THE AUTOMATIC LIGHTENING LOCATION SYSTEM AND ITS IMPLICATIONS FOR THE NIGERIAN ELECTRONIC POWER SYSTEM

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ABSTRACT

The incidence of cloud-to-ground lightening flashes in a usual occurrence during thunderstorms. In order to minimize the numerous hazards caused by lightening on electric power systems, knowledge of the lightening phenomenon is necessary. In most tropical countries including Nigeria, the frequency of lightening flashes is fairly high and the lightening ground flash in known to be responsible for the vast majority of power outages experienced in the power supply systems of these countries.

An automatic lightening location system of the lightening Location and Protection (LIP) type has been used in Sweden to investigate some parameters of ground flashes. The results obtained are presented and analysed. The application of lightening information to electric power system is also discussed. Lightening data is found to be very useful for proper planning and operation of power systems. The implications of the lightening location system for the Nigerian electric power system are also highlighted.

1. INTRODUCTION

Due to the fact that the occurrence of ground flashes is unpredictable, electric generating stations, transmission lines and substations have to be adequately protected. High voltage transmission lines are often equipped with continuous overhead earth wires which arrest any lightening flashes arriving on them. This practice often increases the initial line costs. At the level of distribution of some protective measures are adopted so as to reduce the damage or destruction of electrical equipment and possible loss of service to customers. Even the power equipment installed at substations have to be protected from the ground flash. Therefore, it is important to have a very good understanding of lightening characteristics in order to achieve satisfactory protection for the power system.

Research on lightening and its impact on electric power systems have for many years been going on in advanced countries (1, 2) where the incidence of lightening is not a frequent as in the tropic areas. Brookes [3] was the first to investigate a general survey of thunderstorm data and published maps of the global distribution of thunderstorm days. According to Muller-Hillerbrand et al. [**4**] and Golde [**5**] the isokeraunic level of a place has for many years served as the traditional tool for estimating the frequency of lightening activity in many countries. However, Horner **[6**] and Changnon and Changnon [**7**] have pointed out that the use of the isokeraunic level statistics as a reliable measure of thunderstorm activity may have serious limitations. Later the idea of measuring the lightening flash density replaced the use of the isokeraunic level. This led to the design of the lightening flash counter (LFC) by some workers [**8, 9**]. In recent years, however, the automatic lightening location system has overtaken the lightening flash counter as a reliable means of measuring various lightening parameters.

The LLP type Swedish automatic lightening location system has been used in this investigation. The results reveal that the system is useful to electric power utilities such as the National Electric Power Authority (NEPA). The paper advocates the development of the power industry in Nigeria will be enhanced by the installation and operation of the lightening location system.

2. METHODOLOGY

Although lightening flashes can be detected by visual and aural observations and by lightening flash counters, the use of the automatic lightening location system is the most recent development in lightening tracking and mapping. Presently, for operational location of ground flashes the lightening location system is based on two principles namely: the time-of-arrival (TOA) principle, in which case it is called the Lightening Positioning and Tracking System (LPATS), and the magnetic loop direction finder technique which is the LLP direction finder system. Details of the TOA method have already been described by Bent and Lyons [10]. The LLP direction finder system has been used for the work reported here.

2.1 The Magnetic loop Direction Finder system.

The automatic lightening location
system (the LLP type) is currently operating **4.**
in may countries including the United States, **5.**
Canada, Mexico, Sweden, South Africa and France [11]. Basically this system is made up of a Position Analyser and at least two Direction Finder (DF) stations as shown in Fig. 1.

The DF station provides the maximum field change of the first return stroke, the multiplicity and time of the flash. The DF stations send their data to the Position Analyser (P A), which computes the actual location of the flash by the method of triangulation since the geographical co-ordinates and the distances between the DF stations are known. The PA is usually connected to a chart plotter for mapping of the located lightening; and to remote display
processor system used to display the location, **5.1**
intensity, motion and evolution of lightening **5.2**
storms in both space and time. Flash data may also be stored on magnetic tapes or in the host computer for future use. Data printouts can be obtained from printer terminals that are connected to the system. A data printout of localized ground flashes normally has columns which represent values for Date, Time, Latitude location, Longitude location, Amplitude and Multiplicity of the localized flashes.

3. THE SWEDISH LIGHTENING LOCATION SYSTEM

This system is the standard high-gain LLP type with a nominal range of 370 km. The DF stations are at distances of between 250 to 500 km apart. The system consists of 8 DF stations connected by telephone lines to a PA located at Uppsala. A magnetic tape recorder, a hardcopy pen plotter, a data terminal and video displays are also connected to the P A. A detailed description of this system has been given by Pisler [2] and Isreaelson et al [13]. The sites of the Swedish DF station stations are shown in Fig. 2. according to Israelson et al [14], the detection efficiency of the system is between 80 and 90 per cent although it may fall to about 60% in certain parts of the system during intensive thunderstorm [**15**].

