A Review of Metal Oxide Surge Arrester Models for Remote Monitoring Application

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Abstract

Metal Oxide surge arresters play a major role in the protection of electrical devices or equipment from lightning and switching surges. These surge protective devices are installed in most industrial, commercial and domestic power or data networks and facilities, yet do not always form part of predictive maintenance strategy. However, due to the critical importance of devices/equipment or networks protected by these types of arresters, condition monitoring of metal oxide-based surge arresters becomes essential practice to ensure or guarantee surge protection. A review of commonly-applied techniques for condition monitoring of MOSA devices yields the need to develop or/and improve suitable models online and remotely-applied monitoring application.

Keywords
Metal Oxide Surge Arresters, Predictive Maintenance, Leakage Current Monitoring.

1. Introduction

Lightning and internal switching events are the main causes of power failures, explosions, fires and prolonged supply interruptions in telecommunication, transmission or distribution circuits. Metal Oxide Surge Arresters (MOSA) are designed for clamping high magnitude of externally or internally-induced transient overvoltages to levels equal or slightly lower than the basic insulation level of equipment or devices under protection. In order to achieve that MOSA behaves like a high resistance path (open circuit) when subjected to standard supply voltage and a very low resistance (short circuit) when an overvoltage occurs. Besides, it is characterized by a non-linear relation V-I and present a dynamic characteristic (frequency dependent) appreciable during the application of fast front surges [1], [2]. These overvoltage protection units often experience degradation and eventually failure as a result of several combination of factors including, temperature, voltage, moisture and high magnitude surge currents.

Condition monitoring of MOSA is important as it provides life information on real condition and protection capabilities of the arrester. However if a MOSA was to be removed from its location, there would be no immediate change to the electrical system, however a large surge event would almost immediately impose destruction to equipment, device or network. MOSA should therefore be included in a predictive maintenance strategy. A dedicated system is thus required to continuously monitor the operating condition of the metal oxide varistor (MOV)-based surge arresters [3], so that systematic maintenance planning can be carried out.

2. Remote Monitoring

MOSAs can be installed in electrical distribution rooms and/or in distant rooms where there is essentially no maintenance staff. This generates a necessity for monitoring from a remote position. There are different techniques used to monitor the condition of MOV-based arresters from a distance, creations offer a choice of remote monitoring tactics, floating the inquiries of professionals and convicts depending on the request needs. The sections below provide a momentary explanation of likely methods, summarized in the table 1 below.

Table 1: Remote monitoring summary structures

Monitoring type	Features	Benefits	Limitations
Direct connection	RS232,RS485	Full information from the unit	Limited distance custom software
Web Connectivity	LAN, WAN	Full information over any distance and flexible network connection	Requires computer access
Addressable Relay	Form C relay to Addressable relay	Connections to building automation software, no space limitations	Limited information from unit

2.1 Direct connection

This is the most common type of connection, which is usually achieved by connection to the form C relay. The amount of information is limited and is mostly only the status of the unit operating or not. Some models have been able to transmit the information on each phase and send three separate signals to a remote station in the same building. The producer that supplied the MOV can also supply this circuit, the above connection can be exploited by connecting to an intended product to supply remote information [4].

2.2 Web Connectivity

For the best thorough monitoring of the information that the MOV can deliver, a web connection is needed, these connections normally fall into three categories: local connections such as RS232/RS485, industrial control systems such as Modbus, and local area network such as Ethernet. The differences in these networks are not as important, since they are in the implementations of the connected hardware and software. The presence of a network connection allows information to be transmitted anywhere it is needed. Modbus is preferred in industrial settings whereas Ethernet connections are the same somewhere else. RS232 and RS485 will need a product specific computer program to properly transfer the information in MOV to the computer program to properly transfer the information in the MOV to the computer system that is already elaborate. The Ethernet enabled MOV can be designed to use TCP/IP and connect directly to a computer by using a web browser which is internet explorer. The information is written into the MOV as a web page that can be downloaded as required without desire for additional software on the host computer [5].

2.3 Addressable Relay

A sophisticated building automation system might not be able to directly connect to a Form C relay. To connect to building automation system, an addressable relay can be used, this device can be addressed on a network and can read the status of a form C relay. This allows form C relay on the MOV to be seen anywhere on the network, with the presence of a wide area network , this allows the status of the MOV to be determined anywhere in the world, conversely the amount of information transmitted is very limited in this application.

The above methods provide an approach of receiving the information the MOV has collected into the user's hands. Conversely, only the last method allows for seamless computer upgrades and software upgrades using an imbedded Web page. The other benefit of the Ethernet connected devices is that it is able to update the firmware by downloading a new image into the device for future issues that are to be resolved [6].

