THE DIGITAL RECORDING SYSTEM FOR LIGHTNING CURRENTS
AND SOME RESULTS OBTAINED FOR WINTER THUNDERSTORMS

Y. Goto, K. Narita, and F. Naito

Department of Electrical Engineering, Tohoku University, Sendai 980

Abstract. To measure accurately lightning current waveforms having a long duration, a digital recording system which is controlled by a simple micro-computer board has been developed. The current waveforms measured by this system in winter thunderstorms are tentatively classified into five types.

1. Introduction

In winter season, numerous frontal thunderstorms occur at the north west coast of Japan. It has been reported that the nature of winter thunderstorms is rather anomalous (Takeuti et al., 1976, Funaki et al., 1981 and Brook et al., 1982).

The ground flash density and the lightning parameters, such as the polarity, the number of strokes per flash, the peak value and the front and tail duration of current waveforms, are required for the engineering application for the protection of power transmission systems against the lightning. The ground flash density of Japanese winter thunderstorm is being investigated by the group of University of Tokyo (Ishii et al., 1981). For the purpose of the investigation of the above lightning parameters, the lightning currents to an isolated meteorological observation tower, which is about 150 m in height and has been constructed on a hill look on Japan Sea at an altitude of 125 m above sea level, have been measured by magnetic link, a magnetic tape recording device and an oscilloscope with a recording camera since the winter of 1976/77 (Goto et al., 1982).

From the results of the lightning observation for six seasons (1976-1982), it has become clear that the majority of the ground flashes, which would have struck the surrounding area, were attracted to the top of the tower, hitting not only the installed lightning rods but also several other extruding portions of the tower.

For measuring total lightning currents, an automatic digital recording system has been developed. This system consists of five Rogowski type coils, an integral unit, an opto-electronic transmission system, two digital transient recorders, and a simple micro-computer with a digital cassette data recorder and has been used for the observation since the winter of 1982. Similar systems have been developed and used in Japan (Ichikawa et al., 1980, Kishijima et al., 1980 and Nakahori et al., 1982).

Using the Rogowski coils for the current pickup sensor and the simple micro-computer for the data processing, the present system has attained two important merits i.e. being both economical and reliable.

We would like to report on the aspects of this system and some results obtained for winter lightning currents.

2. Recording system for lightning current waveforms

Figure 1 shows the block diagram of our automatic digital recording system for lightning current waveforms.

When the lightning strikes the top of the tower, the lightning current is detected by Rogowski coils installed on five current paths of the tower top portion. Induced voltage signals are integrated and converted into a pair of light signals, which are transmitted to the measuring room by optical fiber cables (about 800 m in length). There the light signals are inverted into the electrical signals, and are stored into the two transient recorders (fast and slow sampling) temporarily.

When the micro-computer senses the triggered state of one transient recorder, the recorded data, along with the date and time, are transferred from the transient recorders to the digital cassette recorder.

Fig. 1. Block diagram of digital recording system for lightning current.

2-1. Rogowski coils and signal transmission system

Two kinds of Rogowski coils which pick up the lightning current are installed on three main steel columns and two slant poles of the tower, and they are designed carefully to induce the same voltage for the same current. To obtain the total lightning current striking the tower, those coils are connected in series.

Figure 2 shows the configuration of the tower top portion and the positions of Rogowski coils.

It was found that the greater part of the lightning current flowed through the tower body and the stay wires to earth. And consequently, the current flowing through the down conductor was less than 10 % of the total current. So the lightning conductor current was neglected in our system.

The induced voltage signal is integrated by a R-C integrating circuit, the time constant being 15 ms.

The integrated signal is converted to a pair of light signals for positive and negative currents with a complementary transistor circuit which is loaded with two LEDs.

The positive or negative analog signal is transmitted to the measuring

Fig. 2. Configuration of the tower top and position of Rogowski coils.

room via the optical fiber cable. Transmission loss of the cable is about 3.4dB/800m. In the room, the light signals are inverted again into a electrical signal by a mixing circuit with two photo-diodes and operational amplifiers whose band width is from DC to 300 kHz.

The electrical signal is branched into two transient recorders and a trigger pulse generator, consisting of a window comparator circuit, which generates trigger pulse for transient recorders.

2-2. Transient recorders and control system.

Two kind of transient recorders are used in this system. One has a memory capacity of 4 KW, 8 bits per word and the minimum sampling time of 50 ns, the other has a memory capacity of 8 KW, 8 bits per word and the minimum sampling time of 1 μ s.

When a lightning current signal exceeds the threshold level of the window comparator, a trigger pulse is generated and the transient recorder data storing starts. The data of both transient recorders are transferred to a cassette magnetic tape along with the date and time of lightning flash by the micro-computer (TK-85). The one side of cassette tape can record the 19 lightning events (the total record is 233 kbyte).

3. Data processing system

For processing data, digitally recorded data on magnetic tape are transferred and stored into a personal computer (PC-8801 or PC-9801) with a cassette data recorder (MT-2). Those data can be stored on 5" or 8" floppy disk, and printed out by a dot matrix printer (NK3618-22) or drawn in the analog form by X-Y plotter (MP1000).

The block diagram of data processing system is shown in Fig. 3.

Fig.3. Block diagram of data processing system.

4. Observation results of lightning current

By our system, 12 records were obtained in the period from December 1982 to February 1983.

