UNIVERSITI PUTRA MALAYSIA

AN IMPROVED LEADER PARTICLE SWARM OPTIMISATION ALGORITHM FOR SOLVING FLEXIBLE AC TRANSMISSION SYSTEMS OPTIMISATION PROBLEM IN POWER SYSTEM

AHMAD REZAEE JORDEHI

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By

AHMAD REZAEE JORDEHI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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Dedicated to my dear mother, caring father, kind wife, lovely brothers and sister

Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfilment of requirement of the degree of Doctor of Philosophy

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Chairman: **Jasronita Jasni, PhD**

Faculty: **Engineering**

Line outage contingencies in power systems are likely to result in overloads in branches, voltage deviations in buses and excessive power losses. The most common approach for alleviating such consequences is using flexible AC transmission systems (FACTS) devices. Since overloads are the main concern in line outage contingencies and thyristor-controlled series compensator (TCSC) has proved to be effective in power flow control, it is used for mitigating consequences of line outage contingencies. When FACTS devices are utilised in a power system, they should be allocated optimally.

From the optimisation perspective, optimal allocation of FACTS devices is a very complex optimisation problem. Heuristic approaches are the most common approaches for solving FACTS allocation problems. Among heuristics, particle swarm optimisation (PSO) has some advantages which make it popular in solving FACTS allocation problems.Despite all PSO advantages, it suffers from premature convergence.Due to PSO's premature convergence, in TCSC allocation problem during contingency, it is not able to find near-global solution. Therefore, considerable amounts of overloads, voltage deviations and power losses are obtained.

Although existing approaches mitigatePSO's premature convergence to some extent, they have some shortcomings that should be addressed carefully.Their explorative capability is not decreased during the run.In most cases, the mutated object is transferred to new position either it leads to lower objective value or not. In most of cases, the mutations are applied to positions or velocities of particles, while applying mutation to the leader may enhance the leader and push all particles toward better regions of search space.They also do not provide any mechanism for jumping out particles after stagnation.

The aim of this research is to develop a new PSO variant called improved leader PSO (ILPSO) by addressing the mentioned shortcomings of existing premature convergence mitigation strategies. It should efficiently mitigate premature convergence problem and result in lower amounts of overloads, voltage deviations and power losses (than existing algorithms) in D-TCSC allocation problem during line outage contingencies.

The proposed PSO variant features a five-staged successive mutation strategy. The security enhancement problem is formulated as a multi-objective optimisation problem while its objectives are minimising overpowerflows, voltage deviations, power losses and also maximising line utilisation factors. The results of applying improved leader PSO to IEEE 14 bus power system shows its significant outperformance over six other optimisation algorithms including conventional PSO, mutated PSO, enhanced PSO, harmony search, genetic algorithm and gravitational search algorithm. Improved leader PSO leads to lower amount of overpowerflows and power losses with respect to other algorithms, whileit also results in low values of voltage deviation.ILPSO has also been applied to Malaysian 87 bus power system (TNB), wherein overloads and power losses are reduced significantly.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

ALGORITMA PENAMBAHBAIKAN KETUA PENGOPTIMUMAN KUMPULAN ZARAH SEBAGAI PENYELESAIAN MASALAH PENGOPTIMUMAN SISTEM PENGHANTARAN AC FLEKSIBEL DALAM SISTEM KUASA

Oleh

AHMAD REZAEE JORDEHI

Januari 2014

Pengerusi: Jasronita Jasni, PhD

Fakulti: Kejuruteraan

Putusan talian luar jangkaan dalam sistem kuasa mungkin menyebabkan lebihan beban di cabang, pelencongan voltan dalam bas dan kehilangan kuasa yang berlebihan. Pendekatan yang paling biasa dalam menangani kesan-kesan tersebut ialah dengan menggunakan peranti penghantaran AC fleksibel (FACTS). Oleh kerana lebihan beban adalah kebimbangan utama dalam putusan talian luar jangkaan dan penggunaan pemampas siri kawalan-thyristor telah terbukti berkesan dalam kawalan aliran kuasa, ia digunakan untuk menangani kesan-kesan putusan talian luar jangkaan. Apabila peranti FACTS digunakan dalam sistem kuasa, ia harus diperuntukkan secara optimum.

