Chapter 6
Dynamic Analysis and Stability Improvement Concerning the Integration of Wind Farms: Kurdistan Electric Network Case Study

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ABSTRACT
This chapter presents an overview of key issues and technical challenges in a regional electric network, following the integration of a considerable amount of wind power. A brief survey on wind power system, the present status of wind energy worldwide, common dynamic models, and control loops for wind turbines are given. In this chapter, the Kurdistan electric network in the Northwest part of Iran is introduced as a case study system, and an analytical approach is conducted to evaluate the potential of wind power installation, overall capacity estimation, and economic issues, based on the practical data. Then, the impact of high penetration wind power on the system dynamic and performance for various wind turbine technologies is presented. The stability of integrated system is analyzed, and the need for revising of conventional controls and performance standards is emphasized. Finally, a STATCOM-based control approach is addressed to improve the system stability.

INTRODUCTION
Conventional energy sources such as fossil fuels and uranium reserves are limited and adversely impacts on environment, therefore greet interest for utilization of renewable energy has been established. For recent expansion of renewable energy applications, wind energy generation among other renewable energies has been experiencing a rapid growth. As the use of wind power units increases worldwide, there is a rising interest on their impacts on power system dynamic/control and finding appropriate solutions.

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The recent investigation studies indicate that relatively large scale wind generation affects the power system frequency and voltage regulation, as well as other control and operation issues. This impact may increase at the penetration rates that are expected to be high in the next several years. On the other hand, most of existing wind turbine technologies cannot provide necessary control capabilities for the regulation issue. The power system control of the future will require a high degree of flexibility and intelligence to ensure that it can continuously balance fluctuating power and regulate frequency/voltage deviation caused by renewable energy sources such as wind (Bevrani, et al., 2011).

This chapter presents an overview of new dynamical challenges in regional electric networks, following a high penetration of wind power. The Kurdistan electric network in Iran is considered as a case study. Mountainous environment, costly process for electricity production from conventional sources, and numerous windy areas make Kurdistan as an appropriate region for installation of wind farms. In this work, an analytical approach is conducted to evaluate the potential of wind power installation and overall capacity estimation, and to study economic issues based on the practical data.

The impact of high penetration wind power on the system dynamic and performance for different wind turbine technologies including fixed-speed induction generator (FSIG), doubly-fed induction generator (DFIG) and permanent magnet synchronous generator (PMSG) is presented. Using DIgSILENT simulation software, the stability of the integrated system is re-analyzed, and the need for revising of conventional controls and performance standards is emphasized. Finally, a control approach to improve the system stability using static synchronous compensator (STATCOM) and energy storage devices is addressed. This work is supplemented by some nonlinear simulations on the Kurdistan power system case study using real data and parameters.

In the next section, a background with a brief literature review is presented. In section 3, an overview of wind energy status around the world and Iran is provided. Section 4 presents a discussion about wind power systems and the main control schemes. Section 5 determines the potential of Kurdistan province for wind power generation. In section 6, a preliminary study on wind energy costs in Kurdistan is performed. Section 7 presents a dynamic analysis on the impact of a high wind power penetration on the Kurdistan electric network and introduces an appropriate control solution for its stability improvement. Finally, conclusion and future research directions are presented in sections 8 and 9, respectively.

BACKGROUND

In order to clarify the interaction behavior between wind farm(s) and the power system, building of an effective dynamic model for wind power systems (WPSs) is needed. Model simplifications and some comparisons between different types of WPSs and wind farm equivalent models are presented in recent performed research works (Mansouri, et al., 2004; Ekanayake, et al., 2003; Slootweg, et al., 2003; Akhmatov, et al., 2006; Fernandeza, et al., 2006; Ledesma & Usaola, 2005).

The role of WPS control strategy to qualify system output and stability augmentation is studied in many papers. Optimization control, power smoothing and voltage control of WPSs are most important topics of related new research areas (Senjyu, et al., 2006; Wang & Chang, 2004).

Increasing the penetration of wind turbine generators in a power system may affect the system security/stability limits, frequency, voltage and dynamic behavior (Muyeen, et al., 2009; Bevrani, 2009; Slootweg, 2003; Bevrani, Tikdari, & Hiyama, 2010). This effect can be mostly caused by fluctuation of wind power. The impacts of wind turbines on the power system frequency and voltage have been studied in many research