The 2014 World Congress on
Advances in Civil, Environmental, and Materials Research (ACEM14)
Busan, Korea, August 24-28, 2014

Introduction to wireless transmission-based instrumentation system for high-frequency anemometers

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ABSTRACT

Owing to the tough conditions of the field measurements in remote areas such as mountain valleys, the commonly used instrumentation system for high-frequency anemometer may not be very appropriate. To facilitate the measurement in those areas, a data wireless transmission-based field measurement instrumentation system for high-frequency anemometers is developed.

In this paper, the architecture of the newly-developed system is described firstly. Then the features of this system are compared with the existing instrumentation systems. Finally, its application to the field is discussed in detail. It can be expected that the proposed system may have a great application potential in the field measurement of strong winds in remote areas, especially in the mountainous area.

1. INTRODUCTION

It is well known that the accuracy of wind characteristics, especially the characteristics of severe winds such as the hurricane (or typhoon), thunderstorm downburst and other gales, will have great influence on the wind-induced structural response analysis and subsequent wind-resistance design of the structure. Compared to other methods of acquiring wind records, the field measurement is the more direct and accurate method and also widely used in wind engineering community. For instance, the mobile instrumented towers, the temporarily established masts or towers and the permanent structural health monitoring systems (Balderrama 2011; Cao 2009; Xu 2000) have been adopted to carry out the short-duration or long-term field measurement. It is noteworthy that the transmission of the collected data by the aforementioned schemes is all based on the wire.

Obviously, the wire transmission-based instrumentation system may not be very appropriate for the field measurement of the mountain areas due to the deficiency of working conditions such as internet and reliable power supply. In these areas, some advanced instrumentation systems such as radar wind profiler and Doppler sodar have been employed to measure the mean wind speed. However, for the measurement of

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turbulent fluctuations in these areas, high-frequency anemometers such as ultrasonic anemometers are still the first choice (Turnipseed 2003) and its corresponding instrumentation systems are still confined to the data logger and radio transmitter/receiver(Turnipseed 2003; Pan 2010). The former is not real-time and data saved in automatic memory card need to be copied manually at the regular time. The latter requires building a base station to receive measured data and the transmission distance is also limited (up to 10km). What's more, the latter will be significantly affected by the power supply in the construction site.

In this paper, a data wireless transmission-based field measurement instrumentation system for high-frequency anemometers is developed. Firstly, the architecture of this newly-developed system is described. Then the comparison between the conventional instrumentation systems and the proposed system is carried out. Finally, the practical application of this system to the field is discussed in detail to illustrate the efficiency of this proposed system.

2. ARCHITECHTURE OF INSTRUMENTATION SYSTEM

This data wireless transmission-based instrumentation system constitutes of the following 5 units, which are shown in Fig. 1.

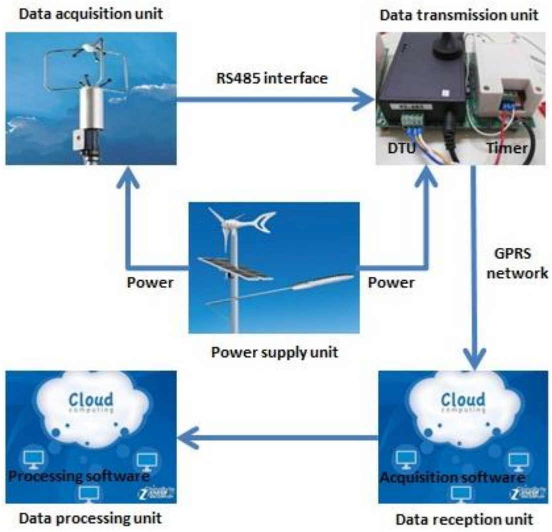


Fig. 1 Architecture of instrumentation system

2.1 Data acquirement unit.

Generally, the high-frequency anemometers such as ultrasonic anemometers acquire the wind speed data with the sampling frequency ranges from 4 Hz to 10 Hz . It is noted that some other data acquirement instruments with high sampling frequency are still suitable for adopting this system.

2.2 Data transmission unit.

Through RS485 interface, the high-frequency anemometer is connected to Remote Terminal Unit (RTU) module. This module has two components: Data Transfer Unit

(DTU) and timer. The former is to collect data and transmit data wirelessly. It is noted that the DTU module allows for data-caching. This function can guarantee almost no data loss. The function of the timer is to restart DTU module automatically at regular intervals such as one month. In this way, the collapse of DTU module can be avoided in the long-term online operation.

