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ESTABLISHMENT OF NEW RESEARCH INFRASTRUCTURE AT DEPARTMENT OF ELECTRICAL ENGINEERING AND MECHATRONICS, FACULTY OF ENGINEERING, UNIVERSITY OF DEBRECEN

Géza HUSI[1], Péter T. SZEMES[2], Nóra TÓTH[3], Éva DUDÁS[4]
[1] Dep. of Electrical Engineering and Mechatronics, University of Debrecen, husigeza@eng.unideb.hu
[2] Dep. of Electrical Engineering and Mechatronics, University of Debrecen, szemespeter@eng.unideb.hu
[3] Dep. of Electrical Engineering and Mechatronics, University of Debrecen, tothnora@eng.unideb.hu
[4] Dep. of Electrical Engineering and Mechatronics, University of Debrecen, dudase@eng.unideb.hu

***Abstract*—**Nowadays, the energy efficiency solutions, renewable energy usage are very important topics because of the rapid decrease of the energy sources. Department of Electrical Engineering and Mechatronics established a Building Mechatronics Research Centre where the researches have the chance to search the methods and technologies to reduce the energy consumption and to increase the amount of on-demand controlled, on-site produced renewable energy. In the laboratories of the Research Centre, engineering students are also involved to get acquainted with modern, industrial technologies, and to take part in researches and projects.

***Keywords*—**Building Mechatronics, research, engineering, measures, projects, Debrecen

I. INRODUCTION

TODAY'S problem is the decreasing of fossil energy sources (coal, petroleum, gas). According to calculations the coal and petroleum sets are running down and they can assure the energy necessity of the world till around 60-80 years. Because of that and the climate changes, the political decision makers draw and start aims and programs, which are going to utilize renewable energies (wind energy, water energy, solar energy, biomass, geothermal energy), efficient utilization of the energy, saving of the energy. In the University of Debrecen, Faculty of Engineering, Electrical Engineering and Mechatronics Department a unique form of education came to existence. Only there is educated Building Mechatronics in Hungary. The Department has a Bachelor of Science Program in Hungarian and since 2013 in English too, furthermore since 2013 a joint Master of Science Program in Advanced Mechatronics Systems in English with the Department of Mechatronics and Robotics, University of Oradea (Romania) and a Master of Science Program in Advanced Building Mechatronics in Hungarian. The Department of Electrical Engineering and Mechatronics is very innovative and it tries to take part in many projects, which aim is to utilize renewable sources, and decrease energy consumptions. The running projects, which was won by the Department is the *Denzero Sustainable energy systems by using optimal integration of renewable energy sources*. The basic aim of the project is the drawing up suggestions to the Hungarian government to reach the optimal application of the energy strategy, furthermore to reach the "Horizont 2020". In this project can be found 10 research groups and the Department is in intelligent buildings group. The objective of the research team is to make a new, cost-effective data collector to control standard building service systems in small town detached houses or in two storey buildings [1]. Beside Denzero project the Department took part in other significant projects: (1) HURO-0901/028/ 2.3.1. E-Laboratory Practical Teaching for Applied Engineering Sciences, (2) HURO/0802/155_AF ROMANIAN –HUNGARIAN R&D PLATFORM FOR NTELLIGENT BUILDING RESEARCH PROJECTS SUPPORT, (3) HURO-0901/179/ 2.3.1. Crossborder Development and Implementation of a Master Program in Advanced Mechatronics Systems.

Researches, PhD students, BSc, -MSc students are able to use laboratories and make researches to improve their knowledge and work in projects. The competence of the laboratory includes the integrated parts of building automation, building supervision and security solutions including the operation of necessary sensors, regulators and interveners, which is defined as building mechatronics [1].

The aim of this article is to introduce the features and research possibilities of the Department of Electrical Engineering and Building Mechatronics Research Centre.

The paper is organized as follows: Section II is about the University of Debrecen, Faculty of Engineering, Electrical Engineering and Mechatronics Department. Section III presents the Building Mechatronics Research Laboratories. Section IV describes the Building Mechatronics Research Centre and Section V includes the summary.

