UNIVERSITI PUTRA MALAYSIA

VOLTAGE STABILITY ASSESSMENT OF POWER SYSTEMS USING VOLTAGE STABILITY INDICES AND ARTIFICIAL INTELLIGENCE TECHNIQUES

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By

OMER HIKMAT MEHDI

Thesis submitted to the School of Graduate Studies of University Putra Malaysia in the fulfillment of the requirement for the Degree of Master of Science

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DEDICATION

I wish to dedicate this thesis to my mother, my father, my two brothers (Caesar & Zaid) and my dearest sister (Sammora) for their love, care, patience and supports for the research. They have always believed in me and have always encouraged me not only during this master period but throughout my life.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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The research presented in this thesis uses the Artificial Intelligence (AI) techniques to assess the voltage stability condition in power systems. Voltage stability index is a feature for evaluating the voltage stability condition. It is generated from the basic power flow equations and/or energy functions. The research is very timely and current and would be a substantial contribution to the present body of knowledge in programming and voltage stability assessment. The methods developed in this research would be faster than presently available voltage stability indices. In this study, five voltage stability indices previously developed, namely, Fast Voltage Stability Index (FVSI), On Line Voltage Stability Index (LVSI), Line Stability Index (L_{mn}), Line Stability Factor (LQP), and Power Transfer Stability Index (PTSI) were utilized by using MATLAB software. All the indices were subjected to various contingencies including variable load increase and line outage. The range of all the indices was found to be falling between 0 and 1. When the voltage stability indices are near to 1, the system

became unstable, thus the system went to instability with increasing the load change or line outage and increasing voltage stability indices depend on the bus type. That is, the transmission line connected to generation bus or reference bus is more stable because it is near to source. The results obtained from the indices were compared with each other, and the conclusions on the performance of the indices were discussed. Two Artificial Neural Networks (ANNs), namely Radial Basis Function Neural Network (RBFNN) and Multi Layer Perception Neural Network (MLPNN) were considered in fitting all the indices for voltage stability assessment of power systems. The data generated from the contingency analysis of all indices were used for training and testing the ANN. Suitable power system features were selected for the ANN which include voltage, active power, reactive power and load angle. Using the mentioned approach, for a given operating conditions, the most critical transmission lines and buses of the systems have been identified. Moreover, the voltage stability assessment by using ANNs was monitored throughout the generalization test. It is appeared that difference between the prediction computed by ANNs, and conventional methods of voltage stability indices tests is considered almost negligible. The analysis of features sensitivity of the ANN has been investigated and found out that the selection of features affect the performance of the ANN. In conclusion, using ANN for fitting the voltage stability indices shows a lot of potential in assessing voltage stability problems. In this research, the first objective was to implement several existing voltage stability indices and compare it with each others. The second one was to apply Radial Basis Function Neural Network and Multi-Layer Perceptron Neural Network for all the indices in order to improve the indices performance in terms of computational time and accuracy. While the third one was to

use feature selection on the input features of artificial neural network to decide the most important features.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN KESTABILAN VOLTAN BAGI SISTEM KUASA MENGGUNAKAN INDEKS KESTABILAN VOLTAN DAN TEKNIK KEPINTARAN BUATAN

Oleh

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Penyelidikan yang dibentangkan di dalam tesis ini menggunakan teknik Kepintaran Buatan atau *Artificial Intelligence* (AI) untuk menilai kestabilan voltan dalam sistem kuasa. Indeks kestabilan voltan adalah satu ciri untuk menyelesaikan masalah kestabilan voltan. Ia dijana daripada persamaan aliran kuasa asas dan/atau fungsi tenaga. Penyelidikan yang dijalankan ini adalah tepat pada masanya dan dijangka akan memberi sumbangan besar kepada peningkatan pengetahuan semasa dalam bidang pemprograman dan penilaian kestabilan voltan. Berbanding dengan indeks kestabilan voltan yang boleh didapati pada masa ini, kaedah yang dibangunkan dalam kajian ini adalah lebih cepat dan lebih ekonomi atau menjimatkan. Dalam kajian ini, terdapat lima indeks kestabilan

voltan, iaitu Indeks Kestabilan Voltan Cepat (Fast Voltage Stability Index a.k.a. FVSI), Indeks Kestabilan Voltan Atas Talian (On Line Voltage Stability Index a.k.a. LVSI), Indeks Kestabilan Talian (Line Stability Index a.k.a. L_{mn}), Kestabilan Talian Faktor (Line Stability Factor a.k.a. LQP), dan Indeks Kestabilan Kuasa Pemindahan (Transfer Stability Index a.k.a. PTSI), yang mana telah dibangunkan dengan menggunakan perisian MATLAB. Semua indeks tertakluk kepada atau telah melalui pelbagai kontingensi termasuk peningkatan beban yang berubah-ubah dan pemutusan talian. Rangkaian semua indeks didapati jatuh di antara julat 0 dan 1. Apabila indeks kestabilan voltan berhampiran 1, sistem menjadi tidak stabil dimana sistem akan mengalami ketidakstabilan dengan peningkatan perubahan beban atau pemutusan talian dan peningkatan indeks kestabilan voltan bergantung kepada jenis bas. Dengan kata lainnya, talian penghantaran yang disambungkan kepada bas penjana atau bas perujuk adalah lebih stabil kerana ianya berdekatan dengan sumber. Keputusan yang diperolehi dari indeks dibandingkan antara satu sama lain, dan kesimpulan tentang prestasi setiap indeks telah dibincangkan. Dua Rangkaian Neural Buatan (Artificial Neural Networks a.k.a. ANNs), iaitu *Radial Basis Function Neural Network* (RBFNN) dan *Multi Layer Perception Neural Network* (MLPNN) telah dipertimbangkan dalam memuatkan semua indeks-indeks tersebut untuk melalui proses penilaian kestabilan voltan sistem kuasa. Data yang dihasilkan daripada analisis kontingensi bagi kesemua indeks telah digunakan untuk melatih dan menguji ANN. Ciri-ciri sistem kuasa yang sesuai telah dipilih untuk ANN yang mana termasuk voltan, kuasa aktif, kuasa reaktif dan sudut beban. Menggunakan pendekatan yang disebutkan, serta keadaan operasi yang sedia wujud, sistem bas dan talian penghantaran yang paling kritikal telah dikenal pasti. Selain itu, penilaian kestabilan voltan dengan menggunakan ANN telah dipantau sepanjang ujian

generalisasi berjalan. Perbezaan antara ramalan yang dikira menggunakan ANN, dengan ramalan menggunakan kaedah konvensional bagi ujian indeks kestabilan voltan dianggap hampir tidak signifikan. Analisis kepekaan ciri-ciri ANN telah dikaji dan didapati bahawa pemilihan ciri-ciri tersebut sebenarnya memberi kesan kepada prestasi ANN. Kesimpulannya, penggunaan ANN dalam memadankan indeks kestabilan voltan menunjukkan potensi besar untuk menilai masalah kestabilan voltan yang sebelum ini memakan masa dan sangat mahal.

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Thank you.

Approval Sheet No. 1

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DECLARATION

I declare that this 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 other institutions.

_____

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