Web-Based Real-Time Data Acquisition System as Tool for Energy Efficiency Monitoring

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***Abstract* — A web-based data acquisition system is proposed as a research tool of the energy efficiency monitoring project of the test stands. Basic requirements for the architecture of the data acquisition system are discussed. The architecture of the data acquisition system is proposed to provide the real-time interface with sensors, to acquire and to log data from all sensors with fixed rate, and to deliver logged data through FTP to the end-user.**

***Keywords* — Web-based, data acquisition system, energy efficiency monitoring.**

I. Introduction

THE data acquisition system (DAS) is an important part of any monitoring and/or control system. Variety of DAS used in different applications is presented in [1]-[5]. They cover a wide range of applications including medicine, weather, renewable energy, and buildings. Web-based data acquisitions systems (WDAS) are representing an advanced technique providing the seamless interface from sensors to the end-user [6]-[8]. Usage of distributed embedded web-servers gives the effective tool for the researchers to run experiments remotely and to share their results [9-10]. The proposed architectures of WDAS are different. However they possess certain common features. These features allow implementation, monitoring, logging, and analysis of experiments without the presence of the researcher [9]. The mentioned features are necessary for the energy efficiency monitoring but they are not sufficient to provide the simultaneous data acquisition from the test stands discussed below.

The 5 test stands involved in the energy efficiency monitoring project have been built using different local materials based on composite structures and renewable recources. They are named after the major materials used in construction as the logs, the plywood, the ceramic bricks,the aerated concrete and the stone wool insulation. The names of the test stands are AER, CER, EXP, LOG, and PLY. All of the test stands, shown in Fig. 1, have the same appearence, size, and orientation in space. The different sensors are located inside and outside of the test stands as well as are built-in building constructions to measure characteristics of the different building constructions and materials.

Fig. 1. The disposition of the test stands.

All test stands have the same set of sensors, that are located in the same way. 40 different sensors include temperature and humidity (T/H) sensors, air velocity flow sensors, a solar radiation sensor, an energy meter, a differential pressure sensor, a heat flow sensor, and an atmospheric pressure sensor. All sensors are labelled. The labeled locations of T/H sensors are shown in Fig. 2 as

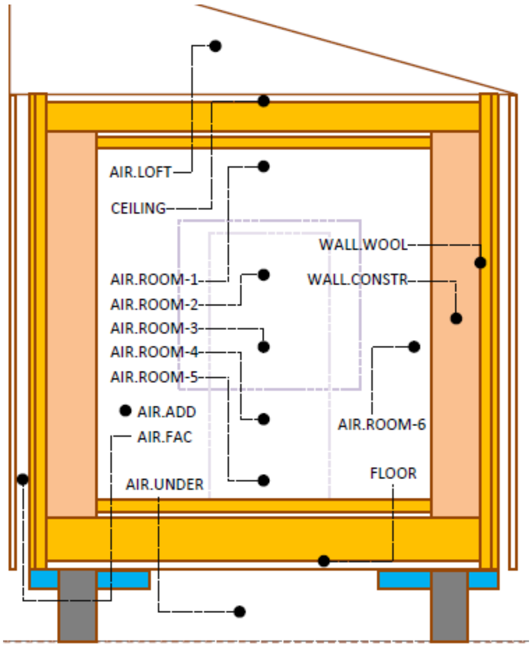

Fig. 2. The location of T/H sensors in a test stand.

black dots. Each test stand is equipped with a climate control and a data logger. The data logger is collecting all sensor data including data from the electric energy meter. To collect meteorological data a weather station is installed on the top of a test stand with the data logger

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installed inside the test stand.

The architecture of the WDAS for energy efficiency monitoring of the test stands satisfying the user's requirements are discussed in the section II. The implementation of the WDAS are discussed in the section III. The measurements and the results obtained using the WDAS are discussed in the section IV.

II. Architecture of the System

It is important to develop the architecture of WDAS that satisfy the user's requirements and provide all necessary services. Previously discussed WDAS are used in different applications. Their architectural characteristics were chosen in order to meet requirements of their applications, and to satisfy their needs. However the characteristics can be split in two parts, one characterizing WDAS general features, another, application specific features. Usually the user requirements cover them both.

