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Research Article

Some Critical Study of Lightning Impulses on Electrical Transmission Line System

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Abstract

Lightning is a physical phenomenon, which is often seen as a source of destruction causing millions of dollars in losses annually. over voltages due to lightning is a great challenge for the transmission system designer and researchers. The researchers almost have to keen to mitigate overvoltage problems. Since, lightning causes significant damages to life and property its prediction is very necessary., Due to prediction of lightning at least we know the probability of lightning in the form of low, medium and high range by using fuzzy logic system. This system provides idea behind the prediction of lightning hazards.

Keywords: *Lightning, fuzzy logic system, over voltages.*

1. Introduction

Lightning is the main cause of faults and outages in electric power overhead transmission line. The distribution of the lightning is different according to the season and region. Of all lightning discharges only around 25% of the lightning bolt reaches the ground. Lightning flashes occur many times over the design life of a transmission line. The initiation of a flashover across line insulation may occur in response to a severe flash. The lightning which strikes the ground wire of the line can create different pattern of flashover on phase conductors. The patterns are depending on many factors such as lightning current magnitude, front and tail time, the characteristics of transmission tower, the position of phase conductors, tower grounding and striking distance. When lightning strikes a transmission line tower, a travelling voltage is generated which travels back and forth along the tower, which is being reflected at the tower footing and at the tower top, thus raising the voltage at the cross-arms and stressing the insulators. The insulator will flashover if this transient voltage exceeds its withstand level (backflash). In order to reduce the number of flashovers on the lines, there are different methods to improve the lightning performance of lines i.e. improving critical flashover of insulators, reducing grounding impedance, installing shield wire for lines without shield wire and installing lightning arresters. The tower footing resistance is one of factors effected the back flashover voltage across the insulator in transmission system. A significant number of the faults on overhead transmission lines are due to lightning. Lightning faults may be single or multiphase, and their elimination causes reclosing cycles, voltage dips and outages. Therefore, the outage rate of a line and the quality of the delivered voltage depend on the lightning performance of the line. In thunderclouds, lightning can take place between a cloud and the earth (cloud-ground discharges), entirely within a cloud (intra-cloud discharges), between two clouds (cloud-cloud discharge), or occasionally between a cloud and the surrounding air (cloud-air discharges).The cloud-ground discharges (CG) occur in the region where the air pressure is much higher than the regions in which the intra-cloud discharges (IC) or the cloud-cloud discharges (CC) occur. The CG discharges are always more energetic than the intra-cloud discharges (IC) or the cloud-cloud-discharges (CC).

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2. Characteristics of lightning

Lightning occurs when a sufficiently large electric charge is accumulated in some region of the atmosphere that the electric fields associated with the charge cause electrical breakdown of the air. Most lightning occurs in thunderclouds, but they also occur in snowstorms, sandstorms, clouds over erupting volcanoes and even the clear air (Gifford, 1950; Baskin, 1952).

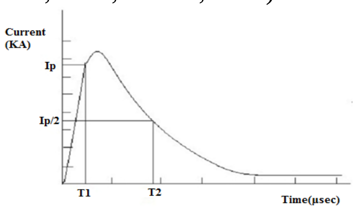

Fig.1. Typical waveform of lightning

Where,

Ip-Peak current value

Ip/2 -Half peak current value

T_1 -Time of peak

T_2 -Time to tail to half peak

The standard lightning impulse shape is generally expressed by the peak current (or voltage) and by the front and tail times T1 and T2 written as T1/T2. T1 and T2 are usually measured in μs, in which case T1/T2 is unit less. Typical lightning impulse curves are shown in figure 1. T1 is the current rises from zero to its peak value (Ip), afterward it is decay to its half value ($I_P/2$) in time T2. Each lightning strike consists of several component parts (each is a current wave called a stroke). The first current wave with a relatively lower dI/dT rate but higher in magnitude and several more (on an average 3) of much higher dI/dT but lower peak currents. Figure 2. shows a typical lightning discharge.

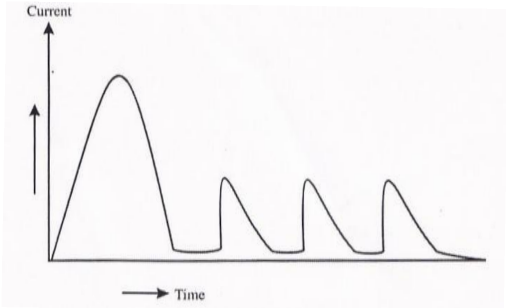

Fig.2. A typical lightning discharge with multiple wave components (strokes)

3. Proposed system

The lightning and its effects are analyzed entirely by carried out a study in MATLAB environment. It will be covering following tasks.

