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SUBSTATION PROTECTION AND THE CLIMATIC ENVIRONMENT OF NIGER DELTA

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ABSTRACT

Substation protection is one of the most important schemes in power system. Rainfall, Humidity, Temperature and contaminations do not produce over voltage but are capable of lowering the flashover voltage and affect the operation of the equipment.

The aim of the study was to identify the climatic factors especially the average lightning days and / or ground flash density so that substation designed for the area will always follow the required or proposed index of lightning resistance for substations.

The average rainfall, humidity and temperature for the area were recorded so that proper and safe selection of substation equipment could be made.

From the records it was seen that the most crucial in the protection scheme was the direct and indirect (induced) lightning over voltage

Keywords: Shielding angle, Ground flash density, MOV arrester, Zone of protection, Direct stroke.

INTRODUCTION

For most transmission lines, relatively large numbers of yearly flashovers are permitted but such number of insulation damage is absolutely not allowed for substations. Flashover of insulation at substation means a short circuit on the busbars which even with the modern means of relay protection can cause most sever system damages. For modern high voltage substations, the index of lightning resistance is calculated as hundred or even as thousand years which is a proof of attempts made by designers to ensure the largest degree of lightning resistance of substation (Martinez and Castro-Aranda, 2003; Rao, 2008).

Substations must be protected from the direct lighting strokes and voltage waves travelling from the line as well as switching surges. Substations can simply be seen as a combination of apparatus that transforms the characteristics of electrical energy from one form or level to another form with the provision of facilities for switching. There are various types of substations and are classified according to their services, design, voltage level and functions. Whatever function a substation is meant for, it is the most sensitive part of the supply system.

For any reliable operation of substation the basic functions must be performed.

- ❖ Protection against direct stroke
- ❖ Protection over travelling surges

Protection against Direct over Voltage: The effectiveness of lightning protection schemes for high and extra high voltage (ehv) stations depends upon the degree of overhead shielding against direct strokes to the station area.

The two ways of protecting the substation and equipment from direct stroke is

(i) Overhead shielding screen (earthed) covering the outdoor substation and the overhead lines approaching the substation.

(ii) Lightning masts installed at strategic location in the station.

The height above the surface of ground at which the leader discharge finally orients itself on one of the objects on earth is called "the height of orientation of lightning H", which in the first instance depend on the height of the lightning conductor h. It is customary to consider that for lightning conductor up to a height of 30m will be, H = kh, where the proportionality k has a value of 10-20 (Razevig, 2003; Uppal I and Rao, 2009)

Fig-1. Protection zone determination

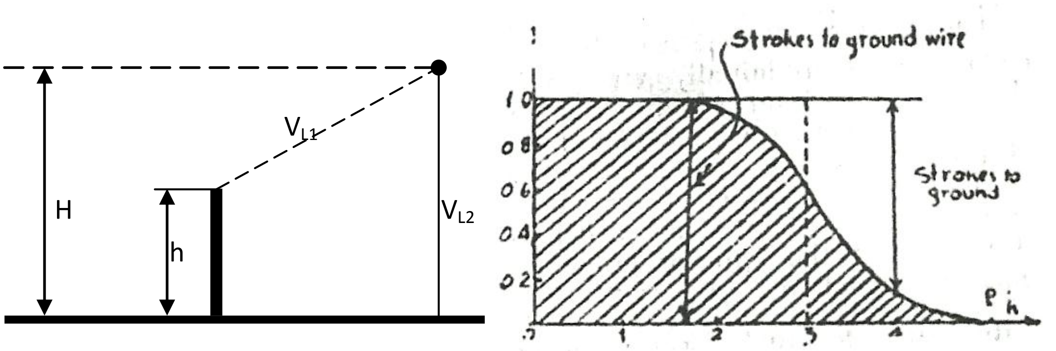
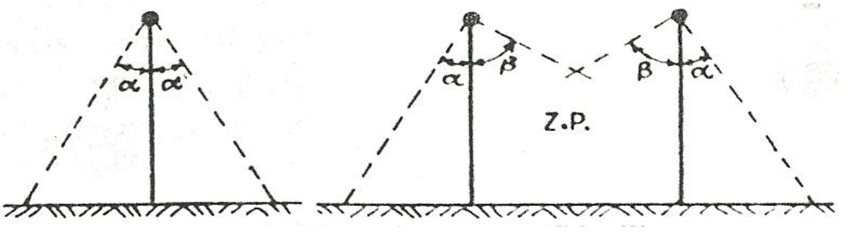


Fig.1a shows the point of orientation of lightning that moves along a horizontal line which lies in the same plane as the lightning conductor. When this point is situated directly above the lightning conductor, the discharge will take place on the conductor. However, in proportion to the displacement of the point of orientation from the lightning conductor, the probability of the lightning stroke to the ground increases. The distance will be critical when the breakdown voltages to the lightning conductor V_{L1} and to ground V_{L2} are the same (Razevig, 2003; Begamudre, 2009). Fig. 1b shows the probability in terms of distance.

