Wind speed measurement and alert system for tunnel fire safety

Nedjeljko Lekić, Radovan Stojanović, Almir Gadzović and Zoran Mijanovic
Faculty of Electrical Engineering
University of Montenegro
Podgorica, Montenegro

Abstract— **This paper describes a system for wind speed measurement and alert. It is used at the portals of tunnel Sozina, 4189m length, en route Podgorica-Bar with primary function is to increase traffic safety in the tunnel. The system provides information for other tunnel systems, such as fire protection, traffic signaling, etc. It consists of anemometers, microcontroller based data acquisition modules and a central PC. The system can collect other types of data and be easily adapted for other purposes.**

Keywords*— *anemometer; central computer; microcontroller data acquisition module; tunnel portals; wind speed.

I. Introduction

WITH the development of transport infrastructure, construction of very long tunnels and an increasing flow of vehicles, it is often seen that tunnel accidents can take away a large number of people's lives and make extremely large material damage (Mont Blanc tunnel 1999. [1], Gotthatd tunnel 2001. [2], Caldecott tunnel 1982. [3], Summit tunnel 1984. [4] in all which there were fires). This has led to a significant upgrade of safety standards, especially when it comes to fire protection. The main issue in the case of fire is the wind, or the inflow of fresh air that rekindles the fire and leads to a complete inability of rescue teams. This is the reason why it is very important to monitor the wind speed across both access sides of long tunnels [5].

This paper presents a description of the system for collecting data on wind speed at both tunnel portals. The greatest attention is given to the reliability of the system in all segments, especially in the field of communication. The system consists of peripheral devices for data acquisition and a central computer with a database.

Following the principle "the simpler the more reliable":

- The peripheral hardware is realized as a microcontroller device without a hard drive, cooler or other less reliable elements;
- Data transfer from the peripherals to the central computer is realized via UDP protocol [6];
- For communication paths, the existing Ethernet infrastructure in the tunnel is used. This infrastructure is the backbone of all vital systems in the tunnel with high priority maintenance.

The system is designed to be universal. In this sense, the peripheral devices can be connected to other types of sensors (digital or analogue) such as thermometers, carbon monoxide sensors (CO sensors), luminosity sensors, sound sensors, etc.

II. System description

The system consists of:

- Anemometer (EVT-11K),
- Data acquisition module (PLC-EC2010),
- PC application and
- Server with database.

Fig. 1 shows the block diagram of the implemented system.

Fig. 1. The block diagram of the implemented wind speed measurement and alert system.

As shown in block diagram, anemometer and data acquisition module are set at both tunnel portals. The anemometer provides signal proportional to the current wind speed. The data acquisition module receives the signal, processes it and sends data to the PC application, via LAN network. The PC application receives data and records it into the database. Furthermore, the PC application provides a graphical and numerical representation of the wind speed at the tunnel portals. In the case that wind exceeds the set threshold, PC application alerts the responsible personnel.

The EVT-11K anemometer generates a sinusoidal signal whose frequency is proportional to the wind speed. The output impedance of the anemometer is 520Ω. At low wind speeds, the signal amplitude is approximately 1V, while at speeds above 70km/h the amplitude exceeds 2V. Fig. 3 shows the measured transfer characteristic of the anemometer. The yellow line represents the default factory characteristic, the blue line represents our control measurements, while the red line represents the best linear interpolation of the measured characteristic.

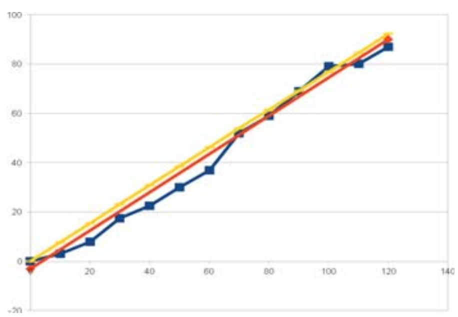

Fig. 2. The measured transfer characteristic of the EVT-11K anemometer.