4. RESULTS

Ground flash lightening data for the 1987 Swedish lightening season which were obtained by using the automatic lightening location system based in Uppsala are analysed and the results are presented and discussed.

4.1 Distribution of Ground flashes

The distribution of negative and positive ground flashes during the lightening season of 1987 is shown in Figs. 3 and 4. Both figures seem to indicate that the peak periods of activity for both negative and positive ground flashes occur in the month of July. The majority of the negative flashes are concentrated between May and September, while the highest counts for positive flashes seem to be from June to July.

4.2 Case Studies

Some negative lightening flashes localized by the Swedish automatic lightening location system have been chosen for analysis. The signal strength, multiplicity, maximum signal strength variation and temporal intensity for the lightening flashes have been analysed and the results are presented.

4.2.1 Signal Strength

Signal strength has been performed on first return strokes in ground flashes that were localized on 12th July, 1987 between 07:56 and 14:07 hours Universal Co-Ordinated Time (UTC) giving a total of 349 negative lightnings spread over a geographic region that lies from latitude 52 degrees 51 minutes to 54 degrees North, and from longitude 15 degrees 11 minutes to 17 degrees 23 minutes East as shown in fig 5. Log normal nalysis performed on the localized strokes and the signal strength normalized to 100km distance is shown in fig.6.

The basic statistics gave a mean value of 4.748 and a standard deviation of 0.418. The mean value of 4.748 corresponds to 115.4 LLP arbitrary units which when multiplied by a system factor of 0.336 given by the manufacturers of the system, gives a mean current value of 39 kA which is close to values in literature [**6**].

4.2.2 Multiplicity

Multiplicity of a lightning flash can be defined as the number of return strokes contained in the flash. The multiplicity distribution of the number of negative flashes localized on 12th July, 1987 is shown in Fig. 7. A typical distribution of the multiplicity of positive flashes as shown in fig. 8. It is seen that while negative flashes have a multiplicity value of at least two, most positive lightning flashes have only one return stroke.

4.2.3 Maximum Signal Strength Variation

Knowledge of the maximum signal strength of lightning flashes is essential for adequate design of electrical equipment such as lightning arrestors and other protective equipment. The maximum signal strength variations in July 1987 for negative and positive lightning are shown in figs 9 and 10 respectively. The results seem to indicate that positive lightning flashes display maximum values than their negative counterparts.

4.2.4 Temporary intensity

Temporal intensity analysis has been performed on lightning flashes localized on 12th July 1987. The analyses for both negative and positive flashes have been carried out over a 24 hour flash duration. A time interval of 10 minutes was chosen in order to dentify the return strokes. The average count intensity per 10 minutes for negative and positive flashes are shown in fig. 11 and 12 respectively. The figures seem to indicate that positive flashes attain maximum count before the negative ones.

5. Application to power systems

The major objectives of an LLP system is to increase our knowledge of lightning characteristics in order to have a better assessment of lightning severity and hence develop new methods for adequate protection of power systems. When lightning strikes a power line an over current is injected into the line. The over voltage may give rise to a flashover across the line insulator string if the over voltage is greater than the basic line insulation level of the line insulation. Hence a proper knowledge of lightning parameters is of vital importance for insulator designs.

The LLP system can be used to construct real-time hardcopy, lightning maps from which supervision of dispatch centres can anticipate the approach of lightning storms, estimate their severity and then preposition holdover or call out repair crews. The use of the LLP system will enhance the effectiveness of the National Control Centre, Osbogbo in the absence of a very functional Supervisory Control and Data Acquisition (SCADA) equipment in Nigeria.

With the use of on-line charting of lightning activity, it could be possible to determine whether a circuit breaker lockout is due to a permanent fault. This could be very advantageous reducing servicing restoration time and costs. The use of the LLP location system saves time, allows for efficient use of resources for power outage restoration and improves the distribution system availability.

In Sweden, the Swedish State Power Board which is the authority that is responsible for the operation of the Swedish power system, has been among the first users of the LLP system based in Uppsala. The Board is interested in the LLP system because of security reasons which include the following:

1. A time warning of upcoming severe storms allows the Board to minimize the probability of expensive outages by making changes in the scheme of power generation and distribution in threatened areas.
2. It improves the safety of field maintenance crews before and during the thunderstorm, and their repair efficiency after the storm.
3. Fault detection in power lines is easier when known to be caused by lightning.
4. It gives enough lead-time for assembling extra personnel to cope with any potential emergency. The Swedish State Power Board sees the LLP system data as very useful for. the planning and operation of its power system, for example, in job planning throughout the system and the probability of alternative route for power supply.