Dari perspektif pengoptimuman, pengagihan optimum bagi peranti FACTS merupakan masalah pengoptimuman yang sangat kompleks. Pendekatan heuristik adalah pendekatan yang paling biasa bagi menyelesaikan masalah pengagihan FACTS. Di kalangan heuristic, pengoptimuman kumpulan zarah (PSO) mempunyai kelebihan yang menjadikannya popular dalam menyelesaikan masalah pengagihan FACTS. Walaubagaimanapun, PSO mengalami penumpuan pramatang. Disebabkan penumpuan pramatang PSO, penyelesaian hampir-sejagat dalam masalah pengagihan TCSC semasa luar jangkaan tidak dapat dikenalpasti. Oleh yang demikian, sejumlah besar lebihan beban, pelencongan voltan dan kehilangan kuasa dapat diperolehi.

Walaupun pendekatan yang sedia ada dapat menangani penumpuan pramatang PSO hingga ke suatu tahap tertentu,ia mempunyai beberapa kelemahan yang harus ditangani secara teliti. Keupayaan ia yang menjelajah tidak berkurangan semasa dikendalikan. Dalam kebanyakan kes, objek yang bermutasi dipindah ke kedudukan baru samaada ia membawa kepada nilai objektif yang lebih rendah atau tidak. Dalam kebanyakan kes,mutasi digunakan pada kedudukan atau halajuzarah, manakala penggunaan mutasi boleh memperbaiki ketua dan

menolak kesemua zarah ke arah kawasan ruang carian yang lebih baik. Ianya juga tidak memberikan apa-apa mekanisme untuk zarah loncatan keluar selepas penggenangan.

Tujuan kajian ini adalah untuk membangunkan satu varian PSO baru yang dikenali sebagai penambahbaikan ketua PSO (ILPSO) dengan menangani kelemahan yang disebut sebagai strategi pengurangan penumpuan pramatang yang sedia ada. Ia secara efisiennya dapat menangani masalah penumpuan pramatang dan menghasilkan jumlah yang rendah pada lebihan beban, pelencongan voltan dan kehilangan kuasa (berbanding algoritma yang sedia ada) dalam masalah pengagihan D-TCSC ketika gangguan luar jangkaan pada talian.

Varian PSO yang dicadangkan mempunyai strategi mutasi berturutan lima-peringkat. Masalah peningkatan keselamatan dirumuskan sebagai masalah pengoptimuman pelbagai objektif dimana objektifnya adalah meminimumkan lebihan aliran kuasa, pelencongan voltan, kehilangan kuasadan juga memaksimumkan faktor penggunaan talian. Penggunaan penambahbaikan ketua PSO pada sistem kuasa 14 bas IEEE menunjukkan prestasi cemerlang yang ketara ke atas enam algoritma pengoptimuman lain termasuk PSO konvensional, PSO bermutasi, PSO dipertingkat, carian harmoni, algoritma genetik dan algoritma carian graviti. Penambahbaikan ketua PSO membawa kepada lebihan aliran kuasa dan kehilangankuasa yang lebih rendah berbanding lain-lain algoritma, ia juga menghasilkan nilai pelencongan voltan yang rendah. ILPSO juga telah digunakan pada sistem kuasa 87 bas Malaysia (TNB), di mana lebihan beban dan kehilangan kuasa dikurangkan dengan ketara.

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I certify that a Thesis Examination Committee has met on January 10, 2014 to conduct the final examination of Ahmad Rezaee Jordehi on his thesis entitled "An improved leader particle swarm optimisation algorithm for solving flexible AC transmission systems (FACTS) optimisation problem in power system" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the relevant degree of Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

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Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Hashim. b. Hizam, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Chandima Gomes, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohammad Shahidehpour, PhD
Professor
Faculty of Engineering
Illinois Institute of Technology
(External Examiner)

NORITAH OMAR, PhD
Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to senate of Universiti Putra Malaysia and has been accepted as fulfilment of requirement for degree of Doctor of Philosophy. Members of the Supervisory Committee were follows:

Jasronita Jasni, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Noor Izzri b. Abd. Wahab, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Mohd Zainal Abidin b. Ab. Kadir, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

_____
BUJANG BIN KIM HUAT, PhD
Professor and Dean
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