

Home automation controller for a water-flow window

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ABSTRACT: Facing the EU energy efficiency and legal scenarios related to buildings (2010/31 EU directive), new sustainable advanced concepts for envelopes are required. These innovative designs must be able to offer an elevated level of energy efficiency based on a high performance architecture. According to this, smart glazings, and particularly active water-flow glazings, represent a promising alternative to other solar control glazings, since they can reduce the building energy demand avoiding well known drawbacks as high cost, glare problems and high response time that affect to other smart glazings. This kind of glazing, as any other active one, needs to be operated by a control system. In order to operate a water-flow based window, a new controller based on an inexpensive microcontroller board has been developed.

1 INTRODUCTION

Glazed surfaces offers to building users natural light and the possibility of having external views at the same time they are protected from uncomfortable external ambient conditions. Those characteristics make them very appreciated for buildings users. However, from a thermal point of view, especially when considering latest EU regulations regarding energy efficiency in buildings (2010/31 UE) [6], becomes evident that windows are one of the key elements that need to be improved in a significant way [3] to achieve Near zero energy buildings (nZEB). It is known that blocking part of the incident solar radiation over the windows is an efficient way to avoid excessive solar gains [5]. On the other hand, water-flow windows, which consist of a double glass pane window and a circulating water chamber between the two panes, uses water properties to absorb a part of the solar radiation. This kind of smart glazing is a promising alternative since they not only reduce the incident radiation that penetrates into the room, but also could be easily integrated with renewable energies. However, the same as other smart windows, as electrochromic or photochromic ones, a control system is required to assure that the system works properly. The need of use a home automation controller for these kind of systems is implicitly accepted [7][4], and the minimum parts required for it has been analysed [8]. Moreover, a proposal about the feasibility of making a controller based on an Arduino board has been suggested [9]. Based on this idea, a new home automation controller has been built from scratch and tested in a water-flow window prototype test box.

2 OBJECTIVES

In order to analyse the real performance of a smart window with a circulating water chamber, a pair of small test boxes has been tested. One of these two test boxes owns a water-flow window (Figure 1) while the other one, which is used as a reference test box, uses a common simple soda-lime glass. Both of them have been tested under real weather conditions in Technical University of Madrid.



Figure 1 Water-flow window test box

According to the thermal comfort standards [2] and previous tests, some parameters like comfort temperature limits, water flow velocity were previously set.

The aim of the experimental essays is to evaluate the thermal performance of the water-flow window. To achieve that, the test box which uses the water-flow window works according to the programmed operations managed by the home automation control system. This system decides about the control actions depending on the measured variables as inside test box temperature or external ambient temperature. To assess the system performance, inside air temperature is measured in both test boxes.

3 EXPERIMENTAL ASSEMBLY AND OPERATING MODES

In the winter season configuration the experimental assembly is formed by two test boxes, one thermally isolated water tank, one pump, one electro valve and three temperature sensors, as shown in Figure 2.