5 . Implications for the Nigerian Power System

The automatic lightning location system can be used in Nigeria to provide the ground flash density data of the whole country. This is useful for power line configuration design and evaluation and evaluation purposes. Again, the LLP system is considered an important operational tool for NEPA for the following reasons:

(i) It will ensure proper selection of line routes, so as to avoid areas that have very high ground flash intensities. This will reduce maintenance costs.

(ii) Lightning data from the LLP system can be used to correlate with fault data records: for example, with circuit breaker and recloser operations.

(iii) Real time lightning maps will aid service restoration.

(iv) It will provide early warnings which could be useful for service or repair crews, so that other work on the lines could be performed without the risk of lightning strikes.

(v) (v) NEPA's public image will be enhanced because the Authority will be in a position to accurately inform its customers of sudden unavoidable power interruptions before it occurs. This will enable its customers to make adequate standby arrangements.

(vi) (vi) It will lead to a better formulation of NEPA's protection strategies for its power lines and substations.

7. Conclusions

The Swedish lightning location system (LLP system) has been used to investigate some ground flash characteristic. Analyses of the data from the system seem to indicate a mean current value of 39 kA for negative ground flashes. The maximum signal strength values for positive point to higher values than those of negative flashes have two or more strokes. Lightning information from the LLP system is seen to be useful for good planning and operation of power systems and its obvious implications for the Nigerian electric power system have also been highlighted.

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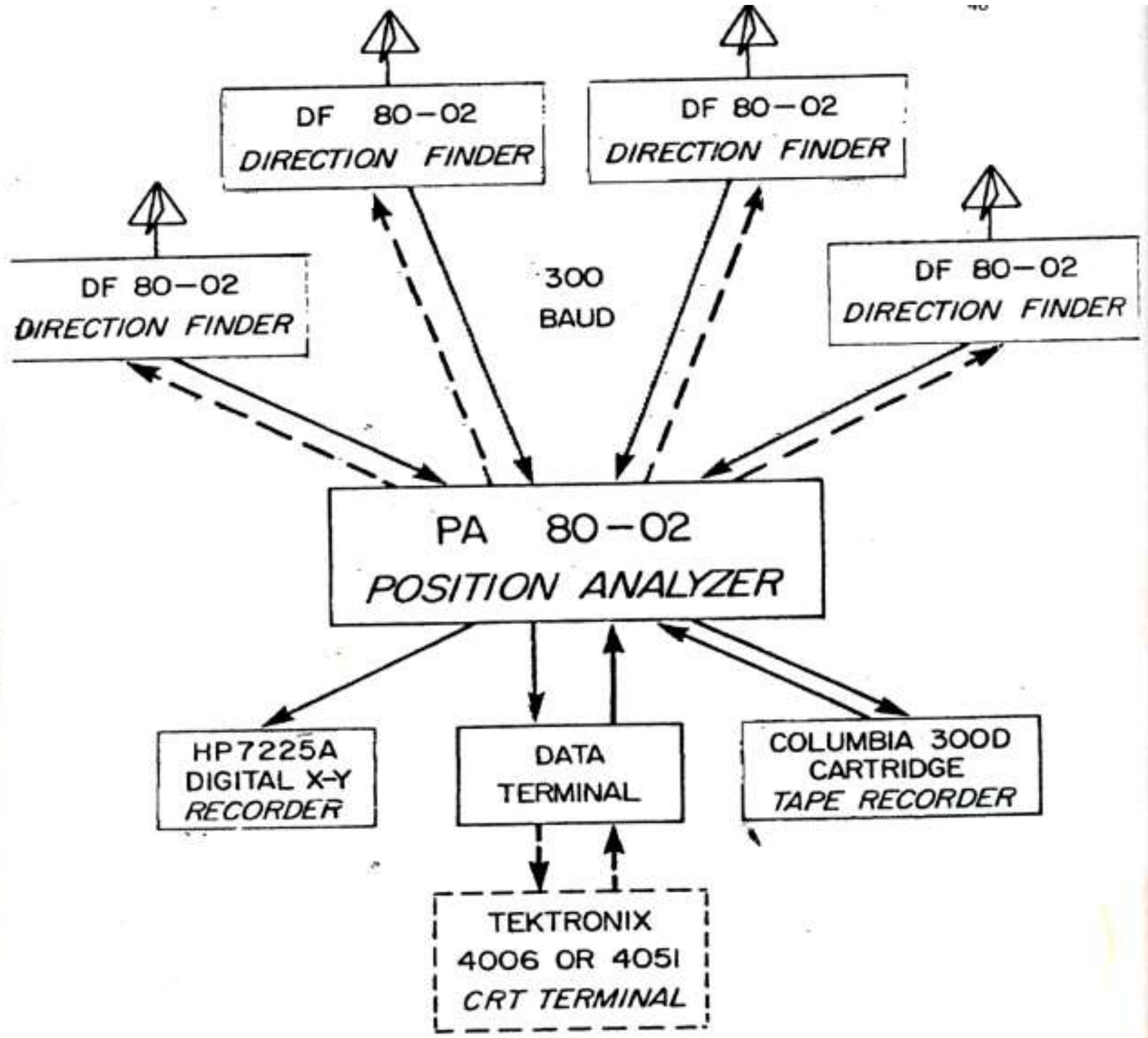


