Abstract

Development of techniques for accurate assessment of wind power potential at a site and optimum site-matching of wind turbine generators are gaining increased importance. Performance of a Wind Energy System depends on factors like variation of wind speed frequency distribution, turbine speed characteristics viz. cut-in velocity v_C, rated velocity v_R, cut-out velocity v_F and hub height. Once the details of the wind resource is known for potential wind power site, efficient design of a wind energy system demands optimum matching of wind turbines to the potential wind site to obtain higher energy production at higher capacity factor.

In the area of assessment of wind power potential and optimum site matching of wind turbine generators, several problems merit immediate attention. These are:

- Development of a methodology for accurate assessment of wind power potential at a site,
- Ranking of different potential wind power sites in a geographical area and development of simple criteria for performance evaluation of different wind turbine generators in general and specifically considering:
  - Performance of different wind turbine generators at the same site, and
  - Performance of different wind turbine generators at different sites with same average wind speed.
- Development of a generalized method for optimum site matching of wind turbine generators, and
- Estimation of capacity factors of a new wind turbine generator to be installed in place of an older or obsolete wind turbine generator existing at a site.

This thesis addresses the above problems associated with wind power plants and makes an attempt to contribute to the solution of the same.

For assessment of wind power potential of a site, most of the investigators have used simple wind speed distributions that are parameterized solely by the arithmetic mean of the wind speed. In this thesis, the three means viz. arithmetic mean (*a.m*), root mean square (*r.m*) and cubic mean cuberoot (*c.m*) of wind speed data are computed and used for a site potential evaluation study. The wind speed distribution is statistically modeled using the Weibull and Rayleigh probability distribution functions. Actual wind speed data available from a site and the characteristic speeds of the installed wind turbines are used to compute the monthly and annual capacity factors. Kappadagudda Wind Power Station (KWPS), located in Karnataka, India is taken up as a case study to validate the analytical results obtained from the statistical models. Actual capacity factors of Kappadagudda wind farm are compared with the analytically computed capacity factors to arrive at salient conclusion that the capacity factors estimated using **cubic means** and **Weibull model** prove to be very close to the actual capacity factors obtained at Kappadagudda wind power station

Based on the above conclusion the ranking of various potential wind power sites and performance evaluation of wind turbine generators at these potential wind sites is taken up. A systematic methodology for performance evaluation of various commercially available wind turbine generators is developed. A survey of all the potential Indian wind power sites is taken up to create database of percentage frequency distribution of as many as 54 potential wind power sites geographically distributed in various Indian states. Salient conclusions are drawn for performance of different turbines at (a) different sites, (b) same site, and (c) sites with same cubic mean wind velocity.

A novel method of matching wind turbine generators to a site using normalized power and capacity factor curves is presented. The site matching is based on identifying the optimum turbine speed parameters from turbine performance index curve, which is obtained from normalized power and capacity factor curves, so as to yield higher energy production at higher capacity factor. Mathematical expressions for normalized power and capacity factor expressed entirely in normalized rated speed are derived. Wind Turbine Performance Index (*TPI*) is a newly introduced concept in this thesis. It is shown that there exists a unique *TPI* curve for every site from which speed parameters of a turbine that will optimally match a site can be obtained. The normalized power, capacity factor and turbine performance index curves are expected to be of great utility in determining (i) Optimum wind turbine speed parameters for a site (ii) ***Turbine Performance Index*** of various commercially available wind turbines, and (iii) to rank them in order of their performance for installation at the site. Two illustrative examples are presented to show the application of proposed curves. In the first illustrative example a site with wind turbines installed and operating is used while in the second a potential site for wind turbine installation is taken up.

A simple method for estimating the capacity factors, when new wind turbines are installed as a replacement for older or obsolete machines at a site is developed. It is well known that the new turbine with higher power rating will have higher hub height than the older machine with lower power rating. The capacity factors are first computed at older hub height at which wind speed distribution characteristics are known, and then they are extrapolated to the hub height of new machine. A generalized formula for obtaining capacity factor CF_{new} at new height z_{new} is derived.

A user friendly interactive software package for optimum site matching of wind turbine generators is developed and tested. A database consisting of Wind frequency distributions of 54 Indian sites and specifications of various commercially available wind turbine generators is created. Different program modules of the software package are described in the thesis. A significant feature of the software is that the user has the flexibility to analyze the wind sites and wind turbine generators not listed in the database.