Chapter 10
Impacts of Wind Generators on the Dynamic Performance of Power Systems

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ABSTRACT

The complexity of power systems has been increased in recent years due to increased utilization of the existing transmission lines using FACTS (Flexible AC Transmission System) devices and for changing the generation mechanism with more intermittent sources and lower inertial units. This changing nature of power systems has considerable effect on its dynamic behavior resulting from power swings, dynamic interaction between different power system devices, and less synchronized coupling. This chapter will analyze the changing nature of power systems and its dynamic behavior to identify critical issues that limit the large-scale integration of wind generators and FACTS devices. The studies in this chapter are conducted on a 16-Machine, five area New England and New York power system. In this chapter, the study of dynamic behavior includes modal analysis, Power-Voltage (PV) analysis, eigenvalue tracking, and dynamic simulations to investigate the dynamic behavior of a complex power system under both small and large disturbances.

INTRODUCTION

Power systems are complex systems that evolve in response to economic growth and continuously increasing power demands. With growing population and the industrialization of the developing world, more energy is required to satisfy basic needs and to attain improved standards of human welfare (Anderson & Fouad, 2002). The structure of the modern power system is becoming highly complex in order to make energy available economically with reduced carbon emissions and the use of renewable energy. In recent years, power demand has increased substantially while the

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expansion of power transmission lines has been severely limited due to inadequate resources and environmental restrictions. As a consequence, some transmission lines are heavily loaded and system stability becomes a power transfer-limiting factor. FACTS controllers have been used to solve various power system steady-state control problems, therefore, enhancing power system stability in addition to their main function of power-flow control (Qiao, et al., 2006).

The management of power systems has become increasingly complex due to several contributing factors (Leung, et al., 2005): power systems are now being operated closer to their maximum operating limits; environmental constraints restrict the expansion of transmission networks; the number of long distance power transfers has increased; and lower inertial Wind Turbines (WTs) have been integrated into the existing grids. This changing nature of a power system significantly affects its dynamic behaviour: the dynamic interactions between different partly synchronised couplings of connected devices cause oscillations; lower inertial and intermittent units absorb reactive power especially during transient periods; and power systems have been restructured in many parts of the world to create competition amongst different power producers (Buygi, et al., 2003) which has resulted in increased complexity and the emergence of several new threats to the stable operations of power systems.

Dynamic reactive devices, such as Thyristor-Controlled Series Capacitors (TCSCs), Mechanically Switched Capacitors (MSCs), Static VAR (Volt-Ampere-Reactive) Compensators (SVCs), and Static Synchronous Compensators (STATCOMs) do not require extensive amounts of land nor are they especially visible when compared with major new EHV (Extra-High Voltage) transmission lines. These characteristics make them much more acceptable to government agencies and the public, and thus, in many cases, these dynamic reactive devices are much less expensive to build than the equivalent number of new transmission lines that may otherwise be necessary. Employed in moderation, such devices are useful additions to the set of tools that system planners and operators should use to relieve voltage or VAR problems and provide flexibility. However, if used to excess, such devices will likely increase the risk of uncontrolled system collapse and significantly increase the complexity of system design and operation. This complexity may introduce new failure modes into the system and reduce its overall reliability in unexpected ways.

Following the issuance of the renewable energy regulations in recent years to give impetus to the development of renewable energy by governments in Denmark, Germany, USA, China, Ireland, Australia, and India, a large number of wind farms are currently interconnected into transmission networks at the 220kV voltage level with higher installed capacities than those of connected wind generators. Being connected to a higher voltage level, their impact is becoming more widespread. The European Wind Energy Association (EWEA) projects that there will be 230 GW and 300 GW of total installed wind power capacity in Europe in 2020 and 2030, respectively. This will result in wind power generation of the same order of magnitude as the contributions from conventional technologies developed over the past century. An overview of the historical development of wind energy technology and the current worldwide status of grid-connected, as well as stand-alone, wind power generation is given (Ackermann & Soder, 2002). The present and progressive scale of integration has brought to a head serious concern about the sustainability.

Wind power has many advantages from the sustainability perspective: aside from equipment manufacture, it carries with it little ecological impact; produces no green house gases; physically takes little room for implementation; and substitutes for a number of environmentally problematic technologies such as the burning of coal or gas, the creation of new hydro reservoirs, and/or the use of nuclear energy. Reducing and