UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : Hong Mee Song

Date of Birth : 1st Feb 1989

Title : An Alternative Method To Solve Combined Economic Emission Dispatch Problems Using Flower Pollination Algorithm

Academic Session : 2013/2014

I declare that this thesis is classified as:

☐	CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐	RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☑	OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserve the rights as follows:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified By:

(Student's Signature)

890201-08-5678

New IC / Passport Number

Date: 26/8/2016

(Supervisor's Signature)

DR. MOHD HERWAN SULAIMAN

Name of Supervisor

Date: 29/8/2016

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter page 2 from the organization with the period and reasons for confidentiality or restriction.

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering in Electrical (Power System).

(Supervisor's Signature)
Full Name : DR.MOHD HERWAN BIN SULAIMAN
Position : SENIOR LECTURER
Date : 23 AUG 2016

(Co-supervisor's Signature)
Full Name : DR.MOHD RUSLLIM BIN MOHAMED
Position : SENIOR LECTURER
Date : 23 AUG 2016

AN ALTERNATIVE METHOD TO SOLVE COMBINED ECONOMIC EMISSION DISPATCH PROBLEMS USING FLOWER POLLINATION ALGORITHM

HONG MEE SONG

Thesis submitted in fulfilment of the requirements for the award of the degree of Master of Engineering in Electrical (Power Systems)

Faculty of Electrical & Electronics Engineering
UNIVERSITI MALAYSIA PAHANG

AUGUST 2016

TABLE OF CONTENTS

	Page
DECLARATION	
TITLE PAGE	i
DEDICATION	ii
ACKNOWLEDGMENT	iii
ABSTRACT	iv
ABSTRAK	v
TABLE OF CONTENTS	vi
LIST OF TABLES	ix
LIST OF FIGURES	xi
LIST OF SYMBOLS	xiii
LIST OF ABBREVIATIONS	xv
CHAPTER 1 INTRODUCTION	
1.1 Background	1
1.2 Problem Statement	3
1.3 Objectives	4
1.4 Scope Of Project	5
1.5 Thesis Organization	6
CHAPTER 2 LITERATURE REVIEW	
2.1 Introduction	7
2.2 Electrical Power System	7
2.2.1 Thermal Power Generation ad Its Characteristics	7
2.3 Simple Economic Dispatch	9
2.3.1 Conventional Method	9
2.4 Economic Dispatch with Nonlinearities	10
2.4.1 Economic Dispatch with Valve Point Loading Effect	10

2.5 Combined Economic Emission Dispatch 14
2.6 Combined Economic Emission Dispatch with Nonlinearities 17
2.7 Summary 20

CHAPTER 3 METHODOLOGY

3.1 Introduction 21
3.2 Economic Dispatch 23
3.2.1 Conventional Formulation of the Economic Dispatch 23
3.3 Emission Dispatch 25
3.3.1 Conventional Formulation of the Emission Dispatch 25
3.4 Constraints 27
3.4.1 Equality Constraints 27
3.4.2 Inequality Constraints 27
3.5 Formulation for Transmission Loss 27
3.6 Formulation for Practical Constraints of Generator 28
3.6.1 Valve Point Loading Effect 28
3.7 Combined Economic Emission Dispatch 30
3.7.1 Conventional Formulation for Combined Economic Emission Dispatch 30
3.7.1.1 Weighting Sum Method 30
3.7.1.2 Price Penalty Factor 32
3.8 Flower Pollination Algorithm 33
3.9 Flower Pollination Algorithm for Combined Economic Emission Dispatch 35
3.10 Summary 41

CHAPTER 4 RESULT AND ANALYSIS

4.1 Introduction 42
4.2 Test Systems 42
4.2.1 Case 1: 6-unit Test System 43
4.2.2 Case 2: 10-unit Test System 55
4.2.3 Case 3: 11-unit Test System 65
4.2.4 Case 4: 40-unit Test System 71

