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Seasonal Variation of Transmission Line Outages in Peninsular Malaysia

I. Mohamed Rawi[1,2]*, M.Z.A. Ab-Kadir[2] and M. Izadi[2]

[1]*Tenaga Nasional Berhad, Brickfields, 50470 Kuala Lumpur, Malaysia*
[2]*Centre for Electromagnetic and Lightning Protection Research (CELP), Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia*

ABSTRACT

Researchers have observed the impact of climate changes on overhead line outages. It is known that overhead lines are very prone to lightning strikes due to their height and location which are normally in an open and exposed area. Studies have also reported that transmission and distribution lines experience very high failure rates due to lightning strikes. The tropics experience greater lightning activities and have higher peaks where transmission lines suffer frequent line outages. This paper examined studies that have been conducted on line outages due to lightning activities, especially in the tropical areas. Lightning detection system is also discussed as well as how to evaluate line performance. Seasonal variation of lightning occurrences and line outage pattern help to predict lightning occurrences and to optimise a suitable power protection system of overhead lines. It has been widely reported that lightning occurrences and line outages are significantly related and lightning activity was more prevalent during inter monsoon seasons.

Keywords: Transmission lines, lightning performance, lightning, tropical weather

INTRODUCTION

Tropical countries experience more frequent line outages due to lightning flash density peculiar to the climate. During certain periods of the year, lightning activities are higher and these observations help researchers understand line outage pattern of high voltage systems. Studies also suggest the use of surge protection devices, improve footing resistance and increase insulation level. To date, there are has been no agreement among researchers on the best solution for optimising the arrester location on the phases or towers along the line. There is also mismatch with regards to the principle used for estimating line performance.

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E-mail addresses:
iryanirawi@gmail.com (I. Mohamed Rawi),
mzk@upm.edu.my (M .Z. A. Ab-Kadir),
aryaphase@yahoo.com (M. Izadi)
*Corresponding Author

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This paper discussed practical approaches in electric utilities for evaluating and improving transmission line performance where monsoon or seasonal variation resulted in transmission line outages (Ahmad, Yahya, & Alam, 2008). It also reviews data from lightning detection network (LDN) to evaluate line performance. The methods prescribed by different researchers to predict and manage the issue with line outages are summarised and discussed and future research topics are recommended in this paper.

LIGHTNING IN TROPICAL COUNTRIES

Tropical countries are located within the "tropics" - a region of the Earth surrounding the Equator, delimiting in altitude by the Tropic of Cancer and Tropic of Capricorn. It is also known as the "torrid zone". The tropics include all areas on the Earth where Sun reaches a point directly from overhead at least once during every solar year. Observed by NASA and NASDA, analysed by many, world lightning maps were generated in terms of thunder days (or keraunic level) and ground flash density level (GFD). Over the years, it has been reported that lightning occurrences were highest in the tropics (Graham, n.d.). There are 103 tropical countries which encompasses the region of North America, Central America, South America, Caribbean, Central Africa, East Africa, West Africa and Southeast Asia.

Keraunic level was the earliest method used for measuring lightning intensity. It was an acceptable method with inevitable flaws. It is measured in thunder days per year, depending on the number of observation stations. It is also not possible to know the severity of lightning strikes and measurement including cloud-to-cloud lightning, which contributes to 90% of lightning and clearly does not affect system performance. Modern sensors were later invented capable of locating the strike location, discharge time, crest current and it's polarity and multiplicity of return stroke (Ahmad et al., 2008). The entire lightning detection system (LDS) measures lightning as GED in flashes per km^2 per year. Data from LDS are very important for users to optimise their design and avoid overspending on the cost of the design (Bouquegneau,

