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AN INTEGRATED DYNAMIC WEIGHING SYSTEM BASED ON SCADA

A prototyped dynamic weighing system has been presented which integrates together three advanced software environments: MATLAB, LabVIEW and iFIX SCADA. They were used for advanced signal processing, data acquisition, as well as visualization and process control. Dynamic weighing is a constantly developing field of metrology. Because of the highly complicated structure of any electronic weighing module, it is vulnerable to many sources of environmental disturbances. For this reason, there is a lot of research concerned with weighing signal processing, mechanical matters and functionality of the system. In the paper, some issues connected with dynamic weighing have been presented, and the necessity of implementing signal processing methods has been discussed. Implementation of this feature is impossible in the majority of SCADA systems. The integration of the three environments mentioned above is an attempt to create an industrial system with capabilities to deal with major dynamic weighing problems. It is innovative because it connects the industrial SCADA, laboratory/industrial product LabVIEW and MATLAB. In addition, the algorithms responsible for process control and data exchange are presented. The paper includes a description of the capabilities, performance tests, as well as benefits and drawbacks, of the system. The outcome of the research is a prototyped system and evaluation of its usefulness.

Keywords: *SCADA, industrial signal processing, system integration, dynamic weighing*

1. Introduction

In many production lines, the mass of the final product is one of the most important factors. Progressive need for higher efficiency of production leads to automa-

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tion of the weighing process, called dynamic weighing. One example of a device which comprises all the components required for dynamic weighing is called a checkweigher [1, 2]. Placed at the end of the production line, it selects objects that fulfil strictly specified requirements connected with mass. However, dynamic weighing is associated with several difficulties that should be considered.

The operation of the electronic weighing module in a checkweigher is based on the shift of a coil. Because of this, it is vulnerable to many sources of external disturbances, such as: change in the temperature or humidity, electrostatic charges, constant or variable magnetic field, air movements and vibrations. Measurement errors are often connected with vibrations (usually coming from the floor) [3]. In order to filter out the influence of this source of error, good quality filters and signal processing algorithms should be implemented [4].

A dynamic system integrates applications connected with data acquisition, signal processing, industrial control and visualization. This paper presents a universal dynamic weighing system, which integrates three environments from different fields: the industrial iFIX SCADA, computer package MATLAB and laboratory/industrial product LabVIEW. Its innovation is associated with the use of three environments which are top in their fields in a single application. A literature survey yields examples of the joint implementation of LabVIEW and SCADA [5, 6]. However, integration of MATLAB–LabVIEW–SCADA in one industrial or scientific application has not been undertaken recently.

The main purpose of the present system is to provide a tool for further work connected with modeling the interaction of device with the environment (the influence of the disturbances mentioned above on the measured signal) and filter design. This system will also be tested during the design of an online digital vibration filter. The main advantages of this system are its great potential at the stage of prototyping and for rapid implementation of changes. Improvement in the implementation time is in particular noticeable when compared with FPGA or microcontrollers. Moreover, selected elements of the system can be easily integrated with existing industrial systems using iFIX or LabVIEW.

2. Specification of a checkweigher

Dynamic weighing is concerned with measuring the weight of objects in motion. In order to perform such an operation, a device called a checkweigher should be used (Fig. 1). This particular checkweigher is designed to weigh objects of masses up to 750 g with 0.1 g resolution. It consists of three conveyor belts (each driven by a separate brushless direct current motor which minimizes vibrations). The second conveyor belt is connected directly to the electromagnetic weighing module. The conveyor belt with the weighing module is mounted onto the main construction with vibration damping elements. The measurement procedure is triggered by an optical sensor mounted above the weighing module. Before an object reaches the second conveyor belt, the sensor detects its presence and generates a signal which starts the data acquisition process. The electromagnetic weighing module generates a raw voltage signal as the output.

