HYBRID WIND SOLAR GENERATING SYSTEM WITH FLYWHEEL STORAGE SYSTEM

By

Eng. Nermen Mohamed Yehia Abd-El-Rahman

A thesis submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE

in

Electrical Power and Machines Department

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HYBRID WIND SOLAR GENERATING SYSTEM WITH FLYWHEEL STORAGE SYSTEM

Key Words:

wind generated power systems, energy storage system using flywheel, tracking the point of power, optimal sizing , renewable energy

Summary :

Energy Storage System (ESS) integrated with the wind systems can drastically smooth the intermittent generation through the storage of energy that can be used during periods of low generation and the energy generated at the end of the night or at the beginning of tomorrow (when demand is extremely low), it can also be stored to be dispatched during peak demand hours when wind production is much lower. The Flywheel Energy Storage Systems (FESSs), act as mechanical batteries, can store mechanical energy and exchange it to electricity through a bi-directional converter and an electric machine. FESSs have a large number of charge and discharge cycles that make them perfect for the integration of wind systems. They can significantly improve the mitigation of power fluctuations by using (MATLAB/SIMULINK). The main objective in this thesis is to develop a comprehensive control philosophy for enhancing the output voltage to introduce power smoothing method using energy storage system which is Flywheel, and to develop optimal sizing for flywheel energy storage system using General Algebraic Modeling Software (Gams).

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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List of Symbols and Abbreviations

AC	Alternative Current
AMI	Modulation Index of The Generator Voltage Input
DC	Direct Current
DER	Distributed Energy Resource
DFIG	Doubly Feed Induction Generator
DG	Distributed Generation
DLC	Direct Load Control
DSM	Demand Side Management
ESS	Energy Storage System
FSWT	Fixed Speed Wind Turbine
HVDC	High Voltage Distributed System
I	Direct Incidenec Solar Radiation
I_0	Reverse Bias Current
IG	Induction Generator
IK	Short Circuit Current
IM	Induction Machine
LV	Low-Voltage
LVDS	Low Voltage Distributed System
MG	Micro Grid
PCC	Point of Common Coupling
Pm	Mechanical Power
PMSG	Permanent Magnet Synchronous Generator
PMGM	Permanent Magnet Synchronous Machine
Pt	The Extracted Mechanical Power From The Wind,W
PV	Photovoltaic
PWM	Pulse Width Modulation
RES	Renewable Energy Sources
Rs	Stator Resistance
Vmsc	The Magnitude of The MSC Output Voltage, V

VRM	Variable Reluctance Machine
Vs	The Magnitude of The Generator Terminal Voltage, V
VSI	Voltage Source Inverter
VSWG	Variable Speed Wind Generator
VSWT	Variable Speed Wind Turbine
Xs	The Generator Equivalent Reactance, Ω
αmi	Phase Index of The Generator Voltage Input
δ	The Phase Angle Between the Two Voltages, Rad
ρ	The Air Density, Kg/m3
ωi	The Angular Electrical Frequency of The Generator

Abstract

The interest in renewable electricity sources is growing continuously. Today, wind energy is a major player and controller of the global energy market. According to the World Wind Energy Association (WWEA), global wind capacity reached 539,291 GW at the end of 2018, of which 52,552 GW were added in 2018, which represents a growth rate of 10.8%.

Wind turbines installed worldwide at the end of 2018 can generate around 5% of global electricity demand. Wind energy has a vital role in electricity systems because it is a clean source and has a low operating cost. However, the penetration of wind energy enforces completely different operational challenges because of uncertainty and intermittent nature. flexible energy resources, like energy storage systems and demand management, are the most solutions to compensate for the energy misalignment associated with the uncertainty and irregularity of wind energy.

In general, the main objective is to increase the power of wind systems. However, the increase in the interconnection of these wind resources depends on several factors and must be monitored and controlled. Wind energy, like the different renewable energy sources, has a stochastic and random character. Changes in the wind speed profile, while trying to collect maximum power, will result in the injection of a fluctuating power profile in the electrical network, which represents a serious threat to the stability of the electrical system.

Energy Storage System (ESS) integrated with the wind systems can drastically smooth the intermittent generation through the storage of energy that can be used during periods of low generation and the energy generated at the end of the night or at the beginning of tomorrow (when demand is extremely low), it can also be stored to be dispatched during peak demand hours when wind production is much lower.

The Flywheel Energy Storage Systems (FESSs), act as mechanical batteries, can store mechanical energy and exchange it to electricity through a bi-directional converter and an electric machine. FESSs have a large number of charge and discharge cycles that make them perfect for the integration of wind systems. They can significantly improve the mitigation of power fluctuations. The main objective in this thesis is to develop a comprehensive control philosophy for enhancing the output voltage to introduce power smoothing method using energy storage system which is Flywheel, and to develop optimal sizing for flywheel energy storage system using General Algebraic Modeling Software (Gams).

Flywheel is the main subject in this research. ESS is taken into consideration as an effective tool to improve the flexibility and controllability not only of a specific wind farm, but also of the entire grid to match the load profile. Main objectives for using ESS are to smooth the fluctuations and shift the renewable generation to match the load.

In this thesis, A model of DGs based on MATLAB/SIMULINK is developed for a more realistic analytical verification. FESS is integrated with both photovoltaic and permanent magnet synchronous generator (PMSG) based wind energy conversion system. A mathematical model for