Hamed Aly

Offshore Wind and Tidal Current Energy Resources

Forecasting, Modeling, and Control

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DEDICATION PAGE

To soul of those who loved me more than themselves, to my parents.

LIST OF ABBREVIATIONS AND SYMBOLS USED

List of Abbreviations (in the order of appearance in the work)

DFIG	Doubly Fed Induction Generator
DDPMSG	Direct Drive Permanent Magnet Synchronous
ANN	Artificial Neural Network
FLSM	Fourier Series Model based on the Least Squares Method
PI	Proportional Integral
R.I.	Research Institute
IEA	International Energy Agency
FORCE	Fundy Ocean Research Centre for Energy
EU	The European Union
UK	United Kingdom
MW	Mega Watt
WWEA	World Wide Energy Association
BC	British Columbia
AB	Alberta
SK	Saskatchewan
MB	Manitoba
ON	Ontario
QC	Quebec
NB	New Brunswick
NS	Nova Scotia
FSIG	Fixed Speed Induction Generator
SSC	Supply Side Converter
GSC	Grid Side Converter
RSC	Rotor Side Converter
AVR	Automatic Voltage Regulator
DC	Direct Current
IGBT	Insulated Gate Bipolar Transistor

STATCOM	Static Synchronous Compensator
FMAC	Flux Magnitude Angle Controller
PSS	Power System Stabilizer
MCU	Master Control Unit
TSO	Transimission System Operator
UCS	Single Unit Control
TED	Tidal Energy Devices
MCT	Marine Current Turbines
UEK	Underwater Electric Kite
RTT	Rotech Tidal Turbine
ANN	Artificial Neural Network
FLSM	Fourier Series model based on the Least Squares Method
PBN	Back Propagation Neural Network
RBF	Radial Basis Function
MRA	multi-resolution analysis
GA	Genetic Algorithms
EOF	Empirical Orthogonal Function
PC	Principal Components
MLP	Multi Layer Perceptron
PCA	Principal Component Analysis
SOFM	Self Organizing Feature Map
RBF	Radial Basis Function
SLP	Single Layer Perceptron
OBD	Optimal Brain Damage
P E	Percentage of Error

List of Symbols (in the order of appearance in the work)

v_w	Wind speed signals model
v_{mw}	Mean wind speed
v_{rw}	Wind speed ramp
v_{gw}	Wind speed gust
v_{nw}	Turbulence
A_r	Amplitude of the wind speed ramp
T_{sr}	Starting time
T_{er}	Ending time
v_{gw}	Wind speed gust
C_p	Wind power coefficient
λ	Tip speed ratio
B	Pitch angle
R	The blade length in m
ρ	The density of the air
ω_t	The wind turbine rotational speed in rad/sec
C_f	The wind turbine blade design constant
P_w	Power extracted from the wind
T_m	Mechanical torque applied to the turbine
v_m	The turbine speed at hub height upstream the rotor
D_t	The turbine self-damping
D_g	The generator self damping
D_m	The mutual damping
H_t	The turbine inertia constant
H_g	The generator inertia constants
K_s	The shaft stiffness
ω_t	The turbine rotor speed
ω_g	The generator rotor speed
Θ_t	The turbine rotor angle
Θ_g	The generator rotor angles

H_m	The lumped inertia constant
ω_m	The rotational speed of the lumped system
D_m	The damping of the lumped system
$Y_j(t)$	Quantity computed by the first hidden neurons
$Y_k(t)$	Quantity computed by the second hidden neurons
$O_r(t)$	Network output
X & Z	Number of input and output neurons
H_1 & H_2	Number of first and second hidden neurons
Wij, W_{jk} & W_{kr}	Adjustable weights between input and first hidden layer, the first and Second layer and the second and output layer
b_i	Number of biases
f	Transfer function
E	Error
η	The learning rate
α	The momentum
V_{tide}	Tidal current speeds.
V_{nt}	Neap tide speed.
V_{st}	Spring tide speed.
C_s	Constant and equals 95 for spring, 45 for neap tide.
P_{ts}	Tidal in-stream power.
ρ	Density of the water (1025 kg/m^3)
A	Cross-sectional area perpendicular to the flow direction.
T_m	Mechanical torque applied to the turbine.
A	Cross-sectional area perpendicular to the flow direction.
C_p	Marine turbine blade design constant in the range of 0.35-0.5.
ω_s ,ω_r, ω_t	Stator, rotor electrical angular velocities, and turbine speed at hub height upstream the rotor.
T_e	Electrical torque of the generator.
D_s	Shaft stiffness damping.
H_t ,H_g	Turbine and generator inertia constants.

K_s	Shaft stiffness coefficient.
Θ_t, Θ_r	Turbine and generator rotor angles.
B	Tidal turbine pitch angle.
S	Rotor slip.
d, q	Indices for the direct and quadrature axis components.
s, r	Indices of the stator and the rotor.
v, R, i, ψ	Voltage, resistance, current, and flux linkage of the generator.
K_{pt}, K_{it}	Coefficients for the proportional-integral controller of the pitch controller.
P_g, P_{DC}	Active power of the AC terminal at the grid side converter and DC link power respectively.
v_{Dg}, v_{Qg}	D and Q axis voltages of the grid side converter.
i_{Dg} ,i_{Qg}	D and Q axis currents of the grid side converter.
C	Capacitance of the capacitor.
v_{DC} , i_{DC}	Voltage and current of the capacitor.
K_{p1}, K_{p2}, K_{p3}	Proportional controller constants for the generator side converter controller
K_{i1}, K_i, K_{i3}	Integral controller constants for the generator side converter controller.
i_{Dg}, i_{Qg}	D and Q axis grid currents.
v_{Dg}, v_{Qg}	D and Q axis grid voltages.
K_{p4}, K_{p5}, K_{p6}	Proportional controller constants for the grid side converter.
K_{i4}, K_{i5}, K_{i6}	Integral controller constants for the grid side converter.
X_c	Grid side smoothing reactance.
$\dot{x}$	State variable.

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