Autonomous meteorological measurement system in cold climates

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***Abstract*—Meteorological measurements were carried out in a remote mountain area by a new system installed at the lower part of the tower for overhead power lines in a winter season where galloping or buffeting of the cables may have occurred. The system autonomously measured wind speed and direction, relative humidity, atmospheric pressure, solar radiation and precipitation with the electric power supplied from rechargeable batteries. The batteries were designed to automatically be charged by photovoltaic cells. Although a heated ultra-sonic and a modified cup anemometer were employed to prevent them from icing or icing related events, the missing data were found because of some problems probably due to icing.**

I. INTRODUCTION

In cold climates, overhead power lines built in highly elevated mountainous areas may suffer from galloping or buffeting due to ice accretion or snow accumulation on the cables when the wind blows at a relatively higher speed. Therefore meteorological data collection must be performed in order to find out what would be the causes of such events and under what conditions they might happen. However there exist some difficulties in doing such kind of measurements because of scarce power supply, the low temperature resulting in freeze of the instruments in a case of precipitation, and remoteness preventing us from the easy access. [1] So as to overcome these problems, a new measuring system has been developed and used for autonomous measurements installed in a tower for extra high voltage overhead power lines in *Tanigawa-dake mountain* in Japan.

II. A NEW SYSTEM

The system comprises of three components. They are for measurement, data transmission and power supply. Data acquisition was done by two anemometers, a wind vane, a thermometer, a hygrometer, a precipitation sensor, an actinometer and a barometer. Wind was measured by three different types of anemometer which were most subject to icing or snowing among those instruments: an ultra-sonic and a cup anemometer. The ultra-sonic anemometer was a heated one to be designed to avoid ice accretion on it. [2] The open face of the cups of the cup anemometer was covered by aluminum membrane which prevented snow particles to accumulate inside it. Furthermore the entire surface of the cups was coated by icephobic paint for the same purpose. [3]

Data transmission was done by using one single cellular phone in a way of packet switching at a regular time intervals, every 10 minutes, or at call even from any place, which enabled us to monitor the meteorological conditions on site. Moreover a cellular phone consumed so small amount of electricity that it affected little to the power supplier, the series of rechargeable batteries in this system. [4]

The power supplier was made up of rechargeable batteries of 12 voltages and 1000Ah which were charged by 10 photovoltaic panels installed on the lower part of the tower. The number of solar panels was strictly limited because the drag force generated by those panels could affect the strength of the tower.[2] Hence much attention should be paid in designing a system of this kind to minimize the electricity consumption. In addition, the smaller number of solar panels and batteries would be, the easier to carry them on our shoulders to the site in mountain from the foot was made.

Test was carried out in the middle of *Tanigawa-dake*, where huge amount of snowfall could be expected throughout the cold season. The location of Tanigawa-dake and the measurement system are shown in Fig. 1.

III. RESULTS AND DISCUSSIONS

1. Data transmission

All collected data stored in a hard-disc for 10minutes were transmitted through the cellular phone. During the campaign of data collection, the transmission of 43338 packets was implemented. Among those, the rate of failure was 0.3%. Moreover the failure happened one-shot, not successively. Hence, transmission of data collected at a remote place at once with using a cellular phone was considered to be a more adequate way than storage of all measured data in a hard-disc on site over the whole period of campaign in light of not only reliability but also certainty.

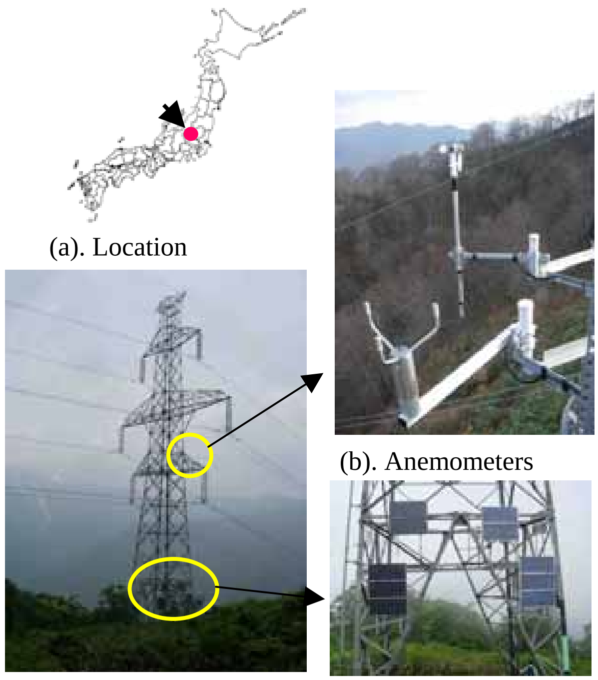
2. Wind measurements

As mentioned earlier, winds were measured by the heated ultra-sonic and the modified cup anemometer. The monthly durations in hour of missing data were in Table 1. In the table, the deficiency rate is calculated along with them. This rate is defined as the ratio of the duration in which data acquisition has not completed by some reason to the total hours of respective months.

