Development of Monitoring System for Conductor Galloping

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Abstract— The overhead transmission lines pass through a variety of terrains and often encounter severe icing conditions. In a strong gale, an ice-clad line in some cases is given a significant lift, and is subjected to a self-sustained oscillation (galloping). Its investigation is very important in order to assess damege on the transmission facility. In order to detect a galloping, various techniques have already been developed, including ITV imaging system using lamp target, insulator tension change system, and a optical fiber gyroscope analysis system. The newly developed galloping monitoring system uses an angular velocity sensor and an acceleration sensor for compactness,cost-saving, and maintenance labor-saving. This paper describes outline of the newly developed monitoring system and the results of its application to the test line to demonstrate that the newly developed system has a practically sufficient accuracy.

I. Introduction

Tokyo Electric Power has developed jointly with J-Power Systems a low-cost conductor behavior monitoring system for exact status monitoring and reasonable maintenance of overhead transmission lines subject to galloping and other abnormal vibrations, and this paper describes outline of this system.

II. Snow damage to overhead transmission lines

The overhead transmission lines pass through a variety of terrains till they feed the power consuming sites. Depending on the climatic conditions of the terrains , they may encounter severe icing conditions. In case ice is encrusted up on the transmission line, its load may force the transmission line to droop more than permitted sag. And when such ice falls off all of a sudden, the transmission line will jump (sleet jump).
In a strong gale, an ice-clad line in some cases is given a significant lift, and is subjected to a self-sustained oscillation (galloping).

III. Conventional galloping monitoring system

On occasion, galloping can continue over a long period of time. Accordingly, it is very important to get hold of the actual status of galloping and its effects on transmission facilities.
Galloping occurs while it is snowing, but is difficult to predict its occurrences. In order to cope with this problem, there have been developed various techniques including: ITV monitoring analysis system using a lamp target; a technique for analysis of changes in tension of conductors; and optical fiber gyroscope analysis technique. (Figure .1.)

A optical fiber gyroscope has no rotating elements susceptible to wear, and is highly resistant to shocks. But it is an energy guzzler, and is fed from a CT fitted on a transmission line.

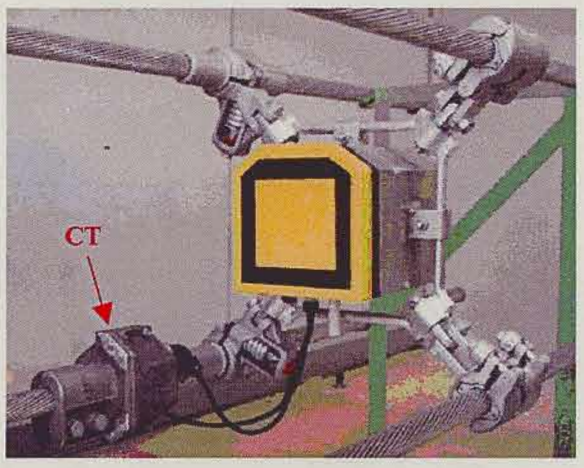


Figure.1. A photograph of optical fiber gyroscope

IV. An outline of the newly developed system

Just a with the conventional system, the newly developed system measures the torsion and oscillation of the transmission line conductor by making use of an angular velocity sensor and an acceleration sensor. As compared with the conventional optical fiber gyroscope, the newly developed system has the following features by miniature semiconductor sensor sensors employed.

(1)Reduced power consumption

The power consumption of the newly developed system has been reduced to about one-thirteenth of that of the conventinal system. As a result, it has been made possible to feed power to the system from a battery (primary battery). (Table 1)

(2) Compactness

The newly developed system weighs one third of the conventional system, and can be supported by 2 bundled conductors of the overhead transmission line.

(3) Low cost

The cost of the newly developed system has been reduced to about one tenth of the cost of the conventional system.

An external view of the newly developed system is shown in Figure 2.