3. Metal Oxide Surge Arrester Models

3.1 The ATP Conventional Model

The conventional model is a simplest model that came from using the ATP software, it only consists of a non-linear resistance. It is used to simulate the slow front surge found on the surge arrester and its diagram can be seen on figure 1. Therefore it is not suitable to represent phenomena which are frequency dependent, so it cannot be used in monitoring these devices.

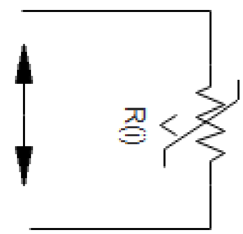

Figure 1: ATP Conventional Model

3.2 The IEEE Model

The IEEE working group developed this model and they called it a frequency dependent model due the complications pointed out. Pointing out these difficulties led to the study of other frequency dependent models. On this prototype a non-linear V-I characteristics is symbolized by the two divisions of non-linear resistances which are labelled as A0 and A1 coupled in parallel. There is an R-L filter separating these two non-linear resistances (A0&A1) seen on figure 2. The only challenging part that is appointed with this model is to calculate the parameters, but the working group came with another way to help achieve good results which depends on physical and electrical data.

When it comes to front slow surges, the R-L channel it almost has no impedance and the two non-linear model divisions are connected in parallel. As for quick front surges, the R-L filter impedance turns out to be more significant. This outcome leads to the non-linear resistance assigned by A0 having more current, than the resistance assigned by A1. Due to the section of A0 having more voltage than A1 at a given current, this outcome leads to the arrester model producing a high voltage. The IEEE model produces good results when it comes to the arrester discharge voltages, as soon as the discharge current ranges between 0.5 and 45μs. [1] .

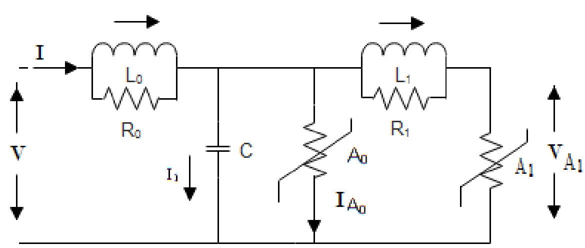

Figure 2: The IEEE prototype

3.3 The Pinceti and Giannettoni model

The Pinceti-Gianettoni prototype omitted the filter and the two resistances are now replaced by only one resistance which is (almost 1 MΩ) connected on the supply terminals as seen on figure 3 below. The only good thing that came with this model is that the physical characteristics of the surge arrester are not important thing is the data which is supplied by the producer [7] .

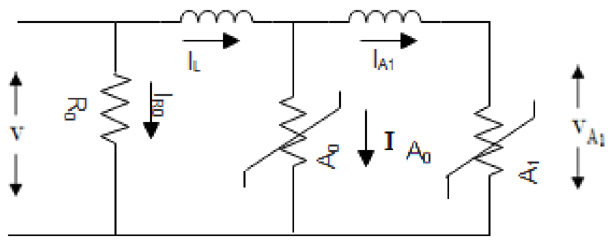

Figure 3: Giannettoni and the Pinceti model

3.4 The Mardira and Saha model

This model the authors (Mardira and Saha, 2011) also derived it using IEEE model, by eliminating all the resistive devices and finding an iterative way of defining the parameters. This model creates great outcomes for releasing current with 8x20µs waveform. It does not need to be modified in anyway, even though it experiences problems when it comes to a wide range of waveforms. Figure 4 below shows the circuit with the resistive components being removed, so it only consists of an R-L filter which is connected in parallel with the non-linear arresters [7].

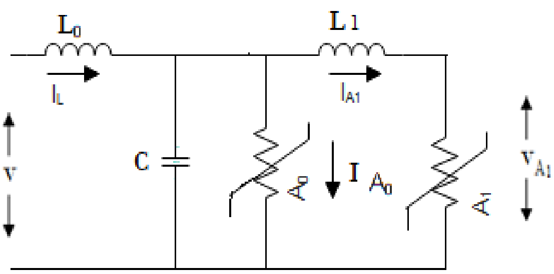

Figure 4: The Mardira and Saha model

3.5 Zadeh Model

This model is an additional from IEEE W.G.3.4.1.1, ignoring the inductance influence that in different models represented the electromagnetic field impact. It just considers L1, which has an impact as a capacitor on the behaviour of various front surge, expanding its importance for quick front surge. The protection R=1 MΩ is executed to keep away from numerical oscillations. The capacitance C symbolizes the terminal-to-terminal capacitance of the arrester. The illustration appears on figure 5 below [8].

