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Exploring Wind Power Systems

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Abstract

Wind energy is free, there is no cartel that controls its distribution and no sanction or blockade on wind is possible. Since it is unlimited, renewable and a pollution free source, there has been a movement the world over to develop highly sophisticated technology to convert kinetic energy in wind to electrical energy. In this paper, the need for exploiting Renewable Energy Sources has been discussed. A brief idea about the Indian energy scenario has been presented along with a detailed study of the Indian Wind Grid Code. Although RES accounts to only 2% of the total electricity generated, the alarming rate at which demand for energy is increasing worldwide leaves exploring RES inevitable, especially Wind Power.

1. Introduction

Energy plays a vital role in the economic, social and political development of any nation. Energy is critical, directly or indirectly, in the entire process of evolution, growth and survival of all living beings and it plays a vital role in the socio-economic development and human welfare of a country. Energy has come to be known as a `strategic commodity' and any uncertainty about its supply can threaten the functioning of the economy, particularly in developing economies. Conservation and efficient utilization of energy resources play a vital role in narrowing the gap between demand and supply of energy. Improving energy efficiency is one of the most desirable options for bridging the gap in the short term. There is high potential for generation of renewable energy from various sources- wind, solar, biomass, small hydro and cogeneration biogas. The total potential for renewable power generation in India as on 31.03.2012 is estimated at 89774 MW. This includes wind power potential of 49130 MW (54.73%). Out of the total installed generation capacity of renewable power as on 31.03.2012, wind power accounted for about 69.65%, followed by small hydro power (13.63%) and Biomass power (12.58%).manuscripts must be in English. These guidelines include complete descriptions of the fonts, spacing, and related information for producing your proceedings manuscripts.

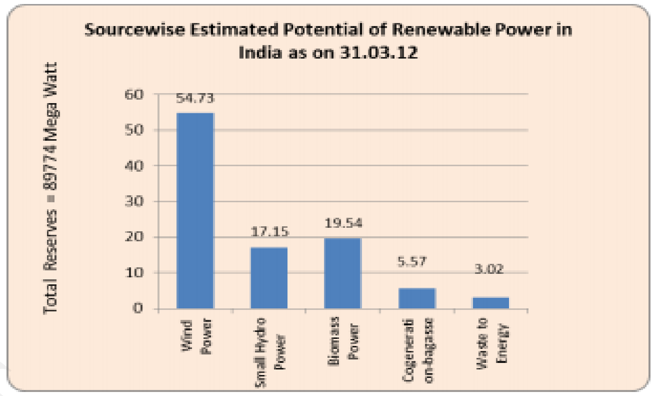

Figure 1.Distribution of RES in Indian power sector.

2. Wind Power System

WT convert wind energy into electrical energy, which is fed into electricity supply systems. The connection of WT to the supply systems is possible to the low voltage, medium voltage, and high voltage as well as to the extra high voltage system. While most of the turbines are nowadays connected to the medium voltage system of the grid future large offshore wind farms will be connected to the high and extra high voltage level. The main components for energy conversion are as shown in Fig. 2.

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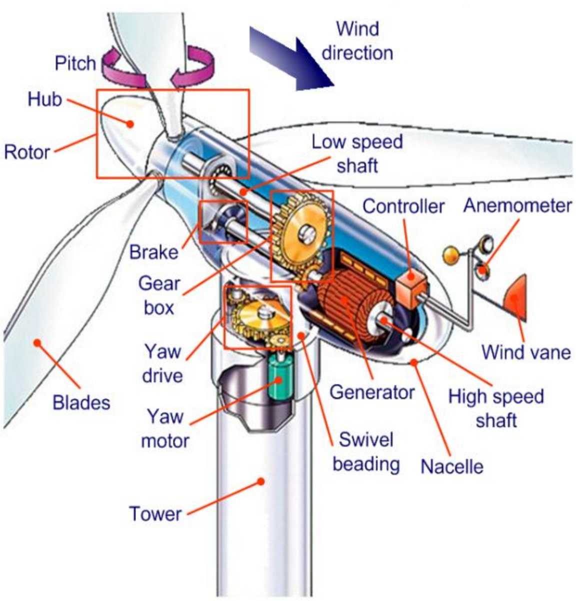

Figure 2.System components of HAWT.