II. INTRODUCE THE UNIVERSITY OF DEBRECEN, FACULTY OF ENGINEERING, ELECTRICAL ENGINEERING AND MECHATRONICS DEPARTMENT

The Department of Electrical Engineering and Mechatronics teaches for its students probably the 21th century's two most promising engineering disciplines [1]. Mechatronics is relatively new branch of science and engineering and is defined as "combination of mechanical engineering, electronic engineering, computer engineering, software engineering, control engineering, and systems design engineering in order to design, and manufacture useful products. (…) It is a multidisciplinary field of engineering that is to say it rejects splitting engineering into separate disciplines" [2]. Mechatronic students take courses from across various fields of knowledge.

Some of the most important are as follows: (a) Mechanical engineering and material science, (b) Electrical and electronic engineering, (c) Computer engineering and computer science, (d) Automated systems and control engineering, (e) Telecommunication and optoelectronics, (f) Robotics [2].

The aim of the Department is to transfer for its students interdisciplinary knowledge. Several market surveys show that it is one of the most required professions nowadays. The topics, subjects and the requirements are the same in both (Hungarian and English language) education forms, i.e. the curricula are totally identical.

The interdisciplinary nature of the curriculum (mechanical and electrical engineering) helps to the graduated students to find easily jobs in domestic and European industries, companies. The Department takes part intensively in international programs (like Erasmus) thanks to mainly the English language Mechatronics course.

The Department of Electrical Engineering and Mechatronics, University of Debrecen (Hungary) associates with Master of Science Program in Advanced Mechatronics Systems with the Department of Mechatronics and Robotics University of Oradea (Romania). For the advanced degree courses of mechanical, electrical and electronic engineering together with courses in mechatronics and robotics have to been accomplished. Specific areas of study consists of mechanics, electronics, design, signal analysis and processing, computer systems, computer science, sensor and actuator technology, automatic control, electrical system design, robotics and microprocessor technology.

Mechatronic engineers have to known cutting edge technologies in both Mechanical and Electrical and Electronic Engineering. This means that they are have to be able to design, construct and maintain intelligent machines, micro-machines, smart structures, intelligent systems, control systems and consumer products such as cameras, washing machines or a fully automated robotic assembly line or they may be involved with defence technology and systems.

III. THE LABORATORY BACKGROUND FOR THE RESEARCH: BUILDING MECHATRONICS RESEARCH LABORATORY

The aim of the Building Mechatronics Research Laboratory at the Department of Electrical Engineering and Mechatronics at Faculty of Engineering, University of Debrecen (head of laboratory: Dr. Péter Szemes) is the elaboration of methods to carry out the intelligent evaluation of measurements, intervention and planning. The international researches carried out in the laboratory promote the activity of planners, operators and builders so that they can use more efficient building engineering and building supervision systems in energetic aspect and the buildings meet the comfort needs of residents, especially their special requirements in the case of environmental effects differing from normal circumstances. [2].The competence of the laboratory includes the integrated parts of building automation, building supervision and security technique including the operation of necessary sensors, regulators and interveners, which is defined as building mechatronics.

Our researchers have a wide-range theoretical and practical experience concerning automation of building engineering systems of intelligent grounds, elaboration of their support by means of building information technology as well as elaboration of objectives relating to the cost-saving intelligent automation of systems provided with conventional.

The laboratory has a strong sponsor background, so its research and teaching activities are carried out by means of the most modern tools.

The laboratory was built by using an EU-fund awarded on the basis of the tender "HURO/0802/155_AFA „Hungarian-Rumanian Research and Development Platform for supporting the building of Intelligent Buildings" and with the co-operation of the European Regional Development Fund. Equipments utilizing renewing energy have been built with the co-operation of ENERGOTEST Ltd, National Instruments and Schneider Electric [2]. The construction and embodiment of the apparatuses manufactured individually and installed into the laboratory promotes the access for teaching, research, presentation and measurement.

A. Hot water storage and heat-pump system

Hybrid multi-circular, modular heat-pump system can also be separately operated.

This system is also suitable for filling air, water and other heat transmitting medium (anti-freezing, termo-oil, salt solution). Its embodiment also enables the application for two-pump and/or soil-sound, pelvis systems or systems to be realized by using large-sized stores.

