

Condition Monitoring of Metal Oxide Surge Arresters – Case Study

Anil S. Khopkar & Umesh N. Soni

Electrical Research and Development Association (ERDA), Vadodara, India.

Abstract:

Lightning overvoltage is frequent phenomenon in power system which cannot be avoided, however damaged caused by it can be controlled to certain extent. Metal Oxide Surge Arresters (MOSA) are connected in the system for the protection of transmission and distribution system against lightning over voltages. During normal operating condition MOSA acts as an insulator whereas, it offers conductive path during overvoltage. Hence, MOSA is a core protective device for transmission & distribution system against lightning over voltages. It consists of zinc oxide (ZnO) elements which has non-linear V-I characteristics. ZnO elements are connected in series and fitted in ceramic or polymer based housing. Due to ageing effect MOSA degrades under influence of continuous operating voltage, pollutants and surge voltages. Degradation of MOSA increases the leakage current flowing through it which results increased in temperature of surge arrester. The resistance of zinc oxide elements decreases as temperature increases. As a results leakage current increases, which again increase the temperature of a MOSA. This results in to thermal runaway conditions for MOSA. Once, it reaches to thermal runaway condition it cannot return to normal working condition. This condition is a primary cause of premature failure of surge arresters. So, condition monitoring of surge arresters should be done at periodic intervals. Various Offline and online condition monitoring techniques are available for health assessment of MOSA. Offline condition monitoring techniques are not much popular as it requires to remove surge arrester from the system, which requires system shutdown. Hence, online condition monitoring techniques are more adopted and hence much popular. ERDA has expertise of various condition monitoring techniques of MOSA and conducted online health monitoring of various ratings of MOSA up to 400 kV. The amplitude of total leakage current (I_T) and amplitude of resistive leakage current (I_R) have been considered as indicators for surge arrester condition monitoring. This paper presents ERDA's experience of the condition monitoring of MOSAs with case studies.

Keywords:

Metal Oxide Surge Arrester (MOSA), lightning over voltage, Total leakage current, Resistive leakage current,

1. Introduction :

In transmission and distribution network overvoltage is generated by natural lightning or switching operations of large loads. For the protection against such overvoltage Metal Oxide Surge Arresters (MOSA) are connected in power system. Ideal MOSA offers very high impedance under normal operating condition whereas, when overvoltage appears in the system, it offers conductive path. Accurate nonlinear V-I characteristics of ZnO, eliminated other types of Surge arresters in the system [1]. Due to ageing effect under continuous operating voltage, lightning impulse over voltage, pollution, temperature & humidity MOSA gets degrade. The inferior performance of MOSA effects protection

level against surge voltages, which further effects protection ration of the system. Failure of surge arrester results in power supply interruption, damage of nearby substation equipment and also risk to nearby working person. So, healthiness of the MOSA is also important like other sub-station equipment. Hence, Condition monitoring of MOSA is very important for safe operation of the electrical power system. ERDA is having facility for online condition monitoring of MOSA. It is based on measurement of total leakage current, resistive leakage current and third harmonic component of resistive leakage current. Since, last more than two decades ERDA involved in the online condition monitoring technique of MOSA. In this paper various condition monitoring techniques for MOSA and ERDA's experience with case studies have been discussed.

2. MOSA Equivalent Circuit:

As shown in figure- 1, MOSA equivalent circuit represented as branch of resistance in parallel with capacitance branch. Where, C represents the equivalent capacitance and R represents the non-linear resistor. When, voltage 'V' applied across surge arrester total leakage current (I_T) flows through surge arrester. I_C and I_R are the capacitive and resistive components of total leakage current (I_T) respectively.

