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IMPACT OF WIND POWER ON POWER SYSTEM STABILITY

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Abstract: Wind energy is one of the fastest growing renewable energies in the world. The generation of wind power is clean and non-polluting; it does not produce any by-products harmful to the environment, but wind power also effect the stability of the system. Wind power always faces problem for the continuous supply of the power to the system. This paper explains the problems faced during wind integration with the Grid. These problems effects power system stability of the system.
Keywords: System Stability, Wind power, flicker, Harmonics, Voltage Dip.

I. INTRODUCTION

Power systems have been in operation since the late 19th century. They were used for powering street lighting, and were soon expanded to include mechanical loads. The growing importance of wind power, which can be observed in many European countries, the USA, Canada and also Australia [1] requires detailed analysis of the impact of wind power on power system stability. Therefore, a number of studies have been carried out recently and are currently carried out for identifying required network reinforcement, reserve requirements and the impact of wind power on power system stability .These studies are dealing with different aspects related to wind power, such as the fluctuating nature of wind power, location of wind resources, various generator technologies and generator control. The results are generally representing a superposition of various wind power aspects and predict required network reinforcements, additional reserve requirements, the impact on power system stability etc. but it is difficult to explain the reasons for encountered problems and required system upgrades from these studies because of the large variety of aspects that have been studied simultaneously. The objective of this paper is to explain and to understand and not to calculate actual numbers and figures. The phenomenon that is subject to investigation of this paper is transient stability, especially transient stability limits on long tie-lines.

II. IMPACT ON POWER SYSTEM STABILITY

A. Impact of Wind Power on System Security

The security of a power system is regarded as the ability of the system to withstand disturbances without causing a breakdown of the power system [2]. For wind power generators to contribute to the security of a power system, they must have the ability to contribute to both the voltage and frequency control in stabilizing the power system following a disturbance, they must be able to ramp up or down to avoid insecure power system operation, they must be able to ride through disturbances emanating from the power system, they must be able to avoid excess fault levels while still contributing to fault identification and clearance, and they should be able to operate in island mode when the supply from the grid is lost [3]. Although, no electricity system is 100 percent reliable, intermittent generation will increase the level of uncertainty and therefore also the reserve capacity band of the power system which in turn increases the generation costs. The effect is minimal at low penetration levels, but could be challenging at high penetration levels [4, 5]. Among these challenges are the effects on the power imbalance, reserve management, voltage control and system stability.

B. Power Imbalance

WECS generate electricity when wind speeds exceed a certain minimum and the WECS output depends on these wind speeds. Wind speeds cannot be predicted with high accuracy over daily periods, and the wind often fluctuates from minute to minute and hour to hour. Consequently, electric utility system planners and operators are concerned that variations in the output of WECS may increase the operating costs of the system [6]. This concern arises because the system must maintain a balance between the aggregate demand for electric power and the total power generated by all power plants feeding the system. The variability and the unpredictability of wind power can cause a power imbalance on the grid [7]. Their output power may not be available to meet the demand when needed, while there could be an excess when the demand is low, thereby causing an upset on the grid.

C. Impact of Wind Power on Reserve Management

Electrical power is expensive to store. Hence, the power produced at the generating station must be consumed by the load. Therefore, there must be a power balance between all the generating plant and the load demand. Any imbalance would affect the frequency of the system which could lead to loss of synchronism in certain cases [8]. The accomplishment of a power balance between the load and the generating plants is more challenging in the case of wind power generation due to its unpredictable nature especially when the generating ratio is high. A system of high wind power integration would expand the reserve capacity due to the variability of the primary resources.

D. Impact on the Power System Voltage Control

The nodal voltage distribution on a power system network must not be less than an acceptable limit. The reactive power contribution capability of a power plant determines its nodal voltage control. A conventional generator has a way of controlling the reactive power to ensure a proper voltage distribution at the different nodes of the network. Most WECS make use of induction generators which are not capable of injecting reactive power to the grid [8]. This often forms one of the limitations of wind power integration.

