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A Real Time Lightning Locating Approcah for the Transmission System in Geographic Information System

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Abstract. The purpose of this paper is development of the coordinates algorithm that combined lightning and transmission line data to quickly search transmission line near the location of the lightning ,and is used to complete the two objectives in the GIS(Geographic Information System): Real-Time warning function, The GIS can quick to show the location of the lightning and the potential impact of transmission lines when lightning alarm occurs; Calculate lightning frequency of the transmission lines over the past few years to know which transmission lines are dangerous sections of the high lightning rate to advance the implementation of the safety measures.

Keywords: Lightning Location Data, Transmission Line, Risk Assessment.

1. Introduction

TPC(Taiwan Power Company) dedicated to the digitization of the existing transmission system and developed online GIS in recent years. The transmission line, towers are marked on the Google Map, and combined the weather information for the development of buffer analysis system to understand towers whether there are potential danger.

Line corridor method is often used to transmission line lightning analysis, that can partitioned transmission line corridor into several regions of equal-area grid, then calculate each grid the number of lightning to analysis of the distribution of lightning [1].Lightning parameter statistics can be calculated by IEEE Std. 1243-1997[2], includes transmission lines each year the number of times per 100 kilometers suffered lightning that is flash collection rate, and calculated shielding failure flashover based on the current intensity and tower height. Now many papers are using [2]-[3] to study lightning-related research, such as: [4]proposed a new risk assessment technology that based on the [2] formulated the equation of lightning performance for the problem on lightning disaster risk of the Three Gorges outgoing lines, establishment and implement of lightning protection improvement, and practical defense effect assessment of lightning protection improvement. [5]this paper combined GIS and statistical analysis of some representative lightning parameters to the study of lightning activity rules in the past number of year, and displayed in the GIS map to assist the lightning preventive construction. [6]-[7]had contrasted the lightning density with different topography of a 220kV transmission line to find out which is the main factor causing the different lightning density, then develop different lightning protection of transmission line based on the lightning activity data.

2. System Architecture

2.1. Lightning location system

The TPC install LLS (Lightning Location System) to collect information lightning in 1989. The system includes six observation stations using the IMPACT (IM-proved Accuracy from Combined Technology), that provided CG (Cloud-to-Ground Lightning) time, location, intensity information. Then installed TLDS (Total Lightning Detection System) in November 2002, the architecture diagram as shown in the upper left corner of the Fig. 1. The system is divided into two parts: LDS (Lightning Detection System) and LIS (Lightning Information System).

Lightning Detection System was comprised of direction finder, position analyzer and data analyzer, The direction finder is SAFIR(Surveillance et Alerte Foudre par Interférométrie Radioélectrique) lightning detection network that consist of seven lightning detection stations to detect all Lightning activity, including IC(Intra Cloud) and CG (Cloud to Ground); The position analyzer was installed at the high-pressure laboratory in the Taiwan Power Research Institute to receives original lightning data that was transferred from each direction finder by the lines of communication, then calculated and stored the location of the lightning(latitude and longitude), peak current and polarity data in database; The data analyzer provides the collection of lightning for researchers in the Taiwan Power Research Institute. The TLDS is only lightning detection system in Taiwan, other agencies also purchased lightning data from TPC for their own system, so TPC established lightning information system for this purpose.

When lightning occurs, LDS will automatically save original lightning data into database, then LIS that also located in Taiwan Power Research Institute automatically download original lightning data for every hour from LDS by the intranet. According to the different needs of the aviation, meteorology, and transportation LIS will provide the lightning data after processing for Hsinshu Science Park, Taiwan Railway Administration, Taiwan Central Weather Bureau, etc. by the internet.

2.2. Geographic information system

This research developed a GIS as shown in the upper left corner of the Fig.1 that installed in the TPC Executive Administration Office. The system collects all TPC transmission line data, including tower coordinates, height, types of transmission lines and types of Insulators in the database, and combined with Google Maps to show data. Let users search line information on digital maps.

