is, the system would have no outages or malfunctions that prevented the system from generating power. Modern wind farms now routinely achieve availability values of 98 per cent or greater as compared with 60 per cent or less in the early eighties.

Power coefficient

Power coefficient is simply the ratio of the power output from the turbine to the power available in the wind.

Cp = Power output of turbine ÷ Power available in the wind]

Results and discussions

Performance of Wind Power Project, Motha

The energy generated, system machine reliability (machine availability, grid availability) and capacity factor or plant load factor for the wind power project during the first year of operation from 14 June 2003 to 14 June 2004 is studied. The power generation report containing energy generation, operating hours, grid OK hours etc., is collected from MEDA, Pune, Suzlon Energy Ltd., Pune and Wind Power Project, Motha. Machine shutdown / break down and various faults (manual stop, gear box oil pressure, yaw error, etc.) were also considered to understand the technical feasibility of the wind power system. Machine performance in terms of energy generation and the efficiency of the system was also evaluated.

The overall efficiency was calculated for different wind speeds by noting down the power generation from the Wind Power Management System (WPMS) software loaded on the computer kept in the remote monitoring room.

Energy production of the wind power project during 2003-04

The energy production mainly depends on the system reliability i.e. machine availability, grid availability and the wind characteristic of the site. The energy production for both the turbines during the first year of operation is given in Table 1. The total energy generated is observed to be 3.73 MWh electrical units, which was found higher than the agreement between MEDA and Suzlon Energy Ltd., Pune (MEDA 2002).

Energy production in the month of August is highest i.e., 0.757 MWh followed by September, July, April. In the month of November it was observed lowest i.e., 0.019 MWh. Energy generation and the generation hours are also related to each other. Highest generation hours are found in the month of August 2004 (1395.5 h) i.e., this month has the highest wind potential for the wind energy generation. The lowest generation hours were observed in November 2004 i.e., 566.68 h. Operation hours of the wind power system were more in the month of January, which is 1444.2 h and lowest in the month of July is 1132.40 h.

Availability for wind power generation

Machine availability and grid availability were worked out by using the operational hours and grid available hours of the wind power project. The energy generation with respect to the generation hour and operation hour of the 2 MW wind power system are given in Table 1.

From the total 24 hours of the day, break down and grid unavailability are subtracted, then operating hours of the system per day are known. Generation hours of the wind power project are either equal or less than operating hours due to wind speed observed as less than cut-in wind speed or more than cut-out wind speed

Grid OK hours is the availability of the grid supply, which is very much required for providing kVAR (reactive power) to the induction (asynchronous) generator. This grid kVAR supply to the induction generator ensures the frequency matching and phase sequence of a three-phase AC supply to be connected to the grid. The machine availability, which is defined as operating hours to the grid OK hours, gives information about the use of the machine for the power generation.

Grid availability gives information regarding availability of the grid OK hours as a fraction of the total period. The system availability can now be considered as the product of operational availability and the grid availability, which gives overall information of the wind power system availability for the electrical generation.

The total generation hours of the wind power system is found to be 12701 h (for A1 and A2 turbine). Operational hours (16286.6 h) and grid OK hours (16644.2 h) were found to be more than the generation hours of the system. The annual average machine availability and grid availability was found as 98.75 per cent and 93.89 per cent respectively. Therefore, the annual average system availability comes to 92.72 per cent. The variation in the monthly averages for the machine availability and grid availability around the year were seen in between the range of 99.43 to 95.49 percent and 97.72 to 83.33 percent respectively. The annual average system availability was found to be in the range of 97.06 to 82.66 percent.