WDAS designed for the energy efficiency monitoring is including some WDAS general features required by the user. It is unattended, distributed, modular, and scalable, providing remote access to the data and to the software. In addition, the proposed architecture of WDAS should provide the real-time interface with the sensors, to acquire and to log data from all sensors with fixed rate, and to send logged data using File Transfer Protocol (FTP). All mentioned WDAS general and specific features were included in the user's requirements. Additionally the user set strict limitations on the size of T/H sensors and on the data acquisition timing.

Selecting the data logger with built-in web-server WDAS architecture, shown in Fig.3, would have a two-level structure. Lower level is including the data acquisition equipment located in the test stands and the weather station, higher, is the networking equipment. Both levels are connected with Ethernet cable.

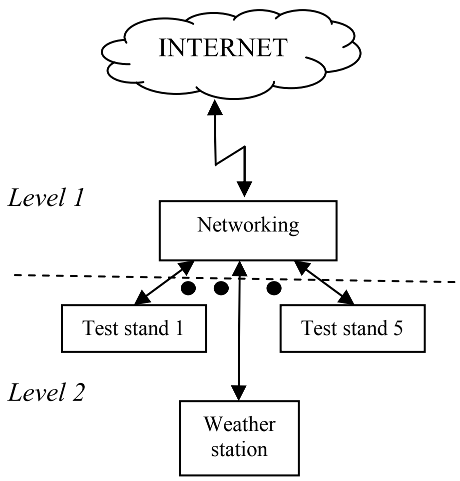

Fig. 3. Selected web-based DAS structure.

The level 1 includes several network switches, routers, and the wireless router providing access to the Internet. The structure of the level 2 components except the weather station is shown in Fig. 4. It includes three major parts: sensors, an interface module, and the data logger. The interface module (IM) is connected with the digital smart sensors that include temperature, humidity, and pressure sensors. Others, analog sensors, are connected directly to the data logger. The user's requirements determine the selection of the data logger and the set of sensors. IM represents the custom part of WDAS introduced to satisfy user's strict limitations on the data acquisition timing.

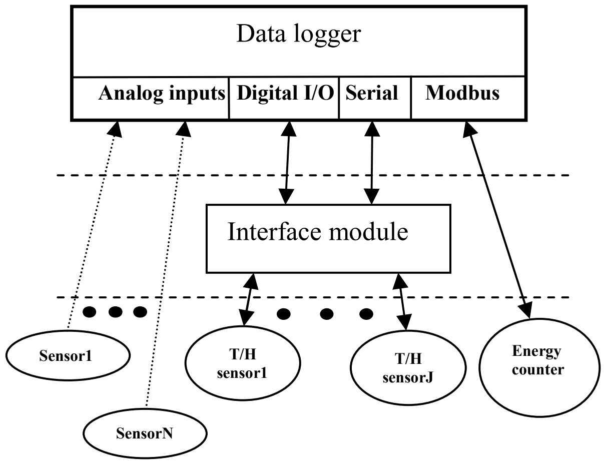

Fig. 4. Selected web-based DAS structure.

III. Implementation and Functionality of the System

The data logger data Taker 82I [11] was selected due its basic characteristics that conforms the most to the requirements of the users of WDAS. It has installed a web-server and a FTP server providing remote access to the data and to the software. It has enough analog inputs for analog sensors, and two serial channels. One of the serial channels is used for Modbus connection, another, for the connection for all digital sensors through the interface module. The interface module consists of two connected configurable interface devices [12]-[13]. It presents a customized solution based on off-the-shelf hardware components and a custom software development that provide necessary modularity, and scalability on the sensors level satisfying user's requirements. Increase of the number of connected sensors can be achieved by adding the additional interface device in the interface module.

A. Web access

Web access is providing real-time access to the data of

Below is a list of all channels in the current job.

R▲	Name	Value	Units	Alarm	Time stamp	Log	Input
✓	LOG-SOL-AIR.ROOM	0.3717541	W/m2		2013-09-02, 14:50:56	✓	1*L
✓	LOG-H-AIR.LOFT	81.080002	%		2013-09-02, 14:50:56	✓	1CV
✓	LOG-P.DIF-AIR.ROOM	4.0541725	Pa		2013-09-02, 14:50:56	✓	1L
✓	LOG-T-AIR.LOFT	14.98	degC		2013-09-02, 14:50:56	✓	2CV
✓	LOG-H-CEILING	59.849998	%		2013-09-02, 14:50:56	✓	3CV
✓	LOG-T-CEILING	19.389999	degC		2013-09-02, 14:50:56	✓	4CV
✓	LOG-H-FLOOR	82.260002	%		2013-09-02, 14:50:56	✓	5CV
✓	LOG-T-FLOOR	14	degC		2013-09-02, 14:50:56	✓	6CV
✓	LOG-H-WALL.WOOL	69.919998	%		2013-09-02, 14:50:56	✓	7CV
✓	LOG-T-WALL.WOOL	17.25	degC		2013-09-02, 14:50:56	✓	8CV
✓	LOG-H-WINDOW	67.160004	%		2013-09-02, 14:50:56	✓	9CV
✓	LOG-T-WINDOW	16.99	degC		2013-09-02, 14:50:56	✓	10CV
✓	LOG-H-DOOR	65.57	%		2013-09-02, 14:50:56	✓	11CV
✓	LOG-T-DOOR	17.77	degC		2013-09-02, 14:50:56	✓	12CV