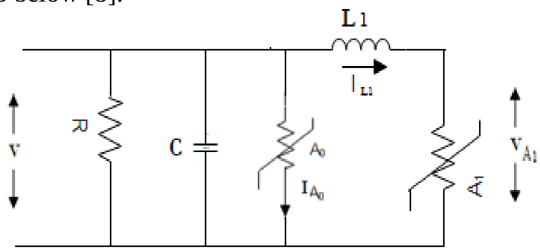

Figure 5: Zadeh Model

3.6 Valsalal Model

The Valsalal demonstrate is dedicated on the recreation of the arrester conduct in the present of quick front surge like the ones that happens in the gas-insulated substation (GIS) during exchanging activity that is resulting from IEEE Model. The authors certify that the comparability capacitance of the arrester is essential in the behaviour when there is a quick front surge, and to be correct it must be verified by limited component strategy. The Valsalal et al model applies similar criteria that Magro et al demonstrate for inductance calculation. The resistance R=1 MΩ looks to maintain a strategic distance from numerical [9].

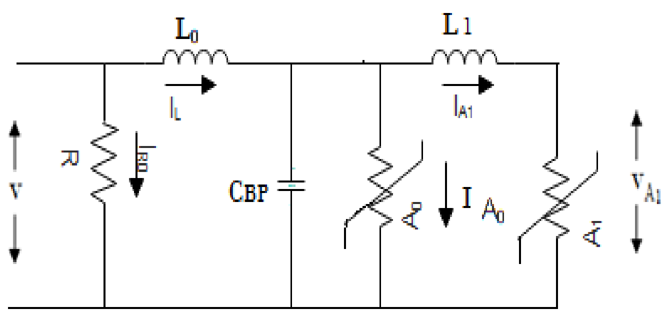

Figure 6: Valsalal Model

3.7 The Fernandez and Diaz model

This model is an improvement from IEEE model. The only thing different is that both electrical and physical parameters are now essential. Then the resistors that were connected in parallel are now replaced with just one resistance, which is connected in parallel with the filter and the inductor, which was connected on A0, is excluded [8]. The major problem with this model is that it is necessary to build a program to calculate the non-linear inductance. Furthermore, many voltage-current points are necessary to represent the surge characteristic.

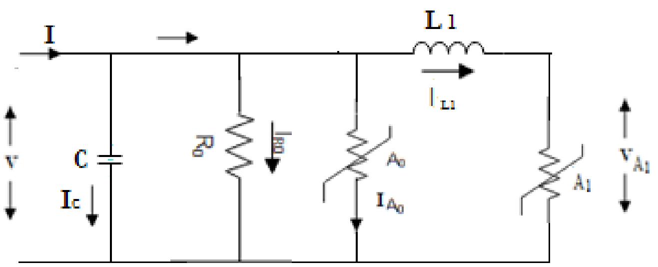

Figure 7: Fernandez and Diaz model

4. Dynamic behaviour for the discussed models

- This study shows that the Conventional Model does not represent the dynamic behaviour of the varistor, since the current and the voltage peak occur at the same time. Besides, the Conventional Model reaches the same voltage peak value for both waveforms (Table 1).
- The IEEE Model presents a relatively higher error for faster front surges (Table 1). It also requires physical data and an iterative method to determine the parameters. The occurrence of the voltage maximum before the current maximum was observed in all models, except for the Conventional .
- The results of the Pinceti and Giannettoni model are very accurate. Physical data are not needed, nor does it require the use of iterative methods, thus not needing much computational effort.
- The Fernandez and Diaz model also presents good results. The major difficulty associated to using this model is determining the inductance value, which is related to curves between the waveform time to crest and the residual voltage.

Table 1 – Models Comparison - Voltage results

Model	8x20µs - 10 kA		1x2µs - 10 kA	
	Voltage [kV]	Error	Voltage [kV]	Error
Conventional	1028.77	1.30 %	1028.77	7.5 %
IEEE	1023.62	0.84 %	1158.03	4.7 %
Pinceti and Giannettoni	1017.60	0.25 %	1121.57	1.4 %
Fernandez and Diaz model	998.25	1.60 %	1137.79	2.8 %

5. Conclusion

Monitoring of MOSAs is a critical aspect of a predictive maintenance strategy for power systems. In order to perform effective modelling of the device, a suitable and accurate model thereof is required. In this paper, six models have been reviewed and not all of them are considered sufficient to related studies. The other models presented are able to represent the frequency dependence with some precision. However, there are problems that were found in the analyzed models, those problems parameters calculation, residual voltage front surge increasing rate representation, the residual voltage peak value and the energy absorption calculation. Even when all the presented models have strong points, the most precise model currently available, attending to the proposed criteria in this paper, is the IEEE model.

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Biographies

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Wesley Doorsamy received the B.Sc, M.Sc. and Ph.d. Degrees in Electrical Engineering from the University of the Witwatersrand in Johannesburg, South Africa in 2008, 2013 and 2015, respectively. He is currently a senior lecturer at the University of Johannesburg and is an active member of both the Institute of Electrical and Electronics Engineers (IEEE) and South African Institute of Electrical Engineers.