III. IMPACT OF WIND POWER ON POWER QUALITY

The degree of deviation from the normal sinusoidal voltage and current waveforms in power system network determines the quality of the power transmitted on the grid [9]. The liberation of the electricity market has resulted in power quality becoming an issue of focus in recent times. Power quality components of a power system comprise of flickers, harmonic distortions, voltage imbalance, voltage sag and voltage swells. The level of tolerance of power quality depends on the kind of load installed by the customer, that is, how sensitive the load is. The occurrence and frequency of power quality problems depend on the strength of the network, type of consumer load fed by the network, electronic equipment utilized, and geographical location of the area, length of the network, load behavior, climate change and the operational practice of the utility operators [10].

A. Harmonics

Harmonics can be injected both at the generation and the consumer end. At the consumer end, harmonics are caused by non-linear loads such as television, personal computers, compact fluorescent lamps, and so forth. At the generation level, sources of harmonics include the Flexible Alternating Current Transmission System (FACTS) such as reactive power compensators and power electronics devices. Variable speed wind generators, that is, WECS made of doubly fed induction generator (DFIG) and synchronous generator (SG), require power converters to achieve controllable grid integration. These converters are sources of harmonics especially in grids with low short circuit capacity. They could cause distortion to the voltage and current waveform of a power system. Harmonics increase line losses and cause excessive heating of equipment which decreases their lifetime. IEEE 519-1992 is a standard that sets the requirements and imposes limits for the harmonic measurement of different order harmonics and the total harmonic distortion (THD). The limits for system voltage distortion are 5% for THD and 3% for any individual harmonics as stipulated by IEEE 519-1992 [10].

B. Flickers

Flickers are the periodic voltage frequency variations typically between 0.5 and 25Hz that cause annoyance from the incandescent bulb [11]. Flicker annoyance is severe at a frequency of 8.8Hz [11]. The wind generators sometimes produce oscillatory output power, which could cause flickers in the power system network. The fluctuation caused by the tower shadow and turbulence effect in wind may cause flickers. IEC 61400-21 furnishes the measurement procedure to calculate the flicker impact of wind turbines.

C. Voltage Dip

Voltage dip also called voltage sag, is a momentary reduction in the rms voltage value beyond a specified threshold for a short duration of time [12, 13]. Voltage dip is considered according to European standard the EN 50160, as a drop in power voltage to a level below 90 percent of nominal voltage for no longer than a minute. It is a very common and serious type of power quality disturbance due to its effects on sensitive equipment and industrial processes [14]. Voltage dip could occur when there is a large load such as motor start up, transformer energizing, capacitor energizing, switching of electronic load, momentary overload or a fault in the system network. It can cause the disconnection of wind generators, which could have a negative impact on the stability of the network due to loss of generation.

IV. CHALLENGES OF WIND POWER ON POWER SYSTEM STABILITY

Kundur [15] stated that “when a power system maintains a state of equilibrium during normal operating condition or returns to acceptable state of equilibrium after being subjected to a disturbance, then the system is said to be stable”. A disturbance could be disconnection of generators, load, lines, transformers or a fault. The stability where a generator remains in synchronism in order to deliver power is known as angular stability and is governed by the relationship between the generator rotor angle and power angle [15]. The stability that considers large disturbances is referred to as transient stability, and small signal stability is one that considers small system disturbances [16]. Small signal stability problems occur when there is an insufficient damping of system oscillations as a result of changes in the operating parameters of power system [15]. Before the advent of wind power plants, power systems mainly consisted of synchronous generators for electricity production. The behaviour and control of these generators following a disturbance are well understood by the utility operators due to their experiences thereof over the years. The advent of wind power introduces induction generators into the power system for electricity generation because they are cheap, robust and support variable speed operations. At the earlier stage of wind power integration, there was little concern about its influence on the overall stability of a power system. With the increasing trend of wind power integration, it may begin to have a significant influence on the power system transient stability margin. The induction generators mostly employed in wind power applications operate asynchronously and are characterized by poor reactive power control capability. Fixed speed induction generators are provided with reactive power compensator to cater for the large reactive power demand from the network. The power electronics devices provide the reactive power to the grid in the case of variable speed generators. Critical clearing method has been widely adopted for transient stability studies [17-19].

V. CONCULSIONS

IEEE 519 is used for harmonic control under defined limit and IEC 61400 for Flickers study. Excitation system and voltage source static var compensators such as STATCOM have been used to increase the stability margin thereby improving the ride through capability of the generators.

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