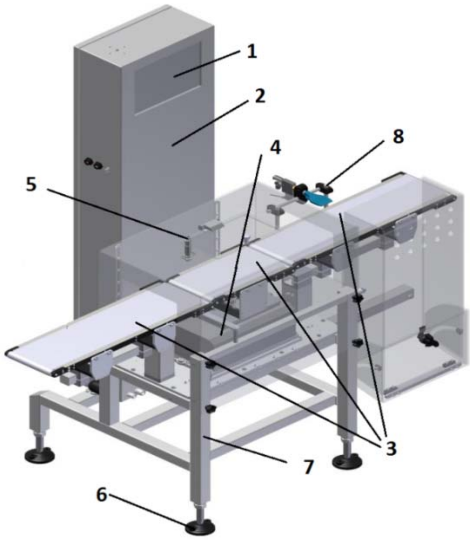

Fig. 1. Checkweigher design: 1 – control panel, 2 – control cabinet,
3 – conveyor belts, 4 – weighing module, 5 – optical sensor,
6 – vibration damping element, 7 – main structure,
8 – device for rejecting objects with incorrect mass

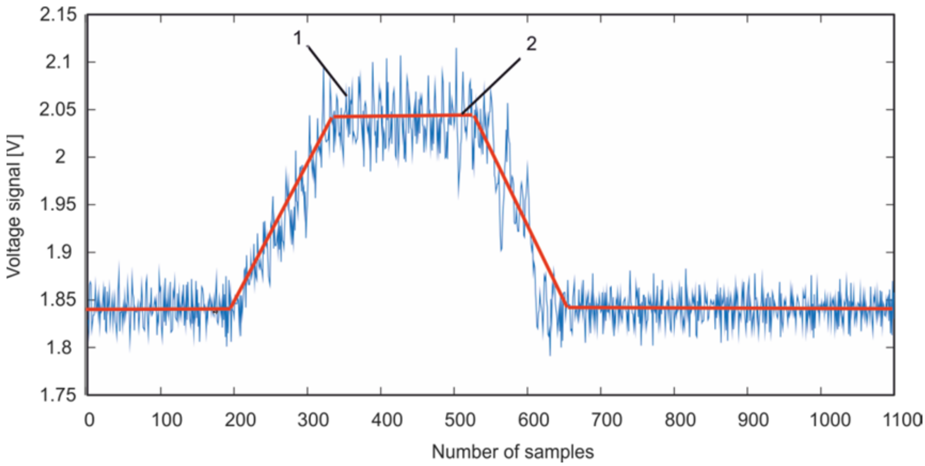

Fig. 2. Measurement signal: 1 – unprocessed signal, 2 – inferred mass

Figure 2 presents the output voltage signal of a checkweigher during weighing. In theory, by selecting the average voltage signal in a stable position (in this example, the samples from 5300 to 5400) and fitting the appropriate mathematical function, it is possible to determine mass. In practice, the signal is distorted by many factors (gap between belts, environmental disturbances, etc.) and it is not possible to select its stable position. It should be considered that in accordance to a simplified model (linear approximation), a 1 mV change in the signal corresponds to 2.87 g. To guarantee high quality measurement and repeatability, it is necessary to implement advanced signal processing methods and filters.

3. Structure and requirements of the system

The requirements of the system concern three different aspects: (1) data acquisition, (2) control and (3) visualization. The former of these aspects is strictly connected with the most important part of dynamic weighing – signal processing. In order to use adaptive processing algorithms, it is necessary to deliver properly prepared data to MATLAB. The primary goals and requirements for data acquisition in the investigated dynamic weighing system are:

- fast triggering,
- reading a voltage signal with the sampling frequency of several dozen kHz,
- at least 24 bit analog-to-digital conversion (ADC),
- possibility of saving data into a measurement file and report creating,
- exchange of data with remote access applications (http, ftp, SMTP, etc.).

All of these requirements, except for 24 bit ADC, can be easily achieved using the LabVIEW software.

Control and visualization are operations connected with a HMI touch screen. Roughly speaking, the specified requirements are:

- the ability to control process parameters,
- the ability to check historical data,
- alarm and error management,
- connection to remote access applications.

The industrial product iFIX SCADA with the Proficy Historian add-on can be used to meet all of the above requirements. The system is complemented by using MATLAB for signal processing. Having argued that the selected environments are suitable for the process of dynamic weighing, it is possible to define the structure of the complete system.

Figure 3 presents the architecture of the system's software. After data acquisition, LabVIEW transfers data to MATLAB using the UDP (user data protocol). After processing the data, MATLAB transfers it back to LabVIEW which then forwards it to the OPC (OLE for process control) server. The database of iFIX can be easily connected to the OPC server via the OPC power tool. This structure allows the transmission of data between all the software environments involved. In this case, LabVIEW is an intermediary between iFIX and MATLAB. However, it is possible to change the structure of the system to one which is based around the OPC server (Fig. 4).

