ANALYSIS OF NEGATIVE DOWNWARD LIGHTNING CURRENT CURVES FROM 1985 TO 1994 AT MORRO DO CACHIMBO RESEARCH STATION (BRAZIL)

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ABSTRACT: This paper presents an analysis of negative descendent cloud to ground lightning captured by a 60 m metalic tower between 1985 and 1994 in the "Morro do Cachimbo", research station (43° 58' 26" W, 20° 00'39" S) of the Companhia Energética de Minas Gerais (CEMIG), Brazil. From the comparison of return strokes with those of another station in Switzerland, it was noted that electric current wave forms are similar in both countries, although the mean peak current in Brazil (41 kA) is greater than that in Switzerland (30 kA) and the time to peak is greater in Brazil (22 µs) than in Switzerland (13 µs). Differences in subsequent strokes were observed too. It was found that the time to peak current is correlated to the time to peak of derivative current with a linear correlation coeficient of about 94%.The mean third return stroke current was found to be stronger than the second and an explanation for that was suggested. M-components recorded at about 200 µs (geometric mean peak current of 2.37 kA) had time to peak lower than those obtained after 1 ms in Florida and Alabama.

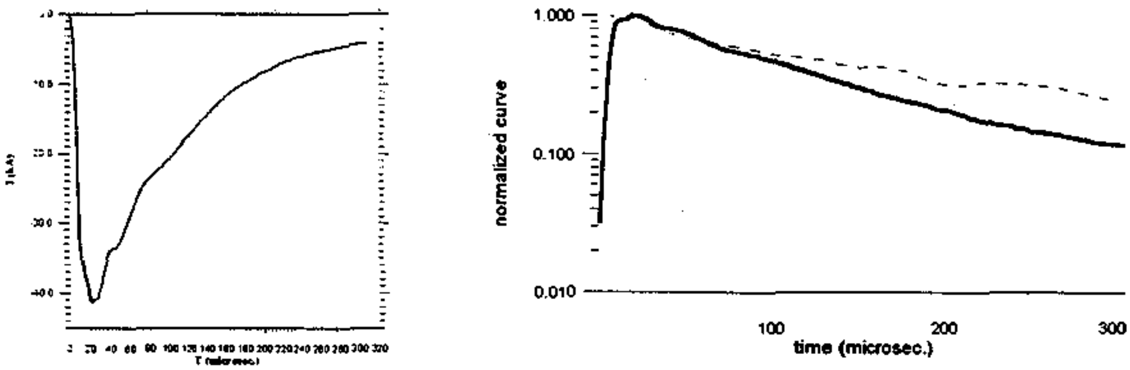
INTRODUCTION

We analyze electric current waveform of 22 negative downward lightning obtained in the CEMIG LIGHTNING RESEARCH STATION (CLRS) in Brazil, between 25/Nov/1985 and 26/Feb/1994. To analyze that, we repeat the same method used for Berger et al (1975) in Switzerland to obtain average curves and then compare both results. The CLRS was acquired from the National Electric Engineering Research Institute (NEERI), Pretoria, South Africa, and installed under orientation of Dr. A. J. Eriksson, and allow to record: a) lightning ground flash activity; b) atmospheric electric field; c) photographic records and video images of lightning within view of two video cameras; d) current waveform and current wavefront to a metallic tower. A 60 m metallic tower is located on the top of a mountain about 1600 m above sea level and 200 m above any other mountain in the region. It captures the discharge and conductes the electric current through a transformer that generates a voltage proportional to the current, before to dissipate it on ground. (NEERI, 1985). The precision in measurements of current and time was initially 760 A and 1 µs and now is 116 A and 0.2 µs, respectively. The data are digitized and stored in a 32 bit HP computer. The collected discharges were summarized by Diniz et al. (1995): 63 discharges (mean number of discharge for year, 7) with 27 (43%) of the negative downward type; there were 17 (63%) negative discharge with only one stroke and 10 (37%) with more than one; median peak current for first and subsequent strokes were 41.3 kA and 16,0 kA respectivly; the mean density of dischage in the region was 5.5 disc./km^2/year.

