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Selection of Lightning Arrester in the Niger Delta Environment

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ABSTRACT: Hundred percent reliability is the utmost desire of every electricity operator, therefore a good designer will always aim at giving the optimum reliable conditions. This requires choosing the best and suitable materials according to the required regulations. The Niger Delta environment, due to its peculiar terrain and harsh climatic conditions requires special attention in terms of choosing the materials in construction. Therefore, a good protective device is necessary not only for equipment but also for personnel. The climate of Niger Delta is known to have heavy rainfall, high humidity and high Isokeraunic level, therefore proper selection of Surge Absorber (diverter) is necessary for a reliable protection from travelling waves and switching surges in lines and substations. The aim of the paper is to study the performance of surge diverters and identify the diverter that is best suited for both performance and construction in this harsh environment. From the records ZnO (linear) arrester has better performance but the type and place of usage determines the reliability (life span) of the diverter. Due to dust and rainfall, the external material is also a major factor in determining erosion of material and watt losses. It is therefore necessary to suggest some maintenance procedure that may help extend the life span of the diverter.

KEYWORDS: Protective Ratio, gapless metal Oxide, Surge diverter, Basic Impulse level, hydrophobicity, Polymer housing.

1 INTRODUCTION

An overhead earth wire provides considerable protection against direct stroke. They also reduce induce over voltages. However, they do not provide protection against surges that may still reach the terminal equipment. Such protection may either be done by diverting the major part of the energy of the surge to earth using surge diverter [1].

A surge diverter is a device that is connected between lines and earth, that is, it is connected in parallel with the equipment to be protected.

When a travelling wave reaches the diverter, it sparks over at certain prefixed voltage (point A) and provides a conducting part of relatively low impedance between the line and ground. The surge impedance of the line restricts the amplitude of current flowing to ground, that is maintaining the residual voltage of the arrester [2, 3]. This is shown in fig.1.

Arresters are of three important types and are classified according to their internal structures. These are:

- Gap type arrester without current-limiting functions
- Gap type arrester with current limiting capabilities
- Gapless metal oxide variators

An ideal arrester should (1) conduct electric current at a certain voltage above the rate voltage (2) hold the voltage with little change for the duration of overvoltage (3) substantially cease conduction at very nearly the same voltage at which conduction started.

The cheapest and the simplest among the first group is the Rod Gap Arrester. They are usually connected across the bushings of various equipments. It has two end rods facing each other, one connected to line and the other connected to

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earth. The selected gap spacing should not only be capable of withstanding the highest normal power frequency voltage but should flashover when over voltage occur protecting the equipment. Once a gap flashes over under a surge voltage, the ionized gap allows a power frequency follow through current, even at low voltage, sometimes may lead to system outage. Another disadvantage is that the rod gaps are liable to be damaged due to high temperature of the arc [4, 5].

The performance of the rod-gap is easily affected by climate variation and the surge polarity.

2 GAP TYPE SIC ARRESTERS

The non current – limiting and the current limiting types, use sintered silicon carbide material which is made for a particular voltage rating. As many disc as are necessary for the arrester rated voltage are stacked in series and provide with voltage grading circuits [6, 7]. These may consist of high voltage resistors, capacitors or a combination of both.

They function in two stages. When over voltage occur the gap sparks over providing a low impedance path to ground. The series resistor reduces power frequency follow current so that the arc across gap is able to reseal. The block diagram of valve arrangement of silicone carbide and metal oxide is shown in fig.2.

In modern surge diverters, the Zinc Oxide Zn0 arresters are used due to its superior volt-ampere characteristics. The Zn0 arrester is often used as gapless as its normal follow current is negligibly small. The volt ampere characteristics of S_ic and Zn0 non-linear elements are shown in fig. 3.

