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Power Quality Aspects of Wind Power Systems

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Abstract: **Wind energy is said to be one of the most prominent sources of electrical energy in years to come. The increasing concerns to environmental issues demand the search for more sustainable electrical sources.. Wind power has to overcome some technical as well as economic barriers if it should produce a substantial part of the electricity. In this paper, some of the technical aspects are treated, particularly those regarding the power system quality and stability. In the late 90's till date, with the wind farms rating hundreds megawatts, the concerns start to focus on the transient voltage stability of the power system. During the same period an International Electro-technical Commission (IEC) task force issued a standard procedure: the IEC 61400-21[1] to fill-in the lack of technical standards on assessment of power quality from wind turbines.**

Keywords: **Electro-technical Commission (IEC) task force, Power Quality Aspects Of Wind Power Systems.**

1. INTRODUCTION

The term ***"Power Quality"*** refers to the **voltage stability**, **frequency stability** & **absence of various forms of electrical noise** (e.g.: flicker or harmonic distortion) on the electrical grid

During normal operation, wind turbines produce a continuously variable output power. The power variations are mainly caused by effects of **turbulence** in wind and **tower shadow**. These effects lead to periodic power pulsations at the frequency at which blades pass the tower, which are superimposed on the slower variations caused by meteorological changes in wind speed. Power quality is actually a combination of voltage quality & current quality. Thus power quality is concerned with deviations of voltage or current from its ideal form. Power quality has nothing to do with deviations of product of voltage & current from any ideal shape.

The popularity of using the energy in the wind has always fluctuated with the price of fossil fuels. When fuel prices fell after World War II, interest in wind turbines waned. But when the price of oil skyrocketed in the **1970's**, so did worldwide interest in wind turbine generators. The wind turbine technology, R&D that followed the oil embargoes of the **1970's** refined old ideas and introduced new ways of converting wind energy into useful power. These are demonstrated in *"wind farms"* groups of turbines that feed electricity into the utility grid.

Today, wind energy is the world's fastest growing energy source and will power industry, businesses and homes with clean, renewable electricity for many years to come. By the end of 2013 the capacity of wind turbines installed globally reached a level of 3, 18,105 MW as shown in Table 1.1 below.

Table 1.1 – Top ten markets by the end of 2013

S. No	Country	MW	%
1	China	91,412	28.70
2	USA	61,091	19.20
3	Germany	34,250	10.81
4	Spain	22,959	7.20
5	India	20,150	6.30
6	U.K	10,531	3.30
7	Italy	8,552	2.70
8	France	8,254	2.60
9	Canada	7,803	2.50

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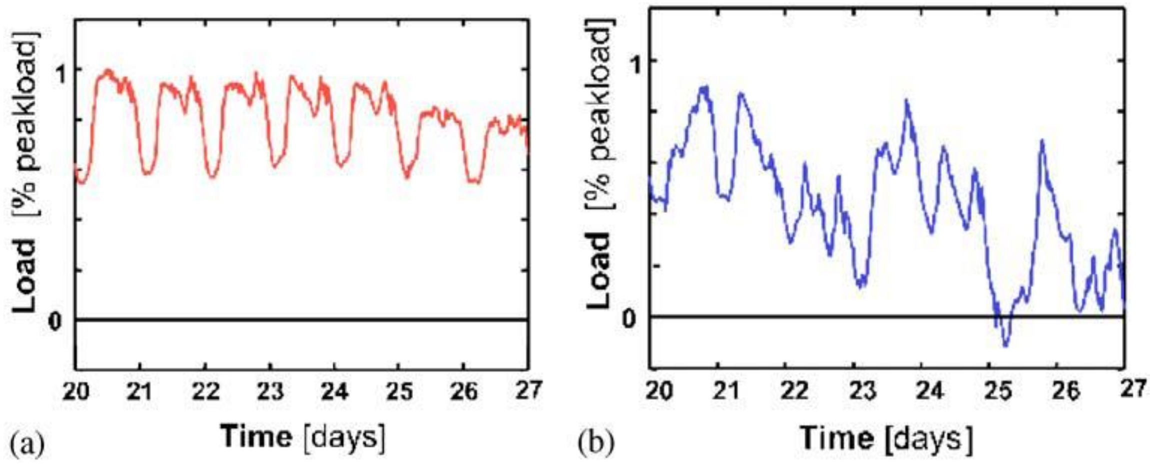
10	Denmark	4,772	1.50
	Rest of the World	48,332	15.2
World Total		**3,18,105**	**100.00**

Source: BTM, 2014, Wiser and Bollinger, 2014

2. FACTORS AFFECTING POWER OUTPUT

(a) Atmospheric Turbulence:

Wind energy is gained by wind-turbines placed in regions with strong wind, which automatically leads to situations which are dominated by strong turbulent flow situations. The effect of turbulence can be viewed on long term and on short term basis. On long terms or on large scales, respectively, it is the turbulent weather which will determine the wind conditions and thus will determine the power production on long terms.



