

**CONDITION MONITORING OF METAL OXIDE  
SURGE ARRESTERS AT POWER DISTRIBUTION**

**SM ARSHAD**

**178008K**

**Degree of Master of Science**

**Department of Electrical Engineering**

**University of Moratuwa**

**Sri Lanka**

**June 2018**

**CONDITION MONITORING OF METAL OXIDE  
SURGE ARRESTERS AT POWER DISTRIBUTION**

Sirajudeen Mohamed Arshad

178008K

Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

June 2018

## DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

.....

S.M. Arshad

.....

Date

The above candidate has carried out research for the Masters Dissertation under my supervision.

.....

Dr. W.D.A.S. Rodrigo

.....

Date

## **ABSTRACT**

Metal Oxide Surge Arresters (MOSA) are proven to be reliable protective devices for power distribution and electrical transmission system. MOSA are subjected to electrical ageing or degradation due to constant AC conduction or transient voltages. Leakage current measured from surge arresters are used to observe its degradation and the resistive leakage component is extracted from the total to determine the health of the surge arresters. If resistive current increases, life of the surge arresters decreases. Generally leakage current is measured using current shunts or current transformers where it's necessary to measure the applied voltage which is very hard to measure in online condition. This proposed study develops a simple but accurate method to separate the resistive leakage current from the total leakage current without any voltage measurements by using a technique called Modified Phase Shifted Method (MPSM) which is totally based on manipulation of the total leakage current waveform and simulated in Matlab & Simulink. A prototype device is designed and developed to sense the leakage current from a surge arrester and transmit those data to Matlab & Simulink to perform the MPSM and determine the its resistive leakage current. This method enables remote and an online monitoring system which can alert the utility whenever the health of the installed surge arrester becomes low.

## **ACKNOWLEDGEMENT**

First and foremost, I would like to express my sincere gratitude to my supervisor, Dr. Asanka S. Rodrigo for guiding and encouraging me towards a successful flow of this dissertation and supporting tremendously throughout the research period.

I would also like to express my sincere gratitude to the course coordinator, all the lectures and visiting lectures in the M.Sc. programme, for their valuable teaching and assistance throughout the course.

I express my thanks and appreciation to my family for their understanding, motivation and patience. I also thank to all my colleagues and friends for giving their fullest co-operation throughout the time of research and writing of thesis.

I also place on record, my sense of gratitude to all who, directly and indirectly, have lent their helping hand in this process.

## TABLE OF CONTENTS

DECLARATION .....	I
ABSTRACT.....	II
ACKNOWLEDGEMENT .....	III
LIST OF FIGURES .....	VI
LIST OF TABLES .....	VIII
LIST OF APPENDICES .....	IX
LIST OF SYMBOLS & ABBREVIATIONS .....	X
1. INTRODUCTION .....	1
1.1 Background .....	1
1.2 Motivation .....	3
1.3 Objective .....	3
1.4 Scope of work.....	4
2. LITERATURE REVIEW .....	5
2.1 Advantages of Metal Oxide Surge Arrester .....	5
2.2 Construction and operation of MO Surge Arrester .....	6
2.3 Characteristics of the MOSA .....	7
2.3.1 Voltage-Current .....	7
2.3.2 Current-Time.....	10
2.3.3 Voltage-Time.....	10
2.4 Factors affecting the life time of MOSA.....	11
2.5 Importance of monitoring of Surge Arresters .....	14
3. SURGE ARRESTER MONITORING METHODS .....	15
3.1 Different types of arrester monitoring techniques.....	15
3.2 Suitability of resistive leakage current for arrester monitoring.....	16
3.3 Comparison of various resistive current measurement methods.....	17
4. SIMULATION RESULTS FOR LEAKAGE CURRENT BEHAVIOUR OF MOV ARRESTERS .....	18
5. EXPERIMENT SETUP TO MEASURE LEAKAGE CURRENT OF MOV ARRESTERS .....	21

6. MODIFIED PHASE SHIFTING METHOD .....	26
6.1 Algorithm of MPSM .....	26
6.2 Implementation of MPSM in MATLAB & SIMULINK .....	29
6.2.1 Acquire signal and Phase shifting Process.....	31
6.2.2 Generation of Capacitive component .....	33
6.2.3 Extraction of Resistive current .....	36
7. CONDITION MONITORING DEVICE DEVELOPMENT .....	38
8. RESULTS AND DISCUSSIONS .....	46
9. CONCLUSION AND RECOMENDATIONS .....	52
LIST OF REFERENCES .....	1
Bibliography .....	1
Appendix .....	2

