ISLANDING DETECTION FOR GRID-CONNECTED DISTRIBUTED GENERATION SYSTEMS USING CONVOLUTIONAL NEURAL NETWORK

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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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(Dean, School of Postgraduate Studies) **Signature and Date**

DECLARATION

I, ADENUGBA FAVOUR TOLUWANIMI (11CK012393) declare that this dissertation is a representation of my work, and is written and implemented by me under the supervision of Doctor Hope Orovwode of the Department of Electrical and Information Engineering, Covenant University. 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 All information cited from published and unpublished literature has been duly referenced.

ADENUGBA, FAVOUR TOLUWANIMI ……

Signature and Date

CERTIFICATION

This is to certify that this dissertation **titled "ISLANDING DETECTION FOR GRID-CONNECTED DISTRIBUTED GENERATION SYSTEMS USING CONVOLUTIONAL NEURAL NETWORK"** is an original research work carried out by **ADENUGBA FAVOUR TOLUWANIMI** 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 research work is dedicated primarily to our father God Almighty, our Lord and Savior Jesus Christ, and the sweet and gentle Holy Spirit, the all-knowing trinity for wisdom, knowledge, and understanding from above in carrying out this research work. Then to family, my dad and mom for their tremendous support and for teaching me all I know till my university days and my brother for support, love, and understanding.

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SYMBOLS

∑ - Summation

ABBREVIATIONS

DG – Distributed Generation

CIGRE - Conseil International des Grands Réseaux Électriques

CG – Centralized Generation

PQ – Power Quality

CNN – Convolutional Neural Network

DNN – Deep Neural Network

ANN – Artificial Neural Network

SVM – Support Vector Machine

NDZ – No Detection Zone

PCC – Point of Common Coupling

AC - Alternating Current

DC - Direct Current

IDMs – Islanding Detection Methods

AFD – Active Frequency Drift

SFS – Sandia Frequency Shift

SVS – Sandia Voltage Shift

SFS – Slip Mode Frequency Shift

UOV – Under/Over Voltage

UOF – Under/Over Frequency

MATLAB - Matrix Laboratory

PJD – Phase Jump Detection

RoCoP – Rate of Change of Power

RoCoF – Rate of Change of Frequency

SPD – Signal Produced by Disconnect

PLCC – Power Line Carrier Communication

SCADA – Supervisory Control and Data Acquisition

WT – Wavelet Transform

TTT - Time-Time Transform

ST – S-Transform

FT – Fourier Transform

STFT – Short Time Fourier Transform

FFT – Fast Fourier

AI – Artificial Intelligence

FL – Fuzzy Logic

RMS – Root Mean Square

RBF – Radial Basis Function

PNN – Probabilistic Neural Network

THD – Total Harmonic Distortion

BFVB – Basic Frequency Variable Bridge

IGBT – Insulated Gate Bipolar Transistor

PWM – Pulse Width Modulation

SVPWM – Space Vector Pulse Width Modulation

CWT – Continuous Wavelet Transform

PSEC/ FD – Power System Event Classification / Fault Detection

ROC – Receiver Operating Characteristics

SNR – Signal-to-Noise ratio

ABSTRACT

In the world today the lack of adequate supply of electricity is still a major problem especially in developing and underdeveloped countries. The global electrification rate is put at 75% and this figure has to go up in the coming years in other to promote sustainable development and eliminate world poverty. Distributed generation (DG) integration with the grid has been increasing worldwide due to the advantages it can provide to the electrical power systems, such as the possibility of reducing transmission and distribution losses, environmental benefits, the increase in the reliability of the power supply and the deferral of transmission and distribution investments. This makes it a suitable mechanism to improve electrification rate all over the world. Unintentional islanding is a major technical challenge that bedevils this system. Some researchers have developed islanding detection models to detect islanding and regard all other events that take place while the grid is still connected as Non-Islanding events while others have developed islanding detection models to detect islanding as well as identify Non-islanding disturbances when they occur (Islanding and Non-Islanding disturbance detection). Both system types are developed in this research. This research presents image-based islanding detection models using convolutional neural network. These models utilize scalogram images obtained from the aggregated phase voltages at point of common coupling (PCC). Therefore the models utilize the PCC voltage as the islanding detection parameter. The power system, islanding, and non-islanding events are simulated in MATLAB, wavelet transform is applied to the voltage signals obtained from the PCC for the different events to obtain the scalogram representation of the event. In both models developed a portion of this image data generated is used to train the classifier while the other part is used to test the classifier. The immunity of the developed models to noise is also investigated, the noise introduced did not have an adverse effect on the models. The results obtained from the simulation proves the ability of the proposed classifiers to detect islanding. The proposed models compare favourably with existing techniques and methods. For the first model, detection accuracy of 99.83% was obtained while for the second system detection accuracy of 99.2% was obtained.

Keywords: Convolutional Neural Network (CNN), Distributed Generation, Scalogram, Unintentional Islanding, Islanding Detection, Non-Islanding Disturbance.