Fig. 1 . A Schematic Diagram of a basic LLP DF System.

FIG. 2: Locations of the Swedish DF stations.

FIG. 3: The distribution of negative flashes from March to October, 1987.

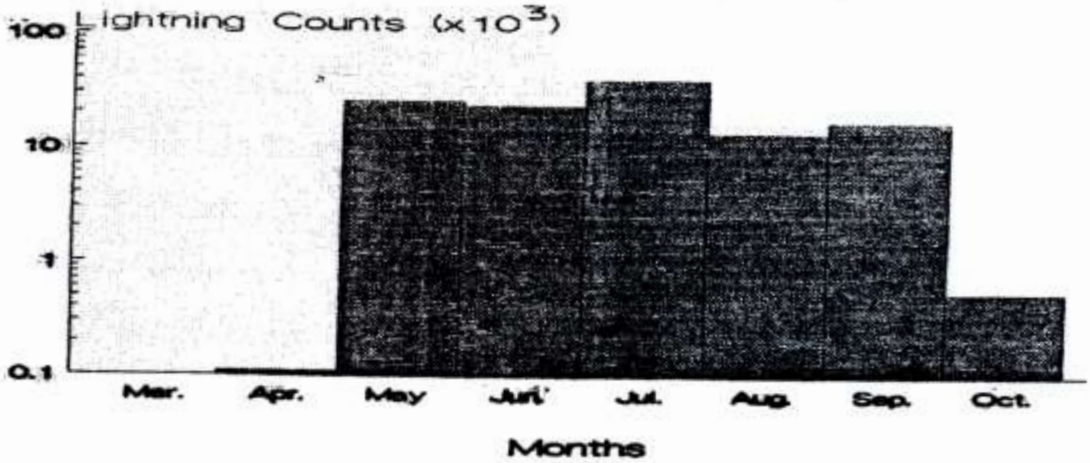
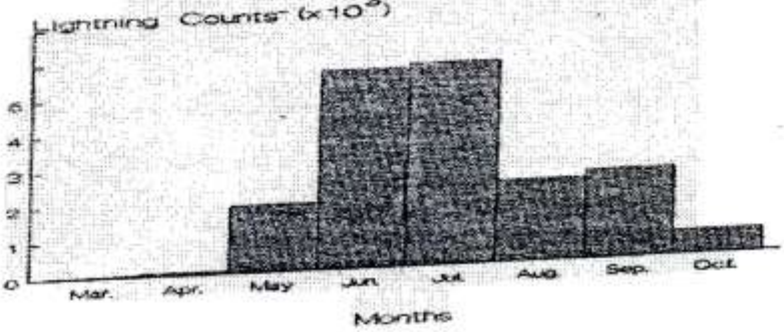


