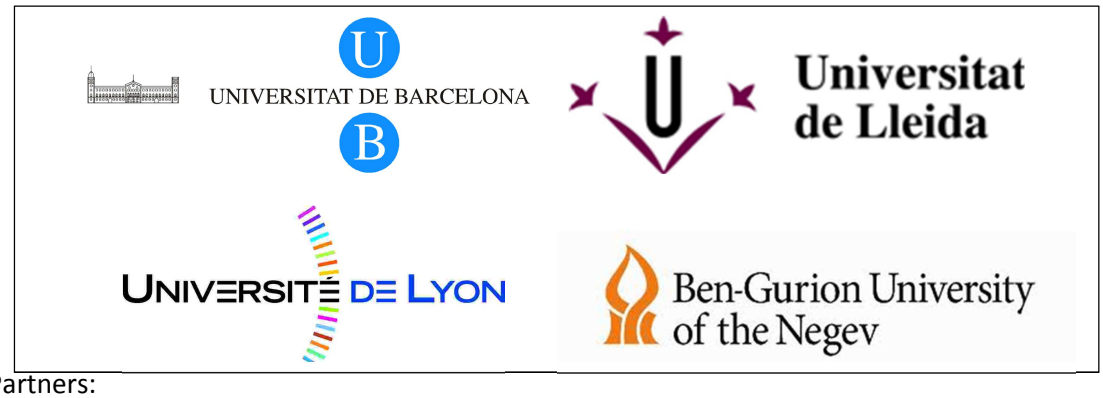
INNOSTORAGE – USE OF INNOVATIVE THERMAL ENERGY STORAGE FOR MARKED ENERGY SAVINGS AND SIGNIFICANT LOWERING CO_2 EMISSIONS

Beneficiaries:



Partners:

D7.2 - Report on Staff Exchanges

	Name and Institution	Date
Prepared by:	Reza Barzin University of Auckland	June 2015
Checked by:	Prof. Dr. Mohammed Farid University of Auckland	June 2015
Approved by:	Prof. Dr. Luisa F. Cabeza Universitat de Lleida	September 2015

Contents

1 Objectives

The Price-based control method for phase change material was developed at the University of Auckland and successfully applied on the test facilities at Tamaki campus, University of Auckland. The thermal energy storage group at GREA centre at University of Lleida was interested to use the proposed system to test it under different climatic conditions.

The main challenge for this project was to use the existing Data Acquisition (DAQ) system and design the new control system using LabVIEW program. This should be noted that the existing DAQ system was not supported by the LabVIEW program.

The objectives were as follow:

1. To visit the experimental facilities and assess the possible options
2. To assess the possible solution to use the existing DAQ system using LabVIEW-based control system
3. To develop the required coding in the LabVIEW software in order to communicate with the DAQ system
4. To develop fully automated control system using LabVIEW software
5. To implement the price-based control system
6. To demonstrate the designed control system to the staff of GREA centre and provide support to run experiment using the designed control system.

2 Introduction

Application-renewable energy resources such as solar heating, PV (photovoltaic) and wind turbines also can result in high energy saving and CO2 emission reduction. However, due to the intermittent nature of these energy resources their availability might not match the demand. For instance, the peak of the solar irradiation occurs during the day, when the heating demand is low and the highest demand occurs during the night when there is no solar irradiation[1]. Thus, the application of energy storage is essential to fully use renewable energies in buildings [2]. The storage can be used to store the energy when it is available and use it when it is needed. Energy storage also can improve performance and reliability of energy systems and play a critical role in conserving the energy [3].

Variable electricity rate or so-called time of use (ToU) electricity, is one of the tools used to encourage people to use electricity during off-peak periods. Many researchers have suggested using thermal energy storage (TES) to store heat or cold during off-peak periods to be used during the peak period [4]. Phase change materials (PCM) however, offer a good thermal storage capacity because of their high storage density and they are used in applications where it is necessary to store heat or cold [5, 6]. A large number of these studies can be found on application of PCM in hot water cylinders [7, 8], fridge and freezers [9], solar power plants [10], and buildings [11].

In 2011, a project was started at The University of Auckland, to use a fully automated smart control system to operate the energy storage in buildings. The designed control system was able to automatically read the online electricity price and try to use electricity mainly during the low price period and stop using electricity when the electricity price is high. The control system also was able to receive weather forecast data in order to use the predictions to

further improve the energy performance of the building. Results obtained from the experimental study showed significant improvement in energy saving.