It can be inferred in the first year of operation of the wind power project that the machine was available to nearly 98 per cent i.e., most of the time of the year the machine was available, and a very less

Table 1: Annual energy generation, machine availability and grid availability with capacity factor of the wind power project at Motha

Month	*Energy generated (kwh)*	*Capacity factor (%)*	*Generation hours*	*Operating hours*	*Grid OK hours*	*Machine availability (%)*	*Grid availability (%)*	*System availability (%)*
June	263872	17.73	1120	1298.80	1320	98.39	91.67	90.19
July	459319	30.86	1188.2	1230	1240	99.19	83.33	82.66
August	757422	50.90	1395.5	1417.3	1433.7	98.86	96.35	95.35
September	685006	47.57	1234.10	1378.40	1399	98.53	97.15	95.72
October	171514	11.52	1231.6	1436.3	1446.8	99.27	97.23	96.53
November	19731	1.37	566.68	1366.3	1376.2	99.28	95.57	94.88
December	69509	4.67	787.4	1440.8	1454.1	99.09	97.72	96.83
January	97316	6.54	916.3	1444.2	1452.5	99.43	97.61	97.06
February	107817	7.49	924	1347.6	1356.6	99.34	97.46	96.81
March	199303	13.84	979.4	1293.3	1302.8	99.27	87.55	86.92
April	430216	29.87	1123.4	1260.3	1319.8	95.49	91.65	87.52
May	471391	31.67	1234.1	1373.3	1388.6	98.90	93.32	92.29
Total	3732416		12701	16286.6	16644.2			
Average		21.16				98.75	93.89	92.72

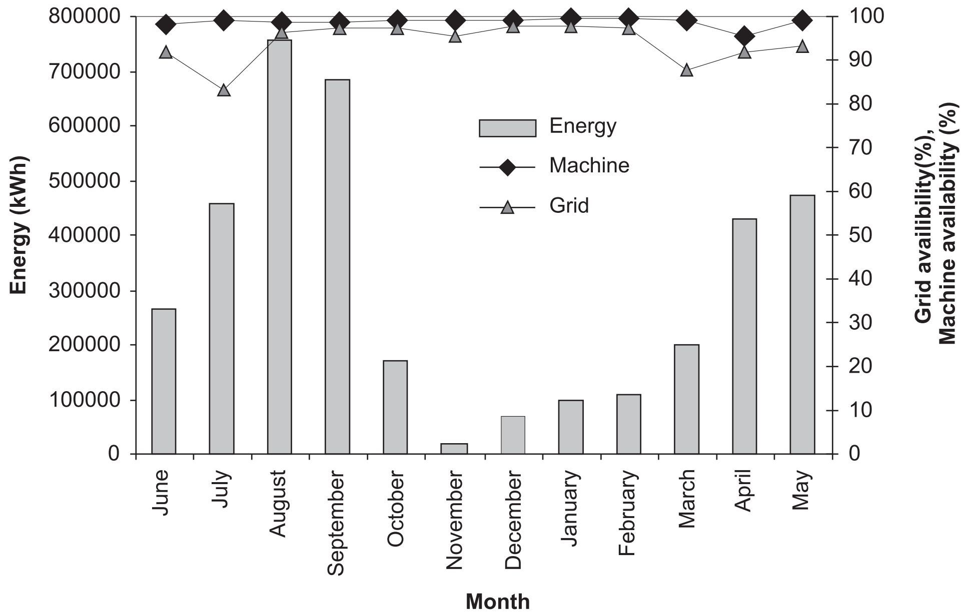

Figure 1: Annual energy generation, machine availability, and grid availability of the Motha site

time period was required for the breakdown. The actual generation hours for both turbines are found as 12701 h in the year i.e., 72.49 percent of the year, which are actually the hours of energy production. The remaining 27.51 per cent of the year was either breakdowns / faults, low voltage of the grid (34 days in the year) and low wind speed (135 days in the year).

The machine availability and grid availability are shown in Figure 1, for one year of operation of the wind power project. Comparing both availabilities, it was observed that machine availability is found more than grid availability in the first year of operation.

Capacity factor / plant load factor of the wind power project

Capacity factor is actual measurement of energy production of the wind power project. The capacity factor of the site was calculated using the total energy generated to the expected energy generated at rated power capacity of the wind turbine (see Table 1).

Annual average capacity factor for the wind power project was found as 21.17 percent. Capacity factor was found maximum in the month of August followed by September, which are 50.90 percent and 47.57 percent respectively.