To obtain the more precise waveform of the lightning current, the memory of the fast transient recorder was divided to four parts (1 KW/part) and sampling time of 0.2 μ s was selected. But fast data could not be obtained due to transfer miss except one record.

To clarify the multi-stroke and the continuing current, the slow transient recorder was operated with sampling time of 20 μ s and the waveform was stored into the memory from 40 ms before the trigger to 120 ms after the trigger for each lightning event.

From January 30 1983, the sampling time of 10 μ s was used and the waveform was stored within 80 ms after the trigger.

Table 1 shows the characteristics of winter lightning currents obtained by the slow transient recorder at Kakumi-hama.

The current peak value should indicate the maximum value of each stroke, but it may be smaller than the actual value because the used

Table 1. Peak value and waveform type of obtained lightning current

No. of flash	Date: Year/Month/Day	Time: Hour/minute/sec	No. and Start time of Component(ms)	Current peak value (kA)	Type of waveform
83-1	'83:1:12	01°57'38"	#1 0	+ 0.6	A
			#2 8.8	+13.6	A
83-2	'83:1:12	02°22'41"	#1 0	- 2.9	C
			#2 8.6	- 2.5	C
			#3 14.2	- 0.9	B
			#4 17.8	- 1.2	B
83-3	'83:1:12	02°25'01"	#1 0	- 3.2	C
			#2 18.2	- 7.0	D
			#3 24.8	- 0.9	D
83-4	'83:1:12	02°42'37"	#1 0	- 3.2	C
			#2 8.7	- 3.2	B
			#3 9.8	- 8.0	D
			#4 17.8	- 1.2	B
			#5 25.7	- 1.9	B
			#6 38.5	+14.6	E
			#7 89.3	- 0.9	B
83-5	'83:1:20	02°49'30"	#1 0	- 3.9	C
			#2 9.8	-16.8	D
			#3 34.1	- 1.2	B
			#4 45.1	- 0.6	B
			#5 48.5	- 1.2	B
			#6 50.8	- 1.6	B
			#7 52.5	- 0.6	B
83-6	'83:1:20	02°50'57"	#1 0	- 1.9	D
			#2 20.8	- 1.2	B
			#3 29.1	- 2.9	B
			#4 37.6	- 0.6	B
83-7	'83:1:20	02°52'47"	#1 0	- 0.6	C
83-8	'83:2:8	23°55'41"	#1 0	+ 2.0	E
				+ 2.0	
				- 1.2	
				- 3.2	
83-9	'83:2:9	00°33'52"	#1 0	- 3.9	E
				+ 2.5	
				-10.6	
				+ 4.0	
83-10	'83:2:9	06°19'44"	#1 0	- 0.9	C
				- 1.6	
				- 0.9	
				- 0.9	
83-11	'83:2:9	22°39'59"	#1 0	>-19.0	C
			#2 1.7	- 2.7	C
			#3 28.6	- 1.2	B
83-12	'83:2:9	22°43'14"	#1 0	- 8.0	C
			#2 7.8	-13.2	D
			#3 9.3	- 7.0	B
			#4 17.6	- 1.4	B
			#5 18.8	- 2.2	B
			#6 23.5	+ 6.3	E
				- 2.5	
				+ 1.6	
				- 1.4	

sampling time is too long.

As shown in the table 1 and Fig. 4, the observed current waveforms are classified into the following five types:

(A) positive single-peak wave like a standard impulse wave

(B) negative single-peak wave like a standard impulse wave

(C) multi-peak irregular waveform observed in lightnings to mountain tops by Berger(1977)

(D) negative single-peak wave followed by continuing current wave

(E) bipolar oscillatory wave

The mechanism and the cause of the occurrence of the lightning currents of these five types, especially, those of type (E), recorded in winter thunderstorms, have not been sufficiently studied yet. So, data in various conditions should be accumulated further.

5. Concluding remarks

The automatic digital recording system for lightning current waveforms has been developed and its aspects have been described.

The field measurement performed at the top of the high tower for winter thunderstorms, confirmed that this system was fully capable to record automatically the lightning current waveforms. The current waveforms thus obtained for winter lightnings are tentatively classified into five types.

To clarify the winter lightning characteristics, further accumulation of data in a various conditions is needed.

Waveform observation by this system made for the first time at Kakumi-hama in December 1982, will be continued.

We firmly believe that the winter lightning characteristics will be made clear by the simultaneous measurements of lightning current waveforms

(A) Positive single peak waveform

(B) Negative single peak waveform

(C) Multi-peak irregular waveforms

(D) Single peak waveforms with continuing currents

(E) Bipolar waveform

Fig. 4. Examples of winter lightning current waveform.

and electric field change. An electric field measuring system is now under construction using a similar methods. It will consist of an antenna for electrostatic field measurement and the transient recorder controlled by a simple micro-computer with a digital recording equipment.

Acknowledgements

This work was carried out by the financial support for Science Research, the Education Ministry of Japan, under the Grant-in-Aid of Special Research for Natural Disaster (2), Project number 57025008 (1982).

The authors wish to express their hearty thanks to Mr. K. Fujikake and his associates of Tohoku Electric Power Co., Inc. for their support and help in carrying out the field work.

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(Received March 13, 1983;
revised May 13, 1983;
accepted May 19, 1983)