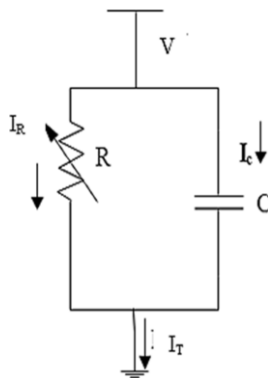


Figure 1: Equivalent Circuit of MOSA current

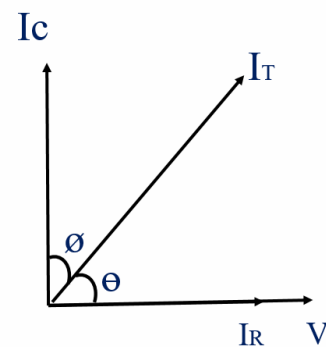


Figure 2: Phasor diagram of leakage current

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 varies with degradation of MOSA [2]. Figure 2 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 [3]. 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 reliable indicator of MOSA condition. Whereas, resistive component of leakage current is sensitive indicator of change in voltage-current characteristics of metal oxide resisters. Therefore, resistive current is use as effective tool to ascertain condition of metal oxide surge arrester [4-5].

3. MOSA Failure mode:

While normal operating conditions MOSA is energized at its maximum continuous operating voltage (MCOV). Temperature of the ZnO blocks rises to nearly above ambient. A point is soon reached where the heat being generated by the blocks is equal to heat dissipates by MOSA into surrounding air. If the power frequency voltage across the arrester increases, e.g. as a result of a system disturbance, fault or switching operation, the large current conducts through MOSA and begin to rise in temperature. If the overvoltage is of sufficient magnitude, the heat generated by the ZnO blocks will always be greater

than what can be dissipated and there is potential thermal runaway. Such condition leads to failure of MOSA. Failure mode of MOSA has been illustrated in figure 3.

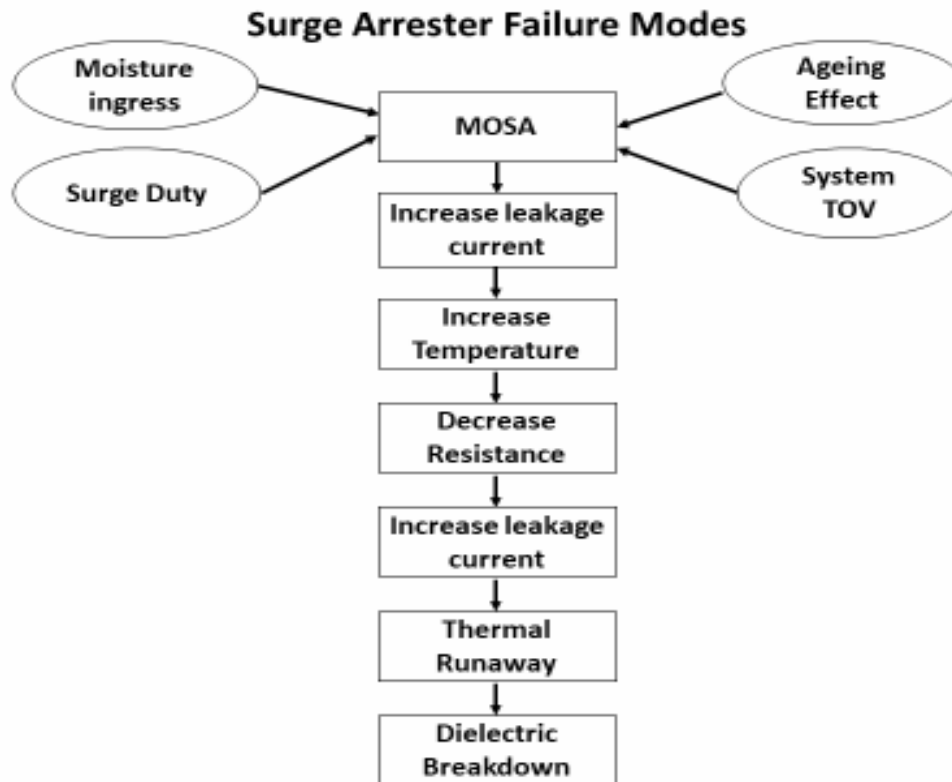


Figure: 3 Surge Arrester Failure mode

4. Condition Monitoring Techniques of Metal Oxide Surge Arrester :

There are few online & offline methods to monitor the health of Metal Oxide Surge Arresters. Comparison of various condition monitoring techniques is shown in Table 1 [3].