One of the purposes of this paper is to integrate new build GIS with existing TLDS in the TPC to display lightning and Tower information and coordinate on the Google Maps at the same time. So this paper developed a transmission line lightning detection system, not only reduce the time of the query data to improve the efficiency of the transmission line Management, but also provide users with an easy to use online GIS, let TPC engineers get the most complete information of the accident in the fastest time.

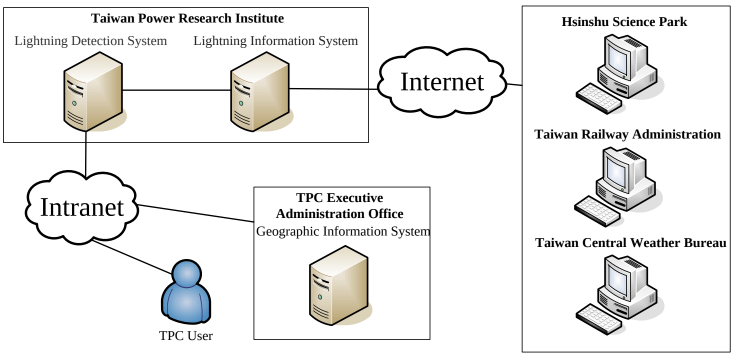

Fig. 1: Diagram of the Lightning Location System.

3. Lightning Impact Area Search Method

In order to find the position of transmission line closest to the position of lightning to count lightning frequency in GIS that is real-time operation ,so the algorithms can't too complex. This paper design a algorithms that uses simple geometric operations to find the transmission line coordinate closest to the each position of lightning.

First ,define what is meant by the position of transmission line closest to the position of lightning; As Fig. 3 shows, There are #1, #2 two towers and connected sections of transmission line in figure If the position of lightning have orthogonal point on the sections of transmission line (points A and Apro in figure), the shortest distance is vertical straight line connecting position of lightning and sections of transmission line; If don't have orthogonal point (points B and C in figure), the shortest distance is straight line connecting position of lightning and nearest the tower.

A power transmission line has many towers, the straight line connecting two towers are called section that can be shown as linear equation: y = ax + b, a power transmission line is composed of several sections. Therefore GIS use section as the smallest unit in the database, information contains numbers and the coordinates of the starting tower, numbers and the coordinates of the ending tower and a, b value of the linear equation.

As Fig. 3 shows, That have a line segment that joins the tower V1(x1,y1) to tower V2(x2,y2). The linear equation y = ax + b substituted into V2(x_2, ax_2+b), let x_2 = 1 substituted into linear algebra orthogonal projection formula that can be rewritten as:

$$Upro = \left(\frac{u_1 + (u_2 - b)a}{1+a^2}, \frac{au_1 + (u_2 - b)a^2}{1+a^2} + b\right) \cdots \qquad \text{…. (1)}$$

$$a = \frac{y_2 - y_1}{x_2 - x_1}, \quad b = y_2 - ax_2 = y_1 - ax_1$$

The straight line distance of U to Upro is:

$$\overline{UUpro} = \sqrt{\frac{(u_2 - b - au_1)^2 a^2 + (au_1 + b - u_2)^2}{(1+a^2)^2}} \cdots \qquad \text{………. (2)}$$

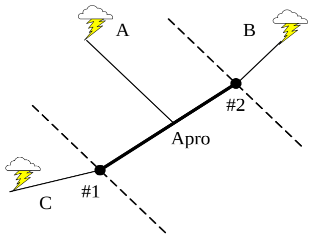

Fig. 2

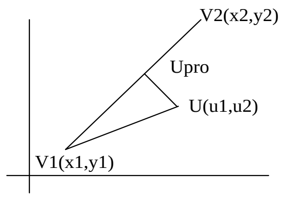

Fig. 3

We set shortest distance between position of lightning and transmission lines shall not be greater than 100 m. That is when the lightning, we just need to search section within a circle whose center is coordinates of lightning of radius 100m to calculate the shortest distance. As Fig. 4 shows, the r is the radius of the circle, and then the coordinates (x, ax+b) of the straight line equation substituted:

$$x^2 + (ax+b)^2 - 2u_1x - 2u_2(ax+b) + u_1^2 + u_2^2 - r^2 = 0$$

$$(1+a^2)x^2 + (2ab - 2u_1 - 2au_2)x + b^2 - 2bu_2 + u_1^2 + u_2^2 - r^2 = 0$$

If this equation have real solutions, indicates that the section is secant line of circle, and the shortest distance to position of lightning is less than the radius r.

