Bridge testing and monitoring with a measurement system based on the industrial communication network

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Abstract: Bridge testing and especially monitoring are very important for evaluating the structure state. Using modern technologies (ICT) it is possible to achieve on-line permanent monitoring and therefore we are trying to design such measurement system based on industrial communication network with PROFIBUS protocol.

Keywords: structure, testing, industrial communication network

1. Introduction

In order to achieve more reliable and economical construction and maintenance of a structure through its life cycle, monitoring is becoming more and more important. The implementation of structural monitoring is being envisaged for large bridges in the Republic of Croatia.

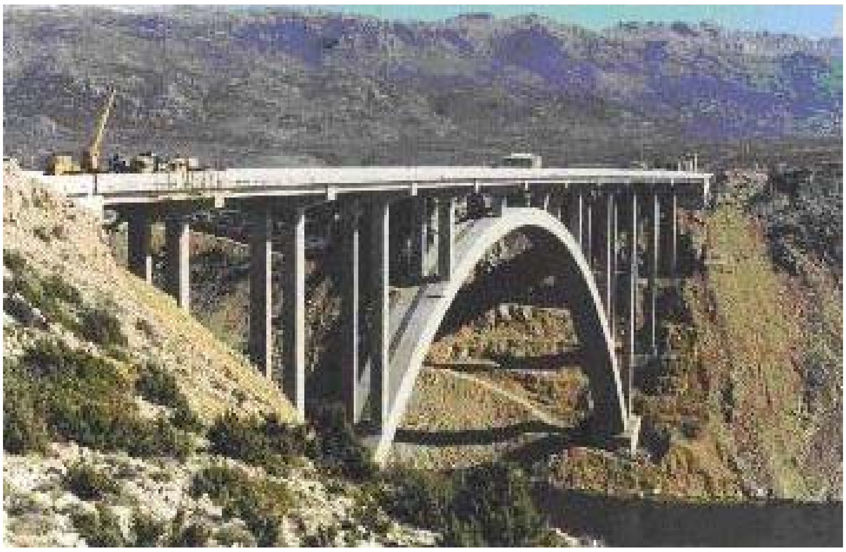


Figure 1. The Maslenica bridge

The first system of monitoring in Croatia at some large bridge is implemented at the Maslenica bridge. The Maslenica bridge was constructed in 1997. It is a concrete arch bridge of 200 m span and overall length of 350 m (Fig. 1).
The measurement system used for this monitoring was mainly analogue. Due to the large distance from a sensor to the data acquisition unit, there were lots of disturbances in measured signals. Disturbances originated mainly from power lines (with frequency of 50 Hz).

Also, this analogue system used lots of cables. Therefore it was decided to design and develop a new digital measurement system. Decision was made to use a digital system based on the PROFIBUS industrial communication network.

2. PROFIBUS measurement system

PROFIBUS (PROcess FIeld BUS) is leading European communication protocol for industrial communication networks. As a communication protocol, PROFIBUS is standardized with the German national standard (DIN 19 245) and European standard (EN 50170). A wide range of qualified vendors offers PROFIBUS devices. That is the reason that PROFIBUS communicates between more than 2 000 000 devices in various industries all around the world. We tried to explore and use its advantages in order to create a better measurement system for bridge testing.
The new measurement system is built of several different devices, all communicating on the PROFIBUS protocol network for data transfer and acquisition. The following devices are used in this system: computer (PC and PCI communication processor card for PROFIBUS), PLC (programmable logic controller – the heart of the system) and distributed analogue input modules (ET 200C). All devices are connected via PROFIBUS cable.
The analogue input modules collect data from sensors (accelerometers, strain gauges, displacement measurement sensors, etc.) Each module has 4 analogue inputs. Sensors mostly give ±5V DC signals so amplifiers were made to convert and amplify such signals to 4-20 mA signals. These signals are, in analogue input modules, transferred into digital signals and sent through PROFIBUS cable to the measurement station. PLC (in fact small industrial computer) ensures that data is collected and recorded at constant time intervals (sample rate). PC shows recorded data and, with additional software, enables data analysis.
This system was built of standard equipment, but modified for outdoor application. In order to reduce cabling, connection box (Fig. 2) with analogue input module and independent 24 VDC power supply was designed and built. Our measurement system has 4 connection boxes (16 signals) so far.

