Synopsis

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It has been now very well realized that the fossil fuel resources are depleting at a pace which will not last for more than a decade. The global fossil fuel production has come to the peak. Also, there is a great political opposition for the nuclear power in the many parts of the world. In this scenario, only renewable energy sources have left to make the great contribution. Due to this, power sector undergoes tremendous changes with the increasing amount of pressure to include renewable energy sources for reduction of carbon footprints. The major sources of energy are the sun and the wind. Mostly, renewable energy sources is utilized by converting in to electrical energy. Integration of wind power source in to existing grid possess many technical challenges. These challenges exhibits in form of power system instability.

It is very serious to depend only on wind power; it possesses serious challenges to security of supply to customers. With increased penetrations, the problems will get aggravated due to the intermittent nature of wind power, uncertainties in the plant availability of power Generation, unpredictable disturbances, available network resources and many other issues. Customer security is evaluated in terms of the customer damage costs of operating wind generation units without necessary standing reserve, which may result in short of power supply to meet load demand.

Wind turbine generator systems completely differ from the conventional grid connected synchronous generator, which is traditionally used in power plants. Due to their different characteristics, these generating systems interact differently with the power system. The penetration level of wind power generation determines the interaction of generators and network elements [1,2]. In the analysis of wind generation-system interaction, local impact and system wide impact are studied separately. In Local Impact, the affected area is restricted to a particular region, either wind farm or single wind turbine. This impact can be caused by any specific wind turbine or wind farm. Local impacts can be summarized as change in the load flow, effect on protection scheme, fault current level, harmonic resonance, rating of the protective gears and variation in node voltages. Unlikely local impact, system wide impact can be seen on the relatively larger area of the system. It is the consequence of increased penetration of the wind power in the system and cannot be attributed to individual wind turbine. The system wide impact can be summarized as the dynamic stability, frequency control, system balancing, voltage controllability, reactive power control, economic dispatch of the power generation unit, and requirement of ancillary services.

First important aspect of stability is the voltage variation under different operting conditions. Voltage performance refers to achieving desired voltages within a specified operating range. While the improvement in voltage performance indicates increased system robustness, however, it is not a true measure of the power systems stability [3].

The maximum load, a system can bear, is used to compute various indices of voltage stability. The maximum loadability is related with the bifurcation point. There are two major bifurcation, one is saddle node bifurcation and another is limit induced bifurcation. The saddle node bifurcation is related with the point, where the system state matrix attains singularity. The limit induced bifurcation appears when generators reach their reactive power limit and will not be in a position to support system voltage by injecting additional power and ultimately lose control.

Inclusion of uncommitted wind generating units in the system will displace the conventional active power sources, accompanied by reduction in reactive power sources. Such changes may force the available power sources to hit their limits [4]. Due to such displacement, there will be a shift in reactive power generation from outgoing unit to the remaining online units.

Allocation of power generation to wind energy sources may change the unit commitment entirely. For each level of wind power capacity, the available online capacity of conventional unit may change. If the active power resource is made offline, the reactive power capacity also gets reduced. A reduction in available reactive power capacity will deteriorate the voltage stability margin. Also with the change in unit commitment, the relative distance of source and sink of reactive power may also get changed, which will significantly affect the voltages, especially in the weaker part of the network.

The stochastic nature of wind adds to the challenges posed by load variation. These two variations together may make the system unstable. Along with load and wind variations, the other parameters like system strength and reactive power availability also plays an important role. In this work, the voltage variation is studied using probabilistic methods, considering uncertainty.

The second aspect is the harmonic stability. Traditionally, harmonics problem has been identified as the power quality issue. But here, it has been recognised as the stability problem. As, it is eventually affecting the stability of wind turbines and hence the stability of the power system.