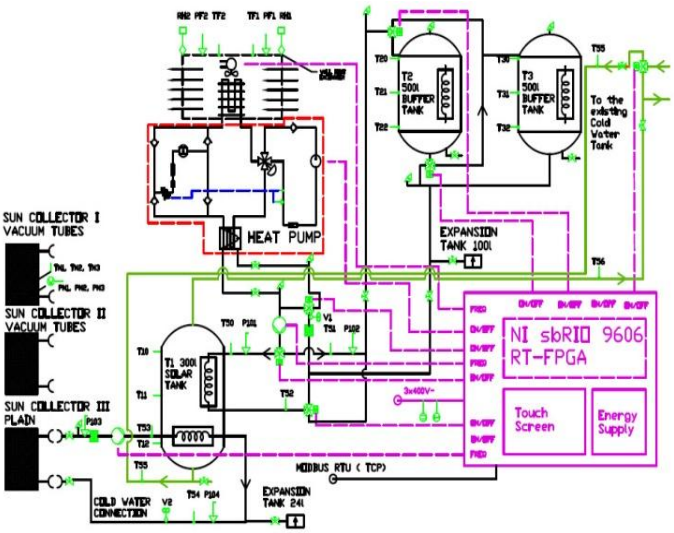

Fig. 1. Hydraulic circuit of the renewable energy unitization system: heat pump, sun collectors and hot water storages

Besides carrying out energetic measurements the heat-pump system is also suitable for carrying out measurements in connection with the scaling of the heat pump by changing different parameters (e.g. use of oil, pressure degrees, temperature degrees, quality of gas). The maximum gas content of a heat pump circle is 2.99 kg. The apparatuses are integrated into the appropriate part of the building [3].

B. Heat-pump system with air channel

The parameters of the compressor of the heat pump can be measured. The monitoring is also possible via the information technological network of the building with remote contact.
The incorporated 100-litre-large heat sink has measuring points and can be connected to outside stores.
The possibility of quick connection and reset is assured in the water circle, because the system is provided with quick outlets. The system is suitable for the co-operation with different heat-transmitting media (anti-freezing, thermo-oil, salt solution).
The one-circle operation is possible in island mode of operation as well as multi-circular operation is possible as complementary heating with an electric capacity of 1200 W. The controlled melt of the system as well as the observation of the safety catch (high pressure, low pressure, liquid circulation, extreme values of temperature, direction of rotation, phase failure, carter temperature) are assured.
The heat pump can be easily reset, installed to another location and after the connection can be immediately switched on, put to use and has incorporated supplementary heating, regulator and circulating pump as accessories [3].

Fig. 2. Compressor based heat pump system

C. Heat-pump boiler

The heat-pump boiler has a separate control, through the HMI interface of which can also locally be measured. Its operation parameters and values can be reached and changed through Ethernet network.
Within rational limits, the apparatus enables the change of the parameters of the compressor, gas circle, evaporating and condenser circle.
The system can be connected to outside stores in the case of one-circle and multi-circular mode of operation and the produced heat energy can also be recovered. The characteristics of the system are as follows:

1) *Measuring points shaped both on the air and water side.*
2) *Measuring and the possibility of measuring the parameters of the compressor.*
3) *Possibility of monitoring through the ETH network*
4) *Possibility of measuring through the ETH network*
5) *Regulated circulating system positioned towards the interior sink*
6) *Incorporated heat sink having a cubic capacity of 250 liters provided measuring points*
7) *Possibility of connection to a solar system (with interior heat change)*
8) *Possibility of connection to an exterior system (for removing the meanwhile produced surplus heat)*
9) *Regulated emission of cooled air into the space of installation.*
10) *Permitted gas load of 2.95 kg*
11) *Observation of conditions (high pressure, low pressure, liquid circulation, extreme values of temperature, direction of rotation, phase failure, carter temperature)*
12) *Utilized maximum electric capacity is 1200W*
13) *Period of heating 250 liters/ 55 °C 4 hours* [3].