Anemometers are connected into the system via PLC-EC2010 data acquisition modules. The basic part of PLC-EC2010 is ATMega16 microcontroller [7]. The electrical scheme of the data acquisition module is shown in Fig. 3. Its function is to receive the sinusoidal signal from the anemometer, extract the wind speed information and send it to the central computer, via LAN network. One data acquisition module can host up to 8 analogue or digital sensors (inputs I0 to I7). Those sensors can be thermometers, carbon monoxide sensors (CO sensors), luminosity sensors, sound sensors, etc.

The sinusoidal signal from the anemometer output is connected to the ADC0 input of the ATMega16 microcontroller, via two resistor voltage divider. The microcontroller performs the AD conversion every 500µs and counts positive half-period of the input signal. In order to eliminate noise influence and obtain high accuracy of the measurements, the software performs some filtering. In this sense, every 500µs, three AD conversions are performed. The maximum and the minimum value are discarded, and the middle value is further processed [8].

The PLC-EC2010 calculates number of positive half-period of the input signal, during time interval of one second, and sends it to the central computer. That information is then used by the PC application to calculate the wind speed.

As it can be seen from Fig. 3, the data acquisition module can drive 8 outputs, too. These are the O0 to the O7 outputs of the non-inverting buffer 74HC541. These outputs are not employed in this use of the acquisition module, but could be in some other, for control purposes.

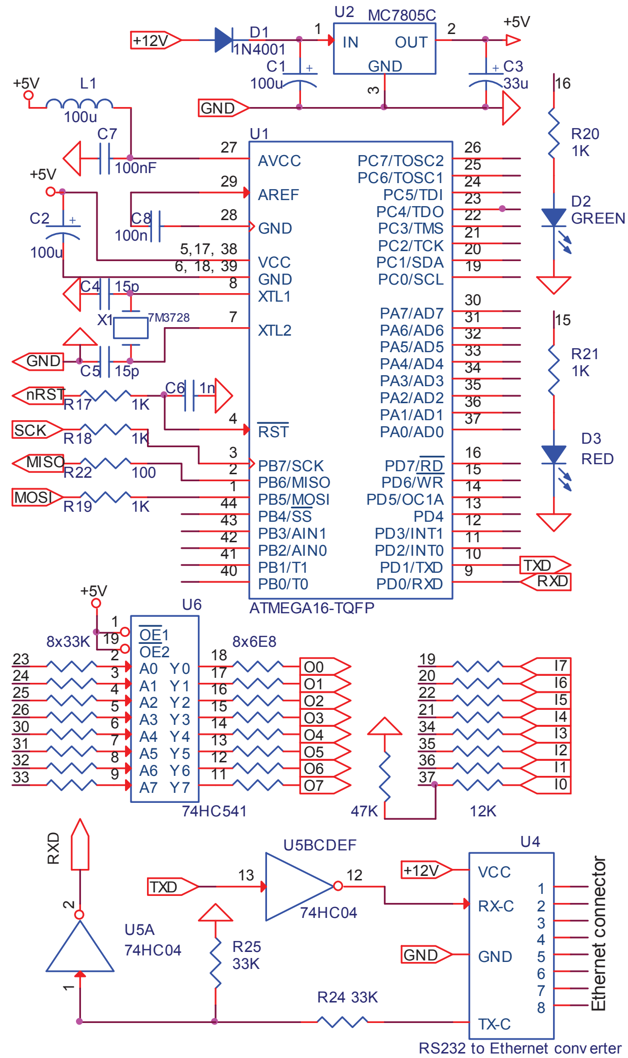

Fig. 3. The electrical scheme of the PLC-EC2010 data acquisition module.

Fig. 4 shows realized PLC-EC2010 data acquisition module, used in the wind speed measurement system at portals of tunnel Sozina.

The communication between concentrator and fast server is based on UDP over a TCP/IP protocol because of two reasons [9]:

- Data packages are small transmitted via one UDP datagram. So there is no need for data splitting or merging;

- In case of corrupted or lost data packet the retransmission is not necessary. On the other hand, UDP protocol is considerably simpler than TCP/IP protocol, and system will very fast reconfigure itself in case of any communication error.

