Power system stability study on multi machine systems having DFIG based wind generation system

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Abstract - Power system stability is related to principles of rotational motion and the swing equation governing the electromechanical dynamic behavior. In the special case of two finite machines the equal area criterion of stability can be used to calculate the critical clearing angle on the power system, it is necessary to maintain synchronism, otherwise a standard of service to the consumers will not be achieved. With the increasing penetration of doubly fed induction generators (DFIGs), the impact of the DFIG on transient stability attracts great attention. Transient stability is largely dominated by generator types in the power system, and the dynamic characteristics of DFIG wind turbines are different from that of the synchronous generators in the conventional power plants. The analysis of the transient stability on DFIG integrated power systems has become a very important issue. This paper is a review of three types of stability condition. The first type of stability, steady state stability explains the maximum steady state power and the power angle diagram. There are several methods to improve system stability in which some methods are explained.

Keyword: DFIG, wind, DG, GSC.

I. INTRODUCTION

Stability is the most significant feature needed in the modern power system. Stability problem in power system has been noticed during the recent years, because of the fast growth in electric and electronic loads. However, the developments and improvements in generation and distribution systems have not met yet this fast growing loads and the increasing in the number of important and sensitive devices in power system. Disturbances and short outages in generators or transmission lines always have negative effect on power system. In addition, a rapid variety in loads in the plant leads to voltage and frequency fluctuations. These disturbances and fluctuations that occur during the transient process cause stability and quality issues in power system [1].

Power system stability is subjected to changes in system or loads levels that may be sudden or gradual and severe or small changes. Stability is an important concept that determines the power system stable operation. In general, rotor angle stability is taken as index, but the concept of transient stability, which is the function of operating condition and disturbances deals with the ability of the system to remain intact after being subjected to abnormal deviations. A system is said to be synchronously stable (i.e., retain synchronism) or a given fault if the system variables settle down to some steady-state values with time, after the fault is removed [2].

Electric power system stability analysis has been recognized as an important and challenging problem for secure system operation. When large disturbances occur in interconnected power system, the security of these power systems has to be examined. Power system security depends on detailed stability studies of system to check and ensure security.

In order to determine the stability status of the power system for each contingency of any disturbance occurs in power system, many stability studies are defined. Power system stability analysis may involve the calculation of Critical Clearing Time (CCT) for a given fault, which is
defined as the maximum allowable value of the clearing time for which the system remains to be stable. The power system shall remain stable if the fault is cleared within this time.

However, if the fault is cleared after the CCT, the power system is most likely to become unstable. Thus, CCT estimation is an important task in the transient stability analysis for a given contingency [3].

Over the past decades, the energy storage technologies have grown and provided some economic and environmental benefits for business and the society. The energy storage system, which is an electrical storage technology, is applied in many electrical and electronic power applications for improving and enhancing stability and the performance of modern power systems [1].

II. LITERATURE REVIEW

Md Ayaz Chowdhury et al. [3] A new quantitative assessment of transient stability for power systems integrated with doubly fed induction generator (DFIG) wind farms is proposed by evaluating the transient energy margin (TEM) through the formulation of the transient energy function (TEF) for multimachine systems. To achieve an accurate TEM, the TEF is modified to account for the separation of the critical machines from the system and an unstable equilibrium point is calculated on the basis of post-fault trajectory reaching the potential energy boundary surface. Simulation results show that such power systems integrated with DFIG wind farms are more sensitive to transient events of higher voltage sag, longer fault clearing time, lower load operation and higher wind power penetration level. It is also observed that machines located far from the fault are also exposed to inferior transient stability because of fault with geographical dispersion of wind farms. As a result, advanced switchgear, faster isolators, more efficient power reserve systems and advanced reactive power compensating devices must be equipped to ensure reliable operation of power systems integrated with the DFIG wind farms during transient events.

Ming Zhou et al. [4] This paper proposes a coordinated control of doubly-fed induction generator (DFIG) based wind farms’ (WFs) post-fault active power and synchronous generators’ (SGs) tripping with the aim of improving transient stability of both the 1st swing and multi swings. To achieve it, the impact mechanism of the WFs’ post-fault active power and SGs’ tripping on the stability margin of each swing is firstly presented by using extended equal area criterion (EEAC). Based on this, a principle of the coordinated control is put forward. WFs’ control period is designed as six stages and the value of post-fault active power in each stage is suggested to improve the stability of the first five swings and maintain the post-fault steady state. To decrease the tripping amount of SGs, SGs are tripped only when WFs’ control effect is not sufficient to avoid the instability.

