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Protection of Overhead Transmission Line from the Direct Lightning Strike Fault by using Different Identification Methods

Sapana S. Shirsat
UG Scholar
Electrical & Electronics Engineering Department
Prof Ram Meghe College of Engineering & Management, Badnera-Amravati

S. D. Nimkar
Assistant Professor
Electrical & Electronics Engineering
Prof Ram Meghe College of Engineering & Management, Badnera-Amravati

K. A. Dongre
Associate Professor
Prof Ram Meghe College of Engineering & Management, Badnera-Amaravati

***Abstract* - The transmission line outages occurs due to the direct lightning strike fault. It is good to study on the identification of direct lightning strike fault for the efficient and relevant repair, which is meaning full to overhead transmission line protection. In this paper, firstly we can focus on the lightning current of phase wires at the observation points of view. Secondly, according to their drawback, another method is introduced. In which, the first method to find the lightning strike fault by using 1.Rogowski coil is introduced. Then 2.Wavelet transform, 3.hilbert transform, 4.Modeling of substation shielding, 5. Travelling wave protection, 6. Using surge arresters, 7.Mahalanobis distance protection method, 8. S-Transform method is explained.**

Keywords: Transmission line, lightning strike fault, Identification methods, S-Transform.

I. INTRODUCTION

THE electricity is one of the most important need of human being. The overhead transmission line plays an important role for the generation, transmission and distribution of the electricity. It is also use in the power grid. So that the protection of the overhead transmission line is essential. The overhead transmission line may get affected due to the various reasons. Such as equipment failure, public or animal contact, power grid failure, maintains and most of the faults occur due to the weather condition. The percentage of the various fault is given in the below figure 1.

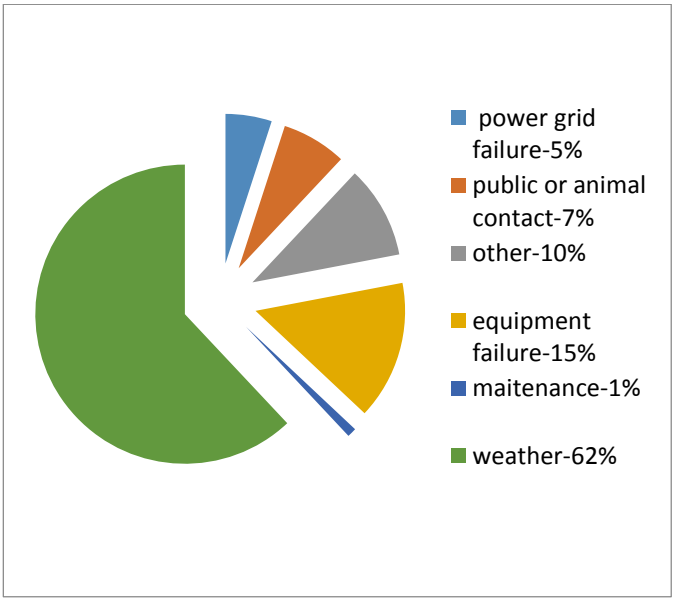

Figure 1. Percentage of cause of power outage [6].

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From the above figure 1, it is clear that the most of the overhead transmission faults are occurred due to the weather condition. In which lightning is one of the reason. An electric discharge between electrically charged regions within clouds, or between cloud and the Earth's surface is known as lightning. The lightning strike faults mainly are of two types. One is direct lightning strike fault and another is indirect lightning strike fault. In this paper, we were study the identification of only direct lightning strike fault methods. There are so many direct lightning strike faults, but in practical condition there are only six direct lightning strike faults and those are classified as:

Shielding failure

1. Without flashover or,
2. with flashover,
3. with one-phase back flashover,
4. with two-phase back flashover,
5. with three-phase back flashover,
6. without back flashover [1].