A. Analysis of Lightning

- The lightning signal which follows with very high frequency and high voltage/currents is plotted using MATLAB.
- The signal values with time are taken from a data set and then its variations are plotted.

B. Effect of Tower footing resistance

- The tower footing resistance and its importance is studied.
- Tower footing resistances for different values are analyzed.
- Its effects are studied.

C. Prediction of Lightning

- Here the values based prediction of lightning can be done.
- For this, probability based fuzzy forecasting system will be used.
- From that the lightning effect can be classified as low, medium and high level of lightning hazard.

4. Why we use fuzzy logic?

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalued logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree.

Fuzzy logic is all about the relative importance of precision (i.e. How important is it to be exactly right when a rough answer will do?) Fuzzy logic is a fascinating area of research because it does a good job of trading off between significance and precision something that humans have been managing for a very long time. In this sense, fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concept of fuzzy logic relies on age-old skills of human reasoning.

Here is a list of general observations about fuzzy logic:

- Fuzzy logic is conceptually easy to understand. The mathematical concepts behind fuzzy reasoning are very simple. Fuzzy logic is a more intuitive approach without the far-reaching complexity.
- Fuzzy logic is flexible. With any given system, it is easy to layer on more functionality without starting again from scratch.
- Fuzzy logic is tolerant of imprecise data. Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.
- Fuzzy logic can model nonlinear functions of arbitrary complexity. You can create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS), which are available in Fuzzy Logic Toolbox.
- Fuzzy logic is based on natural language. The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic.

4.1 Fuzzy inference system

A fuzzy inference system with five functional blocks is shown in figure 3. The function of each block is as follows:

- A rule base containing a number of fuzzy IF–THEN rules;

- A database which defines the membership functions of the fuzzy sets used in the fuzzy rules;
- A decision-making unit which performs the inference operations on the rules;

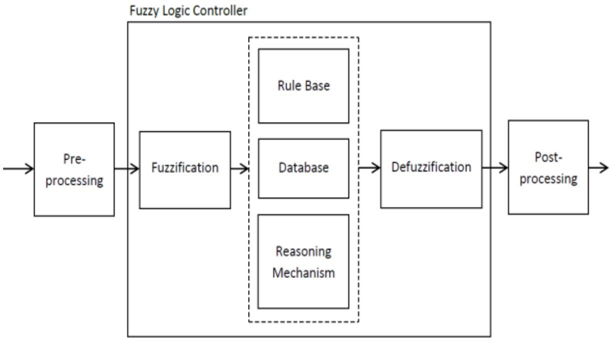

Fig.3. Fuzzy Logic Controller Structure

- A fuzzification interface which transforms the crisp inputs into degrees of match with linguistic values; and
- A defuzzification interface which transforms the fuzzy results of the inference into a crisp output.

5. Effect of tower footing resistance on lightning impulses

The tower footing resistance affects lightning outage rates on transmission and distribution lines and also the ground potential rise at towers during ground faults. Following a lightning stroke to a tower, high currents flow into the ground through the tower footings, giving rise to soil ionisation and thermal effects. As a result, the ground resistance of the tower base decreases by an amount which depends on soil resistivity, the current magnitude and the tower footings construction. For power system operation, it is desirable that this resistance has a low value to prevent line back flashover and maintain the ground potential rise within safety tolerance limits.

5.1 Tower footing resistance and its significance

The tower footing resistance is extremely important parameters in determination of lightning flashover rates. The lower the tower footing resistance, the more negative reflections produced from tower base towards the tower top and these hence help to lower the peak voltage at the tower top. It is defined as, the resistance offered by tower footing to the dissipation of current. The effectiveness of a ground wire depends to a large extent on the tower footing resistance. Tower footing resistance of all the towers shall be measured in dry weather after their erection and before the stringing of earth wire. The tower footing resistance can be calculated as

$$R_t = \frac{R_g}{\sqrt{1+\frac{I}{I_g}}} \quad (1)$$

Where RT - Tower footing resistance (ohm),
R_g - Tower footing resistance at low current and low frequency.(ohm),
I - Surge current into ground (KA),
I_g -Limiting current initiating soil ionization (KA)

$$I_g = \frac{1}{2\pi}\left(\frac{E_0\rho_0}{R_{g^2}}\right) \quad (2)$$

Where ρ_0 - Soil resistivity (ohm-meter)
E_0 –Soil ionization gradient (about 300 KV/m)
To reduce outage rates and exposure of human life to danger due to lightning strikes, the tower footing impedance must be kept to a minimum. In cases where the tower footing resistance is higher than the standards value (10Ω or less), additional measures may be considered to lower the resistance. Such measures may include use of a vertical or horizontal electrode or even using a special resistance reducing material to achieve a lower tower footing resistance.