4.3 Summary 81

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion 82

5.2 Contribution 83

5.3 Areas for Future Research 84

REFERENCES 85

APPENDICES

A B-Loss Coefficients Of Ten Generating Unit For Test Case 3 90

B Comparison Table Of Various Optimization Techniques For Test Case 2 91

C Comparison Table Of Various Optimization Tecniques For Test Case 4 92

D List of Publications 93

LIST OF TABLES

Table No.	Title	Page
4.1	Specifications of test systems	43
4.2	Fuel cost coefficients and generation limits for six generator system	44
4.3	Emission coefficients for six generator system	44
4.4	Showing result for w in one decimal value of six generator system with load demand of 1000 MW	45
4.5	Showing result for w in two decimal value of six generator system with load demand of 1000 MW	47
4.6	Showing result for w in three decimal value of six generator system with load demand of 1000 MW	49
4.7	Showing result for w in four decimal value of six generator system with load demand of 1000 MW	51
4.8	Best Compromising result for six generator system with load demand of 1000 MW	52
4.9	Comparison of the results for test case 1	53
4.10	Fuel cost coefficients and generation limits for ten generator system	56
4.11	Emission coefficients for ten generator system	56
4.12	Showing result for w in one decimal value of ten generator system with load demand of 2000 MW	57
4.13	Showing result for w in two decimal value of ten generator system with load demand of 2000 MW	59
4.14	Showing result for w in three decimal value of ten generator system with load demand of 2000 MW	61
4.15	Best Compromising result for ten generator system with load demand of 2000 MW	62
4.16	Comparison of the results for test case 2	63
4.17	Fuel cost coefficients and generation limits for eleven generator system	66

4.18	Emission coefficients for eleven generator system	66
4.19	Showing result for w in one decimal value of eleven generator system with load demand of 2500 MW	67
4.20	Best Compromising result for eleven generator system with load demand of 2500 MW	68
4.21	Comparison of the results for test case 3	69
4.22	Fuel cost coefficients and generation limits for forty generator system	72
4.23	Emission coefficients for forty generator system	73
4.24	Showing result for w in one decimal value of forty generator system with load demand of 10500 MW	74
4.25	Showing result for w in two decimal value of forty generator system with load demand of 10500 MW	76
4.26	Best Compromising result for forty generator system with load demand of 10500 MW	78
4.27	Comparison of the results for test case 4	79

LIST OF FIGURES

Figure No.	Title	Page
2.1	Schematic diagram of basic thermal unit	8
3.1	General flow chart of methodology	22
3.2	Operating cost curve of thermal generator	24
3.3	Emission curve of thermal generator	26
3.4	Operating cost curve with valve point loading effect	29
3.5	Pseudo code of Flower Pollination Algorithm	39
3.6	Flow Chart of FPA for CEED	40
4.1	Trade-off result using weighted sum method by one decimal value step size for six generator system with 1000 MW load demand	46
4.2	Trade-off result using weighted sum method by two decimal value step size for six generator system with 1000 MW load demand	48
4.3	Trade-off result using weighted sum method by three decimal value step size for six generator system with 1000 MW load demand	50
4.4	Trade-off result using weighted sum method by four decimal value step size for six generator system with 1000 MW load demand	52
4.5	Convergence characteristics of proposed FPA with different number of population for test case 1	53
4.6	Convergence characteristics for proposed FPA with different switch probability for test case 1	54
4.7	Trade-off result using weighted sum method by one decimal value step size for ten generator system with 2000 MW load demand	58
4.8	Trade-off result using weighted sum method by two decimal value step size for ten generator system with 2000 MW load demand	60

4.9	Trade-off result using weighted sum method by three decimal value step size for ten generator system with 2000 MW load demand	62
4.10	Convergence characteristics of proposed FPA with different number of population for test case 2	63
4.11	Convergence characteristics for proposed FPA with different switch probability for test case 2	64
4.12	Trade-off result using weighted sum method by one decimal value step size for eleven generator system with 2000 MW load demand	68
4.13	Convergence characteristics of proposed FPA with different number of population for test case 3	69
4.14	Convergence characteristics for proposed FPA with different switch probability for test case 3	70
4.15	Trade-off result using weighted sum method by one decimal value step size for forty generator system with 10500 MW load demand	75
4.16	Trade-off result using weighted sum method by two decimal value step size for forty generator system with 10500 MW load demand	77
4.17	Convergence characteristics of proposed FPA with different number of population for test case 4	79
4.18	Convergence characteristics for proposed FPA with different switch probability for test case 4	80