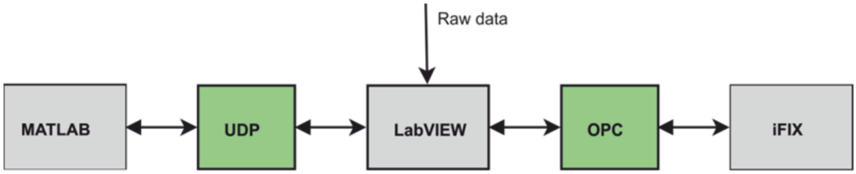

Fig. 3. Structure of the system

The UDP protocol is included in the original system (Fig. 3). This is necessary because of the lack of an appropriate MATLAB toolbox to connect to the OPC server. During the design and testing stages of the project, it is permissible to use a free UDP toolbox or transfer data via text files. In the case of implementing such a system in a real application, it would be recommended to use an OPC toolbox.

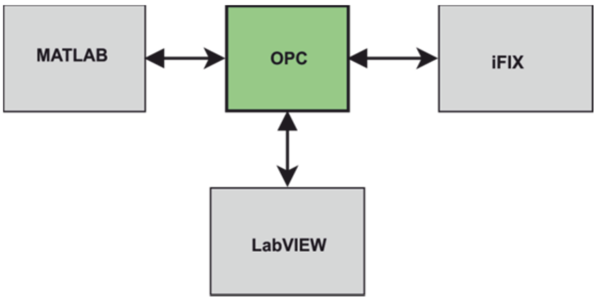

Fig. 4. Structure of a system based around the OPC server

Since both UDP and OPC toolboxes are very popular in industrial applications, it should be emphasized that the proposed system architecture is open to further developments, e.g. inclusion of other environments.

4. Algorithms and properties of the system

The key activities of the system are individual measurement procedures. They are repeated frequently, with the time between consecutive measurements depending mainly on the rotational speed of the BLDC motors. The measurement procedure can be divided into three consecutive stages: data acquisition, signal processing and data transfer/visualization (Fig. 5). The system switches between different operating sections on the basis of flags, set by the environments involved. Flags are held on the OPC server and/or in the MATLAB variables database.

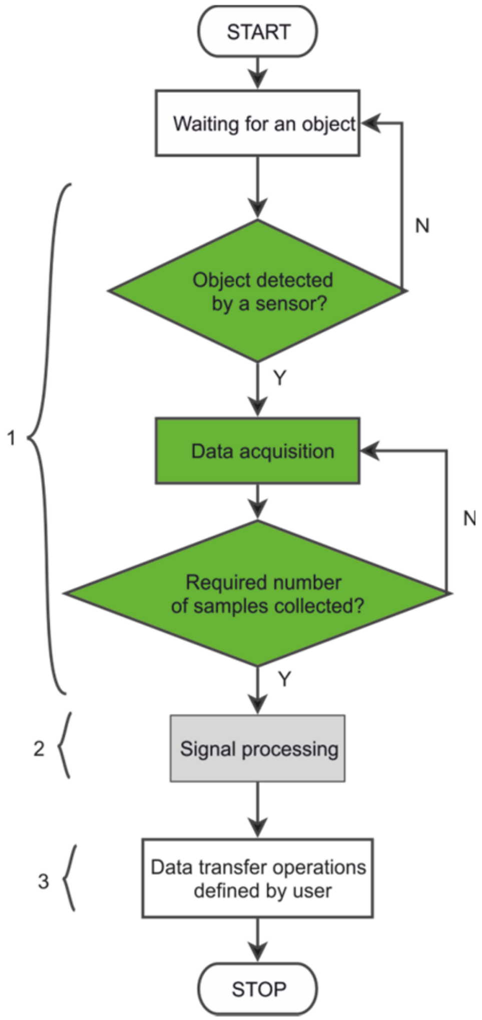

Fig. 5. Simplified algorithm of a single measurement procedure with the three stages highlighted

4.1. Data acquisition

The operations of data acquisition can be described by the simplified algorithm presented in Fig. 6.