Fig. 5. LOG test stand real-time data screenshot.

each test stand. The web interface allows users to configure the data logger, to access logged data, and research current measurements as mimics or in a list using the web browser. LOG test stand real-time data partial screenshot is shown in Fig. 5. It also can be displayed as a mimic shown in Fig. 6.

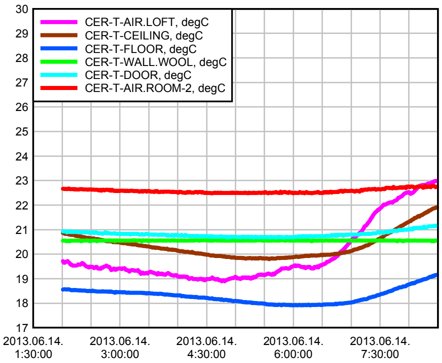

Fig. 6. Temperature changes in the CER test stand

B. FTP access

FTP access is possible to the data that are located on FTP server. FTP service provides data to an office over the internet without the need for polling or specific host software. According to the selected settings the logger data is sent once a day. The FTP data are available for all users connected to the network. The partial screenshot of FTP data from EXP test stand is shown in Fig.7. Each row contains a timestamp and all sensors data.

```
Timestamp,"TZ","EXP-SOL-AIR.ROOM (W/m2)","EXP-P.DIF-AIR.ROOM/A (Pa)"","EXP-T-AIR.LOFT (degC)","
2013/10/27 15:19:50,n,3.233314,2.08519,88.23,14.98,15.77,99.99,14.48,99.99,14.37,97.46,17.7,91.74,16.
2013/10/27 15:20:50,n,5.598009,1.494114,88.24,14.99,15.75,99.99,14.48,99.99,14.37,97.46,17.69,91.71,1
2013/10/27 15:21:49,n,5.286694,1.42577,88.29,15.01,0.09,15.74,99.99,14.48,99.99,14.37,97.46,17.69,91.
2013/10/27 15:22:49,n,4.642785,1.614216,88.35,15.01,15.75,99.99,14.48,99.99,14.37,97.45,17.66,91.69,1
2013/10/27 15:23:49,n,5.473495,1.691456,88.32,15.02,15.75,99.99,14.48,99.99,14.35,97.48,17.67,91.72,1
2013/10/27 15:24:49,n,5.971551,1.575909,88.33,15.03,15.74,99.99,14.48,99.99,14.37,97.48,17.66,91.71,1
2013/10/27 15:25:49,n,5.577863,1.713216,88.35,15.03,15.77,99.99,14.48,99.99,14.37,97.47,17.64,91.71,1
2013/10/27 15:26:49,n,5.182326,1.691708,88.38,15.04,15.75,99.99,14.48,99.99,14.37,97.47,17.64,91.68,1
```

Fig. 7 FTP data screenshot.

C. Data acquisition

The data acquisition from the sensors is performed by the data logger DT82I program by sending queries to the sensors. There are two sections in the program. One is used for the digital sensors including temperature, humidity, and pressure sensors. Another is used for the sensors with the analog signal output. The partial screenshot of DT82I program section, shown in Fig. 8, is containing the queries to the energy meter and to the interface device.

```
BEGIN"config"
' Generated by dEX Configuration Builder Version 1.29.1924
(Firmware Version 9.08.3932)
' Target device: DT82I-3
1MODBUS(AD1,R4:1106,MBL,=29CV,W)
1MODBUS(AD1,R4:1018,MBF,=45CV,W)
2SERIAL("\e\w[1000]{X}{K}%*s%1c%6f[1CV]%1c%6f[2CV]",W)
2SERIAL("\e\w[1000]{X}{L}%*s%1c%6f[3CV]%1c%6f[4CV]",W)
2SERIAL("\e\w[1000]{X}{M}%*s%1c%6f[5CV]%1c%6f[6CV]",W)
```

Fig. 8. The energy meter and digital sensors data acquisition program.