FIG. 4 : The distribution of positive flashes from March to October, 1987



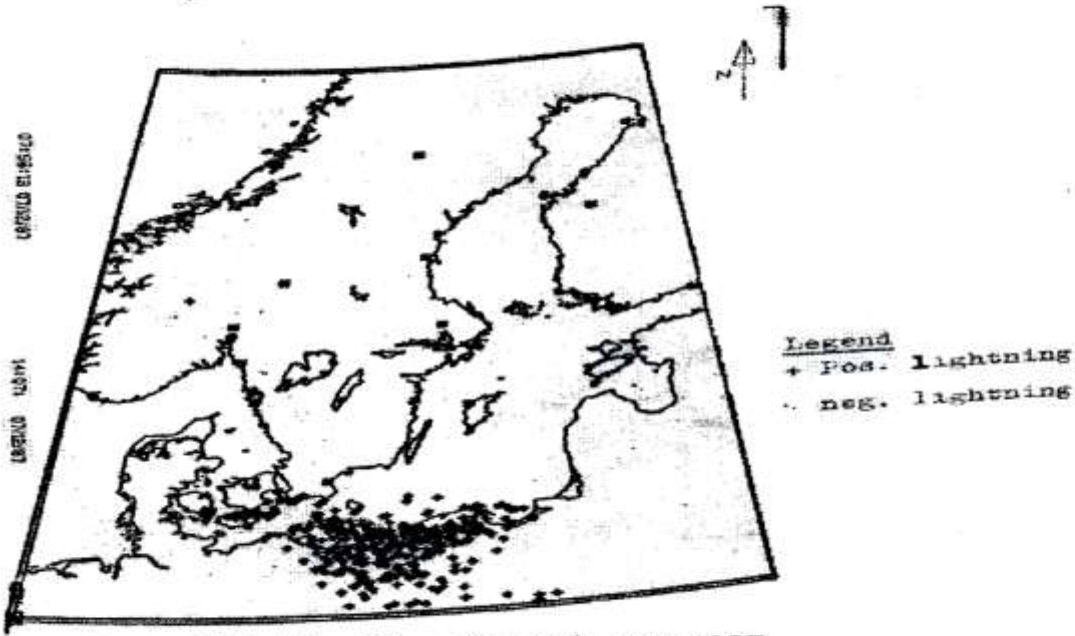


Fig. 5 Lightning Chart for 12th. July 1987

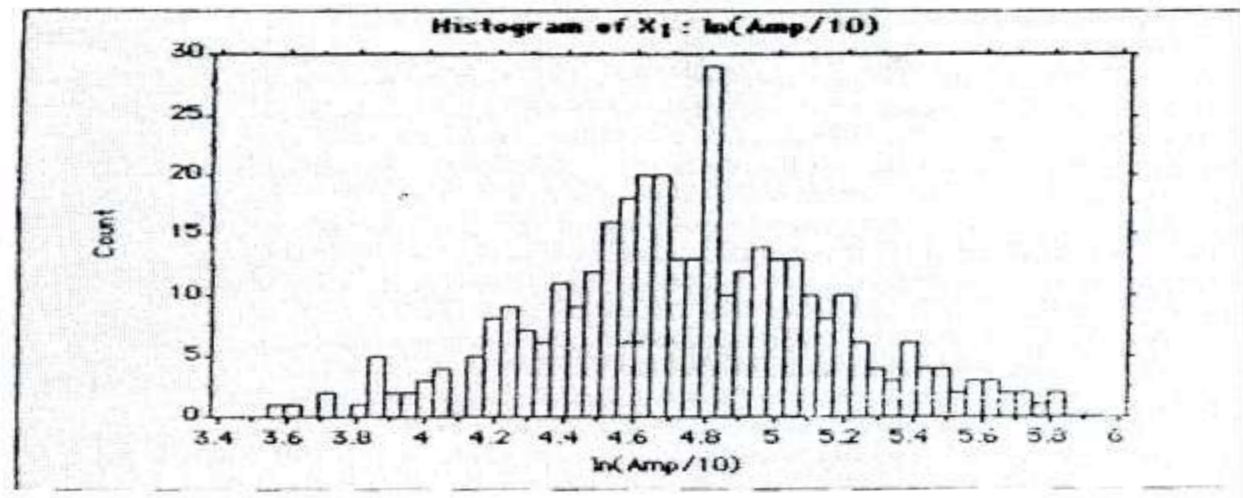


Fig. 6 **Signal Strength Distribution for 349 Lightnings on 12 July 1987**