There is therefore an area of protection by shield wire which could be defined in terms of radius or the angle of protection, $\propto and \ \beta$ as shown in fig.2

Fig-2. Zone of Protection



$\propto = 30$ and $\beta = 60$

The height of ground wire determines the angle of protection in some cases.

Several techniques have been used including the electro-geometric model technique. With latest knowledge on shielding effect of overhead lightning conductors more accurate estimation of shielding wire failure can be achieved (Uppal I and Rao, 2009; Wikipedia., 2009) A more practical and meaningful measure of shielding effectiveness is the shielding failure risk, defined as the number of years in which one shielding failure event is predicted. If a constant value for instance 100 years is adopted for all stations, the designer has to be aware of the fact that in order to meet this requirement, large stations need more effective shielding than small ones. In other words the shielding angle must be reduced as the station area increases (assuming that other factors does not change significantly).

Shielding performance must be related to the overall reliability of the power system, taking into account the economic balance between cost of the lightning protection scheme and the probable loss resulting from shielding failure events. Once a shielding failure risk has been specified, a tentative decision will be made concerning the shielding method and its overall dimension most suitable for a particular station. The factors that influence such decision are as follows:

- ❖ Choice of vertical or horizontal lightning conductors, electrical, mechanical and aesthetic requirements.
- ❖ Lightning conductor height above ground and effective height above equipment
- ❖ Number and preferred location of lightning conductors including supports. These factors are inter-related, therefore a new station design may require several solutions before the optimum shielding system is determined.

Protection against Travelling Over Voltage

Lightning (surge) arrester are devices that help prevent damage to apparatus due to high voltages. The arrester provides a low impedance path to ground for the current from lightning stroke or transient voltages and then restores to normal operating conditions (Mousa, 1991). Lightning arresters (surge absorbers) are used primarily to protect major equipments like transformers, rotating machines, shunt reactors and even the entire substations (CIGRE . 1991; Gustavo and Alessandro, 2003). Lightning arresters are connected between the line and earth at the substation and power stations. From fig. 3, when the travelling surges reach the diverter and attains the prefixed voltage, a spark is formed across the gap as shown at point P. The diverter then provides a low impedance path to earth through the arrester material. This will hold an IR voltage which depends on the non-linear resistance characteristics of S_1C material (Nagrath and Kothari, 2001; Gupta, 2008). These materials by what they are made have a I – V characteristics.

I = KV^{α}

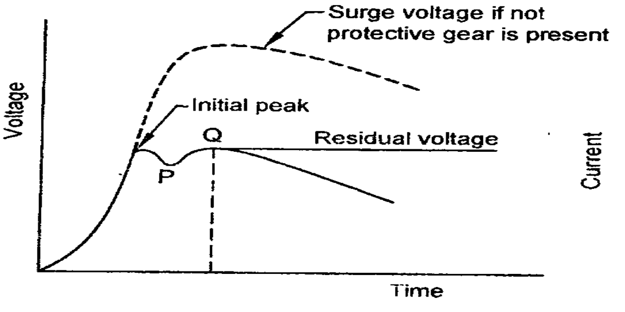
I = discharge current

V = voltage across element

α = an exponent more than unity

K = constant

Fig-3. V – I Characteristic and Residual voltage IR



Generally, arresters could be grouped into three categories:

(i) The Rod Gap

(ii) The Expulsion Type

(iii) The Non-Linear Arresters

The arrester mostly found in the modern use is the non-linear arrester type. They can be considered in three categories:

(i) The Gap type arrester without current limiting functions

(ii) The Gap type arrester with current limiting capability

(iii) The Gapless metal Oxide varistor (MOV)

In fig. 4 the diagram shows the Gap (S_1C) type and the metal oxide arrester (Z_nO).

Fig-4. S_1C Arrester and Z_nO Arrester

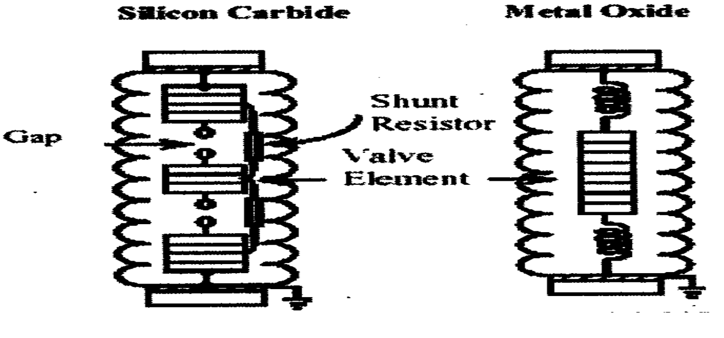
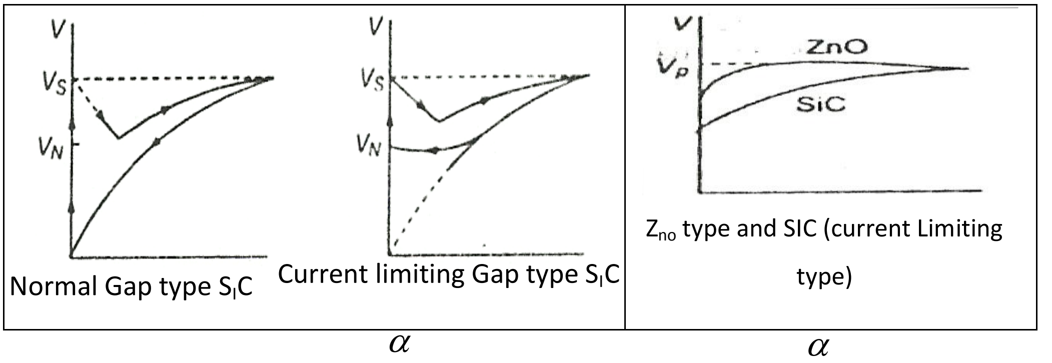


