**SMART PROTECTION SYSTEM FOR FUTURE POWER SYSTEM DISTRIBUTION NETWORKS WITH INCREASED DISTRIBUTED ENERGY RESOURCES**

**PASCHAL, W.H MAC-BRAIDE**

**DE.2015/0729**

**THIS PROJECT IS SUBMITTED TO RIVERS STATE UNIVERSITY, NKPOLU-OROWORUKWO PORT HARCOURT IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR, DEGREE IN ELECTRICAL ELECTRONICS ENGINEERING, IN THE FACULTY OF ENGINEERING.**

**SUPERVISORS**

**ENNGR. PROF. C.O. AHIAKWO**

**ENGR. DR. I.C. OKARA**

**APRIL, 2021**

## ABSTRACT

This thesis investigates the impact of increased penetration of distributed energy resources (DERs) on the power system distribution network protection system which has been designed on the premise of passive radial network with unidirectional power flow.

**CERTIFICATION**

This is to certify that this project work was carried out by **PASCHAL W.H MAC-BRAIDE** with the matriculation number **(DE.2015/0729)** and submitted to the Department of Electrical Engineering of the Rivers State University Nkpolu-Oroworukwo Port Harcourt. For the award of Bachelor of Technology in Electrical Engineering.

**Engr. Prof. C.O. Ahiakwo** ......................................... .................................

(*Supervisor*) Signature Date

**Engr. Dr. I.C. Okara** ......................................... .................................

(*Supervisor*) Signature Date

**Engr. Prof. D.C Idoniboyeobu** ......................................... .................................

(*HOD*) Signature Date

**External Examiner**  ......................................... .................................

Signature Date

**DEDICATION**

I dedicate this work to God Almighty.

**ACKNOWLEDGEMENTS**

This work has been carried out at the Division of Electric Power Engineering, Department of the Rivers State University Port Harcourt Nigeria.

I would like to thank my supervisors Engr. Dr. I.C. Okara and Engr. Prof. C.O. Ahiakwo for their guidance, encouragement and support. I am grateful for their decision on employing me.

I would also like to thank my Parents Mr and Mrs Harjie Mac-Braide for their support and prayers for me to excel in my academic work.

