Contributions to the Development of Dedicated Systems for Building Measurements

Septimiu Sever Pop
Abstract of PhD Thesis

Scientific coordinator:
Prof. Dan PITICĂ, PhD.

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Contents

1 DESCRIPTION OF MEASUREMENT SYSTEMS USED IN CONSTRUCTION MONITORING
   1.1 The automate measurement systems from UCCH activity
   1.2 The characteristics of transducers used in UCCH activity
   1.3 Resistive transducers
      1.3.1 Temperature transducers
      1.3.2 Force and movement transducers
      1.3.3 Compensate of resistive transducers connection wires
   1.4 Inclination transducer, mechanical pendulum
      1.4.1 The electronic systems used in pendulum measurement
      1.4.2 The principle of measurement with optical barrier
      1.4.3 The principle of measurement with parallel light beam
      1.4.4 The principle of measurement based on triangulation
   1.5 Concluding remarks
   1.6 Selective bibliography

2 MEASUREMENT OF RESISTIVE TRANSDUCERS USED IN CONSTRUCTIONS MONITORING
   2.1 The classical method used to measure resistive transducers from hyro-energetic construction
      2.1.1 The measurement of the transducer with one resistive element
      2.1.2 The measurement of the transducer with two resistive elements
   2.2 The PSPICE model of the resistive transducers
   2.3 Resistive transducer measurement method using constant current source
      2.3.1 The constant current source
      2.3.2 The instrumentation amplifier
      2.3.3 The performance of measurement method
      2.3.4 Correction of offset and gain errors
      2.3.5 Computation of the transducer resistance and physical parameter
   2.4 Method for measuring the resistive transducers with good adaptation to the variation of resistance
      2.4.1 The principle of resistive transducer measurement from useful range
      2.5.2 Analysis of errors sources
   2.6 Comparative analysis of measurement methods
   2.7 Remarks and personal contributions
   2.8 Selective bibliography

3 INCREASING THE CONFIDENCE IN THE MEASUREMENTS RESULTING FROM CONSTRUCTION MONITORING
   3.1 Increasing the confidence by applying the estimate methods
      3.1.1 Measurement series analyses
      3.1.2 Correlation of the series of measurements
   3.2 Estimate method with digital filter
      3.2.1 FIR, IIR digital filter
      3.2.2 Adaptive filter
      3.2.3 Mean filter
      3.2.4 Numerical approximation
   3.3 Particular case
      3.3.1 Processing of measurements with digital filter
      3.3.2 Processing of measurements with adaptive filter
      3.3.3 Processing of measurements with mean filter
      3.3.4 Processing of measurements with numerical approximation
      3.3.5 Estimate of measurements with successive processing
3.3.6 Comparative analysis of correction methods
3.3.7 Estimation of temperature distribution inside the dam
3.3.8 Measurements processing from pressure transducer
3.4 Remarks and personal contributions
3.5 Selective bibliography

4 DEVELOPMENT OF AN OPTICAL SYSTEM FOR PENDULUM MEASURE
4.1 Theoretical foundation of the optical telependul
  4.1.1 Mechanical construction of the telependul
  4.1.2 Light propagation and shadow formation
  4.1.3 Considerations on the use of optical sensor TSL 1410R
  4.1.4 Analysis of the pixel circuit response
4.2 shadow position detection Techniques
  4.2.1 Data acquisition from optic sensor
  4.2.2 Computation of wire shadow position with optical sensor
  4.2.3 Detection of shadow position by detecting the edges
  4.2.4 Evaluation of methods for detecting the position of the shadow
4.3 Experimental model of telependul
  4.3.1 Performance evaluation for telependul with ideal parameters
  4.3.2 Mechanical parameters correction
  4.3.3 Align the measurement system with reference system
4.4 Performance evaluation of experimental optical measurement system
4.5 Remarks and personal contributions
4.6 Selective bibliography

5 Final remarks and personal contributions
  5.1 Contribution to the measurement of resistive transducer
  5.2 Contribution to the analysis of measurements resulted from construction monitoring
  5.3 Contribution to the development of optical system used in pendulum measurement
  5.4 Final remarks concerning the use of developed measurement systems and new research directions