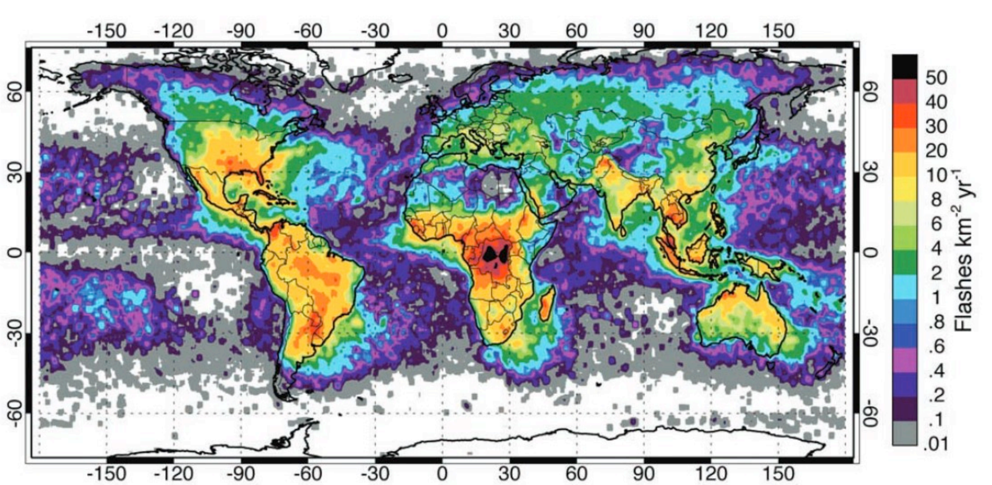

Figure 1. Annualised distribution of total lightning activity in flashes per km^2 per year

2014). Figure 1 shows an intense 50 flashes per km^2 per year in Central Africa and as low as 2 flashes per km^2 per year in Central Europe. These two areas shall not use the same design of (surge protective devices). From the map, areas around the equator experience lightning activity as high as 50 flashes per km^2 per year, referred as ground flash density or isokeraunic level.

Mean annual flash rate in the tropics are also very high (Cecil, Buechler & Blakeslee, 2014), notably in Central Africa. It is also very important to note that observed flash rate in the Malaysia region is between 10 and 30 flashes per km^2 per year.

In the tropics, lightning occurrences are higher in certain months. It is also reported that Southeast Asia has sharp increases of lightning activity in April, particularly Bangladesh which experiences high flash rates in April to May. This is due to shifts in the season from pre-monsoon to monsoon which increases the progression of thunderstorm activity (Cecil et al., 2014). Indonesia and Malaysia have very similar double-peak activity where lightning activity increases in April and October (Ab Kadir et al., 2012; Zoro & Mefiardhi, 2005).

Table 1
Lightning statistics

Description	Location	Source	Value
Average positive flash polarity	South East Brazil[Note 1]	(Pinto et al., 1996)	35%
	Peninsular Malaysia[Note 1]	(Mohamed, 2011)	23.0%
	Peninsular Malaysia[Note 2]	(Abdullah, Yahaya, & Hudi, 2008; Abdullah & Hatta, 2012)	17.6%
Average peak amplitude	Pekan area, Malaysia	(Ibrahim & Ghazali, 2012)	32kA
	Peninsular Malaysia	(Abdullah et al., 2008)	37kA
	Northern Australia	(Abdullahet al., 2008)	37kA
	Java Island, Indonesia	(Abdullah et al., 2008)	37kA (+)
			41kA (-)
Highest peak amplitude	Peninsular Malaysia	(Abdullah et al., 2008)	484.4kA
	Japan (non-tropic)	(Takami & Okabe, 2007)	130.2kA
Frequent lightning activity	Peninsular Malaysia	(Kadir et al., 2012; Abdullah et al., 2008; Mohamed, 2011)	April – May Oct – Nov
	Bangladesh	(Cecil et al., 2014)	April - May

[Note 1] One year observation period
[Note 2] Period of observation was for eight years

Table 1 shows that in the tropics, positive flashes are higher, where positive lightning discharges account for 10% or less of global cloud-to-ground lightning activity (Rosa et al., 2000). Average peak amplitude was observed to be around 32kA to 37kA (positive) and 41kA (negative). Peak amplitude of lightning current was also found to be very high compared with other non-tropical countries. A common inter-monsoon period in tropical countries, namely April to May and October to November, indicated higher lightning activities.