The direct lightning strike fault which is damages to the overhead transmission line, to protect the overhead transmission line from direct or indirect lightning strike faults, many scientists invented the different methods. At the starting okabe et al took a photos of the lightning strike process by using the high speed camera capable of direct observing the position of the lightning strike point and insulator string situation to protect the overhead transmission line [1]. But this method is not convenient and also it is practically not accurate method. Due to that reason this method has the so many drawbacks, other methods were invented. And those are given below. *Protection of Overhead Transmission Line by Using Rogowski Coil:*

By setting the Rogowski coils on insulator strings and tower ground supports, we can successfully identify the lightning strike fault. A Rogowski coil works by sensing the magnetic field in the space around the conductor. Ampere's law provides the relationship between the current flowing on the conductor and the magnetic field around it [2]. The voltage will generate according to faraday's law, if a single turn coil is placed perpendicular to this magnetic field so that flux lines can link the coil.

There are many advantages of Rogowski coils:

1. It is portable, flexible and light in weight.
2. It has non instructive nature.
3. They have very wide band width (0.1Hz to 1GHz).
4. They cause no damage by large overload.
5. It has high capacity to measure the large current (m Amp to M Amp).
6. They have excellent transient response capability.
7. It is very safe because, there is no direct electrical connection to the main circuit.

The lifetime of the Rogowski coil is 85 years but the lightning strike faults are random, such that numerous Rogowski coils are needed to cover the entire transmission line and hence it is costly [1]. This is the main drawback of this method due to that reason other methods were introduced.

A. *Protection of Overhead Transmission Line by Using Wavelet Transform Method:*

To identify the direct lightning strike fault, Wavelet transform method is used. This is the mathematical method that is the advantage of this method. The Wavelet transform was proposed in 1980's. Another name of this method is "Mother Wavelet." In this method, the concept of frequency is used, instead of scale due to which it can only allow the fixed number of cycles per scale and thus it is usually called a Multi resolution strategy because the resolution remains constant along scale [3].

The continuous wavelet transform of $\mu \pounds L^2(R)$ at delay T and scale λ is given by [3],

$$W(T,\lambda) = \int_{-\infty}^{+\infty} \mu(t)\, \Psi * T,\lambda(t)\, dt \dots\dots\dots\dots\dots (1)$$

Where, $\Psi*$ is the complex conjugate of the wavelet function $\Psi \pounds L^2(R)$. The wavelet transform satisfies the energy conservation property.

$$\|\mu(t)\|2 = \frac{1}{C\Psi} \iint_{-\infty}^{+\infty} |W(T,\lambda)|2\, dT\, \frac{d\lambda}{\lambda 2} \dots\dots\dots\dots (2)$$

This is an important property establishes that any variation of energy in the time or wavelet domain causes an equal variation in the other domain [3]. Due to which the wavelet can be classified as an energy conservative. This transform is same as that of Fourier transform. The continuous wavelet transform is used to detect the analyze voltage sags and transient [1]. The main disadvantage of the wavelet transform is that it will degraded performance under Noisy situation [4].

B. *Protection of Overhead Transmission Line by Using Hilbert Transform Method:*

Wang et al [1], introduce the Hilbert-Hung transform method to identify seven kinds of common power system overvoltage by using the characteristics parameters of instantaneous amplitude spectrum, Hilbert marginal spectrum and Hilbert time-frequency spectrum [1].

Normally the Hilbert transform are used for the feature extraction of distorted waveform. This transform generates a quadrature signal which can easily evaluate the analytical signal. The Hilbert transform gives a better approximation of a quadrature signal only if the signal approximates a narrow band condition [4].

The Hilbert-Hung Transform method is the mathematical method and it is used to recognize only direct lightning strike fault, but it is not used to identify its specific types. So that it is the disadvantage of this method.