BIBLIOGRAPHY

ANEXE
ANEXA 1 AMC for UCCH physical parameter and used transducer
ANEXA 2 Technical document with teletelmeters from TAU dam
ANEXA 3 Effective tolerance of resistance
ANEXA 4 Amplifier TL1014, MATLAB model
ANEXA 5 Calibration characteristics
ANEXA 6 The coefficients of approximation function
ANEXA 7 The coefficients of digital low pass filter
ANEXA 8 Triangulation principle
ANEXA 9 Optical refraction correction
ANEXA 10 The constructive principle of optical telependul
Abstract of the Thesis

Long lasting buildings like bridges, tunnels, dams, require supervision during exploitation time as a guarantee of their safety. To prevent accidents that could become catastrophic continuous monitoring is necessary. Malfunctioning or destruction of those buildings could have catastrophic effects on the country’s economy.

The PhD thesis focuses on monitoring the hydro-energetic construction, especially dams. In the safety analysis of hydro-energetic construction a series of physical parameters is used, describing the building's response to actions influence quantities. The main parameters of influence are ambient temperature, water level in the lake, lake water temperature, earthquakes, etc.. The monitored parameters are: temperatures within the dam, the inclination, interstitial pressure and negative pressure, flow rates of infiltration, movement, etc..

The data obtained from dams monitoring are generally used for two purposes:
- To establish the exploitation regime
- To verify the dynamic behavior model

Physical parameters are measured with transducers placed in the construction. They are spread throughout the building structure forming an information gathering network. The transducers number may reach hundreds. Generally, the monitoring of Romanian dams is done manually by measuring transducers with manual measuring instruments. The dam beneficiary, Hidroelectrica and the Compania Națională Apele Romane requires the informatisation of the monitoring process and data management.

Objectives

The purpose of this research thesis is to develop new systems to realize a modern management of dam behavior following three main directions:

- Measurement of resistive transducers within dams;
- Introduction of numerical tools for analyzing historical measurements obtained during dam monitoring to recover the correct data;
- As part of the rehabilitation and revival of UCCH activity, this thesis studies new measurement systems. A prototype system is proposed for measuring the pendulum; mechanical transducer used to measure the batter of dam.
This work contributes to the development of Dedicated Systems for Building Measurements, using both theory and experimental methods, according to modern technologies.

**Structure and Content**

**Chapter 1** is an overview of existing measurement systems. It presents the organization of measurement systems and the transducers used to obtain information about physical parameters. The emphasis is on describing existing resistive transducers and electronic measuring systems of the pendulum. Depending on the physical parameters measured, there are two types of resistive transducers. A common problem of resistive transducers is the error introduced by connecting wires. Partially, broken transducers with the compensation wire damaged are also studied. In this case investigations were undertaken to determine the resistance of connection wires to minimize measurement errors. The second part of the first chapter presents the current state of the pendulum measurement systems. Optical detection methods are used to determine the wire position.

**Chapter 2** analyses different types of circuits to identify the optimal method of measurement to measure resistive transducers. The proposed methods determine the transducers resistance based on voltage - current relationship. The wires compensation is made by software using measurements from various branches of the resistive sensor. The circuits are SPICE simulated and modeled in MATLAB to highlight their performance.

**Chapter 3** analyses the historical measurements obtained from resistive transducers in order to detect erroneous data. Data recovered from each transducer is tested using correlation with the physical size of influence. An automated monitoring system periodically reads the sensors. The efficiency of automated systems is greater as less measurement is affected by disturbances. The presence of error is mainly caused by difficult work conditions of equipment and transducers. The error is a random error. To detect the errors, the measurement system makes an on-line processing based on dynamic limit. The automated acquisition systems can not detect on-line errors caused by perturbation phenomena. Measurement error correction can be made only through a post factum processing. Historical measurements are interpreted as a discrete signal; their processing is done with signal processing techniques and numerical approximation.

The statistical model EDF (Electricité de France) considers that the dam reaction is influenced by three factors: the level of lake water, temperature and dam age. The correct data recovered are considered valid only if it keeps the characteristics of the influence parameter.