5.2 Effect of average tower footing resistance on the lightning outage rate

To investigate the effect of the average tower footing resistance on the lightning outage rate, a study carried out by Whitehead on a 500 kV transmission line showed that the outage rate was approximately proportional to the average tower footing resistance as can be seen in Table.1. For an average tower footing resistance of 30 Ω, the lightning outage rate was 1.0 per 100 km per year.

Table 1 Lightning outage rate vs tower footing resistance for 500 kv line

Average tower footing resistance (ohms)	Lightning outage rate (outage/100 KM-YR)
10	0.5
20	0.75
30	1.0
40	1.25

The influence of the tower footing resistance on the lightning fault rate was also studied by Tomohiro et al., as shown Table.2., where it is shown that the lightning fault rate increased with the increase in tower footing resistance.

Table 2 Tower footing resistance vs. lightning fault rate

Tower footing resistance, (Ω)	Lightning fault rate,%
Less than 10	10
10-20	20
20-30	35
30-40	65
40-50	95
More than 50	100

5.3 How to reduce tower footing resistance?

The tower footing resistance can be minimized by adopting the following techniques
a. Use of short length radial conductors bonded at the injection point, rather than a single long length conductor.

This produces the effect of having a number of conductors in parallel.
b. Terminating radial conductors with vertical electrodes. These measures are more effective in low to medium soil resistivity.
c. Using large bending radii when changing the direction of horizontal conductors. Sharp bends tend to increase the inductance.
d. The use of earth enhancing compounds to improve the soil resistivity in the proximity of the conductors which will reduce the tower footing resistance.

5.4 Factors related to tower footing resistance

Tower footing resistance depends on
1. Type of electrode configuration
2. Soil resistivity

A earth electrode is a metal plate, metal pipe or metal conductors electrically connected to the earth. The materials generally used for earth electrodes are made of copper, aluminum, mild steel and galvanized iron in order of preference. The factors that influence the earthing resistance of an electrode or group of electrodes includes the composition of the soil in the immediate neighbourhood, the temperature of the soil, the moisture content of the soil and the depth of the electrode. Thus, the composition of a soil gives a very good indication as to what order of resistivity is to be expected. It is well known that the resistance of an earth electrode is heavily influenced by the resistivity of the soil in which it is driven and as such, soil resistivity measurements are an important parameter when designing earthing installations.

- *Types of earth electrodes*

Earth electrodes must ideally penetrate into the moisture level below the ground level. They must also consist of a metal (or combination of metals) which do not corrode excessively for the period of time they are expected to serve. Because of its high conductivity and resistance to corrosion, copper is the most commonly used material for earth electrodes. Other popular materials are hot-galvanised steel, stainless steel, aluminium and lead.

Earth electrodes may be rods, plates, strips, solid section wire or mats.

Three types of copper rods are commonly available.

• Solid Copper

• Copper clad steel rod (copper shrunk onto the core)

• Copper Bonded steel core (copper is molecularly bonded to nickel plated steel rod)

Soil resistivity is defined as the resistance between the opposite faces of a cube of soil having sides of length one meter and can be expressed in Ohm-metres. Soil resistivity is the key factor that determines what the resistance of the charging electrode will be and to what depth it must be driven to obtain low ground resistance. The resistivity of the soil varies widely throughout the world and changes seasonally. Soil resistivity is determined largely by the content of its electrolyte which consists of moisture, minerals, and the dissolved salt. It figures has a direct impact on the overall sub-station resistance and how much earth electrode is required to achieve the desired values. The lower the resistivity the fewer the electrodes required to achieve the desired earth resistance value. It is an advantage to know the resistivity value at the planning stage as it gives an indication for how much electrode is likely to be required. The reason for measuring soil resistivity when selecting a location for a sub-station or central office is to find a location that has the lowest possible resistance. Once a site has been selected, measuring the soil resistivity will give you the information necessary to design and build a ground field that will meet your ground resistance requirements. There are a number of factors affecting soil resistivity, soil composition being one of them. Soil is rarely homogenous and the resistivity of the soil will vary geographically and at different depths. The second factor affecting soil resistivity is moisture or the amount of water in the ground. Moisture content changes seasonally, varies according to the nature of the sub layers of earth. Since soil resistivity is so closely related to moisture and moisture is present in the soil we can logically assume that as moisture increases resistivity will decrease and vice versa.

6. Effect of temperature, rainfall, water vapour on lightning

The various factors correlates with lightning phenomena are mentioned below. They are as follows

6.1 Temperature

The lightning phenomenon requires high surface temperature. Temperature sets the stage of conditions conducive to producing lightning. When warm or hot air rises and meets the cooler or cold air in the upper atmosphere, as a result of this storm is produced and in these conditions electricity is produced. It is this electricity that produces electrical discharges that travel from cloud to cloud or cloud to earth that we view as lightning. This discharge is so intense it produces a glare of light and the thunder we hear occurs from the atmosphere being super-heated as the lightning discharges.