LIGHTNING DETECTION NETWORK

Use of LDN in performance study

The Malaysian Meteorological Department (MET) measures the keraunic level in terms of thunder-days (T_d) per year. The MET reports that the average recorded thunder-days in Malaysia (specifically in KLIA, Sepang) is 309 per year. The highest recorded thunder-days was in Subang in 1987 where 362 days were reported with lightning activities (Malaysian Meteorological Department, 2016). This analysis was based on readings from 36 weather stations until 2010. However, T_d was not accurate for system analysis due to several weaknesses, such as its inability to distinguish between intra-cloud lightning which does not harm the system and cloud to ground strokes which could damage it. Furthermore, the counting was limited to the weather stations in nearby areas and level of lightning intensity (kA) was not measured (Whitehead & Driggans, 1990).

The situation has changed after the successful installation and operation of TNB Lightning Detection Network (LDN) in 1994 which has helped researchers to conduct a more holistic lightning study and analysis, thus optimising the system design. Noradlina et al. (2008) reported that over nine million lightning strikes were recorded between 2004 and 2007 while 11.1 million strikes were recorded between 2008 and 2011, taking into account 3.7 million flashes reported with mean multiplicity of three strokes per flash observed by LDN. The system has an accuracy of 500m and 95% detection efficiency whereby it is able to detect lightning 600km from the sensors. The IMPACT ESP sensors uses Time-of-arrival (TOA) and Magnetic Direction Finding (MDF) method in order to satisfy the accuracy and efficiency requirements (Abdullah et al., 2008).

Stroke counts and polarities

In evaluating lightning performance, it is also important to know the stroke polarity. Previous researches have predicted that between 5% and 10% of lightning occurrences are positive flashes. However, percentage of positive flash occurrences are above the stated predicted value, especially in tropical areas. Pinto et al., (1996) observed 63.4% negative and 35.0% positive stroke polarity and the rest are bipolar flashes in Southeastern Brazil between 1992 and 1993. Earlier studies in Malaysia have reported yearly lightning stroke polarity count ranged from the ratio of 69:31 to 86:14 between negative to positive strokes (see Table 2).

Table 2
Observation on lightning polarities in Peninsular Malaysia

Year	Negative strokes	Percentage	Positive strokes	Percentage
2004	1,835,053	69%	843,089	31%
2005	1,681,775	86%	277,417	14%
2006	2,448,549	86%	404,613	14%
2007	1,049,653	85%	187,249	15%
2008	3,131,865	85%	552,645	15%
2009	2,347,809	80%	586,953	20%
2010	1,684,101	82%	369,681	18%
2011	1,997,610	86%	325,194	14%

TRANSMISSION LINE PERFORMANCE

Reported line performance by electric utilities

Electric utility companies face a high number of line outages due to lightning. In Southern China for example, statistics indicated about 70% of line outages are resulted from lightning activities (Zhao et al., 2013) while in Brazil, CEMIG declared 67% of transmission line outages are due to the same cause (Cherchiglia et al., 2002). In Indonesia, 66% of 150kV line outages were reported to be due to lightning (Warmi & Michishita, 2015). Similarly, in Australia, Gillespie and Stapleton (2004) reported 40.5% of 275kV network outages were due to lightning.

In evaluating overhead line performance, a list of available standards such as IEEE Std. 1410 an IEEE Std. 1243 can be used. However, it is always a challenge for users from the tropical countries as these standards and procedures are generally designed to be used in non-tropical countries such as United States of America, Canada and Europe (Baharuddin, Abidin, & Hashim, 2006). A recent work by CIGRE WG C4.410 specified calculated on high voltage line performance ranging from 4.7 to 4.9 flashes per km^2 per year which are incomparable to the GFD value in tropical countries which typically are between 10 and 30 flashes per km^2 per year (See Table 3).

