

**OPTIMAL POWER FLOW SOLUTIONS FOR  
POWER SYSTEM OPERATIONS USING  
MOTH-FLAME OPTIMIZATION ALGORITHM**

**SALMAN AMEEN ALI ABDULLAH ALABD**

**MASTER OF SCIENCE**

**UNIVERSITI MALAYSIA PAHANG**



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I hereby declare that I have checked this thesis and, in my opinion, this thesis is adequate in terms of scope and quality for the award of Master of Science.

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A handwritten signature in black ink, appearing to read 'DR. MOHD HERWAN SULAIMAN', is placed over a horizontal line.

(Supervisor's Signature)

Full Name : DR. MOHD HERWAN SULAIMAN

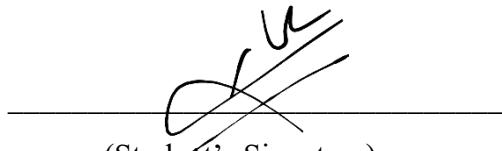
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Full Name : SALMAN AMEEN ALI ABDULLAH ALABD

ID Number : MES19001

Date : 4<sup>th</sup> October 2021

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**SALMAN AMEEN ALI ABDULLAH ALABD**

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## **ABSTRAK**

Bidang penyelidikan berkenaan Aliran kuasa optimum (OPF) telah menjadi bidang yang menarik perhatian para penyelidik, kerana ia menjadi alat utama yang membantu sistem utiliti dalam menentukan operasi ekonomi dan keselamatan yang optimum dalam grid elektrik. Tujuan utama OPF adalah untuk mengoptimumkan fungsi objektif tertentu iaitu: meminimumkan kos bahan bakar, pelepasan, kehilangan transmisi, penyimpangan voltan dan lain-lain semasa memenuhi batasan operasi tertentu seperti, keupayaan penjana, kapasiti talian, voltan bus dan keseimbangan aliran daya. Penghantaran daya reaktif optimum (ORPD) adalah sub masalah aliran daya optimum. ORPD mempunyai kesan besar terhadap keselamatan dan operasi ekonomi dalam sistem grid elektrik. Masalah ORPD mengandungi pemboleh ubah berterusan dan diskrit sehingga dianggap sebagai masalah tidak linear yang bercampur. Sub-masalah lain dari OPF adalah penghantran ekonomik (ED) yang merupakan salah satu masalah kompleks dalam sistem kuasa yang bertujuan untuk mencari peruntukan output unit penjana yang optimum untuk memenuhi permintaan beban dengan kos penjanaan ekonomi terendah, sambil memenuhi kekangan kesetaraan dan ketaksamaan. Tesis ini mencadangkan teknik pengoptimuman metaheuristic yang terbaru: Moth-Flame Optimizer (MFO) untuk menyelesaikan salah satu masalah yang paling penting dalam sistem kuasa iaitu aliran daya optimum (OPF). Tiga fungsi objektif akan diselesaikan secara serentak: meminimumkan kos bahan bakar, kehilangan transmisi, dan meminimumkan penyimpangan voltan menggunakan faktor tertimbang. Untuk menunjukkan keberkesanan MFO yang dicadangkan dalam menyelesaikan masalah yang disebutkan, sistem ujian 30-bus IEEE dan sistem ujian 57-IEEE akan digunakan. Kemudian hasil yang diperoleh dari algoritma MFO dibandingkan dengan algoritma terkenal lain yang dipilih. Perbandingan membuktikan bahawa MFO memberikan hasil yang lebih baik berbanding dengan algoritma perbandingan yang lain. Dalam sistem ujian 30-bus IEEE, MFO memberikan pengurangan sebanyak 14.50% berbanding 13.38% dan 14.15% untuk koloni lebah buatan (ABC) dan Penambahbaikan Gray Wolf Optimizer (IGWO).

