USE OF COMBINED APPROACHES TOWARDS MITIGATING FAULTS CAUSED BY LIGHTNING ON TNB DISTRIBUTION OVERHEAD LINES

Mohd Faris ARIFFIN
Distribution Division, TNB – Malaysia
farisar@tnb.com.my

ABSTRACT

TNB is continuously seeking effective methods to improve the lightning withstand performance of its medium voltage distribution overhead lines. Through engineering practice assessment findings, improvement initiatives can be strategized and rectification regimes can be implemented to mitigate transient interruption on the medium voltage distribution overhead lines. However, due to the multiplicity of causes contributing to the frequent transient interruptions, a combination of approaches needs to be subscribed to improve the lightning withstand performance of these medium voltage distribution overhead lines.

Shielding of equipment from direct lightning strikes is considered the first line of defence as some of TNB medium voltage distribution overhead lines are unshielded and are designed to be used with wooden cross-arm. Without shielding, these overhead lines require the use of surge arresters as protection from voltage surges caused by direct lightning strikes. However, these surge arresters are highly exposed to risks of being damaged by lightning surges due to the high incidences of lightning strikes in Malaysia. With the surge arresters failing, the probability for the equipment installed on the medium voltage overhead to be damaged by lightning surges is very likely. Finally, in order to ensure effective discharge of the lightning current to ground, effective grounding is necessary. Unfortunately, some TNB medium voltage distribution overhead lines run through sandy or rocky grounds where soil resistivity can be very high.

This paper attempts to illustrate the combined methodologies that have been used to reduce transient interruptions on medium voltage distribution overhead lines and mitigate failures of the various overhead line equipment especially automatic circuit reclosers.

INTRODUCTION

Currently, TNB operates and maintains 1,245kM of 11kV, 156kM of 22kV and 5,285kM of 33kV bare overhead lines. Unfortunately for these overhead lines, Malaysia is located in a very active lightning region with an isokeraunic level of 200 thunder days per year. As such, these overhead lines are vulnerable to transient interruptions caused by lightning. For example, in 2010, 47% of the interruptions on the medium voltage bare overhead lines were transients.

In order to mitigate transient interruptions, beginning in 2010, TNB implemented Engineering Practices Assessment or EPA. Findings from the EPA were recorded and highlighted to the relevant stations in TNB Distribution so that rectification works and improvement on the overhead lines can be implemented according to the "*Insulation Coordination Guideline for TNB Distribution Overhead Lines*". The initiatives that were taken between 2010 and 2011 [1] include:

1. EPA Mitigation Activities

Mitigation activities to manage **controllable** threats that can cause transient interruptions include the followings:

a. Vegetation management deployment
b. Animal guard deployment
c. Hot spot detection of poor contacts or connections
d. Ageing component replacement

2. Insulation Coordination Mitigation Activities

Mitigation activities to manage **uncontrollable** threats that have caused numerous transient interruptions include the followings:

a. Tower or pole footing improvement;
b. Shielding improvement;
c. Surge arrester optimized placement;
d. Insulators critical flashover voltage improvement

These concerted efforts have shown encouraging results where by 31st August 2011, transient interruptions on the medium voltage overhead lines were reduced by **25.66%**.

Unfortunately, due to the intensity of the lightning incidences in Malaysia, major breakdowns on equipment caused by lightning are still occurring despite implementing rigorous EPA activities on troublesome overhead lines to detect potential threats that can lead transient interruptions. Further analysis reveals that additional improvement initiatives are still needed in the following area of concerns:

1. shielding of unshielded overhead line conductor from direct lightning strike
2. grounding of overhead line poles for fast discharge of high current caused by lightning
3. protection of overhead line equipment from voltage surges caused by indirect lightning strike

SHIELDING OF UNSHIELDED OVERHEAD LINES – USE OF FRANKLIN ROD

Overhead lines shielding is not an uncommon practice and is recommended for protection against direct lightning strikes [2]. Shielding of overhead lines is the first line of defence against direct lightning strikes. However, some overhead lines in TNB are unshielded as they are designed with the use of wooden cross-arm.