2.3 Data reception/processing unit.

Via the GPRS network, the measured data are transmitted to a cloud server system from the RTU modules according to the specified Transmission Control Protocol/Internet Protocol (TCP/IP). In the cloud server system, the TCP-based data acquisition software and the data processing software are deployed. The first one is developed to receive data and generate text files based on 1-hour data. It should be noted that the unprocessed cashing data are also included in the text files. Through the second software, the 1-hour data including cached data in the generated text files will be reconstituted in chronological order firstly. Then, these processed 24 text files will be assembled to one text file for 1-day data. After the final text file has been created, it will be packed automatically and sent to the prescribed email address in regular time by the cloud server system.

2.4 Power supply unit.

The solar power supply system is employed to provide power supply to the data acquisition and data transmission units. Because the solar power supply system is susceptible to the weather, two approaches can be used to improve the performance of power supply system. One is to increase the capacity of power supply such as enhancing the capacity of the solar panel and lead-acid battery or using the wind and photovoltaic hybrid power system. Another approach is to save energy. Currently, the intelligent switch has been developed by authors, which can shut down or restart the whole system automatically according to the threshold wind speed.

3. CONTRAST WITH EXISTING INSTRUMENTATION SYSTEMS

Two commonly used instrumentation system, data logger and radio transmitter/receiver, which are denoted by system 1 and system 2 respectively, are compared to this newly-developed system which is denoted by system 3. The detailed comparison between these systems is listed in Tab. 1. It shows that the proposed system has more advantages compared to the existing instrumentation systems.

Tab. 1 Comparison of different instrumentation systems

Traits	System 1	System 2	System 3
real time	no	yes	yes
total cost	low	high	low
field monitoring	need	need	no need
mains supply	no need	need	no need

4. PRACTICAL APPLICATION TO FIELD MEASUREMENT

In order to evaluate the performance of the developed instrumentation system, it was deployed to collect wind data from the construction site of Puli Great Bridge at Yunnan Province of China. This bridge site is located in a typical mountain valley area, as shown in Fig. 2. The detailed implementation scheme is as follow:

1) Description of high-frequency anemometers. Two Young ultrasonic anemometers (Model Number 81000) are used to collect the wind speed. The sampling frequency of the anemometer is set to 4 Hz for grasping the high-frequency fluctuating wind.

2) Selection of RTU module. The RTU module of the industrial grade is selected, which has high reliability and can work in the harsh environment. It also allows for plug and play, and is easy to use. The cache memory of this RTU module is 64 KB, which can store about 10-minute data under sampling frequency of 4 Hz. Fig. 3 shows the RTU used in the field.