The partial screenshot of the logger DT82I program section, shown in Fig. 9, is containing the queries to the analog sensors. The queries are sent periodically with the period of 1 minute accordingly to the time stamp values shown in Fig. 5, and Fig. 7. The queries to the digital smart sensors are sent to IM. IM processes the queries and addresses them using the appropriate protocol of the digital smart sensors.

```
RB"LOGGING"(„b:",ALARMS:OV:100KB:W60,DATA:OV:80MB)
  LOGONB
  2V(„LOG-Q-WALL~W/m2",=36CV,W,40,NA)
  1*L(N,"LOG-SOL-AIR.ROOM~W/m2",LM,S1,NA,100)
  1L(N,"LOG-P.DIF-AIR.ROOM/A~Pa",LM,S2,NA,100
```

Fig. 9. The analog sensors data acquisition program.

IV. Measurements and Results

Each data logger is reading data from analog channels and from digital channels. At present all measurements are performed every minute and saved to the logger memory. The logger measurement data file is sent to the user FTP server once a day. Measurements can be displayed directly using Web access to the logger memory, and using data from the user FTP server. Fig. 10 shows daily inside temperature changes of all test stands in August obtained from the user FTP server. Fig. 11 shows averaged daily inside temperature and relative humidity changes of all test stands in August.

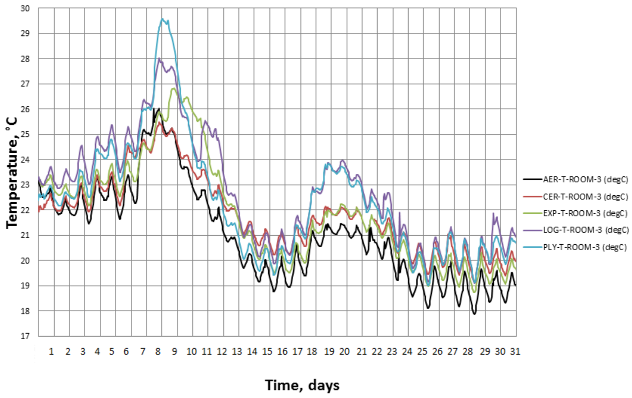

Fig. 10. The inside temperature of the test stands with fully covered windows in August 2013.

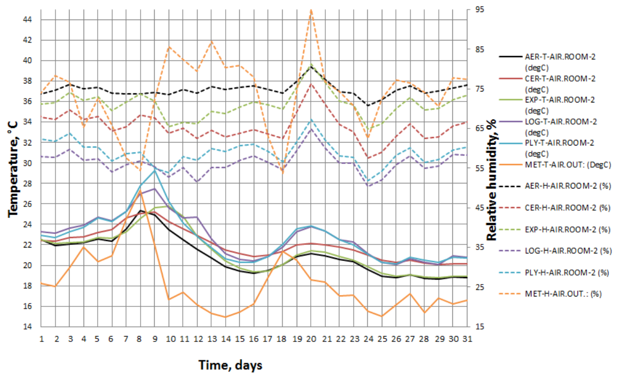

Fig. 11. The averaged inside temperature and humidity of the test stands with fully covered windows in August 2013.

Fig. 12 shows a day air flow velocity changes measured by the air flow velocity meter next to the climate control unit. The air flow velocity changes are caused by the climate control unit cooling activities. About once an hour it is turned on.

All results obtained from all 5 test stands and the weather station is placed on the user FTP server.

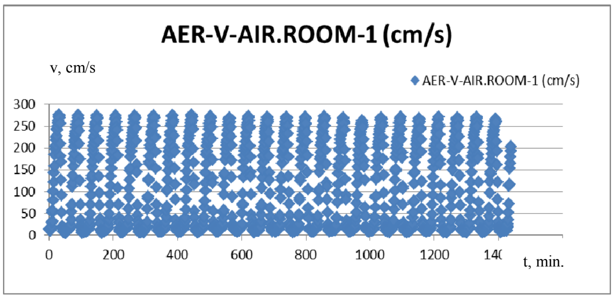

Fig. 12. AER test stand air flow velocity measurements.

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