D. Vacuum-tube solar collector (1000W)

Due to its shaping, the vacuum-tube solar collector is mounted onto a stand and can be easily moved as well as easily and quickly connected to water-system. The outflow of the heat transmitting medium is assured by means of self-closing quick-connectors.
The connection can be realized with flexible tubes in any position.
The shape also assures the safe storage out of use.
The characteristics of the system are as follows:

1) *Vacuum-tube solar collector PERSC 1800/12V+;*
2) *Direct-flow and heat-pipe embodiment;*
3) *Shaped measuring points (temperature, mass current,) both on input and output side;*
4) *Measurement of fall-in light capacity;*
5) *Measurement of the temperature of the absorption surface;*
6) *Shaped with a mobile stand and flexible tubes;*
7) *Semi-automatic de-aeration after connection;*
8) *Efficient electric capacity is 850 W/m2;*
9) *Efficient surface is 1.26 m2* [3].

It can be measured in mass current, input and output temperature, surface temperature and fall-in light capacity. The produced hot water is led to the buffer sink and then to the HMV system of the building.

E. Flat solar collectors

The characteristics of flat solar collectors are as follows:

1) *1 pc 1.9-2.2 kW/2.4-3.0m2*
2) *1pc thin-table flat solar collector 1.8 kW* [3].

F. Buffer stores

The main aspect of the three buffer stores was to examine as many connection combinations as possible and the possibility of connecting them to an exterior system. Therefore, the stores have been provided with motor-driven, remote-controllable valves and specially shaped electric control at the points of connection to each other.
The control supervises the extreme values of safe connection, reconfiguration and operation. It measures the values of temperature, pressure and flowing conditions.
When necessary, it co-operates with heat-pump systems and solar-collector systems. The operation and the measuring of the system is assured through the ETH network. The necessary de-aeration, expansion, circulation and security subsystems are also integrated into the system. The characteristics of individually shaped buffer stores (3 x 1 m3) are as follows:

1) *Storage volume: 1000 liters per store*
2) *Two heat exchangers per stores*
3) *9 pcs 6/4" connection stub for connecting the system*
4) *3 pcs measuring workshops*
5) *Filling-draining stub*
6) *Heat insulating coatings (2 °C/24 hours)*
7) *Provided with de-aeration valves*
8) *Provided with security overpressure valves*
9) *Corrosion-proof embodiment*
10) *It has type permission and pressure tests have been carried out* [3].

The buffer stores are suitable for storing warm water received from solar collectors and heat exchangers and in the case of necessity forwarding them to the HMV system.

G. 6 pcs solar cells (PV) to be used for research

Solar cells can be mounted onto the rotating stands owned by the Faculty of Engineering; however, they can also separately operate. Solar cell tables out of use are put into storage-carriage cars, which provide the conditions the safe storage and easy transport.
The solar-cell systems is suitable for re-feeding into the network and does not include any own solar cell element [4].
The system is provided with a minimum battery capacity and charging control, all elements are connected to a measuring system, for assuring the possibility of presentation and modeling the storage facilities. Data of the measuring system can be accessed through the ETH network.

1) *Mono-crystal solar cell module MSD85W-D 85W*
2) *Mono-crystal solar cell module MSD185W-C 185W*
3) *Poli-crystal solar cell table KD95-SX 90W*
4) *Poli-crystal solar cell table KD185G 180W*
5) *Amorphous solar cell table 40W*
6) *Solar cell manufactured with „thin-film" technology, flexible 10W*
7) *Re-feeding unit 1000W*
8) *„SOLAR" Battery 17VA* [3].

H. Rotating stand

The rotating and tilting solar-cell, resp. the solar-collector trestle developed in 2010 in the institute can assure the optimum position of solar cells in comparison the fall-in angle of current radiation in the case of taking the actual meteorological conditions into account.

IV. BUILDING MECHATRONICS RESEARCH CENTRE

This part of the study is based on *the G. Husi, P. T. Szemes, E. Dávid, T. I. Erdei, G. Pető: Reconfigurable Simulation and Research Toolset for Building Mechatronics* publication [5]. Mechatronics is defined as the combination of mechanical engineering, electronic engineering, computer engineering, software engineering, control engineering, and systems design engineering in order to design and manufacture useful products [5].
Building Mechatronics consists of followings:

1) *Building automation and building controlling*
2) *Building security and object security*
3) *Building informatics, communication nets and the maintenance of informatics solutions that can help the*

operation of a building.