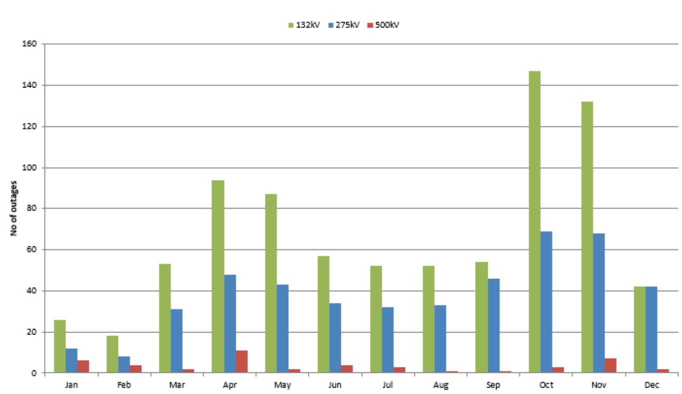

Figure 2. Transmission line outages due to lightning in peninsular Malaysia (from 2002 – 2015)

Table 3
Observation on line outrage rates in electric utilities

No	Utility or line name	Country	Tower footing resistance (Ω)	No. of shield wires	Line voltage (kV)	Outage rate (per 100km/yr)
Tropical countries						
1	CEMIG	Brazil			34.5	62
2	CEMIG	Brazil			69	40
3	CEMIG	Brazil			138	30.33
4	Angostura-B	Mexico	15	2	115	14.55
5	KKRI-GMSG	Malaysia	10	2	132	4.26
6	ATWR-BTRK	Malaysia	5	2	500	0.51
Non-tropical countries						
1	Ontario-Hydro	Canada	200	1	115	5.72
2	NEA	Australia	10	1	132	1.86
3	ECNSW	Australia			132	4.47
4	Com. Edison	USA			138	4.97
5	Tokyo	Japan			140	2.24
6	TVA	USA	30	2	161	1.99
7	Seq. to Charleston	USA			161	3.83
8	S. Jackson to Cordova	USA			161	0.55
9	SECV	Australia	28	1	220	1.02
10	CIGRE line #30				230	0.24
11	Tokyo	Japan			250	1.12
12	ECNSW	Australia			330	0.93
13	OVEC	USA	5	1	345	4.72
14	CIGRE line #31				345	3.44
15	Johns to Cordova	USA			500	0.3
16	Brown F. to West P.	USA			500	0.94
17	CSPG	China		2	500	0.74
18	Powerlink	Australia	10 - 20		132	3.3
19	Powerlink	Australia	10 - 20		275	0.3 – 0.7
20	Powerlink	Australia	10 - 20		330	0.3 – 0.7

In peninsular Malaysia, transmission line consists of 132 kV, 275kV and 500kV systems. From 2002 until 2015, total number of outages were recorded and compared with the lightning activity throughout the year.

Figure 2 shows a double-peak pattern on the total number of line outages in peninsular Malaysia for all transmission line system voltages i.e. 132kV, 275kV and 500kV. From the statistics, outages due to lightning are higher between April to May and between October to November. This pattern was observed in the annual lightning activities which are also higher during the monsoon interchange season, i.e. inter-monsoon period which are notably from April to May and October to November (Ab Kadir et al., 2012)

CONCLUSION

In tropical countries, higher outage rate due to lightning is observed . It is therefore important to have extra protection on the transmission lines to avoid frequent interruptions on the power systems by installing transmission line arresters, adopting special grounding designs to provide lower tower footing resistance, installing additional earth wires to provide additional shielding on the phase conductor and increase system insulation level i.e. insulation string length. Lightning activity increases in the tropics during inter-monsoon seasons which are between April to May and October to November. This is consistent with the number of transmission line outages observed in peninsular Malaysia where higher number of outages were reported during these periods. Therefore, extra precautions have to be taken by the system grid owner or the electric utility companies before lightning peak season sets in. This is to avoid recurrence of line outages on overhead transmission lines. Continuous observation on the LDN data is essential to understand lightning behaviour in this lightning-prone region especially with regards to the monsoonal variation.

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