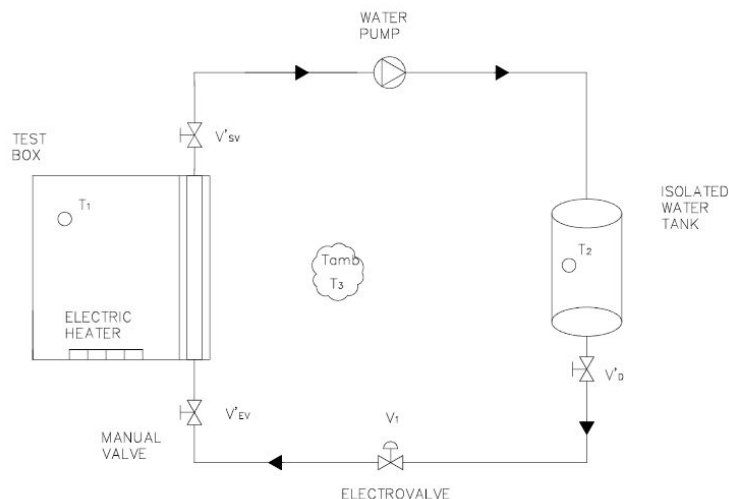


Figure 2 Experimental assembly layout

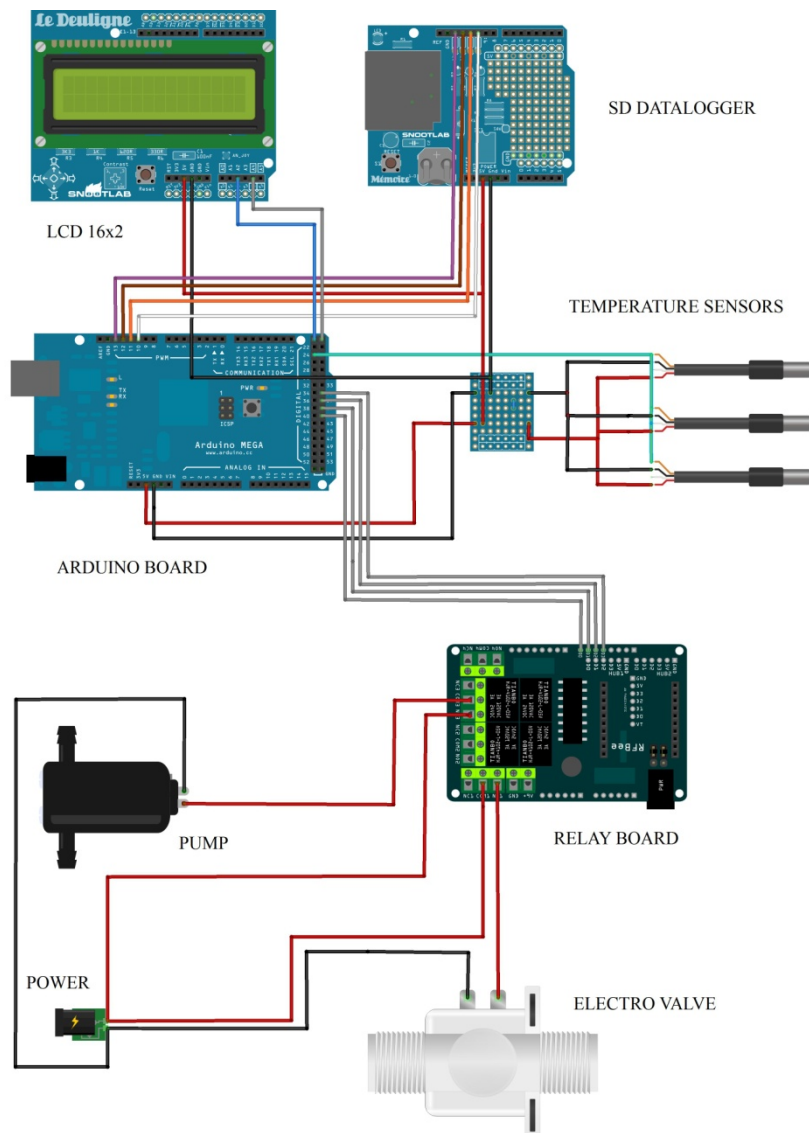
The control system has three operating modes: HEAT STORAGE/FREE HEATING , HEATING and SYSTEM OFF. If the system is stopped, before the sunrise the air inside the box is cold. When the sun rises up, the air inside the box becomes warmer. At a certain time solar gains makes that the temperature of inside air (T_1) exceeds the pre-set higher comfort temperature limit (e.g. 21°C), and the system goes to HEAT STORAGE/FREE HEATING MODE. The pump is then activated, and the electro valve is opened, so the stored water (which is cold) circulates across the water chamber. The cold water circulation has a twofold effect: on the one hand it absorbs a part of the incident solar radiation, and on the other hand it removes part of the heat from the inside air. The energy removed by the water is stored as heat water in the isolated water tank. The system operates in this mode until some time after the sunset when the internal temperature goes between the higher and lower comfort temperature limits (e.g. 21°C and 23°C) and the control system changes to SYSTEM OFF MODE, the pump is turned off and the electro valve is closed. Since there is no solar radiation, the temperature goes down below the lower comfort temperature. At this moment, two operation modes are available: if stored water temperature (T_2) is higher than the lower comfort temperature limit (e.g. 23°C) the system activates the HEAT STORAGE / FREE HEATING MODE. In this mode the stored hot water flow across the water chamber and releases a part of the stored heat. On the contrary, if stored water temperature (T_2) is lower than the lower temperature limit but still higher than the external temperature (T_3), the system activates HEATING MODE, then the electric heater and the pump are turned on and the electro valve is opened. The system will work within this mode until the sunrise when inside temperature will exceed the lower comfort temperature limit again. Since in HEATING MODE, which is supposed to be activated along the night time, the flowing water is always warmer than external air, the energy consumption of water-flow window test box will be lower than the reference box, which only has two operation modes: HEATING MODE and OFF MODE.