Their characteristics can be mathematically expressed as

$V = K_1 i$ for a linear resister

$V = K_2 i^{0.2}$ for silicon carbide resistance

$V = K_3 i^{0.03}$ for a Z_{inc} Oxide resister

If the current were to increase a 100 times, the corresponding increase in voltage would be 100 times for linear resistor.

For S_1C resistor it would increase 2.5 times but for Z_n0 resistor the increase would be 1.15 times. This means that for the same residual voltage and the same discharge current, the follow current would be in kilo amps for linear resistor (in absence of series gap) and for S_1C, it will be in Amps but for Z_n0 arrester it would be in milliampere (mA).

For various improvement of the metal oxide varistor (MOV), the compact and sintered granules of Zinc Oxide with a small amount of other carefully selected metal oxide additives to improve the V – I non linearity [2, 8]. The Zinc Oxide grains have a low resistivity, while the additives (oxides $B1_2\ 0_3$, M_n0, $Cr_2\ 0_3\ Sb_2\ 0_3$) which form the boundaries between the grains provide high resistance. The two are strongly bonded when sintered at high temperature.

With such a high degree of non linearity it is entirely feasible to use these elements without series gaps in an arrester with a current of only tens of μA at operating voltage. The volt-amp. Characteristics of zinc oxide and silicon carbide valve element is shown in fig.4

For SiC valve I = KV^a, where a = 4 – 6

For ZnO valve I = KV^b, where b = 25 – 30 and K is a constant.

3 ARRESTER HOUSING

In earlier construction the valve elements were mounted within a ceramic housing. The metal oxide element was surrounded by a gaseous medium and the end was generally sealed with rubber O-rings. With time in service, especially in hostile environment the seals tend to deterioration, allowing the ingress of moisture. In the 1980s polymeric housed surge arresters were developed.

It extends from distribution to heavy duty station arresters for voltage up to 400KV. In their design, the surface of the metal oxide element column is bonded homogeneously with glass fibre reinforced resin. The construction is void free, gives the unit a high mechanical strength and provides a uniform dielectric at the surface of the metal oxide column. The housing material is a polymer (EPDM) – Ethylene propylene diene monomers) which is a hydrocarbon rubber, resistant to tracking and particularly suitable for application in regions where pollution causes a problem [2, 7, 9].

Another polymer material that may claim more superiority is the silicon rubber which is very ideal for harsh conditions.

A complete polymer housing MOV is shown in fig 5.

The advantages of the polymeric – housed arresters over their porcelain housed equivalents are:

- No risk to personal or adjacent equipment during fault current operation
- Simple light modular assembly – no need for lifting equipment
- Simple installation
- High strength construction, eliminate accident damage during transport
- Reduces pollution flashover.

4 SELECTION OF ARRESTERS

The most important property of a surge absorber is the protective ratio (C_p) which is defined as

$$C_p = \frac{Peak\ Impulse\ Insulation\ level\ of\ Protected\ Equipment}{Rated\ Arrester\ Power\ Frequency\ Voltage\ (RMS\ Value)}$$

The selection of lighting arrester with a specific voltage rating is governed by the value of earthing co-efficient or earthing factor (EC). These are defined and are based on a single line to ground fault condition.

$$E.C = \frac{RMS\ Value\ of\ healthy\ phase\ voltage\ at\ arrester\ location}{Line\ to\ Line\ voltage\ at\ arrester\ location}$$

The earth fault factor, $Eff = \sqrt{3}\ E\ C$

The second important quantity of arrester selection is the discharge current. This is the current having a designated crest value and wave shape which is used to classify a surge diverter with respect to durability and protective characteristics. The standard wave form for the discharge current is taken as $8/20\mu s$.

The norminal value of discharge current is selected from the standard values depending on the application as follows:

10KA – Station Arrester type

5KA – Intermediate line type

2.5KA – Distribution – type

1.5KA – Secondary type

The highest ratings are used for the protection of major power stations, while the lowest ratings are used in rural distribution system.