RESULTS

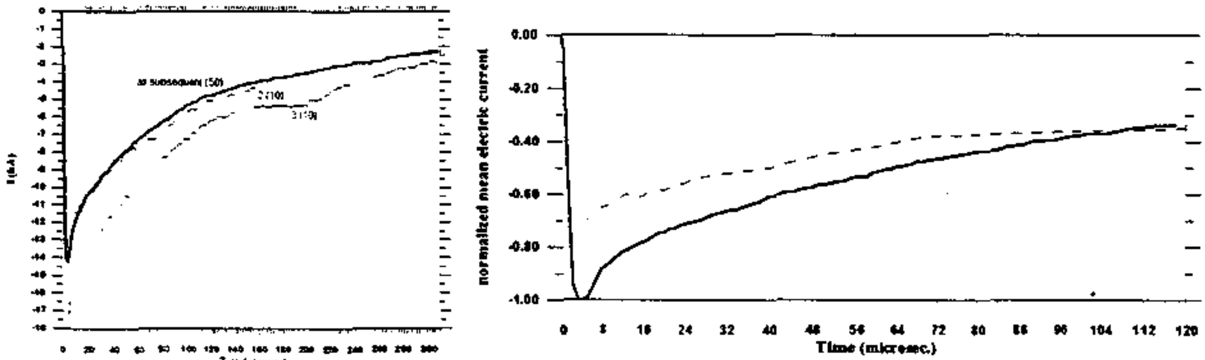
A) Average curves. To obtain average curves we considered 22 descendent negative discharge, corresponding to 22 first strokes and 50 subsequent strokes. In figures 1a and 2a we show average curves without normalization for CLRS first and subsequent strokes, respectively. We compared the shape of waveform and three parameters were used to characterize these differences: peak current (I_{peak}), time to peak (T_{peak}) and time to half value (T_{hpeak}, the time when $I = 0.5*I_{peak}$, decreasing). Differences are shown in figures 1b and 2b, where normalized curves are presented. For first strokes the inclination of the tail in a mono-log paper are different, although in both cases (Switzerland and Brasil) they are closed to straight lines. In figure 2a we present average curves for all subsequent strokes (full line, 50 strokes), for second (10 strokes) and third strokes (10 strokes). There was no significative difference in shape between curves 1a and 2a when normalized compared with curves 1b and 2b, respectively, obtained using Berger's method of pre-normalize curves before averaging them. Strokes in CLRS showed higher I_{peak} and T_{peak} than Switzerland data for first and subsequent strokes. The values obtained for first strokes were, respectivley:41 kA, 22 µs (T_{hpeak} = 88 µs) in Brazil versus 30 kA, 13 µs (T_{hpeak} =112 µs) for Switzerland and for subsequent 14 kA and 4 µs (T_{hpeak} =60 µs) in Brazil versus 12 kA and 1 µs (T_{hpeak}= 37 µs) in Switzerland. The third strokes average waveform presented itself more intense than second in CLRS (Lacerda et al. 1997a, and Lacerda, 1998).

B) Derivative current for first and subsequent strokes. In figures 3a and 3b we show the normalized average derivative current (di/dt) for first and subsequent strokes, respectively. The dashed line is the average normalized current. Peak values used for normalizing curves were around 5.76 kA/µs and 4.92 kA/µs for first and subsquent strokes, respectively. As we used the worst time scale precision for obtaining the derivative current pattern showed



(a) (b)

