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Technical challenges in connecting wind energy converter to the grid

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Abstract: Most developing nations of the world are looking towards renewable energy sources as a sustainable option. Among all the energy sources, the one that is matured to the level of connecting it to the grid (either distribution or transmission) is wind energy. As wind energy is increasingly integrated into power systems in some countries of the world, the stability of already existing power systems is becoming a concern and of utmost importance to the power system engineers and operators. This is because the connection of wind generators to the existing grid poses new challenges which have a significant impact on the system and equipment operations in terms of steady state, dynamic operation, reliability, power quality, stability and safety for both the utility and customers. These challenges are due to the fluctuating nature of the wind and the type of wind generator used. In order to supply quality voltage, SVC and STATCOM can be used to control the reactive power at the point of common coupling. Also the use of variable speed wind turbine generator can help in lowering the flicker level. This paper therefore gives the overview of the causes of these challenges, its effect on the existing power system and possible ways of improving the challenges.

Keywords: Flicker, Grid, Power Quality, Stability, Wind Generator

1. Introduction

Energy plays a vital role in the economic, social and political development of any nation [1]. Most developing nations of the world are looking towards renewable energy sources as a sustainable option. Among other sources, Wind energy has been described to be one of the mature and cost effective resources [2]. This is because electricity generated from wind is free from harmful emissions, very clean and has almost infinite availability of the wind energy that is converted into electricity [3].

When good sites with enough wind speed to drive the wind turbine have been discovered, the next step is to connect the wind turbine to the grid but the connection of wind generators to the grid posses new challenges to engineers as these have a significant impact on the grid system and equipment operations in terms of steady state, dynamic operation, reliability, power quality, stability and safety for both the utility and customers [4].

Technical challenges can be broadly classified into two: those from the grid that affect the Wind Energy Generator (WEG) and those from the WEG that affect the grid [5]. This paper emphasizes the latter. In reality, stability and reliability studies should be carried out whenever wind power is connected to power system to predict possible severe consequences on the power system being studied [6]. A number of literature works argue that the connection of wind turbines into the electric grid may influence or affect power quality and /or stability of the system due to the random nature of the wind and the characteristics of the wind generators [7] - [10]. Because of the reason above, it is important to predict the impact of the wind turbines on the electric grid before the turbines are installed or connected at power distribution level.

This paper therefore describes the possible causes of these challenges, its effect on the existing distribution power system and possible ways of improving the challenges.

2. Stochastic Nature of the Wind

Wind is a perfect example of a stochastic variable. Due to this stochastic nature, the output power generated by the wind turbine is fluctuating in nature.

The theoretical power in the wind is given by [4], [7-10]

$$P_{ae} = \frac{1}{2}\rho\pi R^2 V_{eq}^3 C_p(\theta_{pitch}, \lambda) \quad (1)$$

where Pae is the aerodynamic power extracted from the airflow [Watt],

ρ is the air density [typically 1.225Kg/m3]

Cp is the power coefficient which is the fraction of power in the wind captured by a wind turbine, which depends on the pitch angle θpitch [degree] and on the tip speed ratio given by

$$\lambda = \omega_{rot}.R/V_{eq} \quad (2)$$

i.e it is the ratio of the blade tip speed ω_{rot}*R to the equivalent wind speed Veq [m/s2],

R is the rotor radius;

ω_{rot} *is the rotor speed.*

Cp is equal to 0.59 which means, the 59% of wind power is the maximum power that a wind turbine can utilize.

Equation (1) shows that the power which a particular wind turbine can extract from wind is a cubic function of the wind speed which is also variable.

3. Connecting Wind Turbine to the Grid

Large wind farms are normally connected to the transmission or sub-transmission grid while smaller installations are connected to the distribution grid. This paper focuses on the technical issue at the distribution grid.

According to [11], the most important concern when interconnecting wind turbine to the distribution grid are

- Steady-state voltage level influence.
- Flickers which are commonly due to rapid changes in the load or the switching operations in the system.
- Response to grid disturbances/faults (Stability).