GREA at University of Lleida, showed interest in application of the control system on their experimental huts as they have more than 20 experimental huts which could benefit from the designed control system. However some modifications were needed in order to be able to use the propose control system for the experimental huts at the university of Lleida. The control system used at the University of Auckland was design using CompactRIO units to receive all required information such as room and outdoor temperature and send the required signals to operate heating/cooling devices. However at the University of Lleida, each hut were equipped with Step DL-01 DAQ system developed by a local manufacturer which was not supported by National Instruments LabVIEW software. In order to be able to use the DAQ system for the project, MODBUS programming needed to be used in order to provide connection between the DAQ and LabVIEW software which was a challenge.

3 Description of work

The experimental huts were visited and all the possible options were taken into account. Also suitable test huts which could be used with the new control system were selected. The required code was developed using MODBUS communication in order to enable LabVIEW software to receive temperature readings from the DAQ system. In the next step, LabVIEW software was used to program the embedded control system to be able to read online electricity price from any given website and control the room temperature within the desired range. A graphical user interface also was designed to enable any user to easily operate the control system.

4 Materials and Methodology

The thermocouples were connected to the Step DAQ system and using the software provided by the company, the DAQ were set to collect temperature data. The next step was to use MODBUS communication and develop a code in order to facilitate communication of the existing DAQ with the LabVIEW software. The code was developed and the DAQ was tested in the LabVIEW environment.

In the next step, a fully automated control system programmed using LabVIEW software in order to receive temperature setpoint for each room and enable the user to set a range of temperature for the controller to operate. The controller also programmed to use two sets of setpoint ranges, in case the user needs to use different temperature setpoint for different periods of the day.

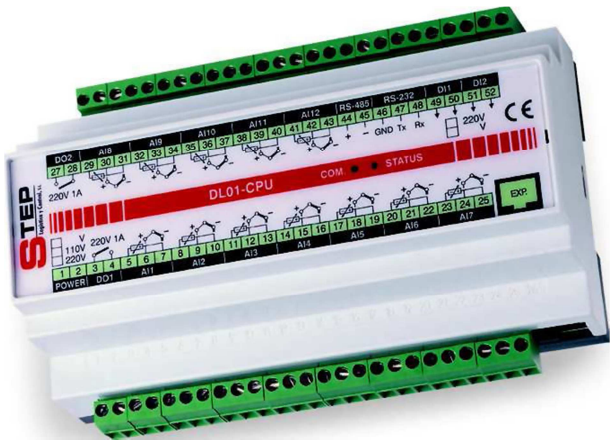


Figure 1 Data acquisition system used at the experimental huts (Step DL-01 DAQ)

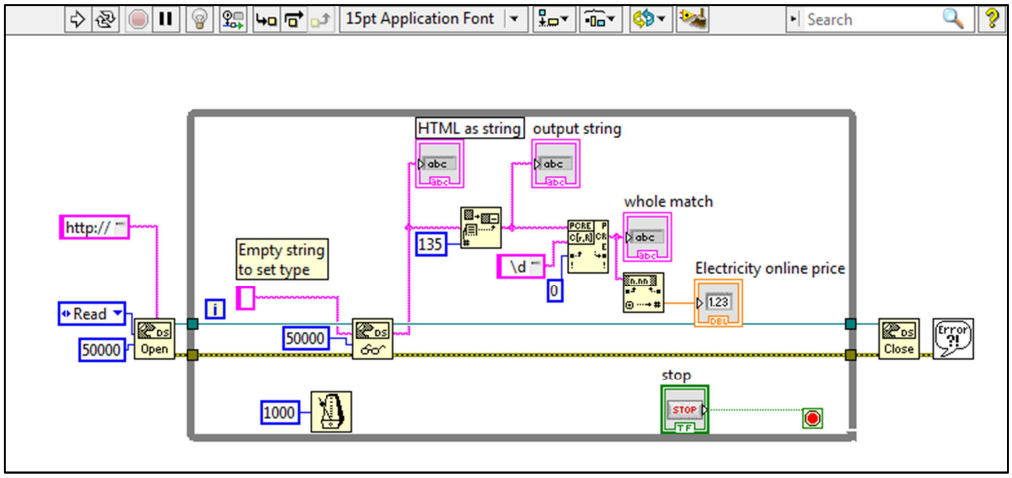


Figure 2. Price based control code developed in LabVIEW environment

The price based control also were developed and added to the designed control system. The user can enter the website URL address of page (which provides online electricity price) and the control system is able to read the selected price and uses that as “online electricity price”. The user also needs to key in the “electricity price constrain” to define for the control system that above what price should be considered expensive (see figure 2).

A graphical user interface also was designed for easy application of the developed price based control system. This enables the user to enter the desired setpoint values, set the price constaint, read temperatures and online electricity price easily as shown in Figure 3.