Table 1: Comparison of MOSA monitoring techniques

MOSA monitoring technique	Sensitivity	Reliability	Ease to use
Infrared /Thermal imaging	High	High	Easy
Surge counter /Spark gaps	Very low	Very low	Easy
Measurement of Total leakage current	Low	Low	Easy
Measurement of Watt loss	High	High	Hard
Resistive current	Very high	Very high	Hard
IR measurement	Low	Medium	Hard

5. Measurement of Resistive Leakage Current:

The resistive component of total leakage current can be determined by several methods, which can be divided in to further groups [4].

Method A: Direct method

A1: Using applied voltage signal as a reference as a reference for direct peak resistive current reading or total current discrimination.

A2: Compensating the capacitive component of the leakage current by using a voltage signal.

A3: Compensating the capacitive component of the leakage current without using a voltage signal.

A4: Compensating the capacitive component of the leakage current by combining the currents of three phases.

Method B : Indirect determination of resistive component by means of harmonic analysis of the leakage current.

This method can be divided in to three different groups;

B1 : Third order harmonic analysis of leakage current

B2 : Third order harmonic analysis with compensation for harmonics in the system voltage.

B3: First order harmonic analysis of the leakage current.

Method C : Direct determination of power losses.

Out of above methods method B2 : Third harmonic analysis with compensation for harmonics in the system voltage is suitable for measurement of leakage of Surge Arrester service condition.

For condition assessment of MOSA, measurement of total leakage current and resistive leakage current at various sub-stations and power station switchyards have been carried out. The results of measured leakage current for 220 kV and 132 kV MOSA has been presented further as case study.

6. Case study on 220 kV and 132 kV MOSA:

For condition assessment of MOSA, measurement of total leakage current and resistive leakage current has been carried out using Leakage Current Monitor (LCM) kit. The measurement of all the MOSAs were carried out online mode. The measured leakage currents for 220 kV MOSA for consecutive three years has been given in table 2.

Table 2 : Measured leakage current of 220 kV MOSA

	220 kV MOSA					
	Total leakage current			Resistive leakage current		
	2023	2024	2025	2023	2024	2025
MOSA-1	657.8	669.4	786.1	35.5	39.3	41.2
MOSA-2	684.3	705.2	684.8	38.4	38.4	38.4
MOSA-3	756.8	787.9	763.7	29.5	34.2	29.6
MOSA-4	597.5	896.1	1074	76.8	72.4	121.7
MOSA-5	704.2	742.2	724.2	59.6	55.6	68.1
MOSA-6	909.8	929.8	975.6	65.1	95.6	168.1

6.1 Analysis of obtained results:

There is no variation found in amplitude of measured total leakage current for MOSA-1, MOSA-2, MOSA-3 and MOSA -5. There is no variation found in amplitude of measured resistive current for MOSA-1, MOSA-2, MOSA-3 and MOSA -5. So all these MOSAs were found healthy.

For MOSA -4, amplitude of measured total leakage current increased from 597.5 μ Ap to 896.1 μ Ap after one year. However, amplitude of the resistive leakage current is almost same. Hence, MOSA-4 declared as healthy. But after one year measured amplitude of total leakage current increased from 896.1 μ Ap to 1074 μ Ap. Also, amplitude of measured resistive leakage current increased from 72.4 μ Ap to 121.7 μ Ap. Since, there is large increment observed in resistive leakage current observed, it was suggested to repeat the measurement after three months. There was no increased trend observed after three month measurement hence, it was advised to clean the MOSA and keep the MOSA in service and observed resistive current trend after one year.

For MOSA -6, amplitude of measured total leakage current increased from 909.8 μ Ap to 929.8 μ Ap and amplitude of the resistive leakage current increased from 65.1 μ Ap to 95.6 μ Ap. Hence, MOSA-6 is healthy but advise to repeat measurement after one year and observed the trend of resistive leakage current. after one year measured amplitude of measured total leakage current increased from 929.8 μ Ap to 975.6 μ Ap. Also, amplitude of measured resistive leakage current increased from 95.6 μ Ap to 168.1 μ Ap. Since, there is continuous increased trend observed in restive leakage current, it was advice to replace the MOSA-6. Yearly trend of measured total leakage current and resistive leakage current has been in shown in figure 4 and figure 5 respectively.