As written in the table, the deficiency rate in December 2005 is quite high. The monthly duration of precipitation and missing data is depicted in Fig. 2, where the possitive correlation in between can be seen as a whole. However, regardless of the mean temperature at the same value, the ratio of duration between precipitation and missing data in December 2005 and February was in a big difference approximately by ten times such as o.62 and 0.061 respectively.

Fig. 3 shows the correlation between the deficiency rate and the temperature and the precipitation. In the figure, precipitation is indicated by its duration in minute. It is clearly turned out that when the temperature is lower and the precipitation lasts longer, the deficiency rate tends to be higher. In the case of -14 degrees centigrade and 9-minute precipitation, the deficiency rate goes up to 100%.

In the present test, only precipitation was measured. The term precipitation at the temperature below freezing includes every event of snowfall, freezing rain and collision of super-cooled water droplet (shown in Fig.4). And at the same time, this means that the exact cause of missing data related precipitation can hardly be found for seeking more effective ways. However missing data would be attributed to the ice deposit formed on the sensor part of the anemometer in various manners.



(a). Location

(b). Anemometers

(b). Installation of the system (d). Photovoltaic cells

Fig. 1 Data acquisition system

Table 1. Missing data

	Missing data (hrs)	Def. rate (%)	Mean Temp. (deg)
Dec. 2005	283.3	38	-7.9
Jan. 2006	148.7	20	-9
Feb. 2006	19.2	3	-7.9
Mar. 2006	21.2	3	-4.6
Apr. 2006	5.5	1	-2.3

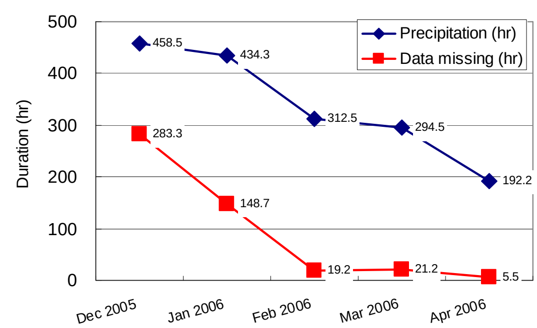


Fig. 2 Precipitation and missing data

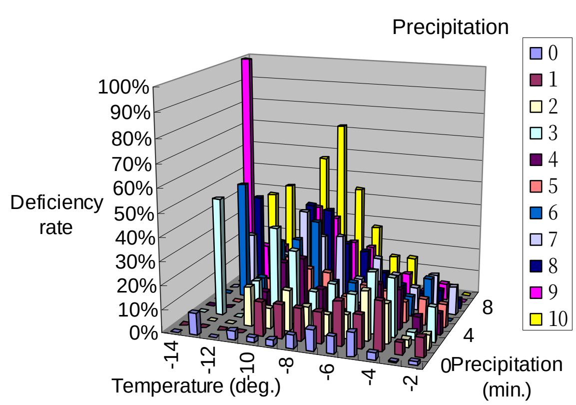


Fig. 3 Correlation between the deficient rate and temperature and precipitation

The ultra-sonic anemometer used in the test was the heated one for being designed to prevent itself from icing due to precipitation. Unfortunately, as mentioned above, icing occurred regardless of installation of the heating element. Heating by an electric heater may consume a lot of energy. In a measuring system like the present one relying on rechargeable batteries, it would not be realistic to increase the heater capacity immoderately. The optimal heating method, therefore, should be invented.

Fig. 4 Ice accretion on the sensor of the heated ultra-sonic anemometer

Measurements of wind direction were done by using the unheated wind vane. It has been mentioned that the wind vane would be robust even under icing conditions so long as its body and tail wing is thin against the wind. Moreover, even if the rotating shaft would stick, it sends signals as if it could work correctly. Therefore verification could not be done in the present test because the anemometer also stopped its working under icing conditions.

3. Others
Measurements of atmospheric pressure, relative humidity and solar radiation were accomplished without problems by the system in the atmospheric icing conditions.

4. Power supply
In the present system, every instrument was operated and data was transmitted with the 12V rechargeable batteries. In order to charge those batteries, 10 photovoltaic cells were employed. The system was functioning without any stops originated from the power supplier in the course of the campaign.

IV CONCLUSIONS

From carrying out meteorological measurements with using a new system, several findings were derived:

- The system could have autonomously operated by the power storage using the rechargeable batteries and the photovoltaic cells.
- Data transmission was performed at the regular intervals by using a cellular phone and its capabilities for packet switching, which required minimized electrical power.
- A heated ultra-sonic and a modified cup anemometer were used for wind measurement in order to prevent them from icing. However they could not work even under not so harsh icing conditions, which resulted in the immediate requirements for a new anemometer or finding out the way of heating with an additional heater with optimal capacity.

V REFERENCES

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