The third important characteristic of an arrester is the protective level offered by it to the connected equipment. The arrester rating is selected based on the system earthing co-efficient with a specified V.I characteristic of the resistance materials. This is generally selected corresponding to 80 percent of the system phase to phase voltage for effectively earthed system and 100 percent for non-effectively earthed systems.

The protective level offered by a lightning arrester is the higher of the following two voltage value.

- Sparkover voltage of the series gap under standard $1.2/50\mu s$ impulse
- Residual voltage (discharge voltage), when discharging the specified test impulse current of $8/20\mu s$ wave shape.

The discharge voltage of the selected arrester should be below the BIL of the protected equipment between 15 – 25 percent.

In any good design, the aim is to keep

- The peak discharge residual voltage (the IR drop)
- The maximum impulse sparkover voltage
- The maximum wave front impulse sparkover voltage reasonably close to each other.

A comparism is seen in table 1

5 AVERAGE CLIMATIC EFFECT AND ARRESTER SPECIFICATIONS

A typical coastal area in the Niger Delta region was selected (BAYELSA STATE). In table 2 some climatic figures are shown.

The pollution level depends on the closeness to the pollutant. In the coastal areas the sea breeze with the salt spray becomes heavy pollutant. The gas flaring environment which is common in Bayelsa State is a source of acid pollution. In this environment the fungi growth is a major problem for outdoor operations of electrical equipments.

In table 3 some climatic specification for satisfactory operations are given by some designers.

6 DISCUSSION

The keraunic level and the rainfall in the area are high, much higher than the climate specification given in table 3. It showed that special consideration is needed for arrester application.

From the analysis of various arrester performances, it was shown that the Zinc oxide varistors are best suited for this environment. A change in current of 0.1A to 10^4A results in a voltage change of 54 percent. That is, under normal operating condition the current conducted may not exceed 1mA. When a surge reaches the arrester, it conducts only current necessary to restrict the voltages (the residual voltage).

The absence of spark gap also eliminates the need for voltage grading system which in turn eliminates the voltage / time lag property in other arresters.

The MOV arresters has excellent performance in terms of energy absorption capability, surge protection and substantial increasing watt loss with normal system conditions due to penetration of moisture into the metal oxide blocks, thereby promoting oxidation [1]. This form of aging no longer takes place in more recent manufactured metal oxide arresters but external watt loss (housing) is possible due to wet surface contaminations.

As some housing materials are known to age more rapidly than others, watt-loss can be expected to increase with normal service aging on some polymer housed surge arrester. Silicon rubber (SR) housing exhibit significant higher leakage current under wet contamination.

Silicon Rubber is highly hydrophobic and exhibit good retention of hydrophobicity, preventing watt loss on the polymer housing, while many polymeric materials with similar initial hydrophobic properties lose their hydrophobicity after a relatively short period. Such materials are (EPDD) and mixture of EPDM with silicone.

Silicon Carbide Arrester (Non Linear Gap)

Environmental factors, ingress of moisture and dust particles into the lightning arrester are the most common causes of failure in SiC lightning arresters. The failure is as a result of inadequate sealing of arrester and as such causes internal degradation.

From investigation of defective SiC arrester, it was identified that the airgap was damaged in most of them [7].

Damaging of airgap usually causes the decrease in the discharge current level, exposing the lightning arrester to high thermal pressure and the total discharge level of the arrester is reduced.

Researches have shown that after 13 years the S_iC lightning arrester decreases significantly.

It is likely that such environment is a more ideal one but in an environment like the Niger Delta the life of silicon carbide arrester may not last for more than 5 to 8 years.

There are two main contaminants in the Niger Delta. These are:

- The salt spray from the ocean to the coastal areas
- The flaring of gases

The Niger Delta is quote to have about one hundred and three flaring sites. In states like Bayelsa State some are not more than 50km from each other.

Under moderate rainfall the salt and acid solutions from these contaminants reduce breakdown voltage and increase watt-loss on the surfaces of these surge arresters. Also due to the salt and acid concentration rust may form on the metal surfaces of the arrester.