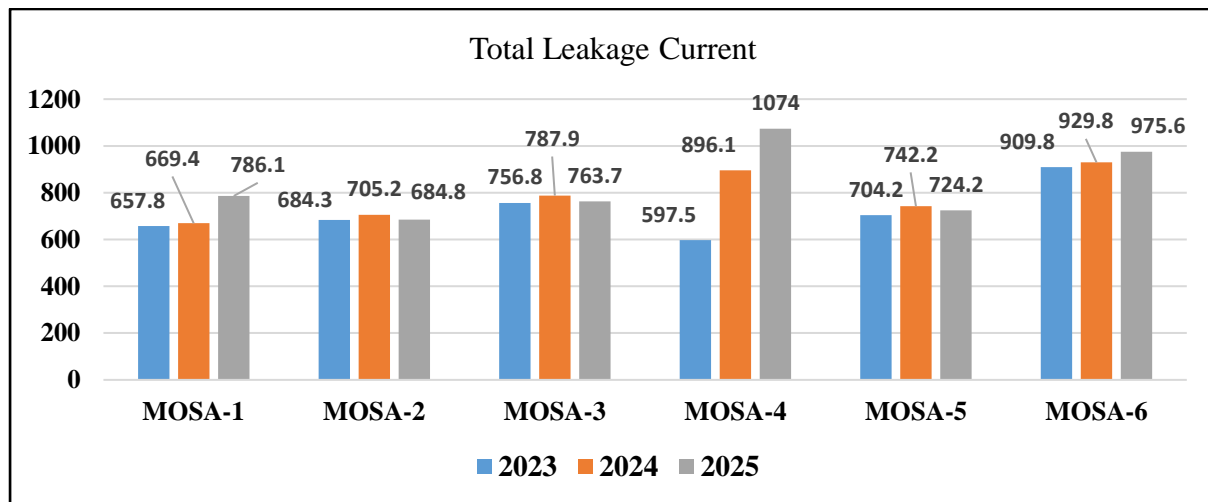


Figure 4 : Yearly trend of measured total leakage current for 220 kV MOSA

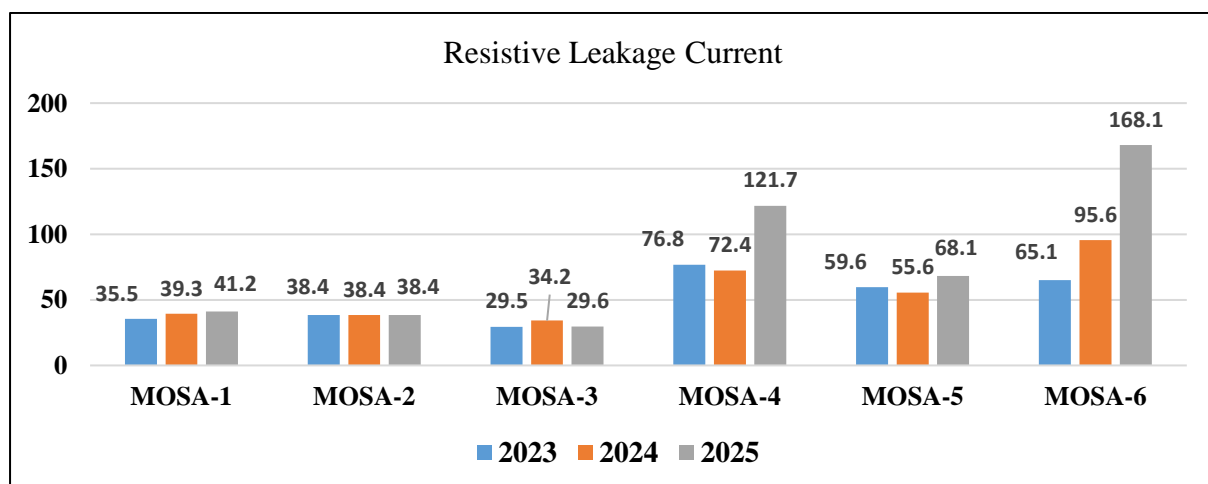


Figure 5 : Yearly trend of measured resistive leakage current for 220 kV MOSA

Table 3 : Measured leakage current of 132 kV MOSA

	132 kV MOSA					
	Total leakage current			Resistive leakage current		
	2023	2024	2025	2023	2024	2025
MOSA-1	345.6	367.6	395.7	58.1	64.4	71.3
MOSA-2	354.2	358.5	379.7	45.7	42.4	48.7
MOSA-3	298.9	321.6	334.9	42.4	51.9	52.9
MOSA-4	336.7	469.7	664.5	45.6	61.2	121.5
MOSA-5	302.6	449.7	666.6	59.6	55.6	124.3
MOSA-6	574.7	605.4	658.1	65.1	76.7	90.4

There is no variation found in amplitude of measured total leakage current for MOSA-1, MOSA-2, MOSA-3 and MOSA -6. There is no variation found in amplitude of measured resistive current for MOSA-1, MOSA-2, MOSA-3 and MOSA -5. So all these MOSAs were found healthy.

For MOSA -4, amplitude of measured total leakage current increased from 336.7 μ Ap to 469.7 μ Ap after one year. Amplitude of the resistive leakage current increased from 45.6 μ Ap to 61.2 μ Ap after one year. Since, there is no large increment observed MOSA-4 declared as healthy. But after one year measured amplitude of total leakage current increased from 469.7 μ Ap to 664.5 μ Ap. Also, amplitude of measured resistive leakage current increased from 61.2 μ Ap to 121.5 μ Ap. As there was large increment observed in resistive leakage current, it was suggested to repeat the measurement after three months. There was no increased trend observed after three month measurement hence, it was advised to clean the MOSA and keep the MOSA in service and observed resistive current trend after one year.

For MOSA -5, amplitude of measured total leakage current increased from 302.6 μ Ap to 449.7 μ Ap and measured resistive leakage current was nearly same. Hence, MOSA-5 was declared as healthy. After one year measured amplitude of measured total leakage current increased from 449.7 μ Ap to 666.6 μ Ap. Also, amplitude of measured resistive leakage current increased from 55.6 μ Ap to 124.3 μ Ap. Since, there is large increment observed in resistive leakage current, it was suggested to repeat the measurement after three months. Measured total leakage current after three month was 708.1 μ Ap and resistive leakage current measurement was 148.1 μ Ap. Since, there is continuous increased trend observed in restive leakage current, it was advice to replace the MOSA -5. Yearly trend of measured total leakage current and resistive leakage current has been in shown in figure 6 and figure 7 respectively.