The Building Mechatronics Research Centre provides real-time investigation and measurement of the energy consumption behaviors of an education building and rooms for recreation.
The purpose of the Research Centre is to create extraordinary and special measurement options. It means to find effective methods for the anomalies of the consumers' behavior and enumeration. Furthermore, find new ways to avoid the losses. In the Intelligent Building two integrated and separated heat pump systems are capable of the heating and cooling of the 1066 m2 total area.
They benefit energy from the outer air by the Air Source Heat Pump and from Solar Collectors. Both of them are free forms of energy and the two heat pump systems provides heating - cooling and the domestic hot water needed by the recreation rooms for visiting researchers [5].
The hybrid multi-circular, modular heat-pump systems can be operated separately and together as well. The systems are also suitable for filling air, water and other heat transmitting medium (anti-freezing, termo-oil, salt solution). Their embodiment also enables the application for two-pump and/or soil-sound, pelvis systems or systems to be realized by using large-sized stores [5].
We would like to obtain higher energy consumption awareness through the examination of the consumers' behaviors. The reduction of the energy use can be reached by the means of energy control and an intelligent building management. We work on the next three levels:

1) *Certification: we utilize exterior references for design or use nominal data to create „medium" energy efficiency survey with the appropriate prescript of the inland authorities or the European Union.*
2) *Operation: we achieve higher energy consumption awareness through the examination of the consumers' behaviors. The reduction of energy use can be reached by the means of energy control and an intelligent building management.*
3) *Investment: we can increase the energy efficiency with reconstruction, in other words we examine the return of the investment involve the full life cycle cost and examination of the consumers' behaviors.*

Our Department and the Faculty of Engineering is obliged to the technologies of the National Instruments. The Faculty provides LabVIEW tuition for at least half year for each student.

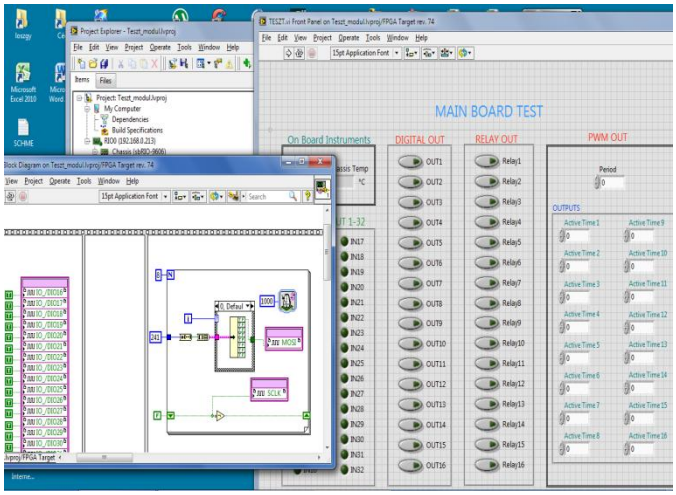

Fig. 3. LabView based development environment to control FPGA based boards

The units driven by renewable energy are controlled by an NI compact controller. We chose the NI sbRio technology which is an FPGA-based technology.

There can be built reconfigurable, parallel working real-time embedded controllers.

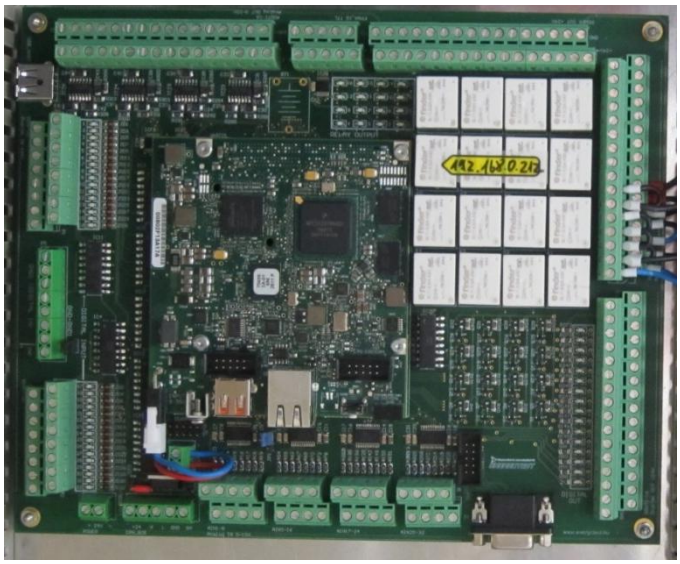
Fig. 4. FPGA based reconfigurable control unit