## LIST OF FIGURES

Figure 1: Surge arrester position in AC line .....	1
Figure 2: Lightning current waveforms .....	1
Figure 3: Diferent rated MOV arresters .....	2
Figure 4: Inside of a MOV arrester .....	2
Figure 5: Operation of a MOV arrester .....	6
Figure 6: Equivalent circuit of ZnO block .....	7
Figure 7: Current - Voltage graph .....	8
Figure 8: Current - Time graph .....	10
Figure 9: Voltage - Time graph .....	11
Figure 10: MOV arrester failure .....	11
Figure 11: Causes of MOV arrester failurs .....	12
Figure 12: Dielectric breakdown of MOV arrester .....	13
Figure 13: Voltage protection by MOV arrester .....	14
Figure 14: Equivalent MOV circuit Modelled in PSCAD .....	18
Figure 15: Simulation results for 25kV & 30kV .....	19
Figure 16: Simulation results for 45kV & 60kV .....	19
Figure 17: Simulation results fro 75kV & 90kV .....	20
Figure 18: Manual impulse generator .....	22
Figure 19: AC High voltage tester .....	22
Figure 20: 475V MOV arrester testing .....	23
Figure 21: Leakage current when arresetr is in good state .....	24
Figure 22: Leakage curretn of 65 $\mu$ A .....	24
Figure 23: Leakage currnet of 460 $\mu$ A .....	24
Figure 24: Phasor diagam of leakage current components .....	25
Figure 25: Flowchart of the MPSM .....	28
Figure 26: Matlab & Simulink .....	29
Figure 27: Overall MPSM model in Simulink .....	30
Figure 28: Acquire & phase shifting process .....	31
Figure 29: Frequency detection process .....	32
Figure 30: Capacititve current generatiob process .....	33
Figure 31: Peak detection process .....	34
Figure 32: Sine wave generator .....	35
Figure 33: Extraction of resistive leakage current .....	36
Figure 34: Zero crossing block .....	37
Figure 35: block diagram of the prposed decvice .....	38
Figure 36: Leakage current sensor .....	39
Figure 37: protection circuit .....	40
Figure 38: Operational amplifier circuit .....	41
Figure 39: MCU development board .....	42
Figure 40: Transcievers .....	43
Figure 41: Overall arrester monitoring device .....	44



Figure 42: User end device .....	45
Figure 43: Leakage current waveforms of 275V surge arrester.....	46
Figure 44: Resistive peak waveform.....	47
Figure 45: Capacitive peak waveform .....	48
Figure 46: RMS values of current componenets for 275v arrester .....	49
Figure 47: Resisitive peak value .....	49
Figure 48: Resistive High/Low alarm.....	49
Figure 49: Leakage current waveforms of 30kV surge arrester.....	50
Figure 50: High resistive RMS results for 475V arrester .....	50
Figure 51: High Capacitive RMS results for 30kV.....	50
Figure 52: Leakage current results of 475V arrester.....	51

## LIST OF TABLES

Table 1: Types of surge arresters .....	5
Table 2: Arrester monitoring methods .....	15
Table 3: Resistive current monitoring methods .....	17
Table 4: MOV arrester log book of an arrester at a site.....	21
Table 5: Test results of 30kV MOV arrester.....	23
Table 6: Test results of 475V MOV arrester.....	23

## **LIST OF APPENDICES**

A – 475V Surge arrester leakage current data

B – 30kV Surge arrester leakage current data

## **LIST OF SYMBOLS & ABBREVIATIONS**

MOSA	– Metal Oxide Surge Arrester
MOV	– Metal Oxide Varistor
ZnO	– Zinc Oxide
SPD	– Surge Protective Device
MPSM	– Modified Phase Shifted Method
MCOV	– Maximum Continues Operating Voltage
MCU	– Micro Controller Unit
PIC	– Peripheral Interface Controller
UART	– Universal Asynchronous Receiver Transmitter
USB	– Universal Serial Bus
MATLAB	– Matrix Laboratory
PSCAD	– Power System Computer Aided Design
RMS	– Root Mean Square
V <sub>c</sub>	– Maximum Continues Operating Voltage
V <sub>r</sub>	– Rated Voltage
V <sub>o</sub>	– Operating Voltage
V <sub>s</sub>	– System Voltage