Shiba Paital et al. [5] A comprehensive review on stability analysis in multimachine power system is presented in this study. The increasing demand of power has led to the expansion of power system and complexity in design as well as operation. This threatens to deteriorate the stability and reliability in the power network. However, with the advances in semiconductor and power electronic control technology, various flexible AC transmission systems (FACTS) are designed to enhance the power system stability. Different power system configurations with the incorporation of conventional and distributed generations (DGs) are proposed whose stability is being tested in the presence of the FACTS controllers.

Issarachai Ngamroo et al. [6] This paper provides a general review of the DFIG wind turbine's impact on power system dynamic performances such as frequency stability, transient stability, small-signal stability, and voltage stability. Besides, ancillary services from the DFIG wind turbine for the power grid, such as frequency support, reactive power, and voltage support, are explained. Especially, the survey emphasizes power oscillation damping methods by the DFIG wind turbine.

III. ANCIILLARY SERVICES FROM DFIG WIND TURBINE

With increasing integration of DFIG wind turbines into power grids, DFIG wind turbines can be expected to become active and reactive power service providers. With sophisticated wind forecasting methods nowadays as well as the power smoothing techniques, DFIG wind turbines can be treated as a dispatchable power source by power utilities [7].
Accordingly, it is possible for DFIG wind turbines to contribute ancillary services such as frequency control, voltage control, power oscillation damping, etc. to power systems [8,9]. In addition, various national grid codes require DFIG wind turbines to offer ancillary services [10]. In the following, we review previous works on frequency control, voltage control, and power oscillation damping from DFIG wind turbines.

IV. DFIG WIND TURBINE

The structure of the DFIG wind turbine and control system. The DFIG principally consists of a back-to-back grid-side converter (GSC) and a rotor-side converter (RSC). The stator windings are interfaced with the power grid, while the rotor windings are connected to the power grid by RSC and GSC. The decoupling of the rotor from the power grid has the merit that the power capacity of the converters is 30% of that of the wind turbine. Consequently, the cost of converters and the harmonic filter is significantly reduced. In addition, the smaller converter size not only results in lower power loss but also leads to higher efficiency. In particular, the salient feature of a DFIG wind turbine is the controllability of the active and reactive power outputs (PDFIG, QDFIG, respectively). Based on the vector control technique [8], both PDFIG and QDFIG can be independently controlled by the control system in Fig. 2. This control system is composed of the speed controller, the voltage controller, and the pitch angle controller. Here, the main control objective of a DFIG is amelioration of power system oscillations.

Therefore, the RSC is appropriate for power oscillation damping. As mentioned in [8], the quadrature-axis current of the RSC (i qr) can be used to control the active power output by the speed controller, while the direct-axis current of the RSC (i dr) can be employed to control the reactive power output by the voltage controller. With the ability of reactive power output control of the DFIG, reactive power compensation is not required as in a fixed-speed wind turbine [10]. This ability not only supports the DFIG terminal voltage during the steady state and grid faults but also eliminates the installation cost of reactive power compensating devices.

V. STABILITY STUDY WITH INTEGRATION OF DISTRIBUTED GENERATION RESOURCES

The modern power system configuration is becoming highly complex with the integration of renewable energy resources like solar, wind, biomass, wave energy and so on. These resources being intermittent in characteristics, greatly affect the important power system parameters such as voltage and frequency thereby making the stability issues more challenging. Various methodologies are being proposed by many researchers to improve the stability in renewable energy or DG based power system. Sometimes, energy storage systems like battery, flywheel and super capacitors are also integrated to compensate the uncertain characteristics of the renewable energy resources.
VI. DG-BASED POWER SYSTEMS

DG-based power systems are the decentralized energy sources which assist the main power grid for improving supply quality and reliability. Dahal et al. [11] proposed an approach for selecting the most suitable capacitor bank in a renewable-energy based distribution system for small-signal stability. Wu et al. [12] made a study on the impacts of wind farm spatial distribution and shunt compensation levels on SSR oscillations using eigenvalue sensitivity analysis. Hussain and Ali have studied the effects of series compensation techniques like dynamic voltage restorer (DVR), series dynamic braking resistor (SDBR), thyristor switched series capacitor (TSSC) and the high-temperature superconducting fault current limiter (SFCL) in a DFIG-based variable speed wind generation system under severe fault conditions. Authors found that the series compensating devices improve transient stability, rotor angle stability, regulates active and reactive power [13].

VII. CONCLUSION

A comprehensive review of the methodology proposed for stability enhancement in multi-machine system is presented in this paper. Stability study is explored in conventional as well as DG-based power systems. A detailed discussion on various issues related to stability in multi-machine systems is presented with the incorporation of the different FACTS controller under different operating conditions in the referenced papers. Also various methods for analyzing DFIG wind turbine’s impact on power system dynamic performance, such as frequency stability, transient stability, small-signal stability, and voltage stability, have been reviewed.

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