**Ain Shams University**

**Faculty of Engineering**

**Electrical Power and Machines Department**

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

**By**

**Eng. Ingy Ali Mohamed Abouzeid**

A thesis submitted in conformity with the requirements

for the degree of Doctor of Philosophy,

in Electrical Engineering, at

Ain Shams University

**Supervisors**

**Prof. Dr. Mohamed A.L. Badr**
Professor of Electrical Engineering
Faculty of Engineering
Ain Shams University

**Prof. Dr. Mahmoud A.H. Mostafa**
Professor of Electrical Engineering
Faculty of Engineering
Ain Shams University

**Dr. Rania Swief**
Associate Professor of Electrical Engineering
Faculty of Engineering
Ain Shams University

**Dr. Dalal Helmi**
Head of Sector of Technical Affairs for Electricity Market and Cross-Border Interconnection
Egyptian Electrical Holding Company

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| **Supervisors Committee** | **Signature** |
|---|---|
| **Prof. Dr. Mohamed A.L. Badr**<br>Professor of Electrical Engineering, Faculty of Engineering, Ain Shams University | ------------------------- |
| **Prof. Dr. Mahmoud A.H. Mostafa**<br>Professor of Electrical Engineering, Faculty of Engineering, Ain Shams University | ------------------------- |
| **Dr. Rania Swief**<br>Associate Professor of Electrical Engineering, Faculty of Engineering, Ain Shams University | ------------------------- |
| **Dr. Dalal Helmi**<br>Head of Sector of Technical Affairs for Electricity Market and Cross-Border Interconnection<br>Egyptian Electrical Holding Company | ------------------------- |

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| **Referees Committee** | **Signature** |
|---|---|
| **Prof. Dr. Ahdab Mohamed Kamel El-Morshedy**<br>Professor of Electrical Engineering, Faculty of Engineering, Cairo University | ---------------------------- |
| **Prof. Dr. Hany Mohamed Hassanein**<br>Professor of Electrical Engineering, Faculty of Engineering, Ain Shams University | ---------------------------- |
| **Prof. Dr. Rania Swief**<br>Associate Professor of Electrical Engineering, Faculty of Engineering, 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 |