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HYBRID INTELLIGENT METHODS FOR PARAMETER IDENTIFICATION AND  
LOAD FREQUENCY CONTROL IN POWER SYSTEM

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Thesis submitted in fulfilment of the requirements  
for the award of the degree of  
Doctor of Philosophy in Electrical Engineering

Faculty of Electrical and Electronic Engineering  
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NOVEMBER 2014

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## LIST OF SYMBOLS

$a$	Participation factors
$B$	big
$B$	Frequency bias
$c_1, c_2$	acceleration coefficients
$D$	damping coefficient
$d(n)$	desired result
$\epsilon$	errors
$G$	length gain
$G_{incr}$	social acceleration coefficient
$G_1, G_2, \dots, G_{incr}$	random number uniformly distributed in $[0, G_{incr}]$ .
$G_{in1}, G_{in2}$	input gain
$G_{out}$	output gain
$G_{tg}$	turbine governor transfer function
$H$	equivalent inertia constant
$K(s)$	dynamic controller
$L1, L2 \quad L, L'$	horizontal distances
$LN$	large negative
$LP$	large positive.
$M(p)$	parametric model
$M(s)$	governor–turbine dynamic model
$MN$	medium negative
$MP$	medium positive
$n(t)$	input noise
$pg$	global best positions
$p_i$	local best positions
$p_{incr}$	cognitive acceleration coefficient
$p_{i1}, p_{i2}, p_{incr}$	random number uniformly distributed in $[0, p_{incr}]$
$R$	droop characteristic
$r_1, r_2$	random numbers between 0 and 1.
$S$	small



SN	small negative
SP	small positive
$T_{ij}$	tie-line synchronizing coefficient with area j
$u(n)$	desired output
$u(t)$	input signal
VB	very big
$v_{i1}, v_{i2}, \dots, v_{id}$	velocity of the $i^{\text{th}}$ particle
$V_{\max}$	maximum velocity value
VS	small
VVB	very very big
$w(n)$	adaptive transfer function configuration
$X_{ij}$	reactance
$x(n)$	input of in the implementation
$x_i, x_{i1}, x_{i2}, \dots, x_{id}$	position of the particle
$y(n)$	actual output
$y(t)$	system output
$y_m(t)$	output from the parametric model
Z	zero
$\beta, \alpha, \delta$	triangular angles
$\Delta e$	change of error
$\Delta f$	frequency change
$\Delta P_C$	supplementary control action
$\Delta P_L$	power load change
$\Delta P_m$	governor valve position
$\Delta P_P$	primary control action
$\Delta P_{\text{tie}}$	net tie-line power flow
$\Psi$	class for models
$\omega$	inertia weight parameter

**LIST OF ABBREVIATIONS**

ACE	Area Control Error
AFRC	Automatic Frequency Ratio Control
AGC	Automatic Generation Control
AGPM	Augmented Generation Participation Matrix
AI	Artificial Intelligence
ANN	Artificial Neural Network
BES	Battery Energy Storage
CES	Capacitive Energy Storage
FD	Figure Of Demerit
GAs	Genetic Algorithms
GRC	Generation Rate Constraint
$H_{\infty}$	Robust Controller
HVDC	High Voltage Direct Current
IGBT	Insulated Gate Bipolar Transistor
ISE	Integral Square Error
ITAE	Integral Of Time Of Absolute Error
LFC	Load Frequency Control
LMI	Linear Matrix Inequality
LQG	Linear Quadratic Gaussian
LSE	Least Square Estimator
MLE	Maximum Likelihood Estimator
MOO	Multi-Objective Optimization
MSF	Multi-Stage Fuzzy
PD	Proportional Plus Derivative
PI	Proportional Plus Integral
PID	Proportional, Integral And Derivative
PSO	Particle Swarm Optimization
PV	Photovoltaic
RBF	Radial Biased Function
RTO	Real-Time Optimization

SA	Simulated Annealing
SePSO	Segmentation of Particle Swarm Optimization
SMES	Super Conducting Magnetic Energy Storage
SOFLC	Self Organizing Fuzzy Logic Control
SVC	Static Var Compensator
WLS	Weighted Least Squares