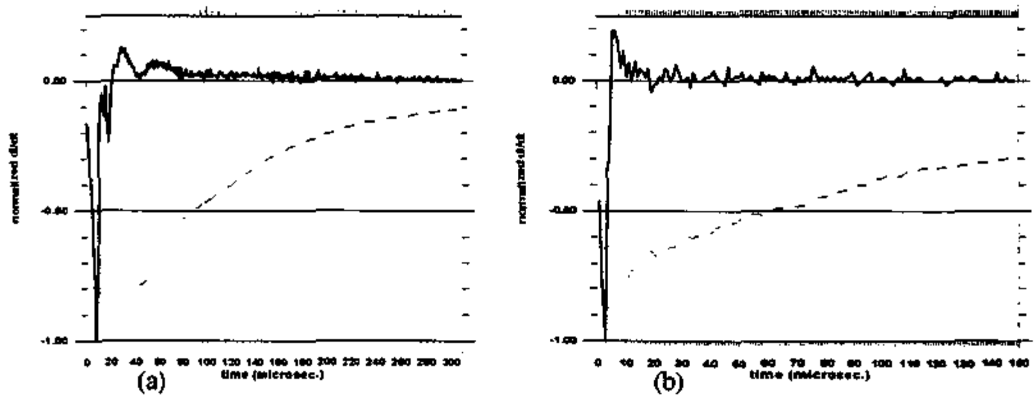
Figure 1 a) Average waveform for first return strokes of CLRS; b) Comparison of CLRS normalized waveform (full line) with Berger's data (dashed line).



(a) (b)

Figure 2 a) Average waveform for subsequent return strokes of CLRS data; the numbers inside brackets are total of analyzed data and outside brackets refer to the order of stroke; b) Comparison with Berger's data (dashed line) for subsequent normalized waveform.

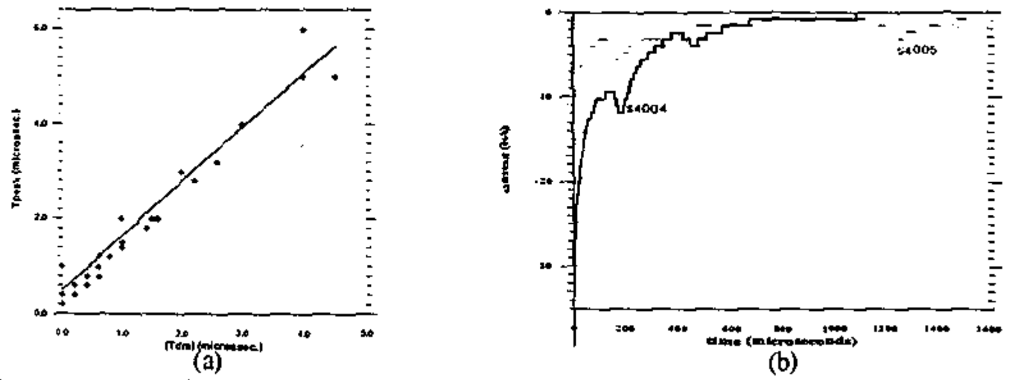
in figures 3a and 3b, the absolute values of di/dt before normalization are probably underestimated. Mean value for maximum di/dt in subsequent strokes calculated using individual curves is around 32.82 kA/µs (Lacerda et al 1997b). This means that these values may be at least 7 times bigger. Even so, we believe that the normalized pattern obtained is still representative of an average pattern.



(a) (b)

Figure 3 a) Average derivative electric current for first stroke; b) Average derivative electric current for subsequent strokes; in both cases (a) and (b) dashed lines are curves 1a and 2a normalized.

c) Correlation between T_{peak} and T_{dm}; m-components. The figure 4a shows the correlation between T_{peak} and the time when occurs the maximum derivative current for subsequent strokes (T_{dm}). The fit equation is $T_{peak}=1.1397*T_{dm}+0.51$, and the coefficient of determination, R-squared is 93,66% (Lacerda et al, 1997b).In 11 return stroke waveforms of subsequent strokes of order higher than 2 we found 13 m-component like those shown in figure 4b, where two strokes. 4004, and 4005 are presented. A detailed study of all m-component can be found in Lacerda et al (1997c) and Lacerda (1998). In table 3 we summarize the parameters studied and compare them with the same parameters obtained in Florida and Alabama (Fisher et al. 1993). The elapsed time Δt_m, is the instant of time when the M-component starts after the beginning of return stroke. I_{cc} is the continuing current level. I_m is the magnitude of m component (peak value) (Thottappillil et al. 1995) with mean value of 308.09 μs. 5.03 kA and 3.22 kA respectively.