Break down / shut down and fault analysis of the wind power project

For very high wind speeds, which are greater than cut out speed and velocities during the gusts, are not considered as faults by the system during these periods, and is rotated out of the wind direction by the yaw control. Maximum break down hours / shut down hours were found in the month of April 2004 (59.5 h) and minimum in the month of January as 8.3 h.

This information is also presented in the pie chart in Figure 2. It was observed that break down hours affected the wind power system availability and the energy generation.

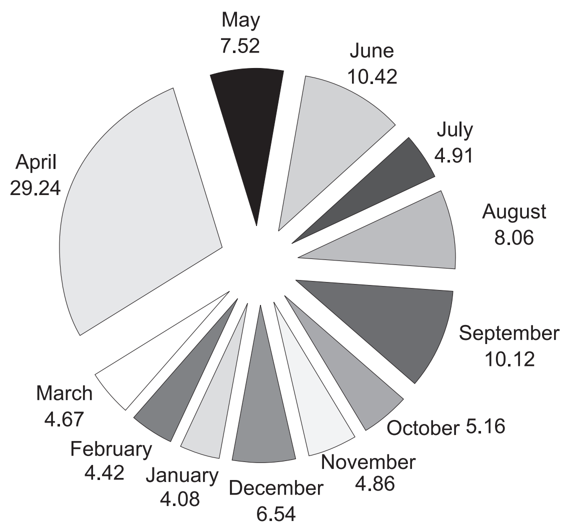

Figure 2: Details of the wind farm breakdown/ shutdown for the one year of operation

Pareto diagram for the fault

Figure 3 shows the Pareto diagram, which represents the different faults occurring in the wind turbine generators. There are four main vital faults found in the operation of the wind turbine i.e., power down, grid down, manual stop and main control supply. Nearly 27.87 percent fault had occurred due to the power down. This parameter mainly affected the wind power generation of the system. Some of the others faults observed were cable unwind, gear oil pressure, yaw sensor, over speed, earth fault and load shedding, which are also found in the operation of the wind power system.

As this was the first year after installation of the wind power project and a regular (weekly, monthly, quarterly) maintenance schedule was observed scrupulously, there was very little break down time. There were no replacements of main parts due to non-occurrence of major faults. So the system is technically very efficient and the microprocessor based electronic control system is found to be very effective for proper operation of the system. The working of the whole system was found to be very smooth.

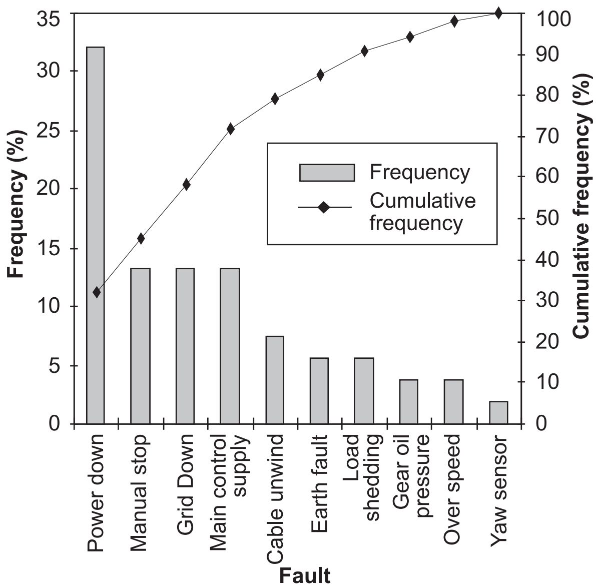

Figure 3: Fault analysis by using the Pareato Chart for the wind farm, Motha

Overall efficiency of the wind power project

For finding the efficiency of the system at various wind speeds, instantaneous data regarding wind speed and power generated is required. Turbine power curve data of the system was collected from the manufacturing company i.e., Suzlon Energy Ltd., Pune (Anon 2004). Actual instantaneous wind power generated information was collected from the computer having the Wind Power Management System (WPMS) package of the A1 wind power system, Motha.