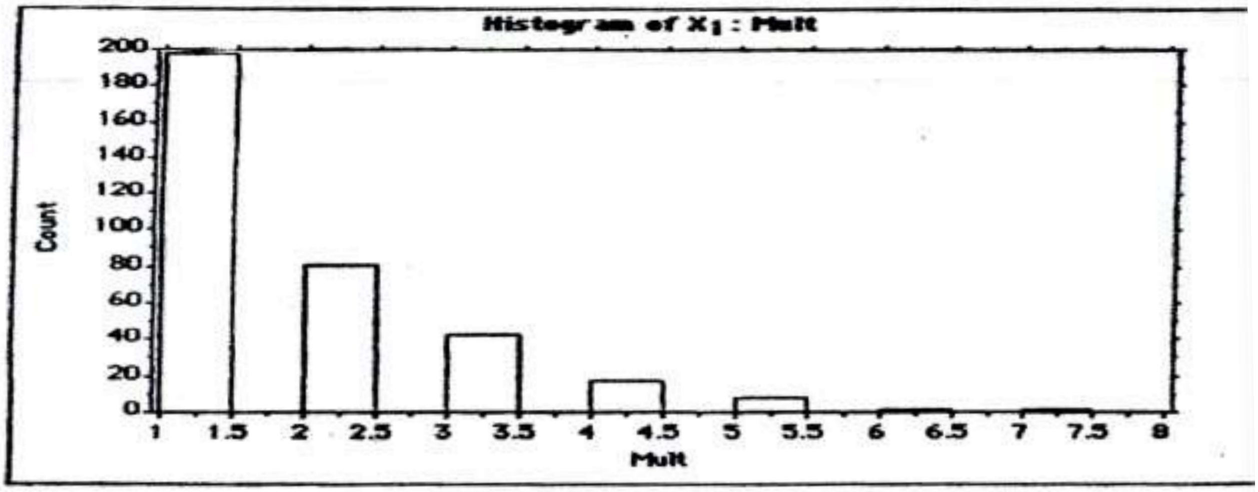


Fig. 7 **Multiplicity Distribution of Negative Lightnings on 12 July, 1987**

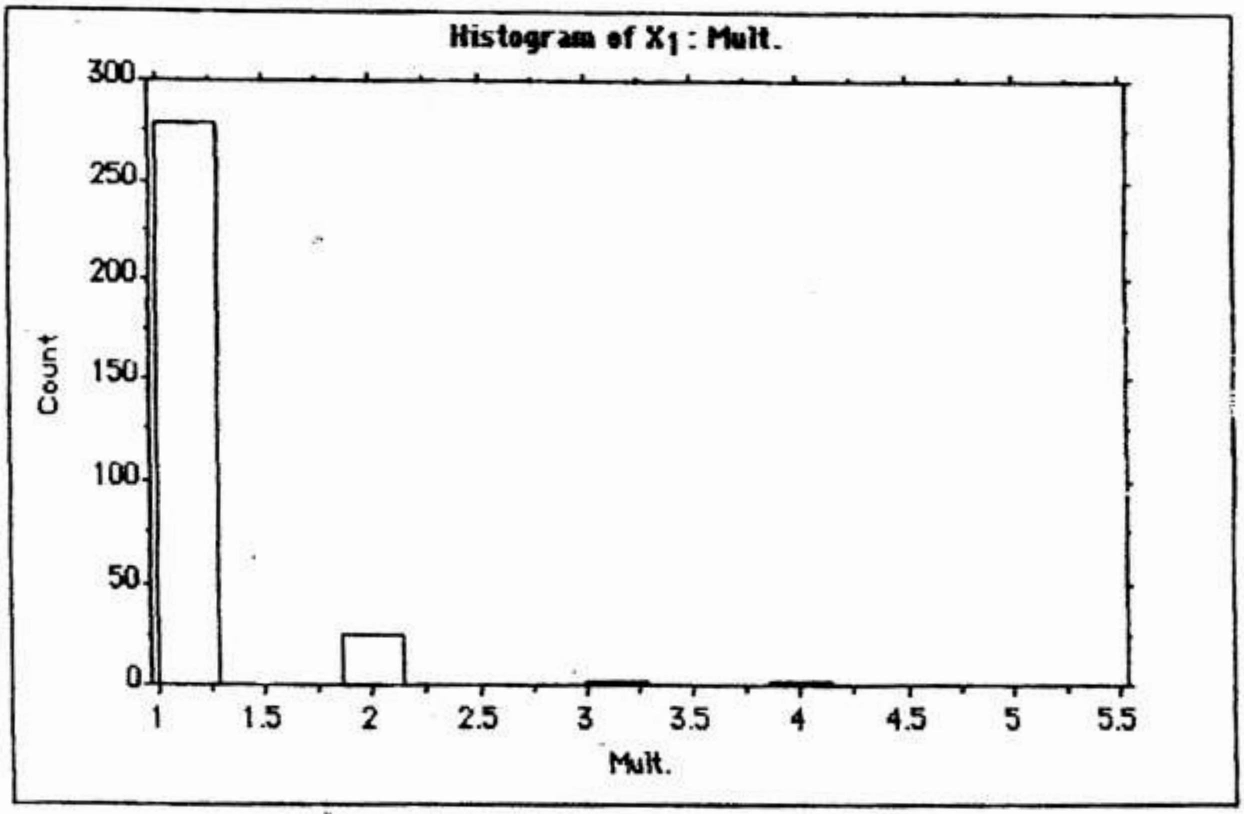


Fig. 8: Multiplicity of Positive Flashes Active on 12th July, 1987.