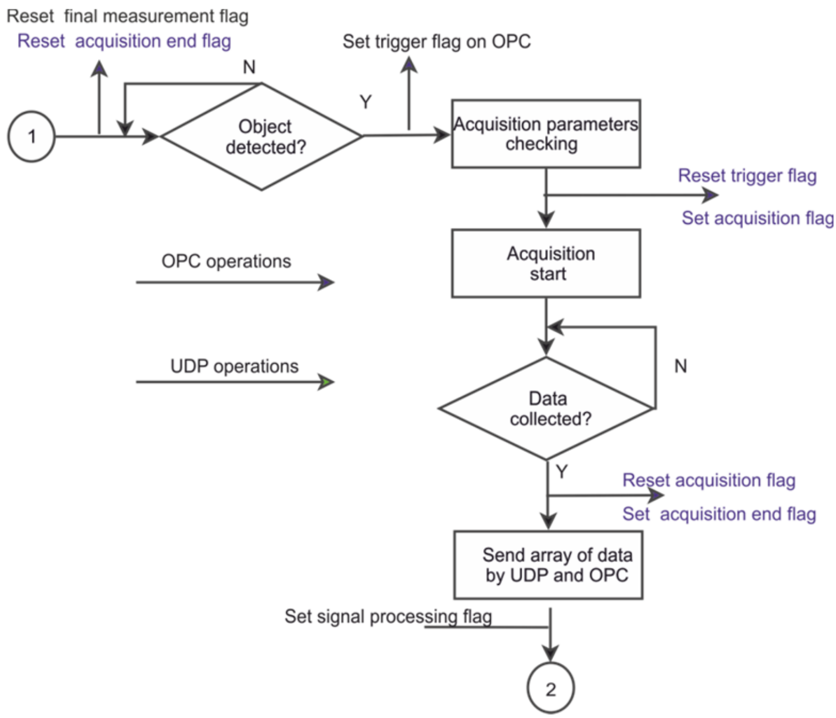

Fig. 6. Simplified algorithm for the data acquisition stage

The data acquisition procedure starts after detecting an object. At the beginning, the system checks the actual parameters of acquisition, as they can be changed at any iteration of the process. Additionally, the triggering flag is set and reset. All of the flags in this section (excluding the signal processing flag) indicate visualization alone. After the voltage signal has been acquired, it is forwarded to MATLAB in the form of a floating point array. Having this array of unprocessed data loaded into the MATLAB database, it is possible to begin the signal processing stage.

4.2. Signal processing

At this stage, signal processing has been implemented. Moreover, the signal from the position sensor is used for filtering (it is used to estimate the position of the object). Figure 7 presents the algorithm of signal processing implemented in the system. Acquisition of the measurements is realized by fitting a parameterized step response function of a first order inertial object:

$$h(t) = -a\mathrm{e}^{-t/b} + c \tag{1}$$

where c is the value of the function as time goes to infinity, because it is the value of the integral component of the PID controller when the signal reaches stability. The outcome of the algorithm is a piece of the signal (its stable part), converted from the filtered voltage signal into a measure of mass (Fig. 8). The final measurement is determined by calculating the average of the highlighted sample (data set M).

