Ain Shams University
Faculty of Engineering
Electrical Power and Machines Department

# Control of a Switched Reluctance Generator for Variable-Speed Wind Energy Applications

A thesis Submitted to the Faculty of Engineering, Ain Shams University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Electrical and Machines Engineering

Prepared by:
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M.Sc. in Electrical Power Engineering

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**Date:**

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# STATEMENT

This thesis is submitted to Ain Shams University in partial fulfillment of the requirement for the Ph.D. degree in Electrical Engineering. The included work in this thesis has been carried out by the author at the Electrical Power and Machine department, Ain-Shams University. No Part of this thesis has been submitted for a degree or a qualification at other university or institute.

**Name:** **Mohamed Eladly Metwally**

**Signature:**

**Date:**

# ACKNOWLEDGMENT

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*Mohamed Eladly*

# ABSTRACT

Wind power technology, as the most competitive renewable energy technology, is quickly developing. The wind turbine size is growing and the grid penetration of wind energy is increasing rapidly. Currently, the growth on wind energy technology thrust more attentions on efficiency and system reliability. This mainly consists of a Switched Reluctance Generator (SRG) for supplying a grid system in wind energy. The SRG, which excludes permanent magnets, brushes with commutators, and rotor windings, could be a favorable wind system. It has several desired features, as a simple with solid structure, facility of maintenance, fault tolerance, and not be expensive. These features are suitable for generators in wind turbine. Nevertheless, in spite of all these useful features, the SRG has not been widely employed in wind applications. The most celebrated SRG disadvantages are its torque ripples with nonlinearity operation, which should be resolved to promote the SRG application in wind energy conversion systems (WECS).

Toque ripple minimization control algorithm of four phases 8/6 poles SRG is carried out by employing Artificial Neural Network (ANN) control. This control technique is based on optimum profiling of the currents at overlapping periods. The research, also, presents new Maximum Power Point Tracking (MPPT) for SRG by modification of classical Hill Climb Searching (HCL) technique using ANN which is investigated to emulate the controller (PI) for closed loop system at different wind speeds. Moreover, the SRG is connected with grid system by using a multi-level diode clamped inverter in order to reduce Total Harmonic Distortion (THD) and reduce the filter size. The results of simulation illustrate a good agreement and support the feasibility of the suggested torque ripple minimization and MPPT techniques.

This research investigates a new angle rotor position and generator speed estimator for the control of variable speed SRG which is developed for WECS in order to reduce total cost, simplify system structure and increase reliability .The rotor position is based on constant current per constant flux and its takes into consideration the linear characteristics of the

SRG when excitation current and flux linkages are small. The model has been investigated and simulated by MATLAB/SIMULINK for grid connected SRG.

In this work, STATCOM with UPFC are investigated to support the low voltage ride- through (LVRT) of WECS and to decrease the speed oscillations of SRG during fault conditions. Also, the performances of these compensators are compared with each other. STATCOM can only improve voltage after fault clearance at the terminals of WECS. Proportion-integral-derivative control of these two equipment scheme is employed, and the parameters of PID for each control are tuned by Firefly algorithm. This is investigated by using a new proposed weighted goal attainment method (WGAM) for achieving improved and fault-tolerant operation.

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# List of Symbols

$\alpha$ Step size parameter in firefly algorithm.

$\beta$ Weighting factor

$\beta_o$ Absorption coefficient in firefly algorithm.

$\gamma$ Absorption coefficient in firefly algorithm.

$\eta$ Efficiency

$\theta_{sk}$ The stroke-angle.

$e$ Generator back emf

$I$ Current.

$C_p$ The turbine power coefficient

$F$ Fitness function value.

$B$ the friction coefficient.

$K_d$ Derivative gain

$K_i$ Integral gain

$K_p$ Proportional gain

$\lambda$ Generator phase flux linkage.

$N_r$ The number of rotor poles

$N_s$ The number of stator poles

$P$ Dimension of search space

$P_a$ Discovering probability in firefly algorithm.

$\rho$ Air density.

$v$ Velocity

$V$ Voltage

$r$ Distance between two fireflies

$S$ Position of particle in PSO

$w$ Weighting function

$C$ Weighting coefficient

$L$ Generator phase inductance

$T_e$ Generator electrical torque

$Lmax$ Aligned generator inductance

$Lmin$ Unaligned generator inductance

$C_p$ Coefficient of the wind turbine.

$\tau_r$ The rotor pole pitch