## ABSTRACT

Optimal power flow (OPF) has gained a growing attention from electrical power researchers since it is a significant tool that assists utilities of power system to determine the optimal economic and secure operation of the electric grid. The key OPF objective is to optimize a certain objective function such as: minimization of total fuel cost, emission, real power transmission loss, voltage deviation, etc. while fulfilling certain operation constraints like bus voltage, line capacity, generator capability and power flow balance. Optimal reactive power dispatch (ORPD) is a sub-problem of optimal power flow. ORPD has a considerable impact on the economic and the security of the electric power system operation and control. ORPD is considered a mixed nonlinear problem because it contains continuous and discrete control variables. Another sub-problem of OPF is Economic dispatch (ED) which one of the complex problems in the power system which its purposes is to determine the optimal allocation output of generator unit to satisfy the load demand at the minimum economic cost of generation while meeting the equality and inequality constraints. In this thesis, a recent metaheuristic nature-inspired optimization algorithm namely: Moth-Flame Optimizer (MFO) is applied to solve the two subproblems of Optimal power flow (OPF) namely: Economic dispatch (ED) and Optimal reactive power dispatch (ORPD) simultaneously. Three objective functions will be considered: generation cost minimization, transmission power loss minimization, and voltage deviation minimization using a weighted factor. The IEEE 30-bus test system and IEEE 57-bus test system will be employed, to investigate the effectiveness of the proposed MFO in solving the above-mentioned problems. Then the obtained MFO methods results is compared with other reported well-known methods. The comparison proves that MFO offers a better result compared to the other selected methods. In IEEE 30-bus test system, MFO outperform the other optimization methods with 967.589961\$/h compared to 971.411400 \$/h, 983.738069\$/h, 975.346233\$/h, 985.198050\$/h, 1035.537820\$/h for Improved Grey Wolf Optimizer (IGWO), Grey Wolf Optimizer (GWO), Ant Loin Optimizer (ALO), Whale Optimization Algorithm (WOA), and Sine Cosine Algorithm (SCA) respectively. In IEEE 57-bus test system, MFO offers a minimization of 19.16% compared to 19.03% and 18.98% for Grey Wolf Optimizer (GWO), Whale Optimization Algorithm (WOA) respectively. Moreover, the MFO have speedy convergence rate and smooth curves more than the other algorithms.

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## LIST OF SYMBOLS

$y$	Dependent variables
$x$	Control variables
$F_1$	First objective function
$F_2$	Second objective function
$F_3$	Third objective function
$P_i$	Power generated by the generator
$a_i, b_i$ and $c_i$	Cost coefficients of generator $i$
$VD$	Voltage deviation
$N_d$	Number of load buses
$F$	Weighted objective functions
$w_1$ and $w_2$	Weighting factors
$P_{i,i+1}$	Real power between two nodes
$Q_{i,i+1}$	Reactive power between two nodes
$R_{i,i+1}$	The resistance of the branches between the nodes $i$ and $i + 1$
$X_{i,i+1}$	The reactance of the branches between the nodes $i$ and $i + 1$
$ V_i $	The voltage at the I node
$P_{L,i+1}$	Real power loss at line
$Q_{L,i+1}$	Reactive power loss at line
$P_L^T$	Total real power loss at line
$Q_L^T$	Total reactive power loss at line
$P_g$	Active power supplied through substation bus
$Q_G$	Reactive power supplied through substation bus
$P_{DG}$	Active power generated by distributed generations
$Q_{DG}$	Reactive power generated by distributed generations
$P_d$	Active load demand of the network
$Q_D$	Reactive load demand of the network
$P_L$	The active power loss of the networks
$Q_D$	The reactive power loss of the networks
$V_{i,min}$	The minimum voltage at the I node
$V_{i,max}$	The maximum voltage at the I node

$T$	Tap settings of transformer
$Q_c$	Shunt VAR compensation
$S_L$	Line flow
$M_i$	$i$ -th moth
$F_j$	$j$ -th flame
$S$	The spiral function
$D_i$	Distance of the $i$ -th moth for the $j$ -th flame
$t$	Current iteration
$N_{SA}$	Number of search agent

## LIST OF ABBREVIATIONS

OPF	Optimal Power Flow
ORPD	Optimal reactive power dispatch
ED	Economic dispatch
MFO	Moth-Flame Optimizer
LP	Linear programming
QP	Quadratic programming
NLP	Non-linear programming
IPM	Interior-point methods
MSA	Moth Swarm Algorithm
PSO	Particle Swarm Optimization
ABC	Artificial Bee Colony
GSO	Glowworm Swarm Optimization
EED	Environmental Economic Emission dispatch
NI	Natural inspired
BIO	Bio-inspired optimization
GA	Genetic Algorithm
EAs	Evolutionary based algorithms
GSA	Gravitational Search Algorithm
BH	Black Hole
SCA	Sine Cosine Algorithm
ICEFO	The improved chaotic electromagnetic field optimization algorithm
HS	Harmony Search Algorithm
TLBO	Teaching Learning Based Optimization
ICA	Imperialist Competition Algorithm
LCA	League Championship Algorithm
GWO	Grey wolf optimizer

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