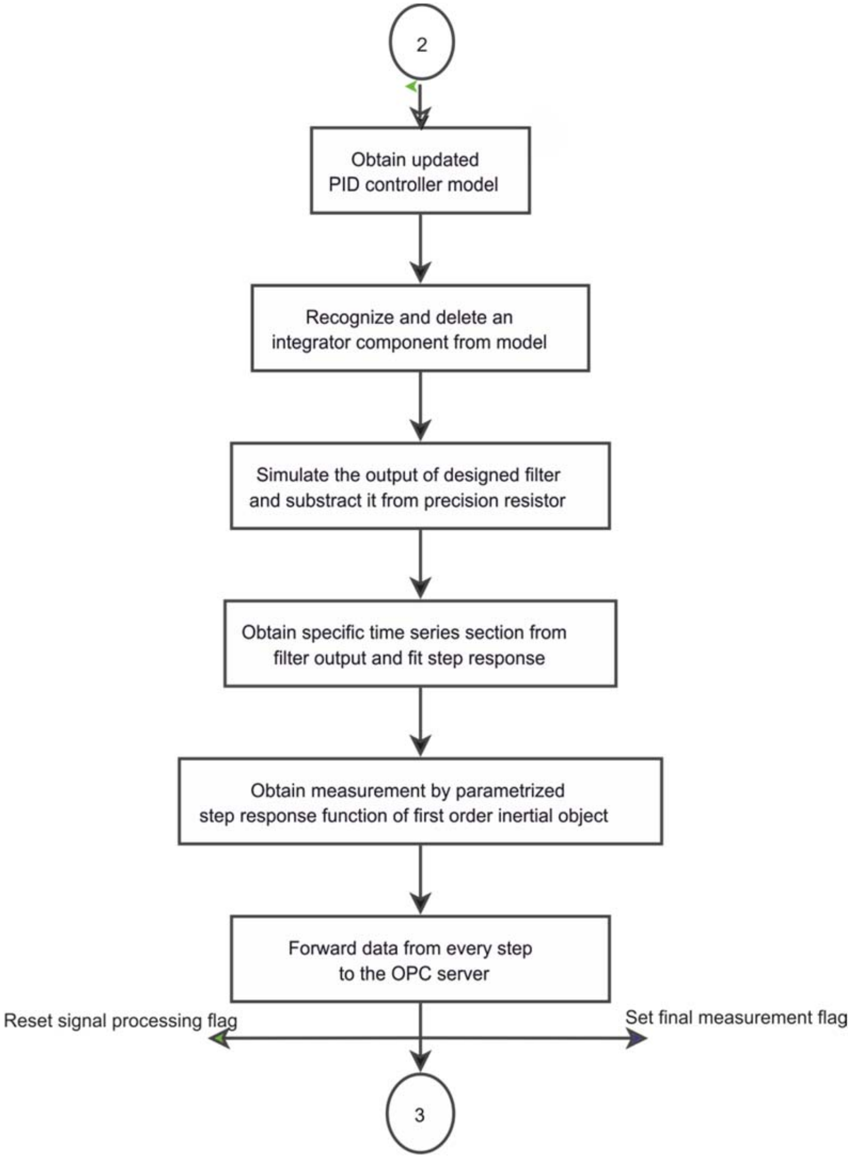

Fig. 7. Signal processing algorithm

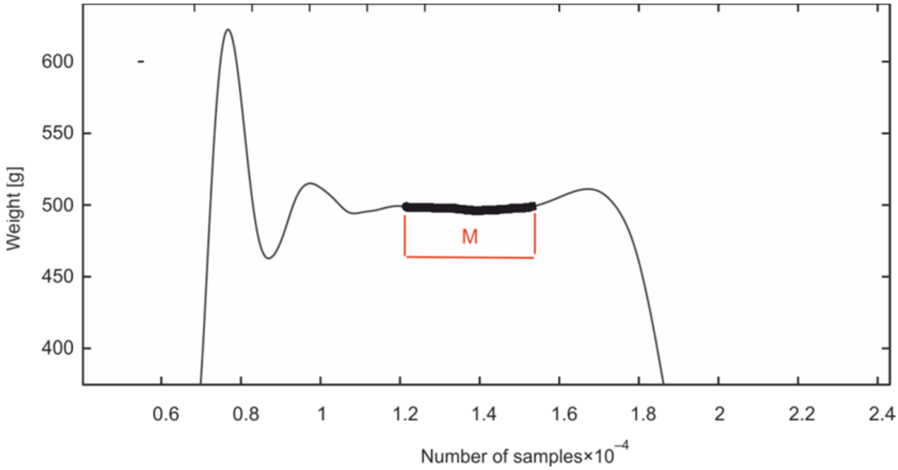

Fig. 8. Final measurement of mass on the basis of data set *M*

The presented algorithm will not be described in detail here, but the interested reader is referred to [4].

At the end of this stage, the appropriate flags are modified and data arrays from each step of the signal processing procedure are forwarded to LabVIEW and iFIX.

4.3. Control and visualization

The data transfer stage refers to the visualization and logging of the data acquired from measurement and signal processing. The whole visualization can be divided into two parts, where the criterion for the division is the update time.

The first part is concerned with final measurement and the signal processing data. After each iteration (when the "final measurement flag" is set), the system logs the data and visualizes it in the form of charts or numerical values. It enables the user to track the signal path to its final form. In addition, it updates several statistical parameters such as average mass, maximum/minimum mass, etc.

The second part is connected with online visualization of the process. This means that the system informs the user about the actual state of the process variables and flags. Moreover, on this basis the system recognizes the current stage of the process and informs the user using the appropriate graphical symbol.

Main menu of the user application and measurement data screen are presented in Fig. 9. The main menu consists of buttons, the taskbar (to change between visualization, the presentation of historical data/actual data and control) and visualization objects.