Another problem in the area is the algae growth. In humid climate algae growth is rapid. These algae die and form black patch on the surface of insulator when conditions are not favorable.

7 Figures and Tables

7.1 Figures

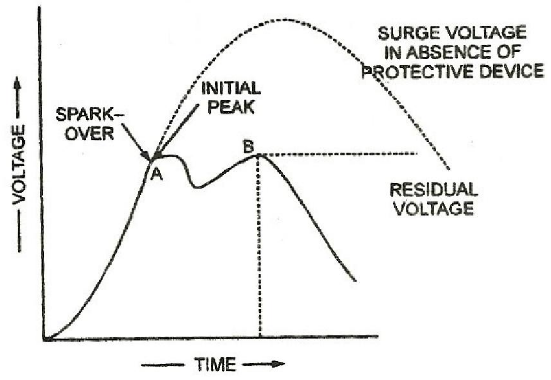

Fig. 1. Voltage Characteristics and Residual Voltage

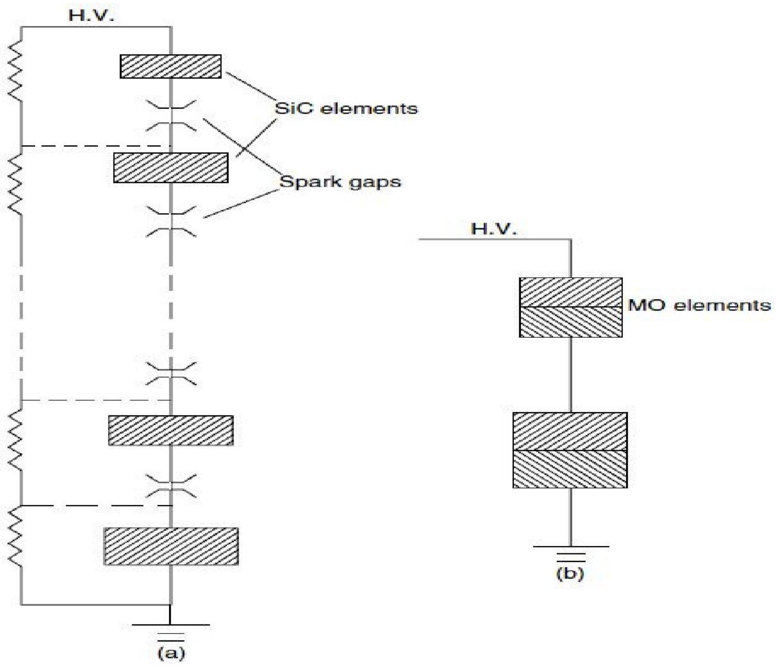

Fig. 2. Block diagram of Silicon Carbide (SiC) and metal oxide arrester (MOA)