**Chapter 4** is dedicated to reviving the monitoring activity of construction. To measure the pendulum wire position a geometric principle was experimented. In cross section, free movement of the wire is modeled with the movement of a point in the plan. The geometric model divides the movement wire space to a network of triangles. Wire detection is performed optically; its position is determined applying the principle of
triangulation. An electronic measurement system is developed to determine the wire position.

**Chapter 5** presents the conclusions and summarizes the author's contribution to the development of measurement systems used to monitor hydro-energetic constructions, highlighting the main results.

No matter how complex they are, the electronic monitoring systems do not solve construction performance problems. Electronic monitoring does not give verdicts; still the construction developers take notice of this information. Based on this information, recommendations can be made to carry out further investigation.

**Original Contributions in this Thesis**

In the second chapter, the author’s contributions are related to the measurement of resistive transducers with one and two elements used in construction monitoring. The main contributions are:

- Determine the resistive transducer types from Romanian dams;
- Determine by simulation and experimentally the measurement performance of a the classic circuit that compute the resistance based on voltage-current relationship;
- Introduces the concept of measurement of resistive sensor in useful range;
- A dynamic method is proposed to measure resistive transducers to satisfy the required performances;
- A measurement method is developed that uses programmable system on chip, the resistance is measured with an accuracy of 16 bits in a large range of values.

In the third chapter the numerical methods are introduced to analyze the measurements of resistive transducer from hydro-energetic building monitoring. The main contributions are:

- Highlighted by statistical analyses and data visualization of disturbance phenomena that affect the measurements;
- Development of a processing method based on signal processing techniques and numerical approximation. This approach is possible because the data obtained from measurements was interpreted as a discrete signal;
- Development of a technique based on digital filtering algorithm. By limiting the spectrum the effect of errors is minimized;
- Development of a technique based on the adaptive filter. This is used in two types of configurations; the first one is with reference signal, influence parameter. The second configuration is the prediction system.
- Development of a method based on numerical approximation
• Checked, the quality of recovered data by a correlation function and signal to noise ratio;
• Compare the recovered temperature measurements with estimated date obtained from thermodynamic modeling of the building;
• Developed MATLAB applications to analyze real historical data.

In the fourth chapter the original contributions are related to the development of an optic measurement system of pendulum wire position based on triangulation principle. The main contributions are:

• Development of an optical method to detect the wire position;
• Methods evaluation by simulation and experimental to establish the wire shadow position using optical sensor TLS1014R;
• The evaluation of the optical method of measurement using constant parameters;
• Modeled constructive parameters so that mechanical and optical imperfections have been reduced;
• Highlight the measurement performance of optical telependul by using a reference measurement system;
• Developed a test stand and automatic determination system of optical telependul parameters;
• Developed a MATLAB application for analyzing data from optical telependul and reference measurement system, which enabled to draw conclusions from a large number of experiments.

All the results were obtained and tested during research activities developed for S.C. Hidroelectrica S.A and were presented in 28 articles and a book published at international conferences.
Awards

SIITME 2008 – Excellent poster award for a young scientist– *Automatic system for distance sensor scaling*

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Septimiu Sever Pop

Contact data:
septimiu.pop@ael.utcluj.ro
Str. G. Baritiu 26+28, Cluj-Napoca
Catedra de Electronică Aplicată a Facultăţii de Electronica, Telecomunicaţii
şi Tehnologia Informaţiei, Universitatea Tehnica din Cluj-Napoca
Tel. 0040-264-401469

Personal data: Date and place of birth: 21.06.1977, Blaj, Alba

Education:
• 2003 – Master of Science degree in “Design Technologies for EMC” –
  Faculty of Electronics, Telecommunications and Information Technology ,
  Technical University of Cluj-Napoca;
• 2002 – Graduated Electronics Engineering – Faculty of Electronics,
  Telecommunications and Information Technology, Technical University of
  Cluj-Napoca;

Professional experience:
• 2003 – Assistant at the Applied Electronics Department, Faculty of
  Electronics, Telecommunications and Information Technology, Technical
  University of Cluj-Napoca;

Scientific and research activities:
• 28 published papers in national and international magazines and
  conferences proceedings;
• 1 published book;
• Project manager for 1 national grant;
• Project member for 26 national research projects;

Awards:
SIITME 2008 – Excellent poster award for a young scientist– Automatic system for
distance sensor scaling

Foreign languages:
• English – good;