The majority of new generation turbines are power electronic based and operates at very high switching frequency. This causes current harmonics injection and voltage deterioration. Weak system produces large harmonic voltage drop, even with small harmonic currents. The power quality problem with small turbines are more imperious than large turbines. However, a large number of wind farms affect the power quality severely. There are also some frequencies at which harmonic impedance become so high that, it may over-dominate the fundamental voltage and result in very high overvoltage. Also, with rapid variation in wind power cause voltage fluctuation, widely known as Flicker. It may damage sensitive equipment / devices and also cause stress on eyes. If power quality gets affected severely, it may affect the stability of wind turbines and hence the stability of power system.

A structured framework is required to analyse the harmonic emission with the Wind Turbine Generator and it′s interconnection with the grid, which can create the resonance condition [5]. The harmonics from wind turbines are stochastic in nature and they are associated with the active power generation level. They may adversely interact with the grid impedance and cause unexpected harmonic resonance. This issue needs to be addressed comprehensively at the planning stage, otherwise it may become more critical as wind power contribution increases in the grid.

Unlike conventional power generation, wind power is distributed in nature. So, it is very complex, when it comes to analysing the harmonic generation from wind converters. However, different approaches have been adopted to address this issue [6,7]. Mainly, power quality assessment is done as per IEC 61400-21 procedure.

The conventional tool for harmonic resonance identification is frequency scan. Though, it shows the presence of harmonic resonance in the system, it doesn't give idea about the root cause of resonance. So, there is an urgent need of a method or technique is felt, which helps in identification and mitigation of root cause of harmonics.

The third important aspect is the small signal stability. The small signal stability is used as a precheck tool for transient stability. Any small signal stable system, may or may not stable under transient. But, small signal unstable condition definitely shows the transient instability. So, the small signal stability is necessary but not sufficient condition for transient stability.

The small signal stability of power system with wind energy sources depends on the stability of Wind Turbine Generator. If the wind turbine is stable, definitely it will help in maintaining the system stability. The wind power variability demands that, the wind turbine stability shall be checked under all conditions. So, concept of probabilistic small signal stability analysis has been emerged [8,9]

With the intent to assess the system stability with wind power, the major objectives of the study have categorized as under.

 Assess the variation of grid voltages with increasing share of wind power Study the effect Harmonics Resonance Phenomena with Wind Power To study how the Wind Turbine gets affected by the small turbulence.

In the view of the above, the thesis is structured into following chapters.

Chapter 1 discusses the stability with penetration of wind power. The concise literature survey and motivation for research on a given topic has been discussed in this chapter.

Chapter 2 is on the voltage stability with wind power. Different methods of voltage assessment have been discussed and comparative evaluation of methods is done to find out pro and cons. Using different methods and different test systems, different cases have been studied and the results are discussed.

Chapter 3 is dedicated to the harmonic stability with wind power. The harmonic resonance phenomena has been discussed in detail. The modal analysis method for harmonic resonance analysis has been used for analysis and design of optimized filter. Finally, the optimized filters performance has been evaluated to check compliance to harmonic standard.

Chapter 4 is on the power electronics converter stability analysis. The converter performance with different topologies of output-filter has been given in this chapter. Finally, the shaping of converter output impedance has been discussed.

Chapter 5 is on the real time case study, which discusses the problem and solution of harmonic resonance from the field. This chapter is based on the real time problem observed in the field. It is explained that, how this problem was tackled with simple solution.

Chapter 6 is on the small signal stability analysis. In this chapter probabilistic small signal analysis of DFIG has been carried out. The small signal stability of DFIG has been analysed using Latin Hypercube Sampling (LHS) method.

Chapter 7 is dedicated to the simulation of DFIG to check the effectiveness of the controller to meet LVRT requirements. In this chapter the simulation has been carried out with different fault duration. The results shows that, the DFIG works well within the boundary defined in grid code and fails outside.

Chapter 8 is conclusion of the work. The conclusion on effect of wind energy sources on voltage stability, harmonic stability and small signal stability has been given. Also, the possible future work has been discussed.

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