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C. Protection of Overhead Transmission Line by Using Modeling Of Substation Shielding:

The modeling of substation shielding against direct lightning strike is one of the method which is used to protect the overhead transmission line. These modeling of substation shielding provide great performance to identify the lightning types at various locations. It is possible to verify that the new proposed methodology is not affected by switching operation [6]. In the context of lightning, substation shielding means ensuring that direct lightning strikes are intercepted by protective masts and ground wires and not by substation phase conductors, bus bar or other equipment [5]. The result of this modeling of substation shielding method is very simple and quick to use due to dimensionless variables.

D. Protection of Overhead Transmission Line by Using Travelling Wave Protection Method:

The Rohring proposed the first travelling wave base fault. The travelling wave protection is used to detect the ultra-high speed fault. The reliability of the travelling wave protection is affected on the application in real power grid. As we know the amplitude of the over-voltage of line is low. When the lightning is strike directly on the overhead transmission line, then due to lightning current with high amplitude directly injects into the line and hence serious over voltage is cause [7]. Since when the magnitude and waveform of the lightning current are related to many factors, such as position and environment of the overhead transmission line, season and climate, due to that the amplitude and waveform are random. The graphical representation of waveform of lightning current is given in figure 2 as below:

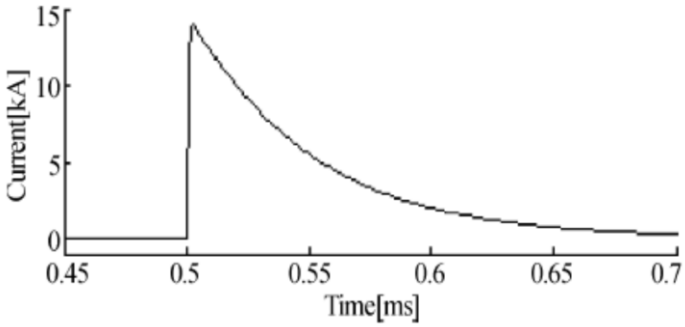

Figure2. Graphical representation of lightning current waveform [7].

The travelling wave protection method has a fast response and it have a very high accuracy. But this is depends on the sampling frequency. Here the speed of the travelling wave is lower than the light speed, so that to achieve the higher accuracy, very high sampling frequency is used. Due to that reason complex equipments are required and hence it will become so expensive. To identify the direct lightning strike fault by using travelling wave protection highly experienced professionals are required and major drawback of this method is that it is not operated by automatically by computers.

E. Protection of Overhead Transmission Line by Using Surge Arresters:

Mainly, due to the bad shield design or too high footing impedances of the overhead transmission line is get damage. For the protection of overhead transmission line from the direct lightning strike fault the surge arresters are used. When the surge arresters are installed on the overhead transmission line then the rate of damage to the transmission line is reduced to zero.

The surge arrester is nothing but a device which is used to protect the overhead transmission line. For the lightning performance improvement of a shielded transmission line that can be achieved after installing metal oxide surge arresters are which is estimate the energy absorption capability of the surge arresters [8]. But, these arresters are use full only the lightning is strike on the arrester. If the lightning is strike on other side rather than arrester then it will damages to the overhead transmission line due to random lightning strike fault. That is the major drawback of this system.

F. Protection of Overhead Transmission Line By Using Hierarchical Identification Method:

Existing all above methods are recognized only lightning strike fault but it is not specific types of fault identification. “Hierarchical Identification Method” is adopted for the numerous direct lightning strike fault types. These methods have two layers, in which first part had some drawback. So that second layer is introduced and due to second layer this method is made too easy for the identification of direct lightning strike fault. Those two layers are

I. Mahalanobis distance protection method

II. S-transform method

I. MAHALANOBIS DISTANCE PROTECTION METHOD

By using the mahalanobis distance algorithm, the 26 groups of training samples are analyzed. In which it is obtained that each 26 groups has two groups. In which one group is near to(a span) the lightning strike point due to which it is greatly affected by the corona effect and other group is relatively far away from the strike point(10 spans) and hence it is slightly affected[1].

