VOLTAGE AND FREQUENCY CONTROL OF STANDALONE WIND DRIVEN SELF-EXCITED RELUCTANCE GENERATOR

By

Joseph Samir Sedky

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 Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

Voltage and frequency control of standalone wind driven self-excited reluctance generator

Key Words:
Self-excited reluctance generator; Dynamic model; Excitation capacitors; Constant output voltage; Constant output frequency

Summary:

This thesis intended to study the performance of standalone wind-driven self-excited reluctance generator (WDSERG) at different running circumstances of excitation capacitors and loads with studying its suitability for wind energy applications. Two different configurations of compensation (short shunt and long shunt) are proposed and the preferred configuration is selected. A complete dynamic d-q axis model and equivalent circuit of the SERG are developed for each configuration. The complete model was utilized for studying varies cases of wind speed, load current and power factor values to obtain the dynamic behavior of the WDSERG. Furthermore, generator speed and load voltage are controlled by the two configurations of compensation using PI controllers to determine the suitable capacitance values for a WDSERG, that will generate fixed load voltage and frequency value through different cases of wind speed and load current.

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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Signature:

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List of Symbols

C_p	Power coefficient of the turbine
C_{sh}	Shunt capacitor
C_{se}	Series capacitor
C	Excitation capacitor
$Capital\ symbol$	Denotes steady state value
C_f	Fixed capacitance value
C_e	Effective capacitance
d	Duty ratio
d	Subscripts denotes d-axis
g	Ratio of the SERG speed to the turbine rotor blade speed
i_s	Stator current
i'	Damper winding current
I_c	Excitation capacitor current
i_l	Load current
I_{dc}	DC supply current
J	Inertia
k	Subscripts denotes rotor damper winding
L_{ls}	Stator leakage inductance
L_m	Magnetizing inductance
L''	Average value of inductance
L'	Difference between maximum and average value of inductance
$L_{aa}, L_{bb}, and\ \ L_{cc}$	Self-inductances of three phase reluctance generator
$L_{ab}, L_{bc}, and\ \ L_{ca}$	Mutual inductances of three phase reluctance generator
L_s	Stator inductance
L'	Damper winding inductance

L'_l	Damper winding leakage inductance
L_L	Inductance of load
max	Subscripts denotes maximum value
min	Subscripts denotes minimum value
P	Number of pair poles
P_{air}	Power contained in air
P_t	Power transmitted to the wind turbine
p	Differential operator
q	Subscripts denotes q-axis
R	Radius of the turbine blade
R_s	Stator resistance
R_L	Resistance of load
S_r	Saliency ratio
T_t	Mechanical torque developed by the wind turbine
T_{max}	The maximum value of aerodynamic torque
T_e	Electromagnetic torque developed
T_{pm}	Prime mover torque
T	Total time of switching
t_1	Time interval switch pair s_1 is on
t_2	Time interval switch pair s_2 is on
T_L	Load torque
un	Subscripts denotes unsaturated value
v_w	Wind speed
v_s	Stator voltage
v'	Damper winding voltage
v_l	Load voltage
v_c	Series capacitor voltage
V_{dc}	DC supply voltage

X_s	Stator reactance
X_C	Excitation capacitor reactance
Z_L	Load impedance
Z_0	Zero-sequence impedance
β	Blade pitch
δ	Load angle
θ_r	Rotor position
λ	Tip speed ratio
λ_s	Stator flux linkage
λ'	Damper winding flux linkage
ρ	Air density
τ	Ratio of the capacitive reactance to the load impedance
ϕ	Power angle
Ψ_S	Stator flux linkages per second
ω	Speed arbitrary reference frame
ω_t	Rotor blade speed
ω_r	Self-excited reluctance generator (SERG) speed electrical (rad/sec)
ω_o	The rated (base) synchronous speed

Abbreviations

BDFIG	Brushless Doubly fed induction generator
CSG	Conventional synchronous generator
CW	Control winding
CM	Control machine
DC	Direct current
DFIG	Double fed induction generator
d-q	Direct – quadrature
emf	Electro motive force
IGBT	Insulated-gate bipolar transistor
MMF	Magneto motive force
MPPT	Maximum power point tracking
PI	Proportional integral
PMSG	Permanent magnet synchronous generator
PM	Power machine
PW	Power winding
PWM-VSI	Pulse-width modulated voltage source inverter
RMS	Root mean square value
rpm	Revolution per minute
SEIG	Self-excited induction generator
SERG	Self- excited reluctance generator
WDSERG	Wind-driven self-excited reluctance generator
WECS	Wind energy conversion system