2.1. Generator System for Wind Turbines

The energy conversion of most modern WT can be divided into two main concepts, fixed speed machines and variable speed machines. Original models of wind turbines were fixed speed turbines; that is, the rotor speed was a constant for all wind speeds. The fixed speed wind turbine does not operate at peak efficiency across a range of wind speeds whereas variable speed wind turbines can operate at maximum efficiency over all wind speeds (ideally). Variable speed configurations provide the ability to control the rotor speed. Generators can further be classified as follows:

- Synchronous Generators: A synchronous generator usually consist of a stator holding a set of three-phase windings, which supplies the external load, and a rotor that provides a source of magnetic field. The rotor may be supplied either from permanent magnetic or from a direct current flowing in a wound field.
- Induction Generators: The AC generator type that has most often been used in wind turbines is the induction generator. There are two kinds of induction generator used in wind turbines that are: squirrel cage and wound rotor.

3. Mathematical Expression Governing Wind Power

Power extracted from wind varies linearly with the density of the air sweeping the blades, and with the cube of the wind speed. It is expressed as

$$P_0 = \frac{1}{2}\rho A V^3 C_P \qquad (1)$$

C_p is the fraction of wind power which is captured by the rotor blades. C_p is called the power coefficient of the rotor or the rotor efficiency. The theoretical maximum amount of energy in the wind that can be collected by a wind turbine's rotor is approximately 59%, known as the Betz limit. Tip-speed ratio is defined as a ratio of linear speed of blade outermost tip to the free upstream wind velocity. It is given as follows:

$$TSR = \frac{\omega . R}{V} \qquad (2)$$

where$R$ and ω are the rotor radius and the angular speed respectively. The tip-speed is the ratio of the rotational speed of the blade to the wind speed. The larger this ratio, the faster the rotation of the wind turbine rotor at a given wind speed.

3.1 Operating Characteristics of wind Mill

All wind machines share certain operating characteristics, such as cut-in, rated and cut-out wind speeds. The speed control requirement of the rotor has five separate regions, as shown in Fig. 3.

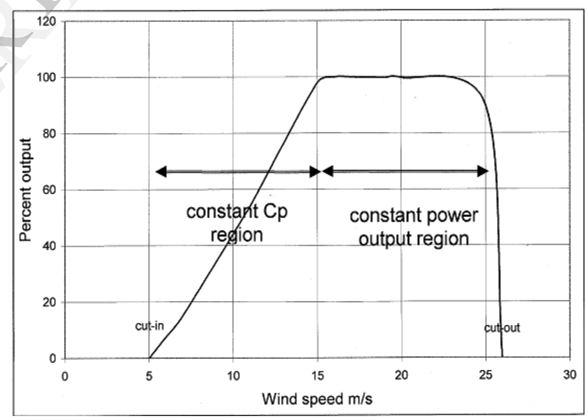

Figure 3. Five regions of the turbine speed control.

The turbine starts producing power at the cut-in speed. Below this speed, it is not efficient to turn on the turbine. At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases. The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power. In the constant maximum C_p region the rotor speed varies with the wind-speed variation to operate at the constant TSR corresponding to the maximum C_p value. In the constant speed region, the C_p is lower than the maximum C_p, and the power increases at a lower rate than that in the first region. At still higher wind speeds, the machine is operated at constant power to protect the generator and the power electronics from overloading. This can be achieved by lowering the rotor speed. At very high wind speeds, most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed. Normal wind turbine operation usually resumes when the wind drops back to a safe level.

