**CERTIFICATION**

This is to certify that this project work was carried out by **Aiyedun, Rasheed Babatunde (160282) and Giwa, Ibrahim Abiola (160584)** of the Department of Electronic and Electrical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Dr. O.A. Adegbola Date

Supervisor

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Prof Mrs. F.A. Semire Date

Head of Department

# DEDICATION

This project work is dedicated to Almighty Allah, The Most Gracious and The Most Merciful for making this project work a reality through the provisions and sustenance which He provided.

# 

# 

# ACKNOWLEDGEMENT

All Praise to the Almighty, our profound gratitude goes to Almighty Allah for his infinite, mercy, grace and strength bestowed on us throughout this program, for lending us his blessing, strength, and the chance and endurance to partly complete our Final year project. We would like to express our sincere gratitude to our supervisors, Dr. O.A. Adegbola, and co-supervisor Prof. D. O. Aborisade and the technical knowledge of Engr. Dr. S.I. Popoola, for their time, generous guidance, patience and encouragement throughout the whole project, from which we have learned a lot during this period. We would love to appreciate the support of ours parents, siblings, colleagues, friends and those who contributed in one way or the other to the success of this work.

We acknowledge the overwhelming support of the H.O.D. Electronic and Electrical Engineering, Prof Mrs. F.A. Semire is acknowledged, thank you for the leadership role exhibited during this programme. A great appreciation to all the staff of the department of Electronic and Electrical Engineering, LAUTECH, for the words of encouragement and the enabling environment given to us during our study.

**TABLE OF CONTENTS**

Title page i

Certification ii

Dedication iii

Acknowledgement iv

Table of Contents v

List of figures viii

List of Tables ix

Abstract x

**CHAPTER ONE: INTRODUCTION**

* 1. Background of Study 1

1.2 Motivation for Study 5

1.3 Aim 7

1.4 Objectives 7

1.5 Methodology 8

1.6 Significance of Study/Expected Contribution 8

**CHAPTER TWO: LITERATURE REVIEW**

2.1 Introduction 11

2.2 Mobile Communication Systems 14 2.2.1 Evolution of Mobile Communication Systems 15 2.2.2 Architecture of Mobile Communication Systems 16 2.2.3 GSM Network Areas 22

2.3 Base Station Energy System 23 2.3.1 Energy Costs in Telecommunication Industries 23 2.3.2 Environmental Impact and Greenhouse Gas Emissions 25 2.3.3 Energy Consumption at a Macro Base Transmitter Station Site 27

2.4 Power Solutions for BTS Sites 28

2.4.1 Mains Power 29 2.4.2 Diesel Generators 29 2.4.3 Renewable Energy Solution 29

2.5 Renewable Energy Technologies 30

2.5.1 Renewable Power Options at BTS Sites 30

2.5.2 Hybrid Power Systems (HPS) 31

2.6 Wind Power Prediction Using Machine Learning (ML) 33

2.7 Time-Series Forecasting 36

2.8 Review of Related Work 36 2.8.1 Data Collection 37 2.8.2 Data Pre-processing 38 2.8.3 Model Development 40 2.8.4 Model Evaluation 42