In order to connect elements into the system it is necessary to set the IP address of the central computer into the PLC-EC2010 module. That's the only setting in the system. Although IP addresses of PLC-EC2010 modules are not important to the operation of the system, we need to know them if we want to remotely access and potentially change the earlier assigned IP address of the central computer. Therefore, on power start or address change, every PLC-EC2010 module sends an e-mail message with a description of all its internal settings.

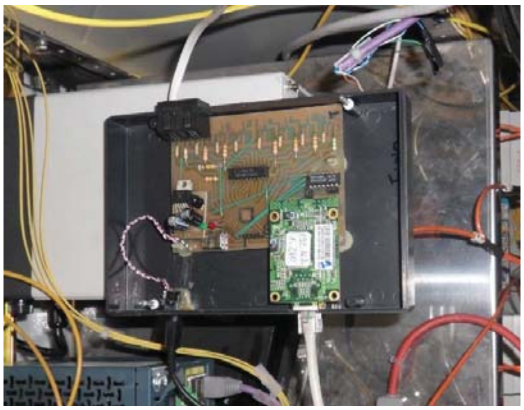

Fig. 4. PLC-EC2010 data acquisition module in the wind speed measurement system at portals of tunnel Sozina

The PC application receives data from PLC-EC2010 data acquisition modules, processes it and records it into the database. The user can choose the graphical representation in a form of charts, Fig 6, or the numeric display, Fig. 7

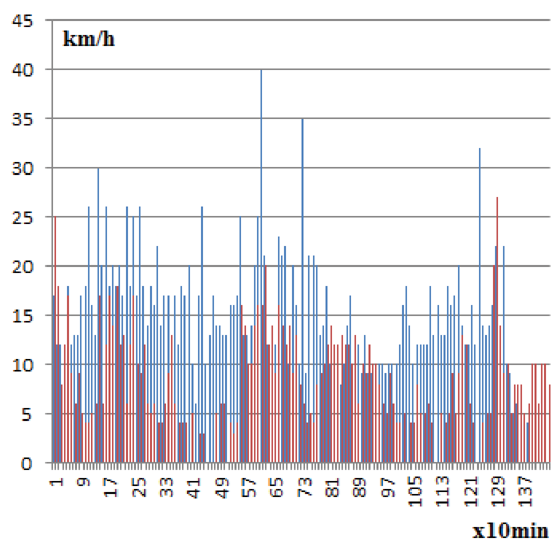

Fig. 6. The graphical representation of the maximum wind speed at southern (red lines) and northern (blue lines) tunnel portal, during one day.

Fig. 7. The numeric display shows current wind speed at tunnel portals.

The PC application can be used to show various useful reports, such as:

- Reports about maximum, average and minimum wind speed for certain periods of the day, week or month;
- Alert reports;
- different weekly, monthly and annual summary reports;
- etc.

III. RESULTS

As an illustration of the collected data, the following diagrams provide a graphical representation of the measured wind speed during one month (February 2014.).

Diagrams on Fig. 8 and 9 show maximum and average wind speed for each day in February 2014, at northern and southern tunnel portal, respectively.

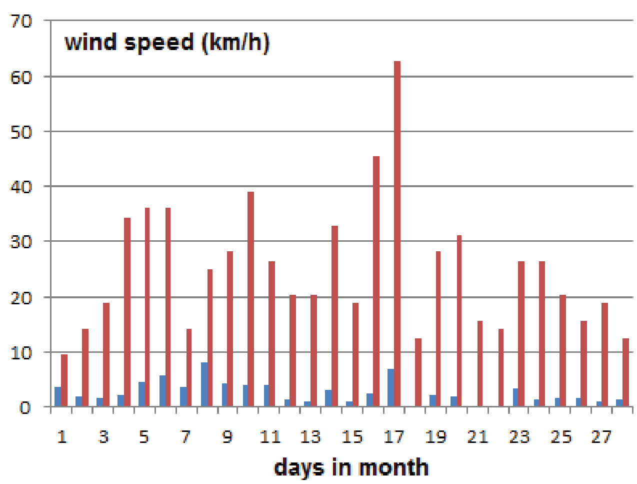

Fig. 8. Maximum (red columns) and average (blue columns) wind speed for each day in February 2014, at the northern tunnel portal.