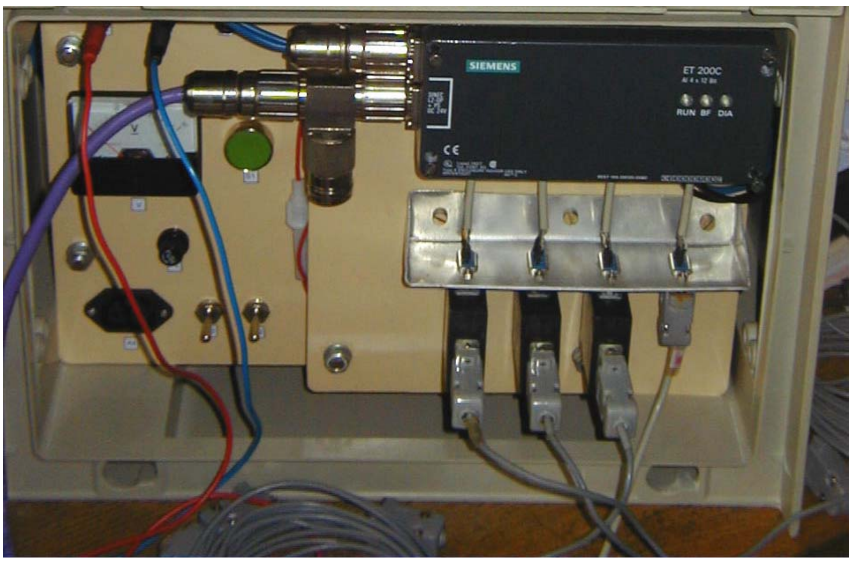


Fig 2 Connection box with ET 200C and 24 VDC power supply

Figure 3 shows a block diagram of the PROFIBUS measurement system. The analogue signal is present in sensor – connection box segment of this measurement system. This segment has maximum length of 30 meters (ET 200C demands this). So in the major part of the measurement system (up to 500 meters) the signal is digital.

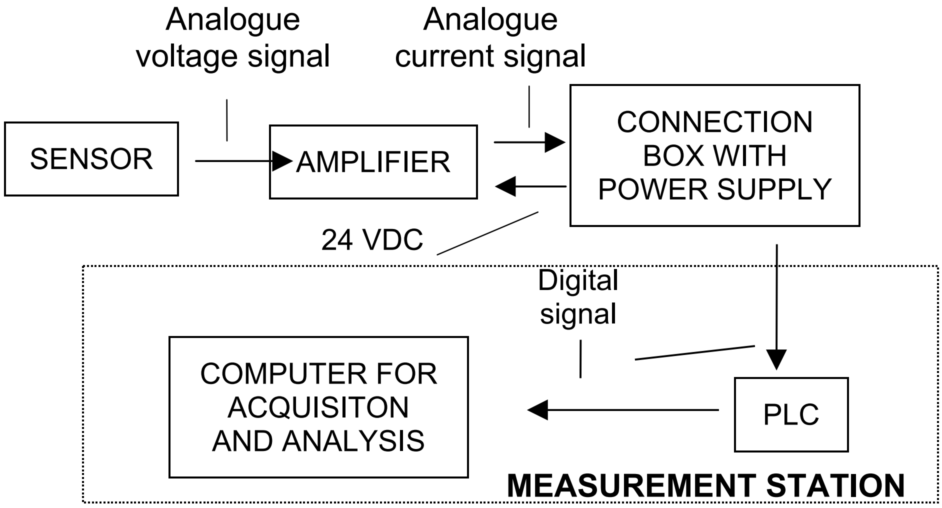


Fig 3 Block diagram of the PROFIBUS measurement system

3. Application and testing of the PROFIBUS measurement system

The new digital measurement system was tested during the Pag bridge testing. The Pag bridge is a 280 m long concrete arch bridge linking the island Pag with the mainland. Figure 4 shows longitudinal section of the Pag bridge. Figure 5 shows the picture of the bridge.