LIST OF SYMBOLS

FT	Total generating fuel cost
N	Number of generating units
F_i	Generating cost of each unit i
P_{Gi}	Power generated by each unit i
$F(P_{Gi})$	Total fuel cost
a_i, b_i and c_i	Cost coefficients for i^{th} generator
$P_{Gi}^{\min}$	Minimum loading limit
$P_{Gi}^{\max}$	Maximum output limit of a generator
Emi_T	Total generating emission
Emi_i	Generating emission of each unit *i*
$Emi(P_{Gi})$	Total emission
α_i, β_i and γ_i	Emission coefficients for i^{th} generator
P_d	Power demand
P_{loss}	Transmission loss
P_{Gj}	The output generation of unit *j* (MW)
B_{ij}	The *ij-th* element of the loss coefficient square matrix
B_{i0}	The *i-th* element of the loss coefficient
B_{00}	The loss coefficient constant
d_i and e_i	Cost coefficients for i^{th} unit with valve point loading effect
η_i and δ_i	Emission coefficients for i^{th} generator with valve point loading effect
T	Optimal cost of generation
w_i.	Weighting factor
h_i	Price penalty factor

N_p	Population of flower
p	Switch probability
x_i^t	Solution vector x_i at iteration t
L	Step size which uses Lévy distribution for L > 0
$\Gamma(\lambda)$	Standard gamma function
x_j^t and x_k^t	Pollen from the same plant species but different flower
x	Solutions for CEED
P	Power output for each generating unit
$P_j^{\min}$	Lower limits of the inequality constraint of objective function
$P_j^{\max}$	Upper limits of the inequality constraint of objective function
X_{best}	The current best feasible solution
λ	Distribution factor
K	The multiplication factor selected in the range [0,1]
X_i^{new}	New solution
X_j^{old} and X_k^{old}	Different flowers from the same plant type
$g*$	Current best solution
F	Scaling factor selected in the range [0,1]

LIST OF ABBREVIATIONS

ABC	Artificial Bee Colony
BCS	Best Compromising Solution
BI	Biologically Inspired
Btu	British Thermal Unit
CE	Controlled Elitism
CEED	Combined Economic Emission Dispatch
CLIM	Classical Lambda Iteration Method
CO_2	Carbon Dioxide
CSA	Cuckoo Search Algorithm
DCD	Dynamic Crowding Distance
DE	Differential Evolution
DED	Dynamic Economic Dispatch
DEED	Cynamic Economic Emission Dispatch
DP	Dynamic Programming
ED	Economic Dispatch
EED	Economic Environmental Dispatch
EmD	Emission Dispatch
EP	Evolutionary Programming
FPA	Flower Pollination Algorithm
GA	Genetic Algorithm
GSA	Gravitational Search Algorithm
GSOMP	Group search optimizer with multiple producers
GWO	Grey Wolf Optimizer
IEEE	Institute of Electrical and Electronics Engineers

IFEP	Improved Fast Evolutionary Programming
LP	Linear Programming
MNSGA-II	Modified nondominating sorting genetic algorithm
MODE	Multiobjective Differential Evolution .
MOEA	Multiobjective Evolutionary Algorithm
MOO	Multiobjective Optimization
MOOP	Multiobjective Optimization Problem
MOPSO	Multiobjective particle swarm optimization
MPSO	Modified Particle Swarm Optimization
MW	Mega Watt
NO_x	Nitrogen Oxide
NPGA	Niched pareto genetic Algorithm
NSGA	Nondominating sorting genetic algorithm
NSGA-II	Nondominating sorting genetic algorithm II
PAES	Pareto Archieved Evolution Strategy
PDE	Pareto Differential Evolution
PF	Penalty Factor
POZ	Prohibited Operating Zone
PSO	Particle Swarm Optimization
QP	Quadratic Programming
SA	Simulated Annealing
SO_2	Sulphur Dioxide
SPEA	Strength Pareto Evolutionary Algorithm
SQP	Sequential quadratic programming
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution