Engineering and Technology Journal e-ISSN: 2456-3358

Volume 10 Issue 03 March-2025, Page No.- 4095-4098

DOI: 10.47191/etj/v10i03.19, I.F. – 8.482

© 2025, ETJ

Online Condition Monitoring Technique for Metal Oxide Surge Arresters Based on Leakage Current Components

Anil S. Khopkar[1], Kartik S. Pandya[2]

[1]Research Scholar, Dept. of Electrical Engg. CSPIT, Charotar University of Science and Technology, Changa, India & Electrical Research And Development Association (ERDA), Vadodara, India.

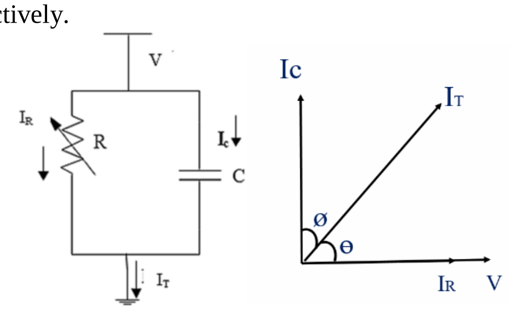
[2]Senior Member IEEE, Associate Professor, Electrical Engg. Dept. Faculty of Engg & Technology, Parul Institute of Engg and Technology, Parul University, Vadodara, India

ABSTRACT: Metal Oxide Surge Arresters (MOSA) are connected in the system for protection of power system against over voltages. MOSA behaves as an insulator under normal working condition and offers conductive path under over voltage condition. Zinc oxide elements (ZnO Blocks) having non-linear voltage-current characteristics is used in construction of MOSA. Ageing effect under various operating conditions such as pollution, moisture ingress caused degradation of MOSA. Degradation of zinc oxide elements increase the leakage current flowing through it which can create thermal runaway conditions for MOSA. Once, it reaches to thermal runaway condition cannot return to normal working condition results in premature failure of MOSA. As MOSA constitutes a core protective device for electrical power system against transients. Condition monitoring of surge arresters should be done at periodic intervals. Online condition monitoring techniques are much popular. This paper presents the evaluation technique for MOSA based on the leakage current analysis. Maximum amplitude of total leakage current (IT), Maximum amplitude of fundamental resistive leakage current (IR) and maximum amplitude of third harmonic resistive leakage current (I3rd) have been analysed as indicators for surge arrester condition monitoring. The ratios of these leakage current has been evaluated for to access the condition of MOSA. The obtained results are validated with other condition monitoring tests.

KEYWORDS: MOSA, over voltage, leakage current, Resistive leakage current, Third harmonic resistive leakage current.

I. INTRODUCTION

Reliable functioning of an electrical power system depends on correct operation of all its components. A substantial failure cause for failure in the power grid is lightning [1]. It is reported that lightning strikes have caused some of the largest blackouts in history [2]. Function of MOSA is to protect the power system equipment against overvoltage. Such overvoltage generated by natural lightning or switching operations in power system. MOSA consists of zinc oxide elements (ZnO) having non-linear Voltage-current characteristics. The nonlinear characteristics of ZnO is highly efficient and eliminated other types of Surge arresters in the system [3]. Lightning overvoltage cause a high peak current when it appears in an electrical circuit and MOSA provides low resistance path so as to discharge instantaneous energy to earth. Thus, MOSA limits the voltage across protected equipment to system tolerable range and avoids damage of electrical equipment. Finally, the MOSA returns to its normal condition i.e high impedance state. MOSA gets aged due to continuous operating voltage, lightning strikes, environmental pollution, temperature, humidity. This increases internal partial discharges (PD) and current flowing through it. Due to ageing effect performance of MOSA gets degrades and perform inferiorly. The inferior performance of MOSA effects protection margin and insulation coordination. If healthiness of MOSA would not monitored at regular time interval, its degradation cannot be identified on time. Hence, Condition monitoring of MOSA is very important for safe operation of the electrical power system. As MOSAs are constructed Zinc oxide elements its equivalent circuit consists of resistive and capacitive element. The equivalent circuit of MOSA represented as non-linear resistance branch in parallel with capacitance branch as shown in Fig. 1 (a). Where, R represents the non-linear resistor and C represents capacitance. V is the voltage applied across surge arrester & total leakage current (IT) is flowing through surge arrester. IC and IR are the capacitive and resistive components of total leakage current (IT) respectively.



(a) (b)

Fig.1: Equivalent Circuit of MOSA

The total Current (I_T) of the MOSA is given by a vector sum of a capacitive current component (I_C) and Resistive current component (I_R). Capacitive current does not vary with the degradation of the arrester and resistive component I_R which varied with degradation of MOSA [4].

$$I_T = I_R + I_C \quad \quad (1)$$

Fig. 1 (b) shows phasor diagram of applied voltage (V), total leakage current (I_T), Resistive leakage current (I_R) and Capacitive Leakage Current (I_C). The resistive components of leakage current exceeds from its capacitive component with the rise in applied voltage [5]. Ideally the capacitance of a ZnO element in the range of 60 pF kV/cm2 to 150 pF kV/cm2. Which resulting in capacitive leakage current of about 0.2 mA to 3 mA under normal service condition. There is no evidence that the capacitive current would change significantly due to degradation of metal oxide resisters. Therefore measurement of capacitive current is not reliably indicator of MOSA condition. Whereas, resistive component of leakage current is sensitive indicator of change in voltage-current characteristics of metal oxide resistors. Therefore, resistive current is use as effective tool to ascertain condition of metal oxide surge arrester [6] [7]. The power loss measurement is frequently used in the laboratories but is rarely used online because simultaneous leakage current and operating voltage measurements are required [8]. In this paper new ageing criteria has been defined for MOSA. Condition monitoring technique based on leakage current measurement have been discussed. The obtained results have been validated using other offline condition monitoring techniques. Obtained results validates and proved the effectiveness of proposed technique for MOSA ageing and condition monitoring of MOSA based on leakage current measurement techniques.

II. PROPOSED METHODOLOGY

Initially condition monitoring tests on new 9 kV and 18 kV MOSA has been carried out. After initial testing both MOSAs kept in ageing process. After that all condition monitoring tests including leakage current measurement carried out on both the MOSAs. Obtained results are evaluated which are given section 4. The methodology followed has been given in figure 2.

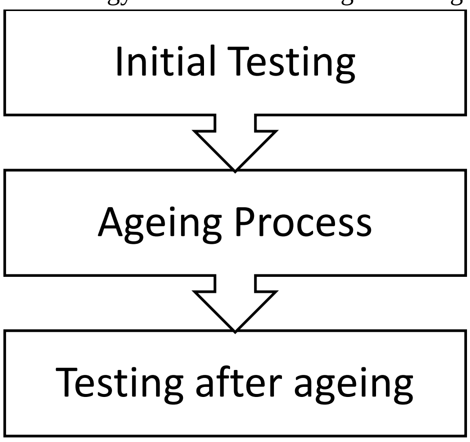


Figure 2: Methodology

III. LABORATORY EXPERIMENTAL

Laboratory experiment on 9 kV & 18 kV metal oxide surge arrester (MOSA) was carried out Experimental set-up includes High Voltage PD free Transformer, 100 kV capacitive Voltage divider & peak volt meter, coupling capacitor, ageing ovens, Impulse current generator etc. The rating of the metal oxide surge arrester used for experiments is given in table 1 and experimental circuit has been given in figure 3.

Table 1 : Rating of MOSA

Parameter	Rating	
Rated Voltage	9 kV	18 kV
Continuous Operating Voltage	7.65	16.2
Nominal Discharge Current	5 kA	5 kA
Maximum Residual Voltage	27 kV	54 kV
External Creepage distance	240 mm	510 mm

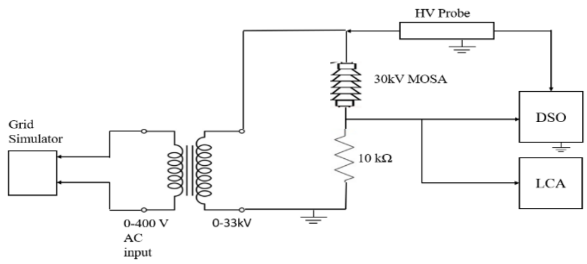


Figure 3 : experimental circuit

Following tests have been conducted on both MOSAs.

1. Measurement of leakage currents
2. Measurement of Reference voltage at reference current
3. Measurement of partial discharge
4. Measurement of capacitance & Tan δ
5. Lightning impulse residual voltage measurement at 500 AP, 8/20 µS Impulse Current

Ageing Process of MOSA :

The ageing process followed has been given in figure 4.

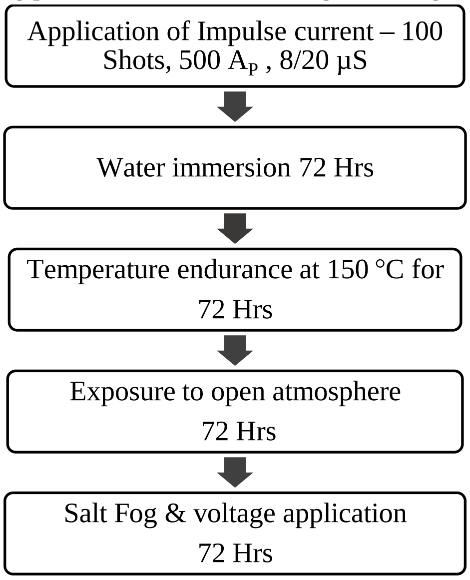


Fig. 4: Ageing process of MOSA

Figure 5 : MOSA immersed in water

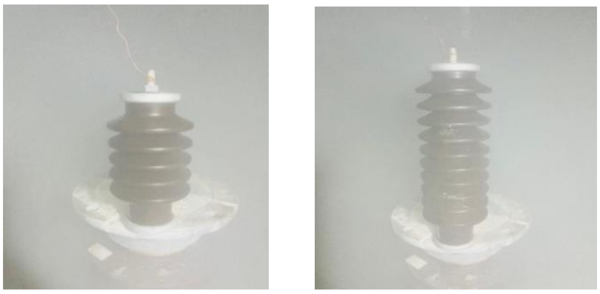


Figure 6 : MOSA under salt fog

IV. RESULTS AND DISCUSSION

Obtained results of all the tests on new MOSAs and after ageing have been recorded and analyzed. The comparison of before and after ageing for 9 kV and 18 kV MOSA has been given in table 2 and table 3 respectively.

Table 2: Experimental results for 9 kV MOSA

Rating of Surge Arrester : 9 kV			
Parameter	Before Ageing	After Ageing	% Variation
Total leakage current, (IT)	405.3	841.2	107.5
Resistive leakage current (IR)	155.3	281.2	81.1
Reference voltage at reference current (Vref)	10.1	9.1	-9.9
Partial discharge (Pc)	1.5	105	NA
Capacitance (pF)	52.102	50.712	2.7
Tan δ (%)	0.009241	0.021245	129.9
Lightning impulse residual voltage (kVp)	23.5	20.12	14.4

Table 2: Experimental results for 9 kV MOSA

Rating of Surge Arrester : 18 kV			
Parameter	Before Ageing	After Ageing	% Variation
Total leakage current, (IT)	443.2	1002.1	126.1
Resistive leakage current (IR)	135.2	276.2	104.3
Reference voltage at reference current (Vref)	18.9	17.3	8.5
Partial discharge (Pc)	1.6	1560	NA
Capacitance (pF)	51.545	51.821	0.5
Tan δ (%)	0.008356	0.02151	157.4
Lightning impulse residual voltage (kVp)	43.4	41.3	4.8

From the achieved results of various condition minoring tests, after ageing MOSA degraded. As a result of degradation leakage flowing through MOSA increased 107.55 % for 9 kV and 126.1 % for 18 kV MOSA. The resistive components of leakage current also increased 81.07 % for 9 kV and 104.3 % for 18 kV MOSA. Marginal variation in reference voltage at reference current & Impulse residual voltage is observed. The value of partial discharge quantity is also increased with increased in leakage current. Increase in value of tan δ is observed 129.90 % for 9 kV and 157.4 % for 18 kV MOSA, however value of capacitance remains almost same. It can be seen that total leakage current, resistive leakage current and tan δ value increased substantially after ageing. Variation in measured parameters for 9 kV and 18 kV MOSA have been given in figure 7 and figure 8 respectively.

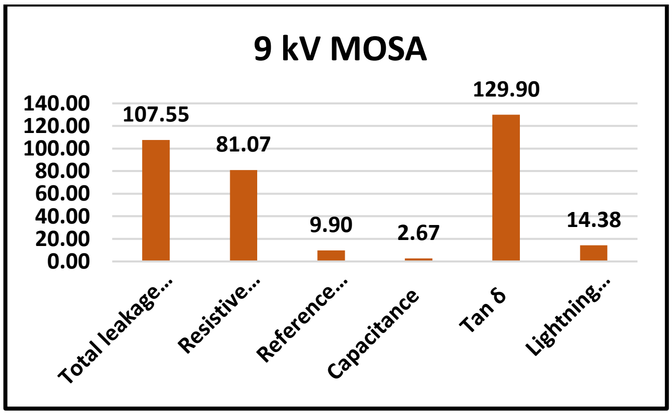


Figure 7 : Variation in measured parameters in %

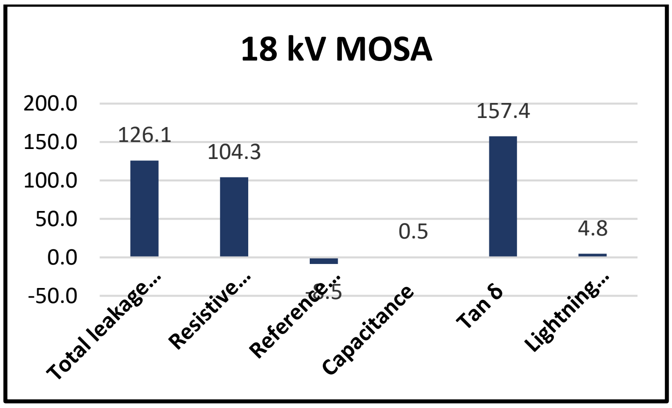


Figure 8 : Variation in measured parameters in %

V. CONCLUSION

It is very important to check health of MOSA at regular interval. Online methods are preferred. Due to ageing effect leakage current flowing through MOSA increases which increase power loss. Resistive component of leakage current increases substantially. Total leakage current includes external leakage current & internal leakage current flowing through surge arresters. Due to pollution external surface leakage current increased, which shows higher leakage current. To avoid effect of external leakage current measurement of resistive leakage current is most suitable technique for condition monitoring of surge arresters. With increase in resistive leakage current, partial discharge quantity and tan δ also increases in linearly. The value of capacitance does not shows variation, however value of tan δ increased after ageing effect, which may be due to moisture penetration. Hence, measurement of resistive leakage is useful technique to check the healthiness of MOSA.

VI. ACKNOWLEDGEMENT

The authors wish to thank Dept. of Electrical Engg. CSPIT, Charotar University of Science and Technology, Changa, India for their support for publication of this paper. Authors also wish to thank the Management of Electrical Research and Development Association (ERDA), Vadodara – India for permission to publish this paper.

REFERENCES

1. Tiago G. Zacarias and Wilson C. S., *"A Bibliometric and comprehensive review on condition monitoring of metal oxide surge arresters"*, Sensor 2024, 24,235. MDPI.
2. Laiz Souto and Philip C. Taylor and Jonathan Wilkinson *"Probabilistic impact assessment of lightning strikes on power systems incorporating lightning protection design and asset condition"*, Int. J. Electr. Power Energy Syst. 2023, 148, 108974.
3. S. Mohammed Arshad, Asanka S. Rodrigo, *"Modified phase shifting of leakage current to condition monitoring of metal oxide surge arresters in power system."* Mortuwa Engineering Research Conference (MERC on), 978-1-5386-4417-1/18, 2018, IEEE pp 300-305. 2018.
4. Z. Abdul Malek, Novizon Yusoff, Mohd Fairoz and Mohd Yousuf, *"Filed Experience on Surge Arrester Condition monitoring – Modified Shifted Current Method"*. UPEC 2010, 31st August – 3rd Sept. 2010.
5. Abdullah Munir, Z. Abdul Malek and Rai Naved Arshad, *"Resistive component extraction of leakage current in metal oxide surge arrester: A hybrid method"*. Elsevier Journal, Measurement 173 (2021) 108588.
6. Surge Arresters – *Selection and Application Recommendation"*, IEC Standard 60099-5, 2013.
7. Surge Arresters – *Metal oxide surge arresters without gaps for a.c. systems*, IEC Standard 60099-4, 2014.
8. Behnam Rajbar, Ali Darvishi, Rahman Dashti and Hamid Reza Shaker, *"A survey of diagnostic and condition monitoring of metal oxide surge arrester in the power distribution network"*, MDPI, Energies 2022, 15, 8091. 2022.

	Anil S. Khopkar is Working as "Asst. Director & Head of Division – R&D and Expert Services at Electrical Research and Development Association (ERDA), Vadodara. He is responsible for various research activities and technology development in areas of Power Systems, Renewable Energy, Product Development and Advanced Materials in field of electrical engineering. He also headed, High voltage Impulse laboratory, Extra High Voltage Partial Discharge laboratory, Cable laboratory, Instrument Transformer Laboratory, Transformer Laboratory as well as calibration laboratory. He has established various test laboratory like, HV Impulse, HV PD lab, Transformer test laboratory etc. He is Member of BIS technical committee of India for High Voltage Testing techniques (ETD 19) and chairman of BIS technical committee of India for Surge Arrester (ETD 30). He is also a member of IEC Technical committee "TC 99/JWG 13 – Insulation co-ordination for HVDC System". He is pursuing his PhD from "Charotar University of Science and Technology (Charusat)" CSPIT, Changa, Gujarat, India. He can be contacted at email: anil.khopkar@erda.org
	Dr. Kartik S. Pandya is working as an Associate Professor in Electrical Engineering Department at Parul Institute of Engineering and Technology (PIET), Parul University, INDIA. His research area includes Computational Intelligence methods, Power System Optimization, Smart Grid, and Renewable integrations. He can be contacted at email: kartik.pandya30364@paruluniversity.ac.in