Table 1
Comparison in power consumption between conventional system and newly developed system

	Conventional system	Newly developed system
Angular velocity sensor	Optical fiber gyroscope (500mA)	Semiconductor angular velocity sensor (approx. 10 mA)
Acceleration sensor	Servo type acceleration sensor	Semiconductor angular velocity sensor (approx. 10 mA)
Transmission device	429MHz Designated small-power device (120mA)	429MHz Designated small-power chip (approx. 30mA)

Figure. 2. A photograph of the newly developed system (for ACSR 330mm^2 x 2 bundled conductors)

V. System configuration

A configuration example of the low-cost conductor behavior monitoring system is illustrated in Figure 3.The system is to be installed at a half point and a quarter point of the span where oscillation becomes large, though its actual location is governed by the expected oscillation mode.The measurement gets started when the swing of the conductors has exceeded a threshold value (trigger value), and the summary data of measurement is transmitted to a control station via a base station.

【A brief description of operational flow】

1)The measurement gets started when the vertical amplitude of oscillation exceeds a threshold value.

2)The system logs data for 3minutes after start of measurement, and transmits it to the base station.

3)After acquisition of the 3-minute data, the base station roughly computes the vertical and horizontal amplitudes, torsional angle and oscillatory frequency for the first one minute. The result of rough computation is transmitted to a control station via an ordinary mobile phone (in a flat terrain) or a satellite mobile phone (in a hilly terrain) or other proper telecommunication equipment. The oscillation data are stored in a storage device (smart media) in the base station.

4)If the oscillation is still continuing, data is logged again and transmitted to the base station. The system is put into a dormant mode in seasons other than winter for the sake of energy economy. The battery for the system is expected to serve for about 5 years.

The system has a two-way telecommunication function and is capable of changing the trigger value at the command of the base station and of self-checking battery voltage, temperature and other parameters. The standard specifications of the system are shown in Tables 2 .

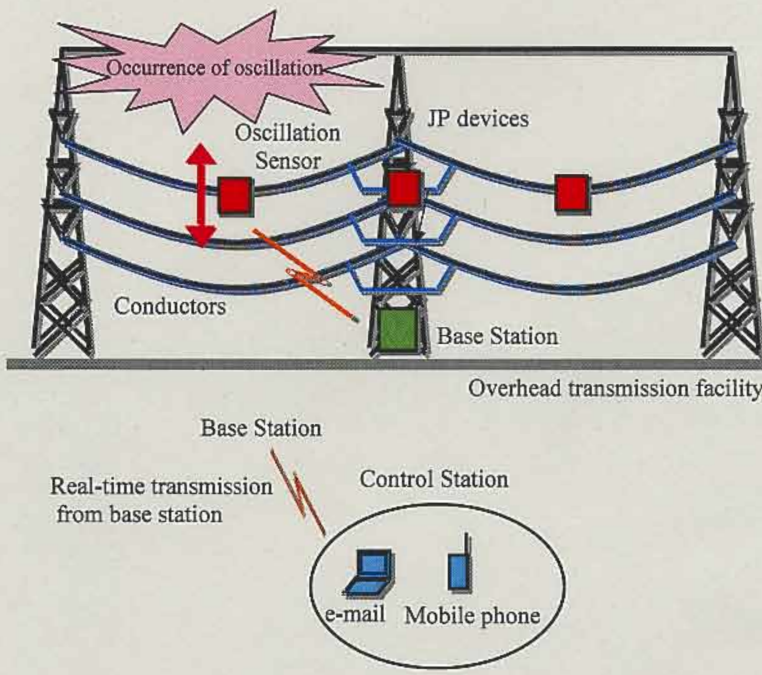


Figure.3.A configuration example of the low-cost conductor behavior monitoring system in overhead transmission lines

Table 2
Specifications of the newly developed system

Item	Specifications
System configuration	Transmission tower base station x 1 unit Oscillation sensor x 1 to 4 units
Dimensions of oscillation sensor	approx. 160mm(W)×160mm(D)×160mm(H) (main body)
Weight of oscillation sensor	Main body, approx. 5kg + Fixing means, 3 kg
Design service life of power supply	approx. 5 years (dependent on the capacity of batteries installed and frequency of oscillation events)
Amplitude measuring error	approx. 5% for vertical and horizontal amplitudes
Scope of applications	2 bundled～ 8 bundled conductors jumper devices; etc.
Data transmission to offices	By e-mail to PC, mobile phone or satellite mobile phone

VI. Results of monitoring demonstration test

A monitoring test was conducted over two spans of 500kV Mogami Test Line (No.3～No.4, No.4～No.5) using 4 units of conductor oscillation sensor and one unit of base station. The test period was from March 3 to 25, 2003, during which time the meteorological observation equipment recorded an ambient temperature of -7.1 to 22.8°C, a maximum snowfall intensity of 4mm/h, and a maximum precipitation intensity of 5mm/h. The transmission line conductor behavior monitoring system and its telecommunication system worked in order.