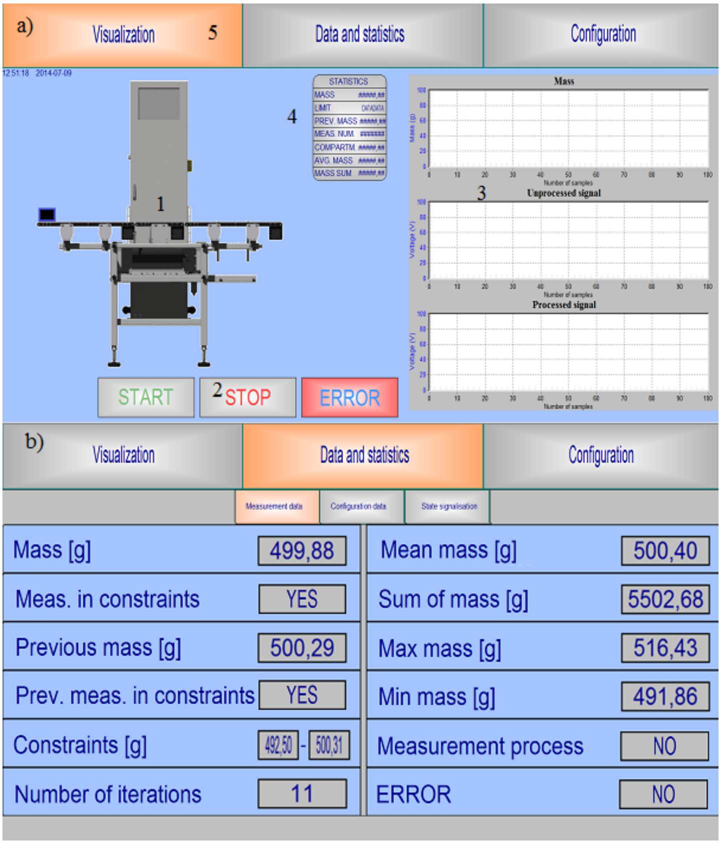

Fig. 9. Main menu of the system in iFIX (a):
1 – visualization of the stage of the process, 2 – function buttons,
3 – main graphs, 4 – measurement of selected statistical data,
5 – main taskbar, and the measurement data screen (b)

The configuration taskbar provides a control panel for both metrological and data transfer parameters. Examples of metrological parameters are: motor speeds, upper and lower limits for acceptable masses or filter choice. Motors can be controlled individually with speeds ranging from 0.5 m/s to 1.5 m/s. At the time of writing, 11 filters are available for the signal processing algorithm used.

Data transfer can be specified in many ways. All the measurement statistics are logged into a text file. As far as remote access is concerned, various approaches can be used. First of all, it is possible to gain remote access to the OPC server, which holds all the actual data (usually, remote access is provided by additional modules). Moreover, the LabVIEW Data communication socket allows the use of different kinds of protocols, such as: HTTP, FTP, UDP, TCP and SMTP. For example, the present system stores a list of email addresses in its database. In the configuration menu, there is a button responsible for sending text log files with historical data to the addresses from the list.

5. Evaluation of the prototype

Having the system prototyped and preliminary tests performed, it is possible to evaluate the system for its compliance with the requirements of the process of dynamic weighing, described in Section 3.

Table 1. Main benefits and drawbacks of the presented system

Advantages	Disadvantages
Wide possibilities connected with signal processing	expensive
Wide possibilities connected with signal acquisition	slow
Large number of options for remote access to the database	
Data easy to track during each stage of the process	
Quick and easy implementation of changes	
Open architecture	

Table 1 presents the main advantages and disadvantages of the system. All the benefits have been discussed in previous chapters. The number of advantages clearly exceeds the number of drawbacks. However, the two drawbacks indicated can be considered as key factors, which disqualify the system from industrial use.

Firstly, the system is composed of expensive environments. All of the operations presented in the paper can be performed by much cheaper means, such as FPGA or a microcontroller. Secondly, the system proved to be slow. Considering all the process operations together (OPC flag setting, signal processing, data acquisition), the procedure for a single measurement lasts about 2 s. In accordance to recent technical communications, where checkweighers are reported to be capable of weighing ca. 400–500 objects per minute, this system is about 12 times too slow.