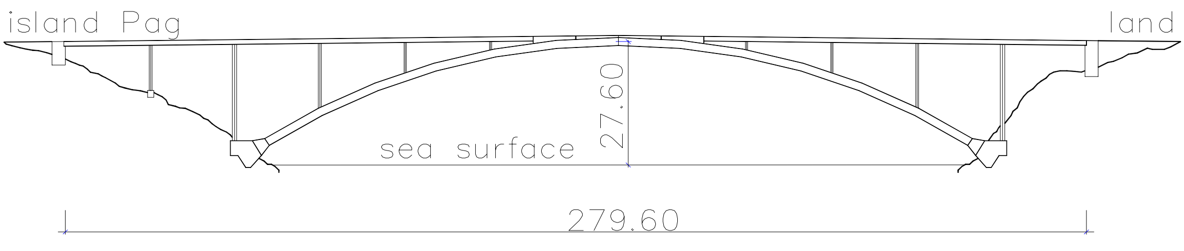
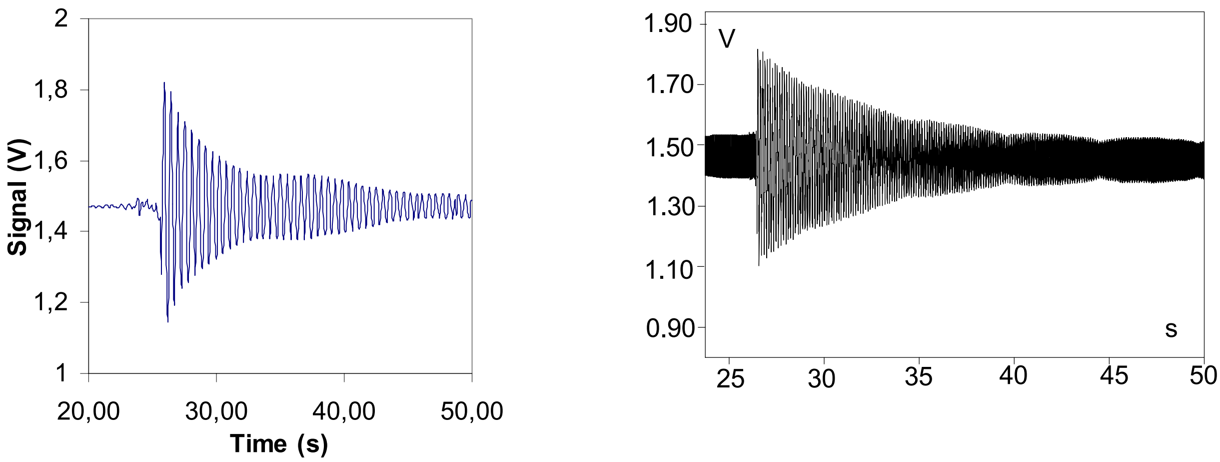


Fig 4 Longitudinal section of the Pag bridge

Fig 5 Picture of the Pag bridge

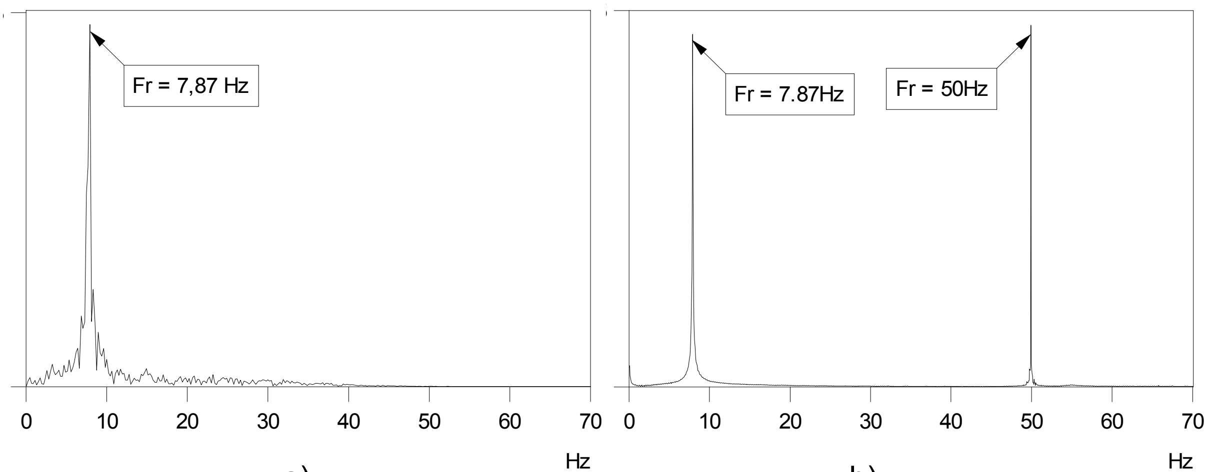
The comparison was made between the old analogue and the new digital measurement system. A signal recorded with both measurement systems is shown on Figure 6. After FFT, the digital system signal has only one dominant frequency in the spectrum while the analogue one shows also a frequency of electromagnetic disturbance (Fig. 7). If these two frequencies are close in the spectrum, the measurement is not accurate and the results are not reliable because the disturbance frequency could not be filtered without losing the real signal frequency.

If there is a need for a new signal to be recorded, the digital measurement system allows simple addition of a new connection box (4 new analogue signals) without additional cabling.
All this shows that the digital measurement system is much more reliable, shorter time is recquired to make it operational, easier to maintain and more accurate.



a) b)

Figure 6: An accelerometer signal measured with: a) PROFIBUS system; b) analogue system



a) b)

Figure 7: Frequency analysis of a signal measured with: a) PROFIBUS system; b) analogue system

4. Conclusions

The presented measurement system was tested during the Pag bridge testing, and it functioned perfectly. Software improvements should be made and then this system is ready for market. But the main purpose for designing and building this system was to improve our own bridge testing procedure. This intention was completely fulfilled.

With the PROFIBUS measurement system the measurement procedure becomes easier and faster. Automation of measurement, analysis, data storage and preparation of test reports is possible, and there is a lot of space to improve this automation in the future.

Also there is a great possibility for bridge on-line permanent monitoring. This will provide a big help in bridge maintenance.

5. References

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