The data transmission distance between the base station and oscillation sensors was 422m at its maximum. During the 23 days (552 hours) of test period, the transmission line conductor behavior monitoring system frequently met with strong gales and detected an aggregate 125hours of galloping with a tension change in excess of 5 kN/line, and a sufficient quantity of demonstration data could be obtained. The data monitored during the period from 18:00, March 5, to 15:00, March 6 is analyzed.

Figure 4 shows the direction and velocity of wind on the average over 10 minutes at h = 35m at the test line site, changes in maximum tension at No.3 ～ No. 4 tower (5-second p-p values), accelerations of the newly developed transmission line conductor behavior monitoring system, and the full vertical amplitudes of the transmission line conductors as calculated from the readings of the acceleration sensors.

1)At 22:00, March 5, the wind direction came to stay at right angles to the test line, and the wind velocity increased steadily. When the wind velocity began to exceed about 10 m/s, the tension started to change. The measurement got started by a trigger signal, and was conducted almost continually from 2:00 to 14:00, March 6. The calculated amplitudes were nearly in conformity with the changes in tension.

2) The oscillation for 11:03, March 6, was compared with the target point data of the test line ITV monitoring. (Figure.5.) The full amplitudes in the vertical and horizontal directions were 4.4m and 2.2m respectively by the newly developed monitoring system, as against 4.2m and 2.3m by the target point data. The error was less than 5%, bearing out that the newly developed system was satisfactorily applicable for practical use. It was also demonstrated by the power spectral density that the oscillating frequencies of ITV monitoring and newly developed systems were in agreement with each other. The amplitude of oscillation matters in case of electrical troubles such as short-circuit failure. In the case of mechanical troubles such as precariously fitted bolts, the magnitude or duration of the tension matters. Shown in Figure 6 is the relationship between the vertical full amplitude measured at the test line and the changes in tension. It provides nearly one-to-one correspondence as evaluation is made with one mode oscillation alone taken into account. For actual overhead transmission lines, it is only necessary to determine the abovementioned relationship in advance for each specific oscillation mode for the changes in tension, the newly developed monitoring system can determine three variables of perpendicular and horizontal amplitudes and torsional angle to make it possible to calculate the tension changes at a higher accuracy.