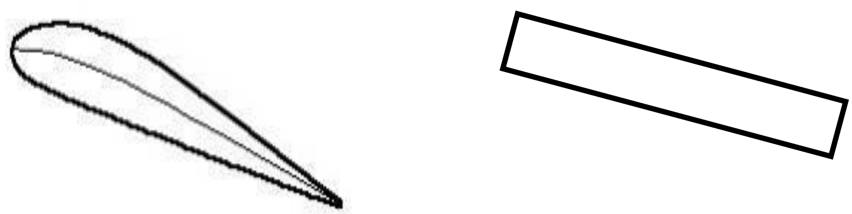
(a): The data are normalized to the maximal value. (b): The produced wind energy has been subtracted from the curve in part (a). Negative values indicate that more electricity is produced by the wind energy than is consumed in this region.

The turbulent fluctuation will cause short-time fluctuations in the power production as well as additional mechanic loads to the machinery.

(b) Blade plan form–solidity:

The various blade plan form types are **Rectangular**, **Reverse linear taper**, **Linear taper**, **Parabolic taper**, etc.

Thus, blades with aerodynamic shapes are preferred over rectangular ones Fig(1)below.



Good **Not so good**

Fig(1): Proper Blade Shape.

(c) Number of Blades: (Two Blade and Three Blade Systems)

At initial stages of wind mill installations a two blade system was used. But, due to various disadvantages associated such as imbalance, fluctuations in voltages and lower power quality issue, this system became lesser in use as a three blade system was introduced. Due to the triangular symmetry, this system is much more stable and a better power output without distortion was obtained.

(d) Tower Shadow:

If a number of wind towers are set up in a particular region, it is definitely possible that a wind tower may stand in the way of another wind tower. In this case, the amount of wind reaching the wind mill blades is less, causing less power output. This effect of reduction of wind power generation due to the presence of wind towers, blocking the path of wind for other wind towers, is given the name as Tower Shadow Effect.

Hence, it is very much necessary to maintain proper spacing and distance between each wind tower for proper working, functioning and maximum efficiency power output in a wind farm.

(e) Wind site terrain:

The wind farm site terrain has influence on power quality due to various regions as roughness factor of the site, its level from the sea bed, nature of wind in that site like direction, gusts, turbulence etc. Hence this effect must be carefully analyzes before the installation of wind mill.

(f) Relative Size of the wind farm and the Grid: If the capacity of wind farm is less than 2% of the grid capacity ,it has negligible effect else must be incorporated.

3. POWER QUALITY ISSUES

This section states the critical power quality issues related to integration of wind farms in weak grids in India. The issues have been identified during a field study tour in India.

The field study tour has identified the following issues to characterize the power quality:

1. Grid Availability and Capacity.

2. Reactive Power.

3. Voltage Unbalance.

4. Voltage Range

5. Frequency Range

6. Harmonics and Inter-harmonics.

7. Voltage Fluctuations.

8. Islanding and Overcompensation.

Of these, reactive power is at present the most important parameter for the electricity boards in India, while grid availability, frequency range, voltage unbalance and voltage range are the primary parameters influencing the wind turbine operation.

4. CONCLUSIONS

The wind farm site visits study permits an easy assessment of the power system quality assessment for any wind farm. Using the appropriate system models, the identification of voltage deviations and inadequate frequency regulation can be done in few minutes even for large power systems. The interaction of the loads in addition to the wind power variation on the power system dynamic operation can be done to characterize the power oscillations.

A very important point to be remembered is that "***The power produced from a large number of wind turbines vary at a relatively lesser rate than the power produced from a single wind turbine due to cancellation effect from the poor wind turbine."*** So, when the numbers of wind turbines are increased, then the power curve gets smoothened.

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