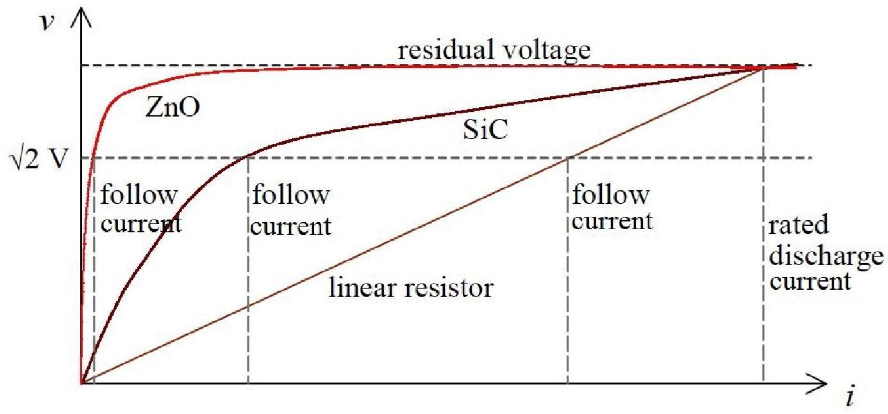

Fig. 3. Volt-Ampere characteristics of non-linear elements

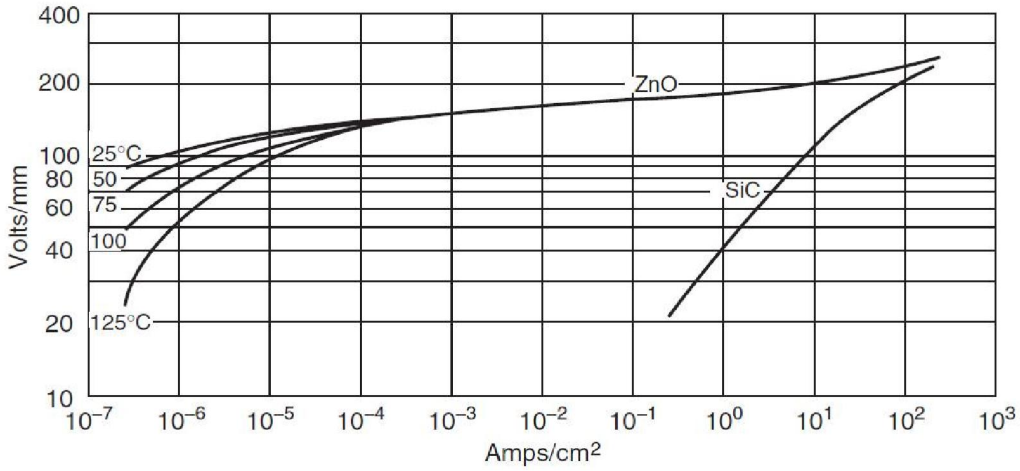

Fig. 4. Volt-Amp characteristics of ZnO and SiC valve element

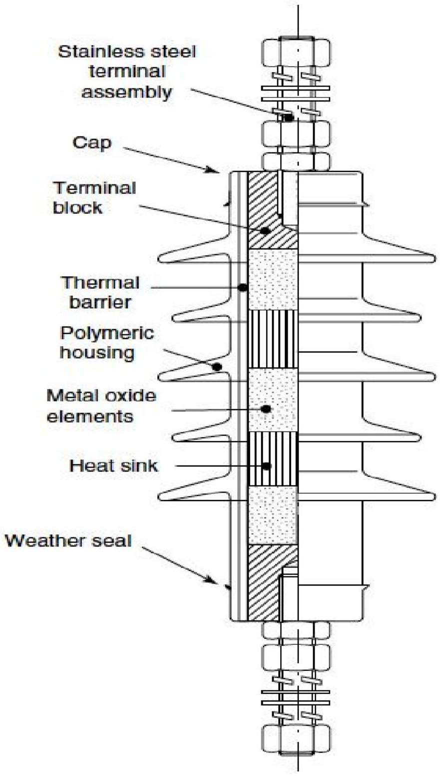

Fig. 5. Polymer-housed arrester

7.2 TABLES

Table 1. Comparative results of residual voltage, max sparkover voltage and sparkover voltage

Arrester Rating KV MM	Minimum Power Freq with stad	Max Imp spark over voltage (1.2/50μs) KV crest	Max. Residual voltage KV crest	Max wave from spark over voltage KV crest
36	1.5 times rated voltage	130	133	150
50		180	184	207
60		216	221	250
75		270	276	310

Table 2. Approximate climatic data of Niger Delta

Rainfall mm	Humidity percent	Lightning days	Pollution	Sun Intensity W/m^2	Pressure mm Hg	Ambient Temp ^{0}C	Soil Resistivity
2100 – 2940	55 – 90	60 – 90	Depend on location	3.5 – 5.1	748	27 – 35	40-80 Ωm

