UNIVERSITI PUTRA MALAYSIA

OPTIMISATION OF DISTRIBUTED GENERATION IN ELECTRIC POWER SYSTEMS USING FUZZY-GENETIC ALGORITHM APPROACH

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By

MUDATHIR FUNSHO AKOREDE

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

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DEDICATION

This thesis is dedicated to my parents, late **Alhajj Salahu-deen Akorede** and **Madam Sefinat Akorede**, for their inestimable contributions in my life.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy.

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Faculty: Engineering

To maximise the benefits offered by distributed generation (DG) in electric power systems, there is clearly a need to determine the optimum size, as well as the best site of that particular DG unit(s) in the network. Recent research has shown that improper placement of DG units in power systems would not only lead to an increased energy loss cost, but could also jeopardize the system operation. To avert these scenarios and tackle this optimisation problem, this thesis proposes two models to guide electric utilities in determining the optimal capacity and location of DG units in power networks.

The first model for meshed electric power networks, which could be employed for subtransmission networks operating at up to 132 kV level, uses two objective

functions. The model maximises the system loading margin as well as the profit of the distribution company (DISCO) over the planning period. The other model is designed for radial distribution networks operating at 33 kV and below voltage levels. The main objective functions considered in this model are maximisation of cost savings arising from energy loss, minimisation of line voltage drop, and maximisation of the transfer capability of the system. This model takes into account, the peculiarities of radial distribution networks, such as high R/X (resistance/reactance) ratio, voltage dependency and composite nature of loads.

To solve the proposed models, Genetic algorithm (GA) is used as an optimisation technique. In the GA, a fuzzy controller is used to dynamically adjust the crossover and mutation rates to maintain the proper population diversity (PD) during GA's operation. This effectively overcomes the premature convergence problem of the simple genetic algorithm (SGA). The accuracy of the proposed models is evaluated on test power systems, and the results obtained are compared with those of the existing approaches cited in this literature, which is highly impressive.

This thesis also investigates the impact of different penetration levels of DG in both subtransmission and distribution networks. In the study, a 15-bus test system is employed and modelled in detail using Power System Analysis Toolbox (PSAT). However, only synchronous type of DGs is considered since it is the most popular type in use. In this work, the impact of DG of different penetration levels on system stability and power quality are thoroughly examined under different fault scenarios. The results obtained suggest that 20 % penetration level of DG is optimal for both normal and during contingencies in the case study system.

This research work is concluded with a software development. The package called Power Flow Analysis and DG Optimisation Tool (PFADOT) is developed using the Graphical User Interface (GUI) of MATLAB. This provides a user friendly interface for the system operator in determining the optimal allocation of a single DG unit in radial distribution networks. The evolved package is tested with several test systems, and the results obtained are validated against an existing related package. The developed package does not only give more optimal results but also does that in a more computationally efficient manner.

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

PENGOPTIMUMAN PENJANAAN TERAGIH DALAM SISTEM KUASA ELEKTRIK MENGGUNAKAN PENDEKATAN ALGORITMA GENETIK SAMAR

Oleh

MUDATHIR FUNSHO AKOREDE

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Untuk memaksimumkan keuntungan yang ditawarkan oleh penjanaan teragih (DG) dalam sistem kuasa elektrik, jelas ada keperluan untuk menentukan saiz yang optimum, serta lokasi terbaik untuk sesuatu unit DG dalam rangkaian. Penyelidikan terkini menunjukkan bahawa penempatan unit DG yang tidak sesuai dalam sistem kuasa tidak hanya akan mengarah pada peningkatan kos tenaga yang hilang, tetapi juga boleh membahayakan sistem operasi. Untuk mengelakkan senario ini dan mengatasi masalah pengoptimuman, tesis ini mencadangkan dua model untuk memberi panduan kepada utiliti elektrik dalam menentukan kapasiti optimum dan lokasi DG dalam rangkaian elektrik.

Model pertama untuk rangkaian kekisi kuasa elektrik, yang boleh digunakan untuk rangkaian subtransmisi beroperasi hingga tahap 132 kV menggunakan dua fungsi

objektif. Model tersebut memaksimumkan margin beban sistem, serta keuntungan daripada syarikat pengedaran (DISCO) selama tempoh perancangan. Satu model lagi di reka untuk rangkaian pengedaran jejari beroperasi pada tahap voltan 33 kV dan ke bawah. Fungsi objektif utama yang dipertimbangkan dalam model ini adalah memaksimumkan penjimatan kos hasil dari kehilangan tenaga, meminimunkan kejatuhan voltan talian, serta memaksimumkan kemampuan pemindahan sistem. Model ini mengambil kira keunikan rangkaian pengedaran jejari, seperti nisbah R/X (rintangan bahagi reaktans) yang tingi, kebergantungan voltan dan sifat komposit beban.

Untuk menyelesaikan model yang dicadangkan, Algoritma Genetik (GA) digunakan sebagai satu teknik pengoptimuman. Dalam GA, pengawal samar digunakan secara dinamik untuk menyesuaikan kadar silang dan mutasi untuk memelihara kepelbagaian penduduk yang tepat (PD) selama operasi GA. Ini dapat mengatasi masalah penumpuan pramasa algoritma genetik ringkas (SGA). Ketepatan model yang dicadangkan dinilai pada sistem kuasa, dan hasil yang diperolehi dibandingkan dengan pendekatan yang sedia ada, adalah sangat baik.

Tesis ini juga mengkaji pengaruh penetrasi yang berbeza di kedua-dua rangkaian DG subtransmisi dan pengagihan. Dalam kajian tersebut, sistem ujian 15-bas digunakan dan dimodelkan secara terperinci dengan menggunakan Power System Analysis Toolbox (PSAT). Namun, hanya DG jenis selaras yang dipertimbangkan kerana ia merupakan jenis yang paling popular digunakan. Didalam tesis ini, kesan daripada DG pada tahap penetrasi yang berbeza pada kestabilan sistem dan kualiti kuasa elektrik secara menyeluruh diperiksa didalam senario kerosakan yang berbeza.

Keputusan yang diperolehi menunjukkan bahawa 20% tingkat penetrasi DG adalah nilai optima bagi kajian kes untuk keadaan normal dan kontingensi.

Penyelidikan ini diakhiri dengan pembangunan perisian. Perisian yang dinamakan Power Flow Analysis and DG Optimization Tool (PFADOT) dibangunkan dengan menggunakan Graphical User Interface (GUI) dari MATLAB. Ia merupakan antara muka yang mudah digunakan oleh operator sistem dalam menentukan peruntukan optima unit DG tunggal dalam rangkaian pengedaran jejari. Perisian ini diuji dengan beberapa sistem ujian, dan hasil yang diperolehi disahkan dengan membandingkan dengan perisian yang sedia ada. Perisian yang dibangunkan bukan sahaja memberi keputusan yang optima tetapi juga melakukannya degan lebih efisen.

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M. F. Akorede

August 2011

I certify that a Thesis Examination Committee has met on **3rd August, 2011** to conduct the final examination of Mudathir Funsho Akorede on his degree thesis entitled **"Optimisation of Distributed Generation in Electric Power Systems using Fuzzy-Genetic Algorithm Approach"** in accordance with the Universities and University College 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 Doctor of Philosophy.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

_____

MUDATHIR FUNSHO AKOREDE

Date: 3rd August, 2011

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