**TABLE OF CONTENTS**

**Contents Pages**

Cover Page

Title Page i

Abstract ii

Declaration iii

Certification iv

Dedication v

Acknowledgement vi

Table of Contents vii

List of Tables viii

List of Figures iv

**CHAPTER 1: INTRODUCTION 1**

1.1 Background Of The Project 1

1.2 Problem Statement 2

1.3 Research Aim 3

1.4 Significance Of The Research 3

1.5 Structure Of The Study 4

**CHAPTER 2: LITERATURE REVIEW** 5

2.1 Overview Of Power System Protection 5

2.2 Basic Components Of Protection Scheme And Their Functions 5

2.3 Conventional Distribution Network 6

2.4 Challenges In Modern Distribution Networks 7

2.5 Integration Of Re Based Ders 8

2.6 Challenges In Distribution Network Oc Protection System Design 9

Due To Increased Penetration Of Re Based Ders

**CHAPTER 3: METHODOLOGY 10**

3.1 Designing The Multistage Mm Arc Fault Detection Algorithm 10

3.2 Research Methodology Utilizing The Mm Technique 10

3.3 Attributes Of The Docas Algorithm 11

3.4 Detecting power system disturbances 12

3.5 DOCAS Attributes for HIF Features Extraction 12

3.6 DOCAS Responce to DC Are-Fault 15

**CHAPTER 4: RESULT AND DISCUSSION 18**

4.1 Thevenin Equivalent Parameter Estimation Photovoltaic

Distribution Energy Resources 19

4.2 Effect Of Pv System Penetration On Feeder Substation Fault Current Level 20

4.3 Docas Algorithm In Adaptive Over Current Protection Of Radial 21

Distribution Feeder With Pv Penetration

4.4 Application Of Mfd Output In Adaptive Radial Distribution 22

Feeder Oc Protection

4.5 Simulations And Discussions 22

4.6 Symulation System Description 22  
4.7 Inverse - Time Over Current Relaying Using MFD Output Signal 29

4.8 Conclusion 30

**CHAPTER 5: CONCLUSION AND RECOMMENDATION 33**

5.1 Conclusion 34

5.2 Summary 34

5.3 Future Directions 39

**REFERENCES 40**

**LIST OF TABLES**

**Tables Pages**

4.1 Fault level increase at different fault location at 28% PV Penetration 27

4.2 Increase in fault current magnitude at different fault distance 28% PV 29

## LIST OF FIGURES

**Figures Pages**

2.1 Typical connection of protective devices 5

2.2 Function character of the protective device 6

2.3 Typical structure of the convention power system 7  
3.1 DOCAS response to DC arc-fault in PV systems, (a) DC arc-fault

voltage, (b) Average MMF output, (c) diff DC fault voltage, ΔV and (c) 17 MFD output.

3.2 DOCAS response to DC arc-fault in PV systems, (a) DC arc-fault

current, (b) Average MMF output, (c) diff DC fault current, ΔI and

(c) MFD output. 17

4.1 A typical radial distribution feeder with PV Penetration 20

4.2 the OC fault detection and diagnostic scheme incorporating the 21

DOCAS algorithm

4.3 Test Feeder for modelled in Simulink for simulations 23

4.4 Characteristic curves for the PV strings at STC 25

4.5 Circuit topology of a DC-DC boost converter 26

4.6 RLSE filter magnitude response for SLG at fault locations

1,2 and 3 at 28% 26

4.7 MFD output corresponding at fault current magnitude for SLG fault at fault

Location 1,2 and 3 at 28% PV penetration 27

4.8 MFD Output corresponding to fault current magnitude for SLG fault 29

at fault location 2 at (a) 0% and 28% PV Penetration.

## LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| ACR ASF ASF  CB | Automatic Circuit Recloser, Alternating Sequence Filter, Alternating Sequential Filter  Circuit Breaker |
| COASF | Close-open Alternating Sequence Filter |
| CT | Current Transformer |
| CTS | Current Tap Setting |
| DER | Distributed Energy Resource |
| DFT | Discrete Fourier Transform |
| DMMF | Decomposed Morphological Median Filter |
| DOCAS | Decomposed Open Close Alternating Sequence |
| DWT | Discrete Wavelet Transform |
| ESS | Energy Storage System |
| FFT | Fast Fourier Transform |
| GFPD | Ground Fault Protection Device |
| HIF | High Impedance Fault |
| IEEE | Institute of Electronics and Electrical Engineers |
| IMPP | Current at Maximum Power Point |
| ITOC | Inverse Time Overcurrent |
| MFD | Morphological Fault Detector |
| MFDi | Morphological Fault Detector output for current signal input |
| MFDv | Morphological Fault Detector output for voltage signal input |
| MM | Mathematical Morphology |
| MMF | Mathematical Median Filter |
| MMF | Morphological Median Filter |
| MPP | Maximum Power Point |
| MPPT | Maximum Power Point Tracking |
| OC | Overcurrent |
| OCASF | Open-close Alternating Sequence Filter |
| OCPD | Overcurrent Protection Device |
| PCC | Point of Common Coupling |
| PVRE  RLSE | Photovoltaic Renewable Energy  Recursive Least Square Error |
| RMPP | Resistance at Maximum Power Point |
| RMS | Root Mean Square |
| SE | Structuring Element |
| SS | Substation |
| STC | Standard Test Condition |
| TDS | Time Dial Setting |
| TMS | Time Multiplier Setting |
| VMPP | Voltage at maximum Power Point |
| VT | Voltage Transformer |
| WT | Wavelet Transform |