ARTIFICIAL NEURAL NETWORK BASED VOLTAGE COLLAPSE PREDICTION FOR POWER SYSTEM NETWORKS

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JANUARY, 2020

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE MASTER OF ENGINEERING (M.Eng.) DEGREE IN ELECTRICAL AND ELECTRONICS ENGINEERING IN THE DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING, COLLEGE OF ENGINEERING, COVENANT UNIVERSITY.

JANUARY, 2020

ACCEPTANCE

This is to attest that this dissertation has been accepted in partial fulfilment of the requirements for the award of the degree of Master of Engineering in Electrical and Electronics Engineering in the Department of Electrical and Information Engineering, College of Engineering, Covenant University, Ota, Nigeria.

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DECLARATION

I, SOYEMI, ADEBOLA OLUYEMISI (11CK012537) declare that this dissertation is a representation of my work, and is written and implemented by me under the supervision of Doctor Isaac A. Samuel of the Department of Electrical and Information Engineering, Covenant University, Ota, Nigeria. I attest that this dissertation has in no way been submitted either wholly or partially to any other university or institution of higher learning for the award of a masters' degree. All information cited from published and unpublished literature has been duly referenced.

SOYEMI, ADEBOLA OLUYEMISI ………………………
Signature and Date

CERTIFICATION

This is to certify that the research work titled **"ARTIFICIAL NEURAL NETWORK BASED VOLTAGE COLLAPSE PREDICTION FOR POWER SYSTEM NETWORKS"** is an original research work carried out by **SOYEMI, ADEBOLA OLUYEMISI** meets the requirements and regulations governing the award of Master of Engineering (M.Eng.) degree in Electrical and Electronics Engineering from the Department of Electrical and Information Engineering, College of Engineering, Covenant University, Ota, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This dissertation is dedicated, first of all, to the Almighty God for His mercies, grace, wisdom and favour throughout the Masters' programme. It is also dedicated to my dear parents Mr and Mrs O.S. Soyemi, siblings Dr Adeola, Dr Adetoun, Engr. Adesola, and Mr Ademola and friends for all their love, guidance, support, and prayers.

ACKNOWLEDGEMENTS

I wish to express my heartfelt gratitude to the Almighty God for His everlasting faithfulness, tender mercies, constant protection and divine enablement upon my life, family and loved ones. Indeed, He has remained faithful despite the many challenges encountered throughout the programme.

Secondly, I am exceedingly grateful to my loving parents for all their support, encouraging words of advice, prayers and care. Their labour shall not be in vain. I also thank all my siblings, relatives and other family friends who supported me in diverse ways.

Furthermore, I sincerely appreciate my supervisor, Dr Isaac A. Samuel, for his moral support, encouragement, constructive criticisms and more importantly, his confidence in me which I earnestly hold in high esteem. It has indeed been a privilege to work under him. May the good Lord sustain him, his family and always bless all the works of his hands. Amen.

I remember in great appreciation other people who played various significant roles towards the accomplishment of the Masters' Degree. I pray that the Almighty God, in all His faithfulness, rewards them all, and grant all their heart desires.

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LIST OF ABBREVIATIONS AND SYMBOLS

AI	Artificial Intelligence
ANN	Artificial Neural Network
CIGRE	International Council on Large Electric Systems
D_{base}	Index Base Value
D_{used}	Index Value used
E	Error
FFNN	Feed-Forward Neural Network
FVSI	Fast Voltage Stability Index
GRNN	Generalised Regression Neural Network
IEEE	Institute of Electrical and Electronics Engineers
ICA	Imperialist Competitive Algorithm
LCPI	Line Collapse Proximity Index
Lmn	Line Stability Index
LQP	Line Stability Factor
MAPE	Mean Absolute Percentage Error
MATLAB	Matrix Laboratory
MLFFN	MultiLayer Feed Forward Network
MLPNN	MultiLayer Perceptron Neural Network
MSE	Mean Square Error
MVAr	MegaVolts-ampere
NLSI_1	New Line Stability Index
NNG	Nigerian National Grid
PMU	Phasor Measurement Unit
P_S, Pr	Real power at sending bus s and receiving bus r
Pu	Per unit
P-V	Real power-Voltage
Q_S, Qr	Reactive power at sending bus s and receiving bus r
Q-V	Reactive power-Voltage
R	Line resistance
RBF	Radial Basis Function

S_S, Sr	Apparent power at sending bus s and receiving bus r
VCPI	Voltage Collapse Prediction Index
V_S, V_r	Voltage at sending bus s and receiving bus r
VSI	Voltage Stability Index
VQILine	Voltage Reactive power Index
X	Line reactance
Z	Line impedance
θ	Transmission Line angle
δ	Angle difference between sending and receiving end voltages
δ_s, δ_r	Voltage angles at sending bus s and receiving bus r
σ	Switching Function

ABSTRACT

Unmitigated voltage instability often results in voltage collapse and or system blackout, which constitute a significant concern in power system networks across the globe but most especially in developing countries. This research work proposes an online voltage collapse prediction model through the use of a machine learning technique such as the artificial neural network and a voltage stability index called the new line stability index (NLSI_1). The proposed neural network approach uses a multilayer feed-forward neural network with the variables of the NLSI_1 as the inputs to the network. In the proposed approach, this is done in two phases; first load flow study is carried out for all load buses in the test-systems then voltage collapse prediction is carried out on the test-systems. Both phases are implemented using appropriate neural network models developed in MATLAB neural network toolbox. The proposed method was tested on the IEEE 14-bus system and the 28-bus, 330-kV Nigeria National Grid (NNG), for the two test systems two scenarios were considered; base case and contingency analysis (that is a variation of the reactive loads in the network). For the base case, all the buses and lines of the IEEE 14-bus system were stable with index values less than unity (<1).

During contingency analysis simulations the 14th bus was ranked as the weakest bus in the system, having a reactive power margin of 74.6 MVAr and a percentage change in voltage magnitude of 38.30%. For the IEEE 14-bus system, the results obtained by the developed neural network and from the conventional method are approximately equal with negligible errors between them, which thereby validates the efficacy of the proposed method. For the NNG system, during base case simulation, the index values for all buses and lines were less than unity (<1). During contingency simulation, load bus 16 was ranked the weakest bus in the system with a reactive power margin of 139.5 MVAr and percentage change in voltage magnitude of 32.06%. The proposed method had an R-value of 0.9975 with a Mean Square Error (MSE) of $2.182415\text{x}10^{-5}$ for the IEEE 14-bus system and the NNG 28 bus system, an R-value of 0.9989 with an MSE of $1.2527\text{x}10^{-7}$. In this dissertation, the results presented indicate that artificial neural networks and voltage stability indices are highly capable of assessing the voltage stability of power system networks.

Keywords: ANN, Critical line, MATLAB, NNG, Power system networks, Voltage stability, Voltage stability indices.