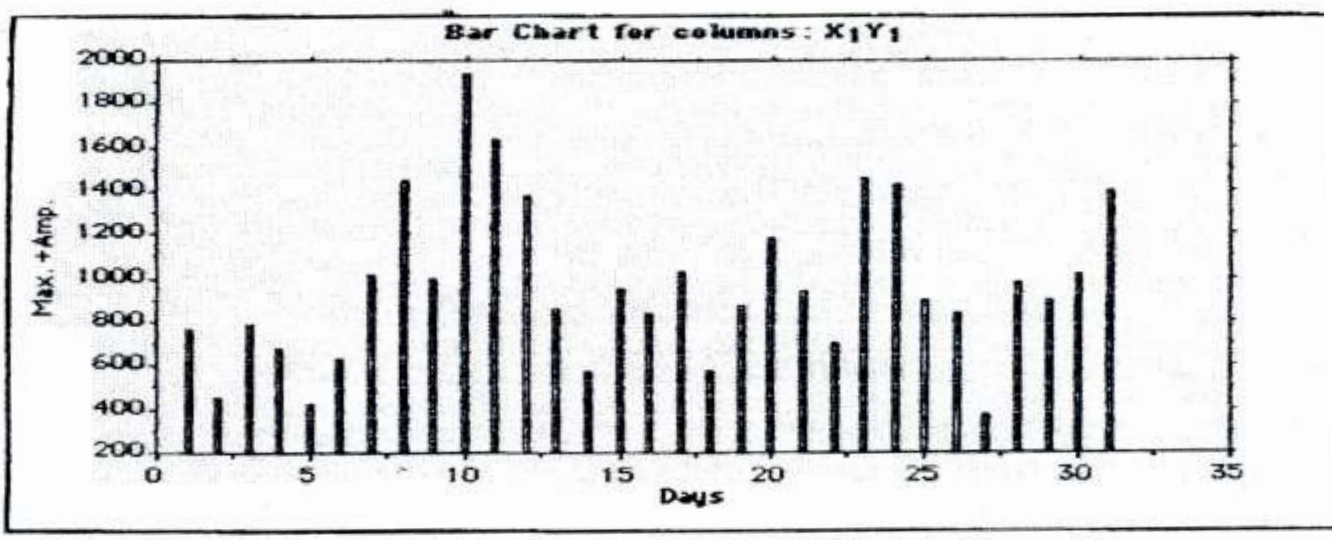


Fig. 9: Maximum Positive Lightning Signal Strength Variation in July, 1987.

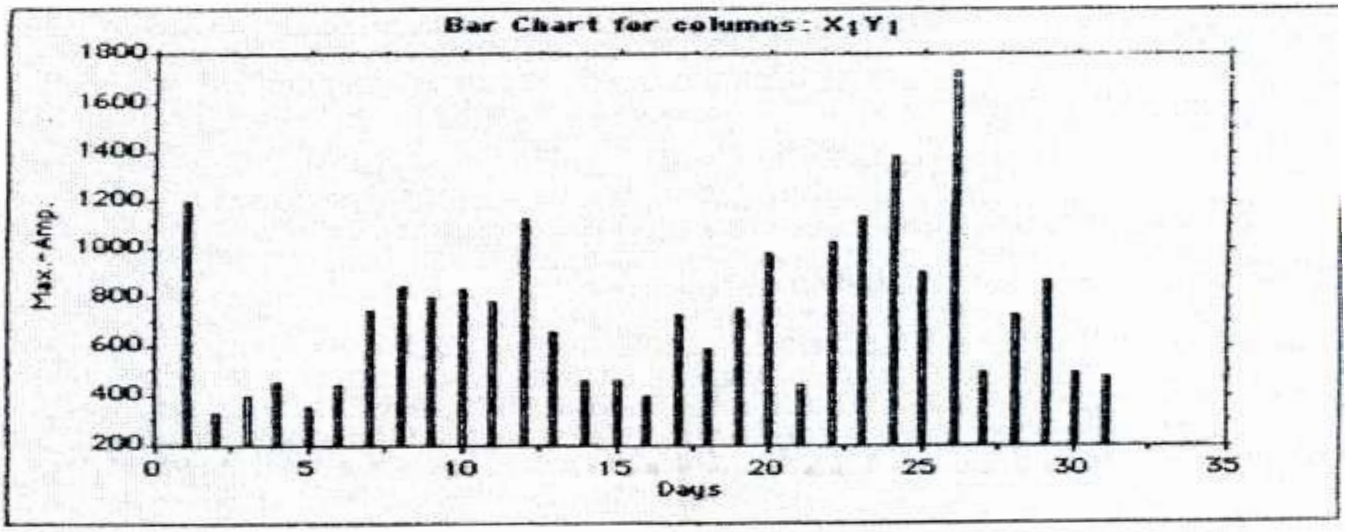


Fig. 10: Maximum Negative Lightning Signal Strength Variation in July, 1987.