When lightning occurs, we can't determine the secant line with all transmission lines, this requires a lot of calculation amount and reduce the processing speed. Also need to check the coordinates of two end of the section to confirm the presence of the secant, as Fig. 4, # 1 and # 2 Tower connected straight line fact no in the circle of lightning. Therefore, in order to save computing time, we need to filter section of the tower coordinates near the position of lightning. But as Fig. 5, most of the length of the line is greater than 100m, if direct search the tower coordinates within the range that will still have many omissions in the database, so it is necessary to increase the search range as Fig. 6.

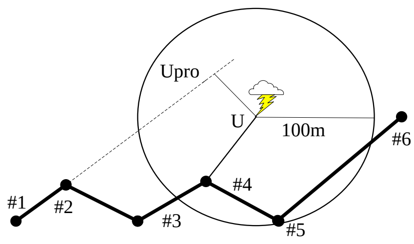

Fig. 4

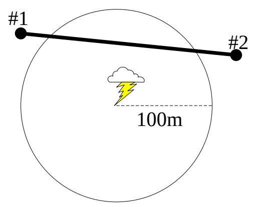

Fig. 5

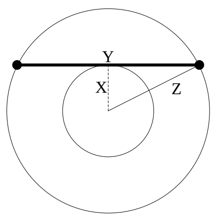

Fig. 6

X is the shortest distance limit 100m, Y is the longest length of the section of transmission line, Z is the Tower search range by $Z = \sqrt{X^2 + (Y/2)^2}$ calculated.

So the system will divided Taiwan into a number of rectangular area, then based on the area's longest length of the section of transmission line to set the Y value of each area. Flowchart shown in Fig. 7, when lightning coordinates occurs, the system will be based on the coordinates fall in the area to determine the Y value, X is 100m to calculate the value of Z as the actual search range of lightning coordinates to filter the tower within the range. Then search out the section of connected tower to check whether section is secant line of radius X of circle to filter small number of the section 100m away from the position of lightning.

As Fig. 4 found #3~#4, #4~#5, #5~#6 three sections out, then used Fig. 2 method to judged whether each section has orthogonal point, or nearest the tower coordinates. For example, sections #3~#4 and #4~#5 doesn’t has orthogonal point, the shortest distance is straight line from position of lightning to Tower #4; Section #4~#5 has orthogonal point, used formula (2) to calculate the shortest distance to the orthogonal point. Finally compare these distance of the sections, we can found out the shortest distance from the position of transmission line closest to the position of lightning.

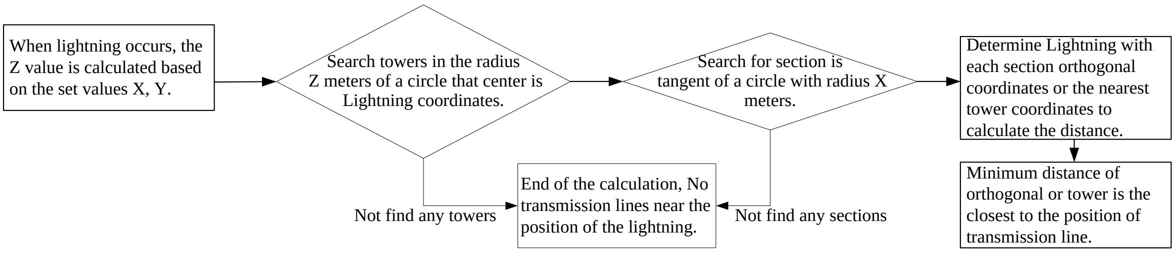

Fig. 7: Lightning impact area search method flowchart

4. Analysis of Application

The Features of the algorithm is fast computing of GIS in real-time, whenever location of the lightning is detected, the system will search section near the lightning coordinates. As Fig. 8, when the transmission line is found near 200m to lightning, the lightning maybe impact transmission system, so specially marked in GIS. Users can click on the lightning symbol to check information about the location, strength and time of the lightning, and can also learn location and distance of transmission line closest to the position of lightning from the map. If TPC user received fault message, they can search for the cause of the fault from the location of the vicinity of lightning.