Power coefficient of the wind turbine was found at maximum i.e., 0.42 at the wind speed of 9 m/s. At the rated wind speed (11 m/s) of the wind turbine, this performance coefficient was found to be 0.36. Overall efficiency of the system was found as high as 34.65 percent at the wind speed of 9 m/s. At the power rating of the wind turbine, overall efficiency of the system was found to be 29.62 percent. The wind turbine power coefficient and overall efficiency for 1 MW capacity of wind turbine are graphically shown in Figure 4. Power coefficient varies between 0.42 to 0.32 for the velocity range of 5 to 12 m/s. The difference in turbine output and electrical generator output is the loss in machine transmission and electrical generation. The mechanical electrical efficiency of the system was found to vary between 80.35 to 82.69 percent, and the maximum efficiency was found at wind speed of 6 m/s.

Conclusions

This study was undertaken to understand the wind energy assessment and the performance of a wind power project in the first year of operation. Relevant data for the analysis was collected from two MEDA, Pune and Suzlon Energy Ltd., Pune on specific aspects of the research programme.

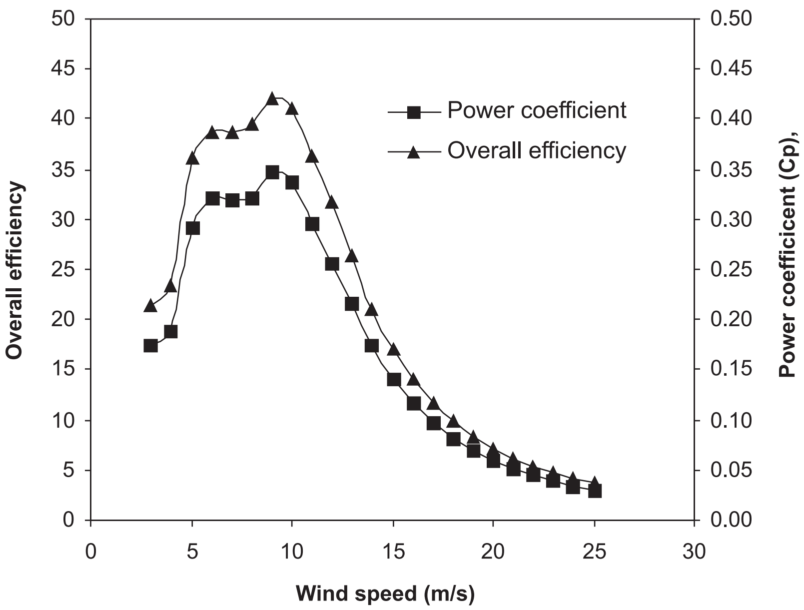

Figure 4: Power coefficient and overall efficiency of 1 MW capacity wind turbine

Performance of the wind power project was studied for wind turbine suitability. Complete one-year data was used for the study of the wind power project. This analysis mainly emphasises on the system energy generation, system reliability and the efficiency of the system regarding wind energy conversion.

In the first year of operation of the wind power project, wind energy generation was found more than the estimated wind energy from the analysis. Energy generation of the system was also affected due to the availability of the operation. These are mainly machine availability, grid availability and the system availability.

Energy produced in the first year of operation is evaluated for the system reliability and the computation of the energy penetration to the utility grid. Fault analysis was done using the Pareto analysis method for the major cause of wind turbine unreliability in the operation.

From the results of this study, the following specific conclusions could be drawn:

1. Wind energy generation for the one-year duration was found to be more than the agreement between the MEDA and the Suzlon Energy Ltd., Pune.
2. The capacity factor in the first year of operation was found to be 21.17 percent.
3. In the first year of operation, the system grid availability was found lower than the machine availability. Grid availability of the system mainly depends on the supply of grid to the power plant from the MSEB. It may impact on the energy generation of the plant.
4. In performance of the system, it was observed that as the wind speed increases, power coefficient of the turbine increases and later on decreases.
5. System overall efficiency was found below the rated wind speed of the wind turbine.
6. The efficiency of the mechanical and electrical components of the wind turbine was found more near to the mean wind speed of the site.
7. Break down was found in the month of April because of the annual planned maintenance of the wind power project.
8. In the operation of the wind power project, power down was found in the vital break down / fault in the first year of operation.

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