However, the lack of applicability of the complete system in industry does not exclude its usefulness in other branches. The last two benefits (fast implementation of changes and open architecture) create two possibilities. The first one is that the created components can be used separately to implement a system in an existing industrial application. This case is strictly connected with the use of LabVIEW and iFIX. This will enable full control of a system of dynamic weighing in synchronization with the production line. The second and the most important one is the rapid implementation of changes, which is very desirable at the stage of prototyping. Designing digital filters and carrying out advanced operations on the signal is much easier with the aid of computing environments like MATLAB compared to programming in VHDL/Verilog or C (FPGA or microcontrollers). Hence, the presented system integrating iFIX, MATLAB and LabVIEW turned out to be a very efficient scientific tool.

It has been mentioned that future research will concern modelling the interaction between a checkweigher and its environment. At this stage, it is impossible to define the appropriate way to achieve a satisfactory model. However, the numerical possibilities of MATLAB facilitate the implementation of various optimization and decision support algorithms for different purposes, such as:

- evolutionary strategies for the optimization of the parameters of fuzzy activation functions (in this case, the goal of fuzzy logic is to switch between different linear AR and ARX models),
- Hurwicz's decision rule for input selection depending on the environment.

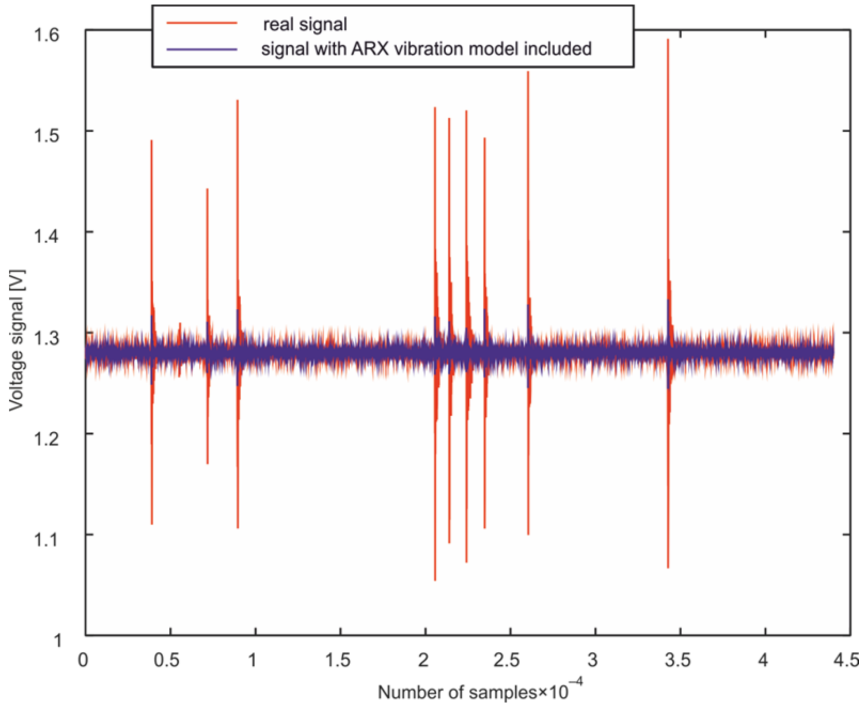

Fig. 10. Real signal affected by ground vibrations and the signal with vibration reduction performed by an ARX model

Figure 10 presents an example of an ARX model used to reduce ground vibrations. In this case, the exogenous input is the vibration level given on the vertical axis.

6. Summary

An innovative system has been presented for a checkweigher based on the integration of three software environments: MATLAB, LabVIEW and iFIX SCADA. The system has its specific strengths and weaknesses. Its high degree of flexibility allows the creation of an application suitable for any specified user. However, its high cost and slow operation prevent complete implementation in an industrial application, although implementation of the control and visualization modules is possible. On the other hand, the system had been found to be attractive in terms of scientific research. Its ability to present data at different stages of signal processing and the visualization of the whole process makes it easier to observe the behavior of the investigated object. Moreover, MATLAB is a highly advanced computing tool, which can be successfully used in the signal processing field. Its main advantage in comparison to FPGA is the possibility of changing the algorithm very quickly.

The system turned out to be useful for planned future research connected with the mathematical modeling of interaction between a checkweigher and its environment (with a focus on vibrations) and the development of a digital vibration filter. All the characteristics of the SCADA system can be implemented in a standard device. However, any change to the standard system is associated with a significant workload. In connection with the complexity of the influence of the environment on dynamic weighing, the development of accurate algorithms may turn out to be unprofitable, e.g. in industrial terms. The system presented in this paper should be used in cases where the architecture of the target device is too complicated to enable easy implementation of changes.

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