(a) (b)

Figure 4 a)Correlation between the time to peak current (T_{peak}) and maximum derivative current (T_{dm}); b) Four m-component in 2 strokes. The first two numbers beside the curve represent the discharge and the last two, the stroke.

Geometrical means (GM) are 237.56 μs, 3.69 kA and 2.37 kA, respectively. These differences occur because CLRS m-components are near m-components, while those of Florida and Alabama are far m-components (Lacerda et al 1997c). Near m-components are faster and stronger than the far m-components. The total analyzed data are presented between brackets.

TABLE 1. Parameters of m-component in CLRS compared with Florida and Alabama.

m-component	Δt_m	I_{cc}	I_m	$t_{1/2}$
CLRS	237.57 μs (13)	3.69 kA (13)	2.37 kA (13)	120 μs (13)
Florida	11 ms (80)	195 A (55)	84 A (62)	874 μs (59)
Alabama	7 ms (78)	159 A (66)	164 A (62)	757 μs (54)

DISCUSSION

Differences between CLRS and Switzerland data presented in this paper are important because they put several questions: a)are these differences due to systems of measurement used to capture and record data, or they are related to the lightning discharge itself? b) are lightning discharge waveform latitude dependent? c)Will differences remain when we extend data analysis of CLRS to cover the period between 1994 to 1999?The answer to the these questions includes to examine normalized average waveform of other set of data obtained in different conditions (Eriksson, 1979; Garbagnati and Lo Piparo, 1970; Fisher et al. 1993; Zundl. 1994; Montandon and Beyeler, 1994) in order to note the similarities or differences between them and increase data set of CLRS with data collected between 1994 and 1999.Trying to solve the second question. Pinto et al (1997) have argued that peak current may be latitude dependent. Peak current has a value of 40 kA from the equador to the latitude of 30° and a value of 30 kA for higher latitudes (Pinto et al. 1997).Third strokes were more intense than second. Rakov and Uman (1990) found similar result analyzing geometrical mean of electric-field peak. In CLRS all the average curve of third stroke are bigger than second. This fact suggests that may be there is a possible new mechanism not well understood between second and third strokes.The CLRS has collected waveforms in a better precision (116 A x 200 ns) after 1994 and will allow to improve the calculus of di/dt. This result could be used to establish voltage across indutive path in direct strokes, and calculate distant radiation in some particular cases.The instant of time of maximum derivative current is correlated to the instant of peak current. This fact may indicate that the current waveform presentes approximatly the same shape, for all discharges (Lacerda et al, 1997b). Near m-component could be better understood from analysis of current waveform in other research stations. M-components introduce a large variety of rate of increase in current waveform which could difficult the performance of electronic devices used in surge protection systems.

CONCLUSION

In this paper is presented an analysis of negative descendent cloud to ground lightning captured by a 60 m metalic tower between 1985 and 1994 in the "Morro do Cachimbo", research station. The main conclusions of this analysis are: 1) Strokes in CLRS showed higher T_{peak} and I_{peak} than Switzerland data for first and subsequent strokes average normalized waveforms. The values found are 22 μs, 41 kA for first strokes, respectively and 4 μs, 14 kA for subsequent strokes, respectively: T_{hpeak} were smaller (88 μs) in first and higher (60 μs) in subsequent strokes than in Switzerland. 2) The third strokes average waveform presented itself more intense than second; 3) The obtained normalized pattern for di/dt was established and even considering that calculated values are underestimated, this average pattern is still representative; 4) Near m-components registered in CLRS are faster and stronger than far m-components registered in Florida and Alabama.

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