The probability density distribution for the power output from arrays of wind turbines.

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ABSTRACT FOR WES 2012.

It is well recognised that a problem for wind power is its random power output that is largely uncorrelated with the pattern of power demand. As a result, it is necessary to have other power sources – principally gas fired power stations – that can be both brought on-line and taken off-line at comparatively short notice. Weather forecasting is now sufficiently accurate that the time scale for the necessary response of these back-up power sources is of the order of a day or so and this is well within the capabilities of gas power stations. However, for those planning a power system, it is important to know something about the statistical properties of large arrays of turbines spread over a grid-connected area so that the frequency with which back-up power is required can be estimated.

This paper discusses the probability density distribution of the power output from arrays of turbines. A relationship is derived for the reduction in the standard deviation of the power output from multiple turbines compared to the standard deviation of a single turbine output. The result is a function of the number of turbines and the spatial power output correlation coefficient between every pair of turbines. It is then shown that a large number of turbines spread rather evenly over an area can be represented a continuous power source distribution. Comparisons are made between the standard deviation of power output from a square array of discrete turbines and a square with a continuous distribution of power sources. In these calculations, the spatial correlation coefficient is taken to be a simple decaying exponential with a length scale for UK weather systems of about 450 kilometres. It is shown that as few as 64 turbines distributed evenly over a square region with an area roughly equivalent to the USA behaves like a continuous power source.

By using hourly wind records for a Met Office weather station, the cumulative probability distribution of power output is calculated for a number of uncorrelated wind turbines. It is shown that these distributions can be well represent by the Weibull distribution and this is then used to calculate the percentage of time that the power output from a widely dispersed distribution of turbines drops below various percentage levels of the mean power output. For example, the power output from a single turbine in a typical mean wind speed of 8 metres/second falls below 10% of the mean power output for around 20% of the time. For turbines distributed over the UK, the figure drops to about 6% of the time and, for a European grid-connected wind turbine system, the percentage of time below 10% of mean power output falls to less than 1% of the time. The analysis gives quantitative estimates of the ameliorating influence of widely dispersed arrays of turbines on the frequency with which back-up power is required.