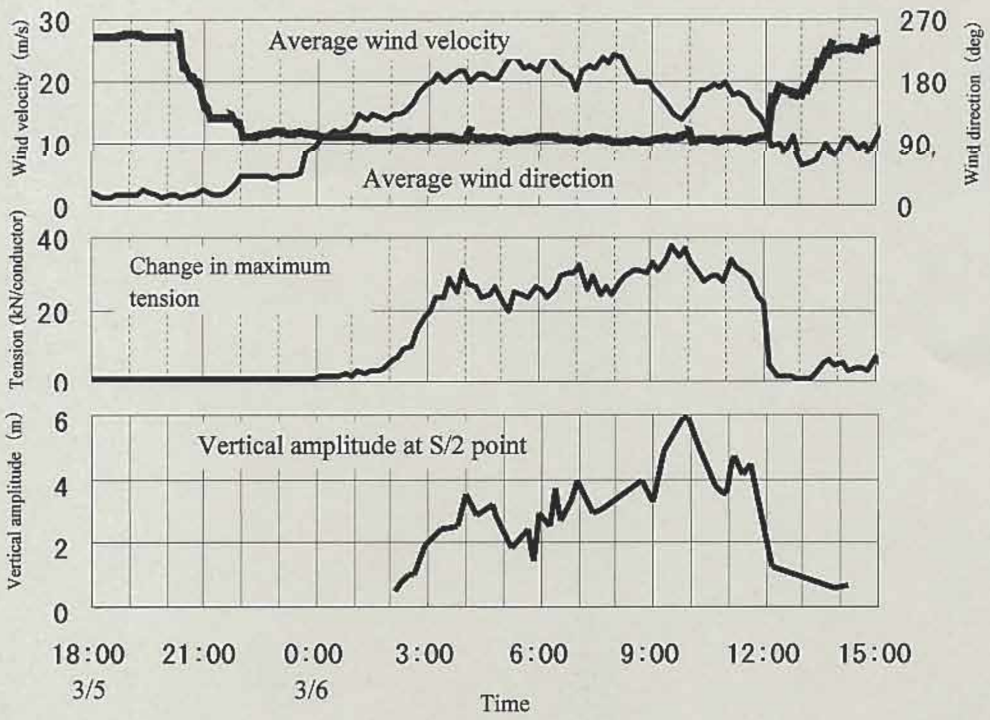
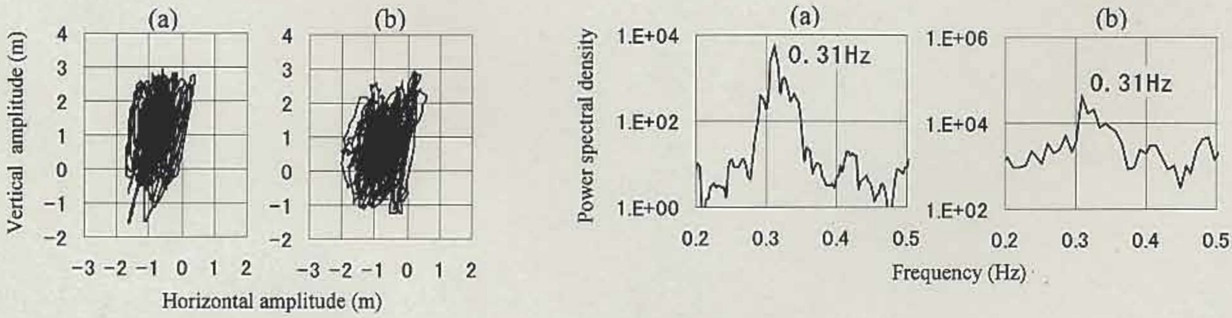


Figure.4. Time-series data of anemometry, tension changes and vertical amplitude



a. Data logged by the newly developed monitoring system
b. ITV imaging target point data

Figure.5. Locus of conductor oscillation, and power spectral density of perpendicular displacement (Data at S/2 point between No. 3 and No. 4 Tower, recorded at 11:03, March 6, 2004)

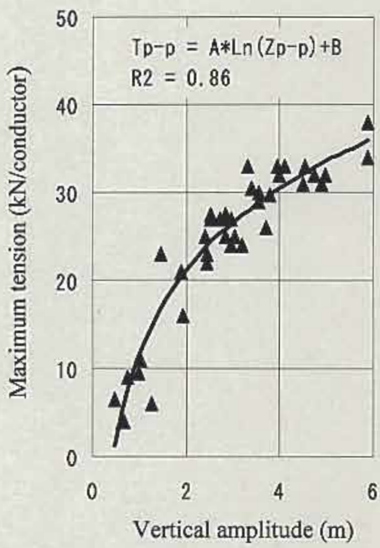


Figure.6.Maximum tension change versus vertical amplitude

Figure.7. Low-cost conductor behavior monitoring system installed on 500kV overhead transmission line (Upper: Oscillation sensor; Lower: Base station)

Ⅶ.Live lines application of the newly developed monitoring system

In November 2004, the 500kV transmission line within of TEPCO Kanagawa Office was rigged up with the system referred to above. Figure 7 shows an installed status of the monitoring system and base station. At this point in time, however, galloping data has not been obtained yet.It has been verified by the self-diagnostic function of the sensor that the monitoring system has been working in order. Further improvement on the monitoring system will be carried out for end-to-end maintenance management by operating it in close association with meteorological sensors for thermometry, anemometry, hyetography, etc.

Ⅷ. Conclusion

The newly developed overhead transmission line conductor behavior monitoring system has been verified by demonstration tests using Mogami Test Line and 500kV commercial line to have sufficient capability and reliability for practical purposes. In addition to real-time monitoring of changes in conductor oscillation amplitude and tension, the newly developed monitoring system will be used to accumulate the time-series data of oscillations for the purpose of rationalizing inspection and maintenance of the overhead transmission facilities.