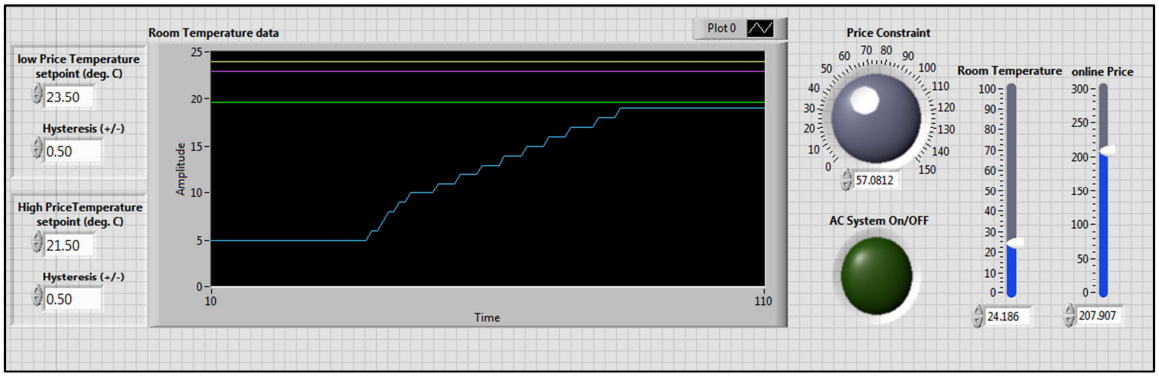


Figure 3. Simplified Graphical User Interface (GUI) for price based control system

5 Results

The designed system was successfully tested at the University of Lleida and operation of the control system was demonstrated to the technical staff. Also it was explained how to modify the existing control system.

6 Outcomes or future work

Some physical modifications were needed at the experimental huts, such as installation of Data Cable and internet connections in order to start the experimental study. Due to the time limit (45 days of stay at the University of Lleida), the university staff did not manage to finish the installation within this period. Remote assistance will be available upon installation to assist successful running of the control system.

7 References

[1] P. Tatsidjodoung, N. Le Pierrès, and L. Luo, "A review of potential materials for thermal energy storage in building applications," *Renewable and Sustainable Energy Reviews,* vol. 18, no. 0, pp. 327-349, 2013.

[2] A. de Gracia, D. David, A. Castell, L. F. Cabeza, and J. Virgone, "A correlation of the convective heat transfer coefficient between an air flow and a phase change material plate," *Applied Thermal Engineering,* vol. 51, no. 1–2, pp. 1245-1254, 2013.

[3] A. Sharma, V. V. Tyagi, C. R. Chen, and D. Buddhi, "Review on thermal energy storage with phase change materials and applications," *Renewable and Sustainable Energy Reviews,* vol. 13, no. 2, pp. 318-345, 2009.

[4] G. Li, S. Qian, H. Lee, Y. Hwang, and R. Radermacher, "Experimental investigation of energy and exergy performance of short term adsorption heat storage for residential application," *Energy,* vol. 65, no. 0, pp. 675-691, 2014.

[5] V. Martin, B. He, and F. Setterwall, "Direct contact PCM-water cold storage," *Applied Energy,* vol. 87, no. 8, pp. 2652-2659, 2010.

[6] M. Medrano, M. O. Yilmaz, M. Nogués, I. Martorell, J. Roca, and L. F. Cabeza, "Experimental evaluation of commercial heat exchangers for use as PCM thermal storage systems," *Applied Energy,* vol. 86, no. 10, pp. 2047-2055, 2009.

[7] M. Nabavitabatabayi, F. Haghighat, A. Moreau, and P. Sra, "Numerical analysis of a thermally enhanced domestic hot water tank," *Applied Energy,* vol. 129, no. 0, pp. 253-260, 2014.

[8] D. N. Nkwetta, P.-E. Vouillamoz, F. Haghighat, M. El-Mankibi, A. Moreau, and A. Daoud, "Impact of phase change materials types and positioning on hot water tank thermal performance: Using measured water demand profile," *Applied Thermal Engineering,* vol. 67, no. 1–2, pp. 460-468, 2014.

[9] M. Liu, W. Saman, and F. Bruno, "Development of a novel refrigeration system for refrigerated trucks incorporating phase change material," *Applied Energy,* vol. 92, no. 0, pp. 336-342, 2012.

[10] A. Mathur, R. Kasetty, J. Oxley, J. Mendez, and K. Nithyanandam, "Using Encapsulated Phase Change Salts for Concentrated Solar Power Plant," *Energy Procedia,* vol. 49, no. 0, pp. 908-915, 2014.

[11] A. Castell, and M. M. Farid, "Experimental validation of a methodology to assess PCM effectiveness in cooling building envelopes passively," *Energy and Buildings,* vol. 81, no. 0, pp. 59-71, 2014.

8 Assessment