UNIVERSITI TEKNOLOGI MARA

NEW TECHNIQUES INCORPORATING COMPUTATIONAL INTELLIGENCE BASED FOR VOLTAGE STABILITY EVALUATION AND IMPROVEMENT IN POWER SYSTEM

NUR FADILAH AB. AZIZ

Thesis submitted in fulfilment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Electrical Engineering

September 2014

AUTHORS'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

Name of Student	:	Nur Fadilah Ab Aziz
Student's ID No.	:	2008535159
Programme	:	PhD in Electrical Engineering (EE990)
Faculty	:	Faculty of Electrical Engineering
Thesis Title	:	New Techniques Incorporating Computational Intelligence based for Voltage Stability Evaluation and Improvement in Power System

Signature of Student	:	....
Date	:	September 2014

ABSTRACT

Recently, there are still many cases of voltage collapse incidents occur all around the world. This is due to the reason that most power systems today are being operated very close to their stability limits because of the exponentially growing demands, the desires to obtain maximum economic benefits and environmental constraints. Therefore, this thesis presents novel techniques for voltage stability evaluation and enhancement in power system. Firstly, a new bus voltage stability index named as Voltage Stability Condition Indicator (VSCI) was developed. The competency of VSCI was corroborated in three tasks; weak bus identification, automatic line outage contingency ranking and weak area identification. In addition, a new method to detect weak areas in a system termed as Weak Area Clustering Margin (WACM) was also developed. In the first part of study, all methods were tested on IEEE 30-bus and IEEE 118-bus test system. Secondly, a new voltage stability prediction technique utilising state of the art machine learning, Support Vector Machine (SVM) was developed. At this stage, two popular SVM selection parameter methods, trial and error and cross validation were investigated and compared. The developed technique used VSCI as the voltage stability indicator to be predicted. The performance of SVM was also compared with the performance of Artificial Neural Network (ANN). To enhance the SVM performance, an outstanding hybrid Artificial Immune Least square Support Vector Machine (AILSVM) that integrates SVM with Artificial Immune System (AIS) was introduced in voltage stability prediction. For comparison, another new hybrid algorithm incorporating ANN and AIS called as Artificial Immune Neural Network (AINN) for voltage stability prediction was also developed. It was found that AILSVM has outclassed AINN significantly in terms of prediction accuracy and computation time. Thirdly, new techniques for load margin improvement were developed. Initially, a superior performance of AIS named as Fast Artificial Immune System (FAIS) to estimate the maximum load margin of a system was developed. FAIS offers a better performance of AIS since several available approaches for cloning, mutation and selection have been explored and compared. The combination of these approaches that delivered the best performance in terms of accuracy and time was utilised in FAIS. Later on, another novel technique that incorporates FAIS and AILSVM known as Fast Artificial Immune Support Vector Machine (FAISVM) for maximum load margin improvement via RPP optimisation was developed. The integration of FAIS and AILSVM has resulted to a very fast and accurate prediction of maximum loading point (MLP) as the objective function for Reactive Power Planning (RPP) optimisation. The proposed technique employed the predetermined support vectors from AILSVM. VSCI was used as the indicator for the MLP of load buses. Another new hybrid algorithm that used Evolutionary Programming (EP) termed as Evolutionary Support Vector Machine (ESVM) was also developed for comparative study. The results showed that FAISVM has outperformed ESVM significantly in terms of load margin improvement, prediction accuracy and computation time. For the second and third part of the study, the developed techniques were tested on IEEE 30-bus test systems. In conclusion, this thesis has developed a new voltage stability index, VSCI and novel techniques known as AILSVM and FAISVM for voltage stability prediction and maximum load margin improvement that utilised biological optimisation method.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND OF STUDY

Power system is a complex interconnected network that consists of four major parts; generation, transmission, distribution and loads. At all times, the power system operation must be stable, able to meet numerous operational conditions and also safe from any potential unforeseen events. However, power systems are currently, being operated closer to their stability limits due to growing demand, maximum economic benefit and environmental constraints. As a result, sustaining a stable and secure operation of a power system today has become a challenging issue. Voltage instability is being considered as one of the main causes of power system insecurity [1]. In the past few years, voltage instability has been reported responsible for the occurrence of blackouts and several major network collapses all over the world [2]. With repeated incidences of voltage instability and voltage collapse, voltage stability problems today are receiving more attention by every power system analyst and researcher.

A system is said to experience voltage instability when a disturbance such as increase in load demand, or change in system condition causes a progressive and uncontrollable loss in voltage. Voltage collapse will then occur if the decreasing voltages are below acceptable limits. In the present day, modern power systems are very complex and heavily loaded thus resulting in high probability of voltage instability occurrence. Under such unstable condition, any small disturbance could threaten the security of power system with subsequent voltage collapse. This will automatically increase the needs of new research lines to evolve new techniques for evaluating and monitoring the voltage stability condition as well as preventing the occurrence of voltage collapse in the system.