Installing new overhead shielding wire on top of existing poles can be cumbersome due to electrical clearance, pole design and economic implication issues. Thus, instead of stringing new overhead shielding wires, Franklin rods are installed on top of the poles instead [3]. This new approach is not considered a standard practice for overhead lines.

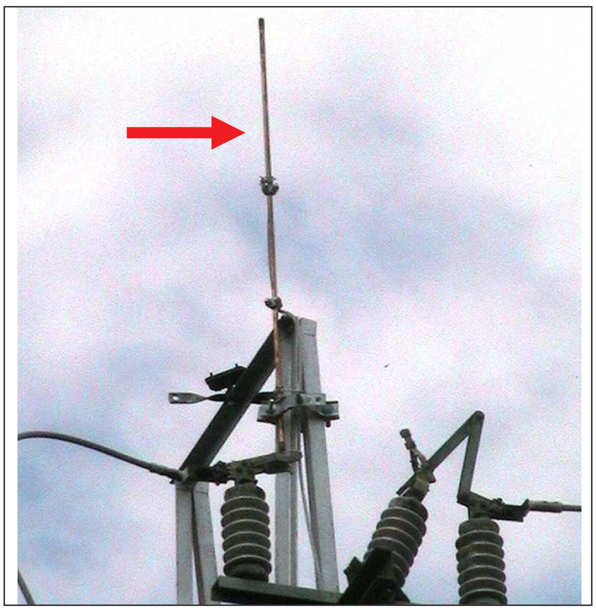


Photo 1: Franklin Rod on Overhead Line Poles

The Franklin rods used are 1 meter long, blunt-tipped copper rods. With the use of these Franklin rods, the probability of lightning strikes terminating at the pole top instead of the phase conductors and/or equipment will be increased as the height of the pole is extended. As such, the stroke distribution will be altered with the higher strike current terminating on the pole top causing less stress on the phase conductors and connected equipment. Moreover, with the phase conductors protected from the high energy strike current, the incidences of transient interruptions can be reduced.

The Franklin rods should be connected to ground with the use of down lead conductors preferably copper conductors. The use of other materials such as galvanized steel wire may not be suitable as the down lead conductor should be capable of discharging the high energy lightning current to ground. Photo 2 shows the risk of using galvanized steel wire as a down lead conductor. The wire strands have snapped probably due to the high energy strike current:

Photo 2: Snapped Strands of Steel Down Lead Conductor

GROUNDING OF OVERHEAD LINE POLES

In order to ensure fast discharge of the high energy lightning current to earth, effective pole grounding is necessary. However, achieving such grounding is a challenge when the overhead lines run through sandy or rocky ground due their high soil resistivity. As such, the native soil of at the pole has to be treated to reduce its soil resistivity.

Furthermore, effective grounding for discharging high energy lightning current at high frequency should be treated differently from grounding the pole for discharging fault current at power frequency. The high energy, high frequency lightning current has to be discharged quickly and the path it has to take to reach ground should be as short as possible.

Use of Earth Enhancing Compound

Fortunately, with the use of earth enhancing compound, the soil resistivity can be reduced to improve the overhead line pole footing resistance. Two commonly used earth enhancing compound is being tested on 11kV Kampar to Gopeng overhead line that runs on sandy ground [3]. The only concern with earth enhancing compound is the risk for it to be washed away by water during heavy rain. Thus, the compound should solidify when in contact with the earth moisture. Table 1 below indicates the improvement of soil resistivity with the application of the earth enhancing compound:

No.	Location	Earthing Resistance (Ω)	
		Before	After
1	Pole EX7/29	16.40	1.90
2	Pole EX7/41	4.85	2.00

Table 1: Improvement of Earthing Resistance with Application of Earth Enhancing Compound

Photo 3 below illustrates the application of earth enhancing compound for pole footing resistance improvement:

Photo 3: Applying Earth Enhancing Compound

The earth enhancing compound at these two poles was applied between July and August 2011. In order to ensure that the compound still retains its properties, the earthing resistance at these two poles was measured again in October 2011. Table 2 shows that the earthing resistance has reduced further:

No.	Location	Earthing Resistance (Ω)	
		August 2011	October 2011
1	Pole EX7/29	1.90	1.70
2	Pole EX7/41	2.00	1.80

Table 2: Further Reduction of Settled Earthing Compound

With the native soil treated and the soil resistivity improved, the pole grounding can be deemed as effective to discharge the high energy lightning current to earth.