The mahalanobis distance method is classified into three classes and those three classes are found under the characteristics quantity CQ1.In class one only one phase has the relatively largest energy. In class two, two phases have the relatively largest energy. And in class three, all phases should have similar energy. The energy ratio of each phase is,

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$$r_a = \frac{P_a}{P} = \frac{P_a}{P_a+P_b+P_c}$$

$$r_b = \frac{P_b}{P} = \frac{P_b}{P_a+P_b+P_c}$$

$$r_c = \frac{P_c}{P} = \frac{P_c}{P_a+P_b+P_c}$$

In which, $P_i = \int_0^{\tau_0} i_i^2(t)\,dt \qquad i = a, b, c$

Where t_0 is 50 μs [1].

According to above equation, it is clear that CQ1= $[r_a, r_b, r_c]$ where, $r_a + r_b + r_c = 1$ ... ...[1]

Hence, the minimum mahalanobis distance d between each group Centre and new point with CQ1 can be used to decide the class in which it belongs.

After getting the details about the mahalanobis distance method, we can see the advantages of this method. This method is more efficient than wavelet transform method and Hilbert-Huang transform method. And second most important that it is the mathematical method so that it's required low cost. Since This method have a more advantage than other method but it also has one drawback that, we can identify only one lightning strike fault at a time. To overcome this drawback, hierarchical identification method is modified and second layer is form.

I. S-TRANSFORM:

The second layer of the hierarchical identification method is nothing but s-transform. The s-transform is an improved theory based on the short time Fourier transform and wavelet transform. The lightning current has numerous high frequency components in the time domain due to that reason s-transform can reflect the partial with high resolution. Basically there total six types of direct lightning strike fault which are seen before.

i. Class One:

In class one, we can find one-phase back flashover shielding failure without flashover and shielding failure with flashover fault. For that we had some conditions, that is when CQ2<K1, then shielding failure with flashover fault is obtained, otherwise they CQ3 and CQ3<K2 then shielding failure without flashover fault obtained otherwise this is the one-phase back flashover fault. Where K1=0.565 and K2=1.74[1].

ii. Class Two:

Class two is classified as two-phase back flashover fault type, thus a CQ2 or CQ3 is not needed [1].

iii. Class Three:

In class three we can identify the three-phase back flashover and shielding success without back flashover. If the CQ2>K3 then it is three-phase back flash over fault and if CQ2<K3 then it is the shielding success without Back flashover fault. Figure 3 of hierarchical identification method can be easy for the understanding, which is given below.

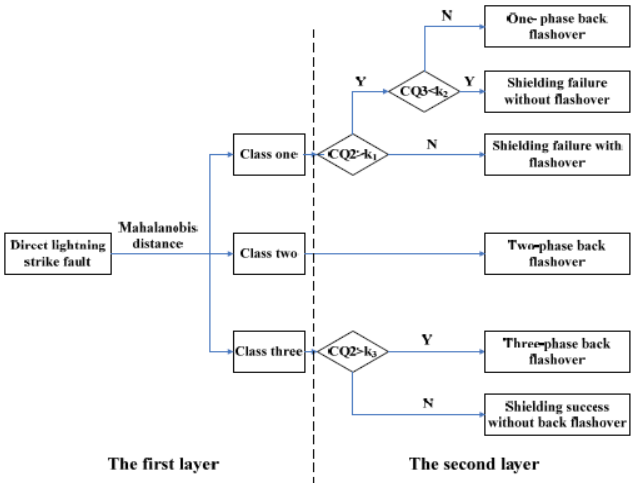

Figure 3 Graphical diagram of hierarchical identification method

The most important advantage of this method is that the accuracy rate is more than 90% and it is very simple for the identification of direct lightning strike faults types and also for application.

CONCLUSION

These all methods due to their drawbacks, gives us a better identification method for the protection of the overhead transmission line due to which the damage of the overhead transmission line can be controlled by those method and rate of accuracy is increases.

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