MODEL ORDER REDUCTION OF LARGE SCALE SYSTEM & CONTROLLER DESIGN

A

THESIS

SUBMITTED TO

MAHARAJA RANJIT SINGH
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IN

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis, entitled **"Model Order Reduction Of Large Scale System & Controller Design"** in fulfillment of the requirements of the award of the degree of Doctor of Philosophy in Faculty of Engineering and Technology and submitted in Maharaja Ranjit Singh Punjab Technical University, Bathinda is an authentic record of my own work carried out during a period from January, 2018 to July, 2021 under the supervision of Dr. Amit Kumar Manocha, Associate Professor, EED, & Director, Punjab Institute of Technology, GTB Garh, Moga, India (MRSPTU, Bathinda, India).

The matter embodied in this thesis has not been submitted by me for the award of any other degree of this or any other University/ Institute.

(ANKUR GUPTA)

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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(ANKUR GUPTA)

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LIST OF ABBREVIATIONS

ACE	Actual control error
AGC	Automatic gain control
ALO	Ant lion optimization
ANN	Artificial neural network
BBBC	Big bang big crunch
BIR	Backward innovation representation
DOF	Degree of freedom
FA	Firefly algorithm
FGS	Fuzzy gain scheduling
FIR	Forward innovation representation
GA	Genetic algorithm
GDB	Governor dead band
GM	Gain margin
GRC	Generator rate constant
HOS	Higher order system
IAE	Integral absolute error
IMC	Internal model control
IPCG	Improved pole clustering with Genetic algorithm
ISE	Integral square error
ITAE	Integral time absolute error
IWO	Invasive weed optimization
LFC	Load frequency control
LTI	Linear time-invarient
MDI	Model dominance index
MEMS	Micro-electronics mechanical systems
MIMO	Multi input multi output
MOR	Model order reduction
MPC	Model predictive control
ODE	Ordinary differential equation
OS	Overshoot

PD	Proportional derivative
PDE	Partial differentiation equation
PI	Proportional integral
PID	Proportional integral derivative
PM	Phase margin
PSO	Particle swarm optimization
PV	Photovoltaic
ROM	Reduced order model
ROS	Reduced order system
RT	Rise time
SISO	Single input single output
SSE	Steady-state error
ST	Settling time
US	Undershoot
VLSI	Very large scale integration

LIST OF SYMBOLS

∞	Infinity
A, B, C, D	State matrices
D	Denominator
d	Estimated disturbance
$F(s)$	Low pass filter
$F_L(s)$	Load fluctuations or disturbance
$G_l(s)$	Transfer function of large scale system
$G_m(s)$	Transfer function of process model
$G_r(s)$	Transfer function of reduced order system
$G_r^-(s)$	Minimal part of reduced order transfer function
$G_r^+(s)$	Non-minimal part of reduced order transfer function
K_d	Derivative controller gain
K_i	Integral controller gain
K_p	Proportional controller gain
m	Degree of disturbance rejecting controller
N	Numerator
P	Controllability
Q	Observability
$Q_{c1}(s)$	Transfer function of IMC controller
$Q_{c2}(s)$	Transfer function of disturbance rejecting controller
r	Assumed order of reduced order system
$R(s)$	Set point
T_i	i^{th} time moment
u	Manipulated input to the process
x	Degree of low pass filter in IMC controller
$Y_m(s)$	Model output
$Y_p(s)$	Process output
η	MDI values
λ	Eigen values
λ_1	IMC filter time constant

λ_2	Disturbance rejection controller time constant
ρ	Residues
σ	Poles
ς	Real part of complex pole
ψ	Imaginary part of complex pole