



Ain Shams University
Faculty of Engineering
Electrical Power and Machines Department

**ENHANCEMENT OF POWER SYSTEM STABILITY
WITH LARGE SCALE INTEGRATED WIND
FARMS**

By

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A thesis submitted in conformity with the requirements
for the degree of Doctor of Philosophy,
in Electrical Engineering, at
Ain Shams University

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Abstract

Wind energy is now becoming one of the fastest emerging renewable energy sources. The share of wind power in the total energy mix is rapidly increasing worldwide; as it is one of the most cost efficient energy sources. Thus, wind turbines with different power ratings are being connected to the power system. These wind turbines utilize different technologies. Variable speed technology, as one of these technologies, attracts considerable interest due to the development of power electronic control capabilities. It allows a flexible and decoupled active and reactive power control. Nowadays, the variable speed Doubly Fed Induction Generator (DFIG) based wind turbine concept is the most popular wind power generator in the wind power industry. A thorough understanding of the modeling, control, the steady state and dynamic analysis of this machine type is thus necessary to optimally extract the power from the wind and accurately predict its performance.

In this thesis, as a first step, the different issues regarding the penetration of wind energy into the power grid, focusing on the Egyptian Transmission Grid Codes (ETGCs) are discussed. The different models comprising the mechanical system of the doubly fed induction generator together with its associated control were then presented. Next, the entire electrical system of the generator was discussed concentrating on both modeling and control of this system.

As a second step, the wind farms' interaction with the power system is investigated under different case studies. In the performed case studies, the wind farms were represented using the aggregated model. The DIgSILENT Power Factory software package, is used as the main simulation tool.

The presented case studies, based on the Egyptian transmission power system data, were used to assess the dynamic behavior of the doubly fed induction generator wind turbine when subjected to a three-phase short circuit at the point of common coupling and to evaluate the performance of a power network comprising two different types of wind farms, FSIG and DFIG, when exposed to a system disturbance and to analyze their interaction during the fault.

The dynamic simulation results have shown that the response of the different networks under study are promising.

Keywords—aggregated model, digsilent, doubly fed induction generator, dynamic response, system support, transmission grid connection, wind turbine.

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Abbreviations

DC	Direct Current
DCSG	Direct Current Synchronous Generator
DFIG	Doubly Fed Induction Generator
DPC	Direct Power Control
DSL	Dynamic Simulation Language
DTC	Direct Torque Control
EMTP	Electro Magnetic Transients Program
ETGCs	Egyptian Transmission Grid Codes
FF	Fundamental Frequency
FSIG	Fixed Speed Induction Generator
GSC	Grid Side Converter
GTO	Gate Turn-Off Thyristor
GVRF	Grid Side Converter Voltage Oriented Reference Frame
IGBT	Insulated Gate Bipolar Transistor
LVRT	Low Voltage Ride Through
MPPT	Maximum Power Point Tracking
MV	Medium Voltage
PCC	Point of Common Coupling
PI	Proportional Integral
PLL	Phase Locked Loop

PMSG	Permanent Magnet Synchronous Generator
PWM	Pulse Width Modulation
RMS	Root Mean Square
RRF	Rotor Reference Frame
SCIG	Squirrel Cage Induction Generator
SFRF	Stator Flux Reference Frame
SL	Switching Level
STATCOM	Static Synchronous Compensator
THD	Total Harmonic Distortion
TSOs	Transmission System Operators
VC	Vector Control
WECS	Wind Energy Conversion System
WRIG	Wound Rotor Induction Generator