These three main interests according to [12] are called local technical issues because they depend mainly on local grid conditions.

The grid to which the wind generator is connected to will suffer voltage fluctuations and flickers, which is as a result of output power variation of the wind turbine.

3.1. Effect of WEG on Distribution network

Traditionally, distribution networks are designed to be passive i.e. they are not designed to accommodate any other source of generation. When Wind turbine generators with different sizes and types are connected to the network, the nature of the network is converted from passive to active [13]. This will significantly impact the power flow in the grid and voltage condition at the customers' end [14]. These impacts can either be negative or positive depending on the distribution system operating condition and the Wind turbine generator characteristics.

Different concepts of wind turbine generators have been developed over the years and are widely used for converting wind energy into electrical energy. They can be divided into two main groups *depending on the type of generator used*:

(a) Asynchronous (Induction) Generator which can be a fixed speed Squirrel cage or Variable-speed doubly-fed. Though Squirrel Cage induction generators have the advantage of being simple, robust, reliable and well-proven but cannot control reactive power, but only 'sucks var' from the system and also has limited power quality (voltage fluctuation, flicker e.t.c) control features. On the other hand, electrical power of a doubly-fed induction machines is independent of the speed, it is therefore possible to realize a variable speed wind generator [15]. In most cases, Doubly-Fed Induction machines allow active and reactive power control through a rotor-side converter.

(b) Variable Speed Direct Drive Synchronous Generator- This type of generator is very large due to the high number of poles [16]. To allow variable speed operation, the generator must be connected to the grid through a frequency converter. This supports the voltage by large reactive current during faults, which are much higher than reactive current support that can be achieved by other wind generator concepts since they are mostly equipped with excitation control systems(except for PM Excited Generators) [17]. Usually, Synchronous generators have the ability to supply and control reactive power. This type of generator is used in off-shore application [16].

Steady-state (load flow) and dynamic analysis need to be carried out on the distribution system to which the wind turbine generators will be connected so as to ascertain if the existing distribution system can accommodate the new generation.

4. Improving the Challenges

It is an established fact that connection of wind turbines to the grid may affect the voltage quality offered to the customers. The reason for this is the rapid variations of the wind turbine output power which is as a result will cause fluctuations in the supply voltage.

The distribution system in question should have high short-circuit ratio which may reduce voltage fluctuation at the point of common coupling [17]. Also since these major challenges (flicker and voltage fluctuation) on the grid are as a result of the generator technology used and the fluctuating nature of the wind, the use of static var compensator (SVC) or STATCOM can be used to reduce the voltage fluctuations and flicker produced by the wind power generation. The SVC or STATCOM controls the reactive power at the point where the wind generator is being connected to the grid in order to sustain the voltage at the point of common coupling.

Also the flicker level produced by variable speed wind turbine generator is lower than that produced by fixed speed wind turbine generator. So, variable speed wind turbine generators can be used in place of the fixed speed.

5. Conclusion

The efficient integration of wind generators into power system is very necessary in order to enjoy green electricity (which is the electricity produced from renewable sources that are environmental friendly and non-polluting) production. But there are challenges experienced in connecting the wind generators to the grid because of the fluctuating nature of the wind and comparatively new types of its generators which result in voltage fluctuation and flicker. Research work on the impact of this new generation (wind) on the existing grid should not also be neglected. The ability of a site to sufficiently accommodate wind generation does not only depend on wind speeds but its ability to interconnect to the existing grid. If the wind generator is to be connected to the grid, the voltage and the frequency limits of the consumers must not be compromised. This is because the overall purpose of the power system operation, independent of wind power generation level, is to supply an acceptable voltage to consumers and continuously to balance production and consumption. In order to supply quality voltage, SVC and STATCOM can be used to control the reactive power at the point of common coupling. Also the use of variable speed wind turbine generator can help in lowering the flicker level.

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