Fig-5. Arrester characteristics $\not{Z}_nO$ and S_1C types

The various characteristics (I – V) are shown in fig. 5



METHOD OF STUDY

Data for climatic and weather conditions were collected from the meteorological station of Federal Minister of aviation. Others were from some environmental study group, Community and Research Development Centre (CREDA) and from Lands and people of Rivers State. Personal observations were made from 2010 to date.

From the available records the necessary data were collected and tabulated as shown in table 2 and table 3.

RESULTS

From table 2 the lightning days per year for 2009 and 2010 are shown. About one fifth of lightning are cloud to ground, therefore the lightning days are kept at 80 to 100 days per year. Some weather forecasters kept some coastal areas from 120 to 150 days per year.

Table-2. Lightning Days for 2009 and 2010

Jan.	Feb.	March	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Months
5.	20	43	49	68	35	31	6	40	54	18	7	Lightning 2009
7	24	45	71	72	40	29	10	42	61	15	6	Lightning 2010

The average rainfall, humidity and temperatures are given in table 3.

Table-3. Seasonal rain, Temperature and Relative humidity

	Seasonal Rain		Temperature		Relative Humidity	
Mean Annual (mm)	Dry Nov. – Dec. (mm)	Wet March – Oct. (mm)	Dry(°C)	Wet (°C)	Dry (mm H_0	Wet(mm H_0
2355-3816.8	187-370	2097-3456.4	32-35°C	24°-28°C	70-90%	65-75%

DISCUSSION

From the table (table 3) the rainfall is considerably high, in some coastal towns rain falls between 250 – 310 days of the year. The humidity is also high especially from April to September, about 68% to 90% in some areas. Some researchers (Ekonomou *et al.*, 2003; Mowete and Adelabu, 2009) have placed the lightning day (thunderstorm A) at about 80 to 100 days per year. That is, the ground flash density is high. This means, proper shielding design is needed. The incoming overhead lines must be properly shielded for at least 2km from the substation to reduce direct stroke on lines (travelling waves).

In the environment considered there is high humidity (68 to 90%) therefore, there may be a likely breakdown of gap below the normal predetermined voltage in some rainy periods and the characteristic of the rod gap which allows follow-up current (dead short circuit) may result to fault situation at some operation time. Darvenzia recommended (Dahiya and Attri, 2009) that all silicon carbide arresters that have been in service for over 13 years be replaced due to moisture ingress. His test reveals that degradation was evident in 75% of arrester. The situation may even be worst in an environment having at least 200 rainy days in 365 days.

From the performance of the gapless arrester ($Ƶ_nO$), the design eliminates the high heat associated with the arcing discharges as may be the case of the gap arresters (S_1C): The MOV arrester has two voltage rating (duty cycle and maximum continuous operation voltage) unlike the silicon carbide that has only the duty cycle rating;. A metal oxide surge arrester utilizing zinc-oxide blocks provides the best performance, as surge voltage level, thereby improving system protection. Failure is reduced, as there is no air gap contamination possibility. Also the leakage current at operating frequency is small (between 1mA to 5mA).

CONCLUSION

The Niger Delta region especially in the coastal areas the humidity is very high, almost throughout the year and rainfall period is about 9 months in the year with high keraunic level, therefore protection of substation requires careful selection of protective devices. From the surge absorber known, it is necessary that the gapless ($Ƶ_nO$) is best suited for the environment. From the foregoing it is proper to ascertain the protective ratio, the discharge current and the protective level of the arrester with the insulation level (BIL) of the equipment for proper co-ordination for reliability of the system.

Proper insulation co-ordination should ensure that the volt time curve of the weakest piece of equipment in the system will lie above the volt time curve of the protective device such as lightning arrester. The weakest piece is always the transformer, the single most expensive equipment with intricately formed insulation. Therefore the incoming voltage surge which would have otherwise damaged the transformer insulation is reduced to that of the volt-time curve (residual voltage) of the lightning arrester such that the transformer is fully protected.

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