Table 3. Recommended climatic data for safe operation

i.	Maximum Ambient air temperature (^{0}C)	50
ii.	Humidity (%)	10 – 100
iii.	Maximum attitude above sea level (meters)	1000
iv.	Maximum Annual Rainfall 9mm)	1450
v.	Maximum wind pressure (Kg/Sq meter)	150
vi.	Isokeraunic level	50

8 CONCLUSION

The rod-gap arrester is not recommended either for main protection or backup protection in the coastal areas of Bayelsa State. Apart from the burning of the rod terminals, the climatic variation will badly affect performances of the gap. With the high humidity in the area the spark over initiation voltage will reduce. Once a gap flashover under surge voltage, the ionized gap allows a power frequency follow through current leading to system outage.

With the high keraunic level and high humidity there will be much of system disturbances due to irregular flashover and the system outages.

Silicon Rubber for arrester housing retains the hydrophobicity for several years and therefore reduces external watt loss. Some metal oxide arresters are designed with the following advantages.

- High resistance to tracking erosion
- Excellent resistance to flashover
- Self extinguishing flame retardancy
- High degree of non linearity.

With these advantages the metal oxide arresters outweigh other arresters in performance and reliability. These qualities coupled with low soil resistivity in Bayelsa State and in most part of the Niger Delta, may provide a better protection for substation equipments and lines.

For every arrester selection, both arrester survival and equipment protection must be considered. Many lightning and switching surges are of a magnitude that is much higher than the design rating.

It is of vital importance to properly select, locate and apply surge arresters in order to avoid damaging equipment. For better reliability of the metal oxide arrester the following points are important:

- It is necessary to regularly check and service the lightning arrester of the network and replace defective ones.
- Equipments in an indoor substations be connected through cables
- Surge absorbers, and surge capacitors and reactors may be needed in some areas of the installation.

REFERENCES

[1] D.R. Miller, J.J. Woodworth, C.M. Daley, “Watt loss of polymer Housed Arrester in a simulated Florida coastal climate”, *IEEE Transactions on Power Delivery*, vol. 14, n° 2, pp. 940 – 947, 1999.

[2] E. Kuffel, W.S. Zaengi and J. Kuffel, *High Voltage Engineering Fundamentals*. Butter Worth – Heinemann, 2nd Ed., Oxford, pp. 500 – 523, 2000.

[3] R.P. Singh, T.V.P. Singh, “Influence of Pollution on the Performance of Metal Oxide Surge Arresters”, *IEEE Conference on ELectaxcom.eng*. vol. 1, pp. 224 – 229, 2000.

[4] S.A. Hosseini, F. Razavi, M. Karami, A.A. Ghadimi, S.S. Karimi Madahi, “A New Method of recognize the status of S_eC Surge arrester in substation”, *Indian Journal of Science and Technology*, vol. 5 n° 5, pp. 2692 – 2700, 2012.

[5] H. Kanashior, M. Tatizawa, P. Zanotti, F. Obase, W.R. Bacega, “Diagnostic of Silicon carbide surge arrester”, *WSEAS Transactions on systems*, vol. 8, n° 12, pp. 1284 – 1293, 2009.

[6] R.D. Begamudre, *Extra High Voltage AC Transmission Engineering*, New Age International Publishers, New Delhi, 2008.

[7] M. Darveniza, O.R. Mercer, R.M. Watson, “An Assessment of the reliability of service gapped silicon carbide distribution surge arrester”, *IEEE Transactions on Power Delivery*, vol. 11, n° 4, pp. 1789 – 1797, 1996.

[8] J.B. Gupta, *A course in Power Systems*, S.K. Kataria & Sons, Delhi, 2008.

[9] A. Bargigia, M. de Nigris, A. Pigini, A. Sivoni, “Definition of testing procedures to check the performance of Zn0 surge Arresters in Different Environmental conditions”. *CIGRE*, pp. 33 – 206, 1992.