4. System Control Requirement

The speed control methods fall into the following categories:

- Yaw and tilt control: The rotor axis is shifted out of the wind direction when the wind speed exceeds the design limit.
- Pitch control: The pitch of the blade is changed with the changing wind speed to regulate the rotor speed.
- Stall control: In this method of speed control, when the wind speed exceeds the safe limit on the system, the blades are shifted into a position such that they stall. The turbine has to be restarted after the gust has gone.
- Rate Control:The instantaneous difference between the mechanical power produced by the blades and the electrical power delivered by the generator will change the rotor speed as follows:

$$J\frac{d\omega}{dt} = \frac{P_m - P_e}{\omega} \quad (3)$$

Where, J is the polar moment of inertia of the rotor, ω is the angular speed of the rotor, P_m is the mechanical power produced by the blades and $P_e$is the electrical power delivered by the generator.

5. Indian Wind Grid Code

The Indian Electricity Grid Code (IEGC) provides technical rules to facilitate the operation, maintenance, development and planning of electricity grid. Indian Wind Grid Code (IWGC) gives the following guidelines:

- Role of various organizations and their linkages
- Planning code for transmission systems evacuating wind power. It specifies the policy and procedures to be applied in planning of transmission lines for evacuating wind power.
- Connection code for wind farms. It specifies the minimum technical and design criteria which shall be satisfied by any wind farms seeking connection to ISTSs/STSs/STUs.
- Operating code for wind farms. The operating code specifies the operating conditions that the wind farms shall comply with for safety and reliable operation of the grid and shall be applicable to the wind farms connected to the grid.

5.1. Voltage Fluctuations

Wind farm operation shall comply with the following permissible voltage fluctuation limits at the grid connection point.
A) Voltage fluctuation limit for step changes which may occur repetitively is 1%.
B) Voltage fluctuation limit for occasional fluctuations other then step changes is 2%.

The voltage fluctuations in a wind farm can occur because of the switching operations (capacitor banks, WTG start/stop), inrush currents during WTG starting etc.

5.2. Power Quality

All wind farms connected to the grid shall endeavour to maintain the voltage wave-form quality at the grid connection point. Power quality in relation to a wind turbine describes the influence of a wind turbine on the power and voltage quality of the grid. The main influences of wind turbines on the grid concerning power quality are the voltage flicker, harmonics (for wind turbines with power electronic equipment), voltage changes & fluctuations & the inrush currents.

5.3. Frequency of Operation of Wind Farms

For the operating range of frequencies between 47.5 Hz to 51.5 Hz, the WTGs shall operate according to the frequency response curve. No WTGs shall be started if the frequency is above 51.5 Hz.

5.4. Reactive Power Compensation

Reactive power compensation is important for wind farms to ensure reliable and trouble free grid operation and stable voltage profile. Adequate planning of reactive power compensation can minimize the reactive power loading on the transmission line. Reactive power compensation of wind farms should be able to maintain power factor between 0.95 lagging and 0.95 leading at grid connection point.

5.5. Fault Ride Through Requirements

With increasing penetration, wind farms have a major impact in Indian power system. So, the behaviour of wind farms should tend to be same as conventional power plants. Staying connected during system faults is a step towards that direction. During fault ride through, the WTGs in the wind farm shall have the capability to meet the following requirements:

A) Shall minimize the reactive power drawn from the grid.

B) The wind turbine generators shall provide active power in proportion to retained grid voltage as soon as the fault is cleared.

Wind farms connected at 66kV and above shall remain connected to the grid during system fault. Wind farms connected at 66kV and above shall have fault clearing time of 300ms.

6. Conclusions

In 2012, despite a slowing global economy, India's electricity demand continued to rise. Electricity shortages are common, and over 40% of the population has no access to modern energy services. India's electricity demand is projected to more than triple between 2005 and 2030. Grid stability is the primary consideration in interconnecting any new system to an existing grid. More and more renewable energy sources, mainly wind energy, are being integrated into the grid. Today, wind generation have a significant impact on Indian power grid. Wind turbine generators (WTG) do not have the same characteristics as synchronous generators and hence IWGC was developed which differs from the grid code of conventional power plants. Because of the variable nature of wind power, the aim of developing an interconnection standard would be to enable the grid to sustain the variability without affecting the power quality adversely.

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