GIS can also be displayed lightning location of transmission lines over the past few years, in order to enables users to understand the lightning distribution to calculated and analyzed. As Fig. 9, there is transmission lines and many of lightning locations that are distance to transmission lines of 200m or less in July 2005, these lightning may damage the transmission lines, so that transmission line need higher lightning protection measures.

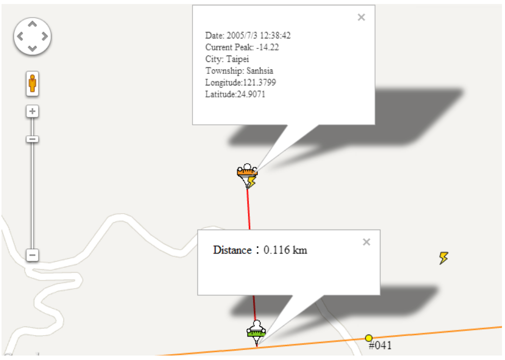

Fig. 8

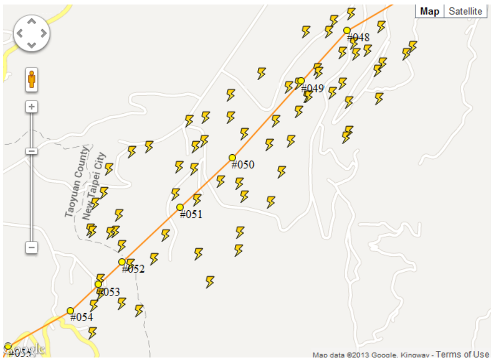

Fig. 9

We can also use the table to analysis of the distribution of Lightning. For example in the summer of 2005, the lightning has higher frequency in the July, and Taipei area has about 2,000 lightning data. Taipei Panchiao to Longtan line has 81towers, 247 lightning data in the July, as shown in Table 1, that is statistic of the number of lightning in part of the section of Taipei Panchiao to Longtan line in July 2005. We marked lightning that are distance to transmission lines between the 0m~50m, 50m~100m and 100m~200m, from this table, it is easy to find out that the difference of Lightning frequency in different section. The smaller the distance is more likely to affect the transmission line, therefore, we can formulate the risk factor, for example: 0m~50m risk factor is 3; 50m~100m risk factor is 2; 100m~200m risk factor is 1, section #41~#42's total of risk factor is 13; section #42~#43's total of risk factor is 9; section #43~#44's total of risk factor is 10. And divided by the length of the section can get risk level of the section.

Table 1. The number of lightning within the Statistical section of transmission line.

Section	Number of lightning at each distance		
	0m~50m	50m~100m	100m~200m
#41~#42	2	1	5
#42~#43	0	3	3
#43~#44	2	0	4

Table 2. Lightning activity information of the transmission line in section #42~#43

NO.	Time	Lightning current peak(kA)	Nearest distance(m)
1	2005-07-01 17:51:26	-16.2	126
2	2005-07-08 17:47:21	-9.97	157
3	2005-07-12 15:22:22	-52.08	76
4	2005-07-13 15:27:13	-13.95	89
5	2005-7-21 16:33:43	-24.21	138
6	2005-07-31 15:45:05	-5.83	72

Table 2 is Lightning activity information of the transmission line in section #42~#43 of Table 1, provide a more detailed analysis of the risk assessment of tower. According to [2]-[3] ,the max lightning shielding failure current can be calculated, then we can compare the calculation results of max lightning shielding failure current with the lightning failure current to determined primarily the lightning failure property, and analysis the lightning disaster characteristics and lightning protection performance of different measures.

5. Conclusions

The method proposed by this paper is a nice method for real-time search for impact area of lightning. Compare with traditional line corridor grid method, which requires no additional computing time of the statistical results of each grid, therefore suitable for online GIS map. In this study, will add voltage, tower higher and more lightning parameters to assess of the lightning disaster risk to improve the lightning protection in the future.

6. References

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