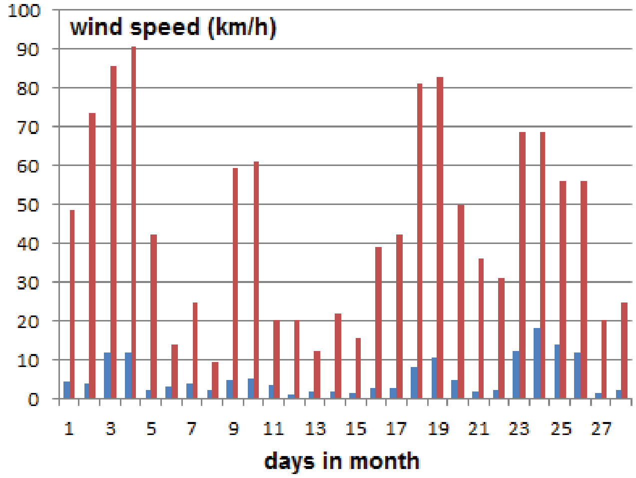

Fig. 9. Maximum (red columns) and average (blue columns) wind speed for each day in February 2014, at the southern tunnel portal.

Diagram on Fig. 10 shows maximum wind speed for each day in February 2014, at northern and southern tunnel portal. Red columns represent maximum wind speed at southern portal, while blue columns represent maximum wind speed at southern portal.

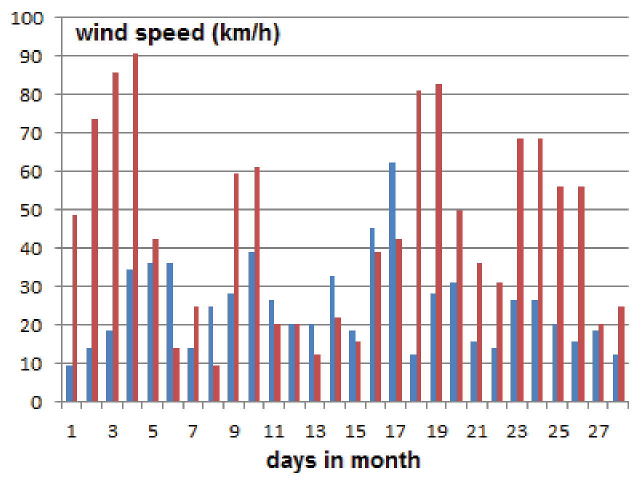

Fig. 10. Maximum wind speed at southern (red columns) and northern (blue columns) tunnel portal, for each day in February 2014.

Diagram on Fig. 11 shows average wind speed for each day in February 2014, at northern and southern tunnel portal. Red columns represent average wind speed at southern portal, while blue columns represent average wind speed at southern portal.

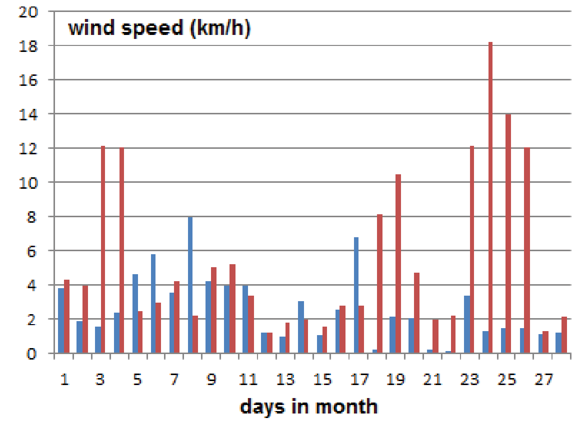

Fig. 11. Average wind speed at southern (red columns) and northern (blue columns) tunnel portal, for each day in February 2014.

IV. Conclusion

The system, in its three years practice, has proven reliable and easy to use. Although primary built for the tunnel needs, it is designed for a more wide usage. Thanks to mobile communications and the Internet, this system could collect data from far remote locations. In this sense, the system could be used in meteorology and telemetry as well.

V. ACKNOWLEDGMENT

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