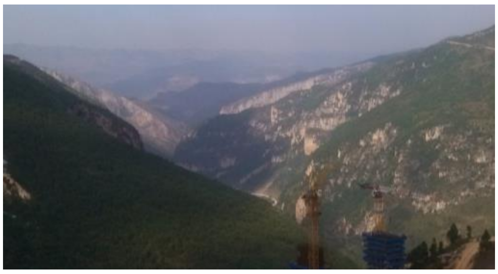


Fig. 2 Geomorphy of Puli bridge site

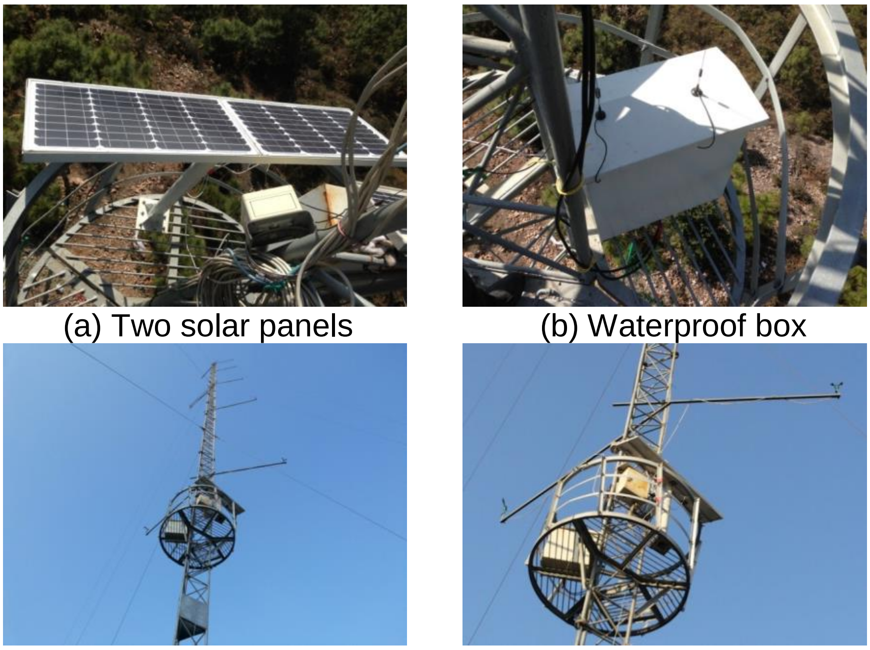
Fig. 3 RTU modules used in the field

3) Configuration of power supply system. The rated power of each ultrasonic anemometer and RTU module is about 2.5 and 1.5 watts, respectively. Therefore, the total power of the instrumentation system is less than 8 watts. On other hand, this solar power system contains two 40-watt solar panels and a 120AH, 12V lead-acid battery. Therefore, this solar power supply system can not only provide the electricity to the anemometers and RTU modules but also generate extra electricity to recharge the battery in normal situation. Besides, the lead-acid battery can work for 120 hours theoretically in the case of no sunshine. The picture of these two solar panels is shown in Fig. 4a.

4) Field installation of the whole system. A waterproof box was customized for packing up the RTU modules, solar panel controller and lead-acid battery, as shown in Fig. 4b. This box is waterproofing and also excellent in heat dispersion. Fig. 4c shows the anemometers layout on the tower. The aforementioned ultrasonic anemometers were mounted at the heights of 30m and 50m from the ground level, respectively. The chose shot of the whole instrumentation system is shown in Fig. 4d. Clearly, the developed system is convenient to be mounted.

5) Allocation of cloud server, software and email system. A cloud server of China Telecom with 80G hard disk and 2G memory is applied to receive data. Meanwhile, the TCP data collector software and data processor software which has been mentioned before in architecture of instrumentation system are developed on this server. For simplicity, their detailed descriptions are omitted. After the text file of 1-day data has

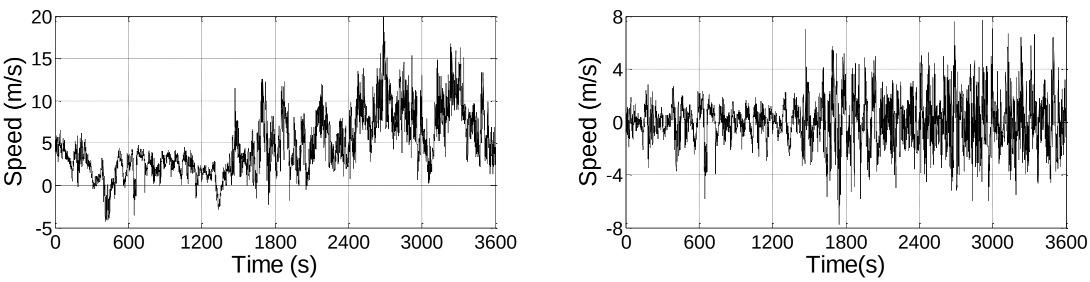
been generated, it will be sent to the prescribed email through the email system.



(a) Two solar panels (b) Waterproof box

(c) Anemometers layout (d) Close shot of the system

Fig. 4 Field installation of the whole system



(a) Instantaneous wind (b) Fluctuating wind

Fig. 5 Selected one-hour data

6) Development of a web-based client. This newly-developed web client can show the real-time data with the format of wind speed, wind direction, elevation angle, sonic speed and sonic temperature. Furthermore, the location of this field in the map can also be seen in this web client.

7) Subsequent data processing. The installation of the whole instrumentation system has been accomplished at the end of 2013. Then the measured data have been sending to the prescribed email every day. Fig. 5 is the selected one-hour data. It shows that this instrumentation system has a good performance of capturing the transient characteristics of fluctuating wind. Furthermore, for the wireless transmission of data via GPRS network, data loss may be unavoidable. However, it can be neglected if the data loss rate is within the acceptable limit. Tab. 2 summarizes the data loss rates from 03/01/2014 to 03/6/2014. It indicates that the averaged data loss rate for one day is less than 0.02%. Roughly, it is equivalent to half a minute data loss one

day. Therefore, the data loss has no influence on the field measurement.

Tab. 2 Statistics of the missing package rate

Date	Missing package rate (%)	
	RTU 1	RTU 2
1 Mar 2014	0.006	0.011
2 Mar 2014	0.008	0.019
3 Mar 2014	0.015	0.020
4 Mar 2014	0.011	0.014
5 Mar 2014	0.012	0.015
6 Mar 2014	0.006	0.021

5. CONCLUSION REMARKS

In this study, a data wireless transmission-based field measurement instrumentation system for high-frequency anemometers was developed. The architecture of the proposed system, main features and practical application were presented in this paper. It can be seen that this newly-developed system has more advantages than the current existing instrument system. Although this system was originally developed for the mountain area, it can also be used in other remote areas such as island or coastal areas.

Acknowledgements
The support by “National 1000 Young Talents (China)” Program is greatly acknowledged.

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