There should be worked out new measurement procedures to define measure and compare the consumptions habits and make a complete definition of consumers' behaviors.
In our research in building energy and Smart Home, it is of high importance to create the reference of the building. For example the building energy certificate (7/2006 TNM as calculation method) is concerned for only residential, educational institutions and business centre [5].
We observe the consumers behavior in real time environment to make values. The ordinary and renewable energy systems in the building are measured and models are created about them and the measured values. In building mechatronics, measurement and data collection is of high importance. The reliability and repeatability of measurements is significant because of the complex energy and substratum streams as well

as the non-repeatable ambient variables. According to our mind, building mechatronic services requires high reliability and precision devices such as sensors, data collectors, data processors and stores.

The University of Debrecen, Engineering faculty, Electric Engineering and Mechatronic Institute and Proker-Plusz Bt. has begun a research for developing a cheap solar cell, resp solar collector scaffolding being able to rotate and tilt on the basis of an innovation contract [6]. According to the cooperation agreement of these two organizations solar cell rotating system has been put up in the court of the Engineering Faculty.

The Electric Engineering and Mechatronic Institute has designed and installed the electronics following the position of the sun both vertically and horizontally in the case of sunshine. These are the results of researches taking six months. The geographical position of the rotating device placed in the court of the University did not correspond to ideal circumstances, because the shadow surrounding buildings influenced the results of measurements in any period of the day [6].

This influence is mainly characteristic in the morning and afternoon. Because of these influential factors such aspects were taken into account during the research of the electric energy quantity produced or to be produced, in which there no changeable exterior circumstances were distorting the measured data. On the basis of measurements and calculations carried out before can be established that solar cells mounted onto a rotating system can produce 20 to 25 % more electric energy than ones in fixed position, especially in direct sunshine [6].

The results of measurements acquired in a whole year are needed for carrying out final and authentic measurements as well as it is worth positioning the device rotating solar cells at an environment without shadow. For evaluating comparable data precise and authentic data (humidity, temperature, solar radiation parameters) shall be taken into account. As a result of the research the Soltesk system was put on the market some days ago and it can already be ordered. The product was put on the market shortly after the finishing of the research [7].

V. CONCLUSION

The professional competences of the Faculty of Engineering, University of Debrecen involves engineering disciplines. The various departments at the faculty focuses on inter - and multidiscipline research topics at the field of building industry, energetic, environmental protection, the utilization of renewable energy sources, the planning of law energy cost buildings, planning of internal environment focusing on people, as well as developing new mechanical equipments based on physiological researches.

The University of Debrecen, Faculty of Engineering, Electrical Engineering and Mechatronics Department is going to research more in the field of building mechatronic associate with foreign partners. Building Mechatronics education can be found just in Hungary. The Department makes use of the Bachelor of Science Program and Master of Science Program in Advanced Mechatronics Systems in English with the Department of Mechatronics and Robotics, University of Oradea (Romania) and a Master of Science Program in Advanced Building Mechatronics in Hungarian.

The Department ensures job for their students developing their professional experiences and it is going to improve the international relations even in more projects.

VI. ACKNOWLEDGEMENT

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1) HURO-0901/028/ 2.3.1. E-Laboratory Practical Teaching for Applied Engineering Sciences
2) HURO/0802/155_AF ROMANIAN –HUNGARIAN R&D PLATFORM FOR NTELLIGENT BUILDING RESEARCH PROJECTS SUPPORT
3) HURO-0901/179/ 2.3.1. Crossborder Development and Implementation of a Master Program in Advanced Mechatronics Systems.

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