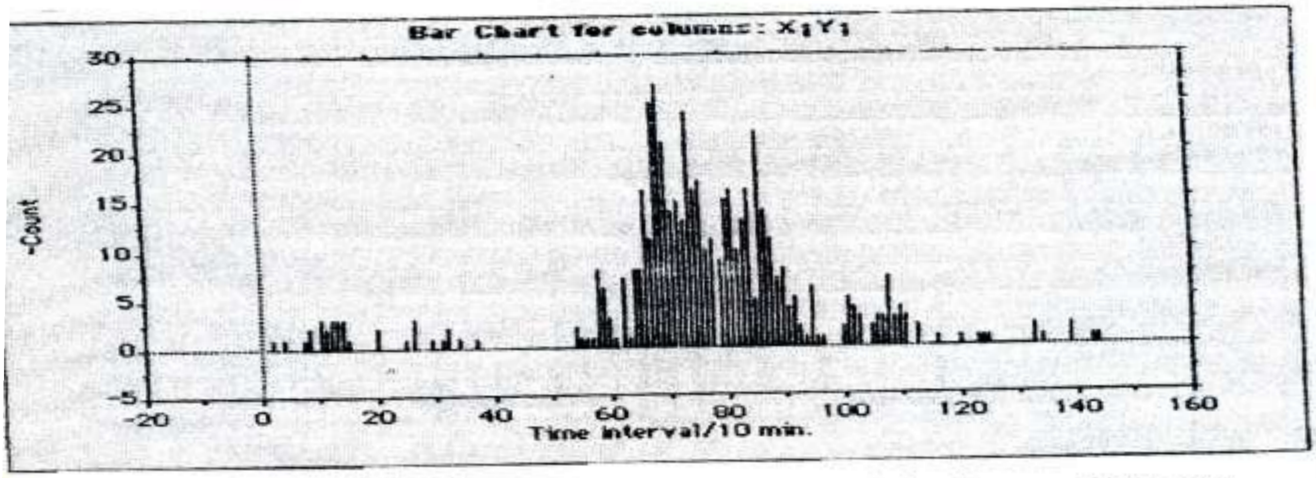


Fig. 11 Average Count Intensity for Negative Lightnings on 12th. July 1987.

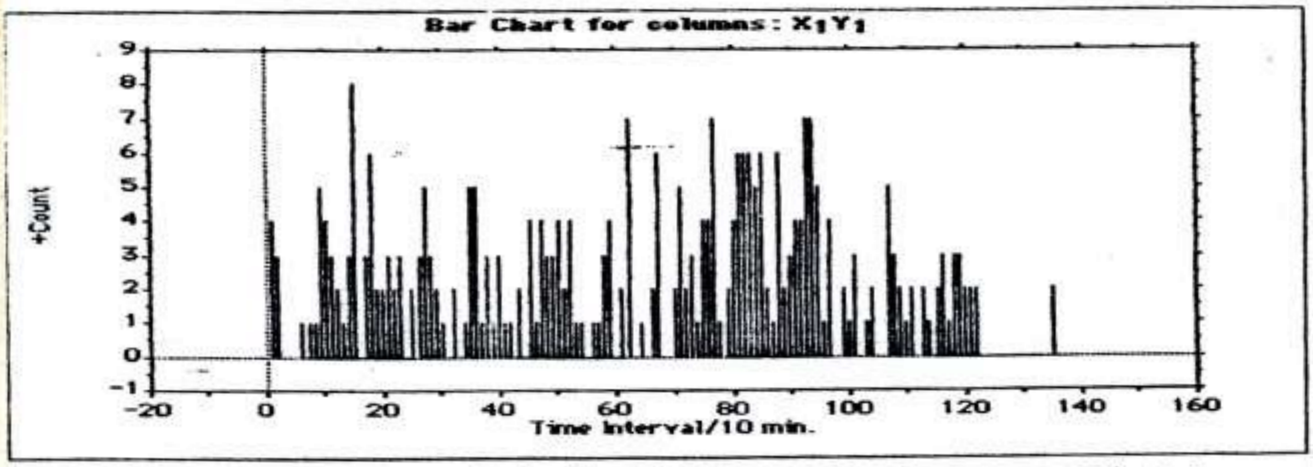


Fig. 12 Average Count Intensity for Positive Lightnings on 12th. July 1987.