2.9 Summary 50

**CHAPTER THREE: METHODOLOGY**

3.0 Methodology 52

3.1 Area of Study 52

3.2 Wind Speed Forecasting Process 53

3.2.1 Data Collection 53

3.2.2 Data Pre-processing 54

3.2.3 Forecasting Model Development 57 3.2.4 Short-Term wind speed forecasting 66

3.2.5 Model Evaluation 67

**CHAPTER FOUR: RESULTS AND DISCUSSION**

4.1 Part A: Description of Datasets 70

4.2 Part B: Performance of each LSTM hyper-parameters 72

4.3 Part C: Comparison of the Proposed Model with other models 87

**CHAPTER FIVE: CONCLUSION AND RECOMMENDATION**

5.1 Conclusion 89

5.2 Recommendation 90

**REFERENCES**  91

**APPENDICES** 99

**LIST OF FIGURES**

**FIGURESPAGES**

* 1. Distribution of renewable energy consumption worldwide in 2017 2

and 2023, by technology

1.2 Estimates of Renewable Energy Potential in Nigeria (MW) 3

2.1Evolution of Mobile Communication Systems 15

2.2 Architecture of Mobile Communication Systems 16

2.3 Power Consumption of Radio Base Station 28

2.4 Machine-learning Classification 35

3.1 Methodology Block Diagram 52

3.2 Map and Location of Kano in Nigeria 53

3.3 Wind Speed Measurement Process 54

3.4 LSTM Model Chart Diagram 60

3.5 Process of Wind Speed Prediction 68

**LIST OF TABLES**

**TABLE PAGES**

2.1 Keywords 11

2.2 Illustrating Common Network Names; it Core Network Component 19

and Their Respective Network Functionalities

2.3 Nigeria’s Case Studies 44

2.4 Other Countries’ Case Studies 47

3.1 Data splitting 57

3.2 Description of activation Functions used in the LSTM model 61

3.3 Description of loss Functions used in the LSTM model 63

4.1 Detailed Description of Dataset 70

4.2 Performance Evaluation of Varying Hidden Neurons 73

4.3 Performance Evaluation of Activation Functions 76

4.4 Performance Evaluation of Optimizers 77

4.5 Performance evaluation of loss Functions 78

4.6 Performance evaluation of Varying number of Batch-sizes 78

4.7 Performance evaluation of varying Dropout 79

4.8 Performance Evaluation of Varying Time-steps 80

4.9 Performance Evaluation of Varying Engineered Features 82

4.10 Performance evaluation of Varying numbers of Epochs 84

4.11 Final LSTM Hyper-parameter Result 85

4.12 Comparison of Proposed Model with Other Model

**ABSTRACT**

The grossly untapped potential of wind energy, which is a clean and prominently available source of energy in the Northern part of Nigeria, constitutes a socio-environ-economic issue which can be addressed by devising the right approach to energy resource management. Telecommunication base stations are among the critical infrastructures that require a reliable supply of energy that should be achieved in a clean and eco-friendly manner, and there are several of these base stations located in regions with excellent wind potentials but being powered by diesel generators. However, accurate prediction of wind output is crucial for handling the unpredictability associated with wind data to ensure the reliability of supply which can guarantee consistent performances of the loading infrastructure. In this study, the predictive analytics capabilities of a contemporary machine learning (ML) algorithm known as the Long-Short-Term Memory Algorithm (LSTM) model were used to estimate the daily available wind potential for providing an electricity supply to a telecommunication base station remotely located in a region with sufficient wind potential in Nigeria. The wind speed dataset covering a period of 10 years (2008 to 2017) for Kano, which is a prominent commercial city in Northern Nigeria, was collected from the Nigeria Meteorological Agency (NIMET), Oshodi, Lagos State, Nigeria for implementing the LSTM wind prediction. The datasets were processed using Python programming and relevant libraries; with feature engineering techniques applied, and the data was transformed into a time-series sequence after standardization. The LSTM model was trained using 70% of the processed data and the remaining 30% of the processed data are deployed for testing the LSTM model for wind output prediction. A series of experiments were carried out to tune the LSTM hyperparameters for achieving high prediction fidelity considering specific error-based statistical analysis. The resulting performance metrics of MAPE = 0.0416, RMSE = 0.1531, MSE = 0.0234, MAE = 0.1199 and R2 = 0.9987, showed that the proposed LSTM wind speed prediction model outperformed all other models in general comparison, demonstrating its effectiveness in wind speed prediction. Finally, based on a techno-economic analysis of the different energy supply configurations, a hybrid renewable energy solution comprising solar and wind energy was proposed as a viable energy solution for telecommunication base stations in Nigeria, where the use of diesel generators will be minimized.