Earth Connection Configuration for Lightning Current Discharge

In order to ensure fast discharge of the high energy, high frequency lightning current, the correct configuration should be used to ensure that the lightning current takes the shortest path to earth and is eventually effectively discharged to ground [3]. From the EPA data collected in 2010, there seemed to be a misconception on effectively earthed distribution overhead line poles. High energy, high frequency lightning current behaves differently if compared to power frequency fault current when they are being discharged to earth. Figure 1 and 2 below shows the different resultant of earth potentials between high frequency lightning current and power frequency fault current when discharged to ground simulated using **Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis** or CDEGS:

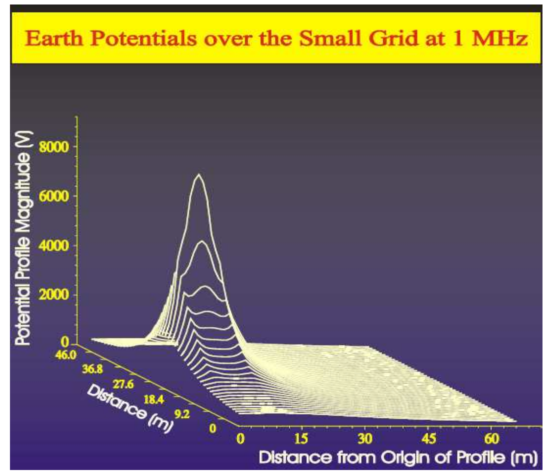


Figure 1: Earth Potentials at 1 MHz

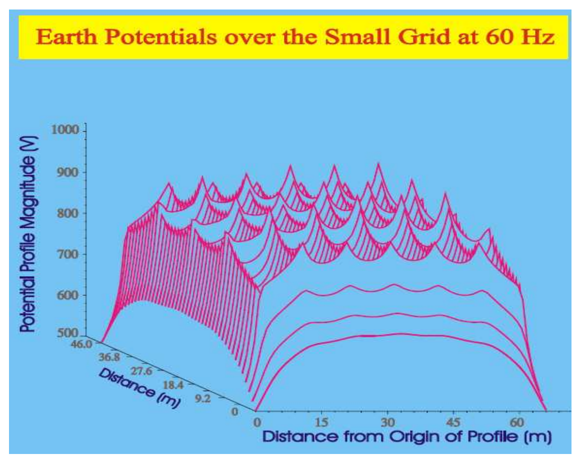


Figure 2: Earth Potentials at 60 Hz

From the above general patterns, it can be observed that high frequency lightning current behaves differently when discharged to earth as compared to power frequency fault current. Thus, the pole earth connection should be configured in such a way to allow fast discharge of the high frequency lightning current through the shortest path to earth.

A combination of copper tape and a number of copper rods are being used to optimize the earth connection at the overhead line poles to ensure the above objective is achieved. Figure 3 below illustrates the recommended earth connection configuration to ensure fast discharge of the high frequency lightning current to earth [3]:

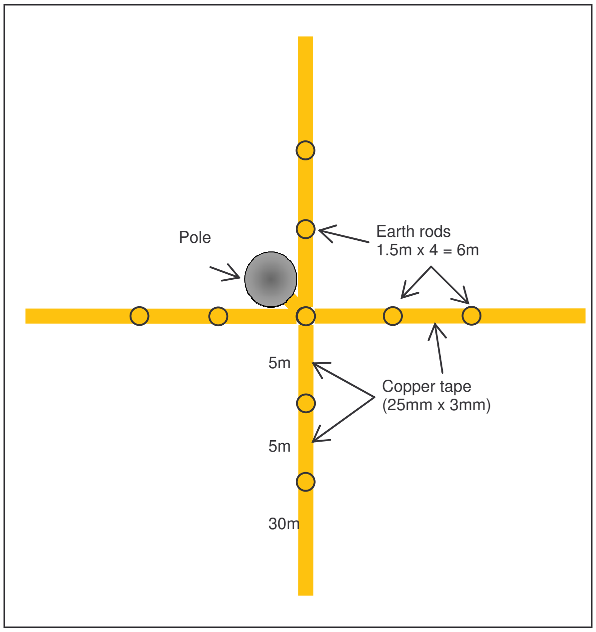


Figure 3: Recommended Earth Connection Configuration

PROTECTION OF OVERHEAD LINE EQUIPMENT –USE OF SURGE ARRESTERS

Overhead lines equipment should also be protected against induced voltage surges caused by indirect lightning strikes with the installation of surge arresters as recommended by IEEE Std 1410-2010. Since installing surge arresters involves economic consideration, they should be optimally placed to ensure maximum protection for the overhead line equipment. Thus, placement of these surge arresters should be prioritized to poles with reduced insulation level that can include poles with overhead line equipment, stay wire installation, dead-end poles and tee-off poles [3].

As lightning current comes with high energy, the surge arresters should also be able to absorb that high energy current and discharge it to ground without those surge arresters themselves being damaged. In order to guarantee such protection, 10kA Line Discharge Class 2 surge arresters have been recommended for the 33kV overhead lines as they are more likely to be hit by direct lightning strikes [3]. As for the 11kV overhead lines, due to their pole height, the use of 10kA Line Discharge Class 1 surge arresters is still retained.

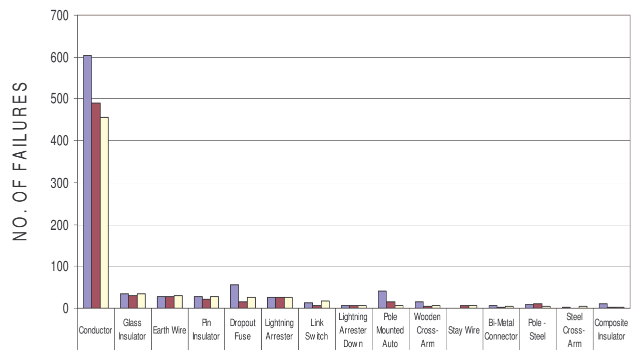
RESULTS

With the use of these combined approaches, transient interruptions were reduced further to **8.71%** by 31st August 2012 as shown in Table 3 below:

Financial Year	Transient	%	Initiatives Done
2009/10	417	-	Normal Preventive
2010/11	310	25.66	EPA/Insulation Coordination
2011/12	283	8.71	Combined Approach

Table 3: Reduction of Transient Interruptions

Failures of overhead lines equipment especially automatic circuit reclosers have also been reduced by 31st August 2012 with the use of combined approaches of Franklin rods, earth enhancing compound and Class 2 surge arresters as shown in Graph 1 below:



	Conductor	Glass Insulator	Earth Wire	Pin Insulator	Dropout Fuse	Lightning Arrester	Link Switch	Lightning Arrester Down	Pole Mounted Auto	Wooden Cross-Arm	Stay Wire	Bi-Metal Connector	Pole - Steel	Steel Cross-Arm	Composite Insulator
2009/10	603	34	27	27	55	26	13	7	41	16	1	6	9	3	10
2010/11	490	29	27	21	15	25	6	7	14	5	7	3	11	1	2
2011/2012	457	35	29	28	26	26	17	7	7	7	6	4	4	4	3

Graph 1: Overhead Line Equipment Failure Reduction

CONCLUSIONS

Continuous EPA, insulation coordination and combined approaches initiatives need to be carried out at other locations to ensure further reduction of transient interruptions by 31st August 2013.

REFERENCES

[1] M.F. Ariffin, 2011, “Managing Transient Interruptions on Aged 22kV Overhead Lines in TNB Distribution Network through Engineering Practices Assessment and Insulation Coordination Guidelines”, The 21st International Conference on Electricity Distribution (CIRED 2011), Paper 1136, 6th – 9th June 2011, Frankfurt

[2] IEEE Std 1410-2010, *IEEE Guide for Improving the Lightning Performance of Electric Power Overhead Distribution Lines*

[3] A.B. Abdul Ghani, N. Abdullah, N.A. Abd Rahman, 2012, “Earthing and Lightning Performance Improvement of the 11kV Kampar – Gopeng Overhead Distribution Line”, TNB Research, Bangi, Malaysia