6.2 Rainfall

As the rainfall increases in the atmosphere, the chances of cloud-ground lightning strikes are also increases. Fig. 4 shows a typical relationship between rainfall and CG lightning strike.

From the above table. it is seen that the grid blocks which received 12 or more strikes each averaged 8.7 cm (3.4 inch) of rainfall. This is almost twice as much as the next lower category (9-11 strikes) and well over 12 times as much as those grid blocks containing 0-2 CG strikes.

That is, the greater the rainfall from convection over the area of study, the greater the CG strikes.

Table. 3 Average rainfall verses CG lightning strikes per grid box

Number of CG lightning Strikes	Rainfall in cm
0-2 (136)	0.5
3-6 (28)	2.2
6-8 (11)	4
9-11 (7)	6.3
12+(6)	8.7

6.3 Water vapour

Tropospheric water vapour is a key element of the earth's climate. It has direct effects as a greenhouse gas, as well as indirect effects through the interaction with clouds, aerosols, and tropospheric chemistry.Water vapour plays a key role in lightning production in the atmosphere. Usually, clouds are the real generators of static charge as found in Earth's atmosphere. But the ability or capability of clouds to hold massive amounts of electrical energy is directly related to the amount of water vapour present in the local system. The amount of water vapour directly controls the permittivity of the air. . During times of low humidity, static discharge is quick and easy. During times of higher humidity, fewer static discharges occur. Permittivity and capacitance work hand in hand to produce the megawatt outputs of lightning.

Conclusions

Nowadays lightning phenomenon becomes very critical and dangerous causes problem for the transmission system designer and researchers. This paper describes the fuzzy inference system used in fuzzy logic controller. The proposed idea provides the warning about the prediction of lightning. By using this proposed idea, we can predict the occurrence of lightning and therefore the corrective action can be taken so that the entire power system can be protected. And hence, the risk to the human life due to lightning is minimized.

References

P. Yadee and S. Premrudeepreechachar,(2007)Analysis of tower footing resistance effected back flashover across insulator in a transmission system.

Yujin Wang, (1998) Experimental studies of the production of nitrogen oxides by simulated lightning sparks Ph.D Thesis.

G. Vijayaraghavan, Mark Brown, Malcolm Barnes,(2004) Practical Grounding, Bonding, Shielding and Surge Protection.

Behnood Rahmani, Hamed Rafezi, Solving fuzzy logic problems with MATLAB,

Varuneet Varun, G. Bhargavi, Suneet Nayak,(2011-12) Speed Control of Induction Motor using Fuzzy Logic Approach, a project thesis submitted in partial fulfilment of the requirements for the degree of *bachelor of technology* in electrical engineering, Department of Electrical Engineering National Institute of Technology, Rourkela Rourkela- 769008, Odisha

N. Harid, H. Griffiths, N. Ullah, M. Ahmeda and A. Haddad**,(**2012**)**Experimental investigation of impulse characteristics of transmission line tower footings. Journal of Lightning Research, 4, (Suppl 1: M6) 36-44

G.Radhika, Dr.M.Suryakalavathi,(January-February 2013) Back flashover analysis improvement of a 220KV transmission line. International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 1, pp.533-536

Mohammad Ahmeda,(2012)Earthing performance transmission line towers Ph.D Thesis, School of Engineering Cardiff University.

Feng Zhenghua, Lu Ling and Feng Junzhong (2011),Research on reducing grounding resistance of transmission line tower grounding grid, The 2nd International Conference on Electrical and Control Engineering (ICECE), pp. 1216-1219, China.

C. Price, M. Asfur;Lightning and climate: The water vapour connection, Tel Aviv University, Geophysics and Planetary Sciences, Ramat Aviv, 69978, Israel

Tomohiro Hayashi, Yukio Mizuno and Katsuhiko Naito (2008), Study on transmission line arresters for tower with high footing resistance, IEEE Transaction on Power Delivery, vol. 23, No. 4, pp. 2456-2460.

Gabriel A.Adegboyega, Kehinde O.Odeyem,(September 2011)Assessment of Soil Resistivity on Grounding of Electrical Systems: A Case Study of North-East Zone, Nigeria, Journal of Academic and Applied Studies Vol. 1(3), pp. 28-38

LEM Instruments Palmersstrasse 2, A-2351 Wr. Neudorf, Ground Resistance Principles, Testing, Techniques & Applications Publication A 99415 E, Printed in Austria.