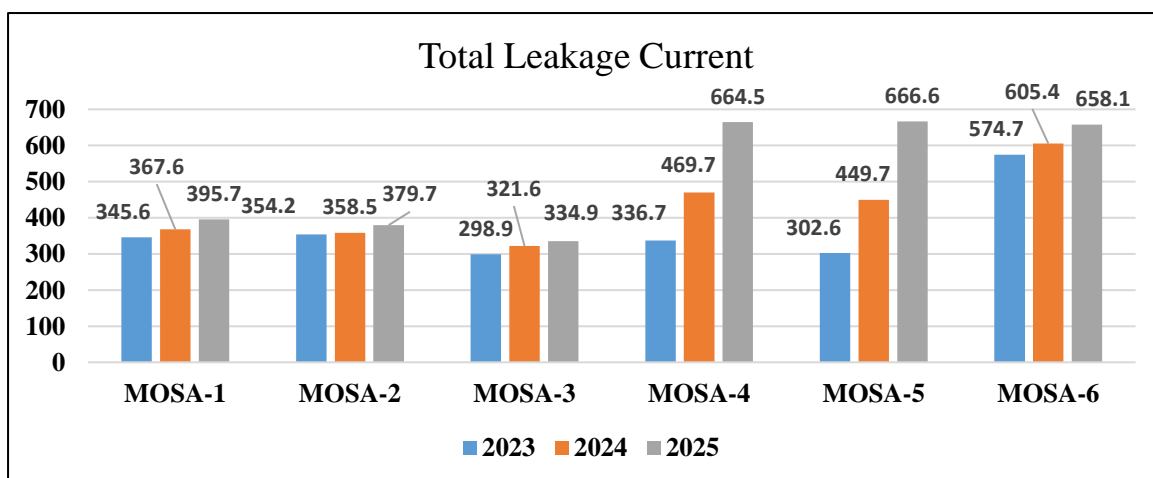


Figure 6 : Yearly trend of measured total leakage current for 132 kV MOSA

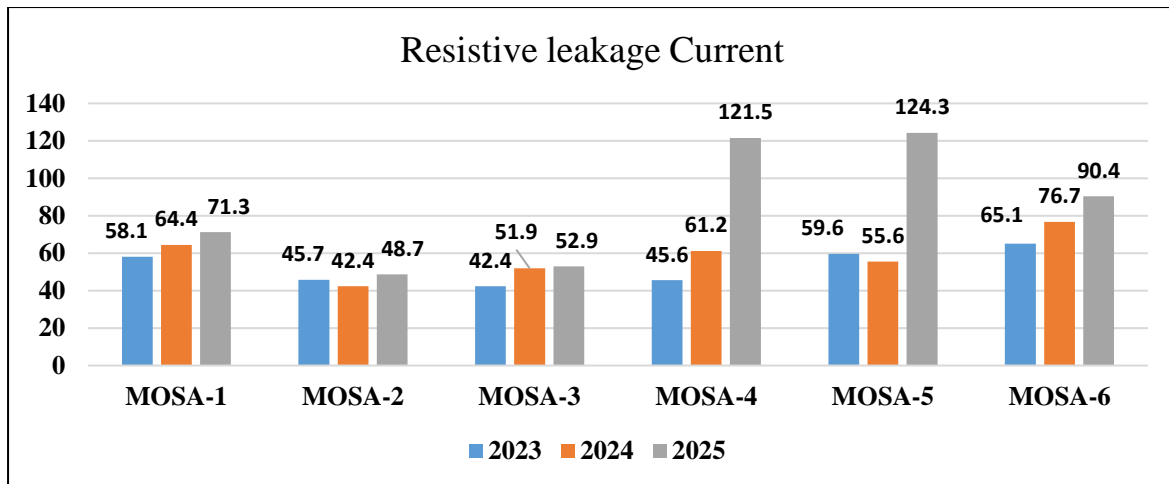


Figure 7 : Yearly trend of measured resistive leakage current for 132 kV MOSA

7. Conclusion:

Measurement of total leakage current and resistive current is important to ascertain the healthiness of the MOSA. Yearly measurement of leakage current is advisable to monitor the trend analysis. Increased trend in resistive leakage current indicates the degradation of MOSA, so when there is increased trend observed on resistive leakage current it must be closely monitored and frequency of measurement should be done quarterly and if trend found increased then MOSA must be replaced, to avoid its failure.



8. Acknowledgement:

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9. References :

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10. Author's Biography :

	<p>Umesh N. Soni is Working as Head of Section- Diagnostic at Electrical Research and Development Association (ERDA), Vadodara. He is responsible for activities related to electrical diagnostic section. He has vast knowledge related to electrical diagnostic of various HT electrical equipment including Power transformer, Rotating machine, Switchyard equipment & HT cables. He has reach experience in the asset management through the various special diagnostic technique like C&TD, SFRA, ELCID, Partial discharge measurement. He has published more than 25 research papers in national and international conferences and journals. He can be contacted at email: umesh.soni@erda.org.</p>
	<p>Anil S. Khopkar is working as “Asst. Director and Head of Division – R&D and Expert Services at Electrical Research and Development Association (ERDA), Vadodara. He is responsible for various research activities in areas of electrical power systems, renewable energy and advanced materials in field of electrical engineering. He is also responsible for expert services related to asset management and diagnostic testing of electrical equipment. Earlier, he 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 and Transformer test laboratory. 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 has published 40 research papers in national and international conferences and journals. He can be contacted at email: anil.khopkar@erda.org.</p>