4 HOME AUTOMATION CONTROLLER

The described working scheme needs to be controlled by the home automation control system shown in **Error! No se encuentra el origen de la referencia.**. The designed controller registers temperature data and consequently acts over the pump and the valves. The control system consists of the following parts:

- Microcontroller board: An Arduino MEGA ADK (Android Development Kit) equipped with an ATmega2560 microcontroller has been used. This board works with a 16 Mhz clock and has 256 KB of flash memory, 54 digital I/O (of which 15 provide PWM output) and 16 analog inputs. Additionally this ADK version owns USB host capabilities, which makes that the board can establish a connection with an Android mobile phone [1]. This board manages all the systems parts, and it can be programmed with the desired *operation mode* the control algorithm from a PC by means of a USB port. All the other shields boards must be connected to it, since it controls the whole system.
- SD logger shield: this board saves the experimental data in a SD memory card. So, gained data that can be analysed later. It includes a RTC chip (Real Time Clock) to get data time stamp, and uses I²C (Inter Integrated Circuit) bus to communicate with the microcontroller board.
- Relay shield: it acts as a switch for every actuator or final control element, receiving the orders from the microcontroller. It is used for pump and heat sink fan speeds regulation, and govern the opening and closing of the electro-valves following the microcontroller board. This relay shield has 8 relays which is enough to manage the seven valves and the pump.
- LCD display: a 16x2 LCD display is used to show information about the operating mode, the monitoring temperatures and other system parameters.

- Temperature sensors: Dallas DS18B20+ digital temperature sensors are used. These sensors have a 0,125 °C precision, and make use of the OneWire communication protocol, which is able to manage several temperature sensors using only one digital pin of the Arduino Board. A wiring diagram which includes all the electronic parts assembly is shown in Figure 3.



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Figure 3 Basic wiring scheme

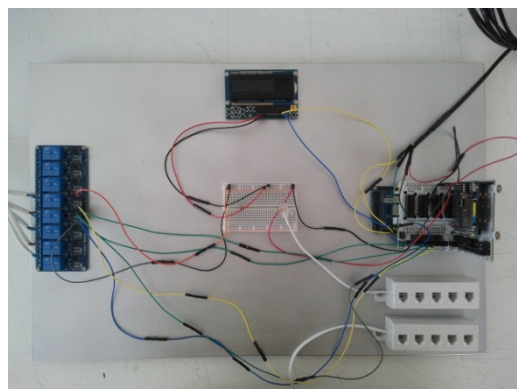


Figure 4 Home automation prototype ver. 2

5 RESULTS DISCUSSION

The developed control system is able to get relevant information regarding temperatures from the test boxes, analyse it, store it and according to them, take control decisions in real time.

By using this home automation control system prototype, a reduction of heating energy consumption of 28% has been achieved for a winter night when compared with test reference box.

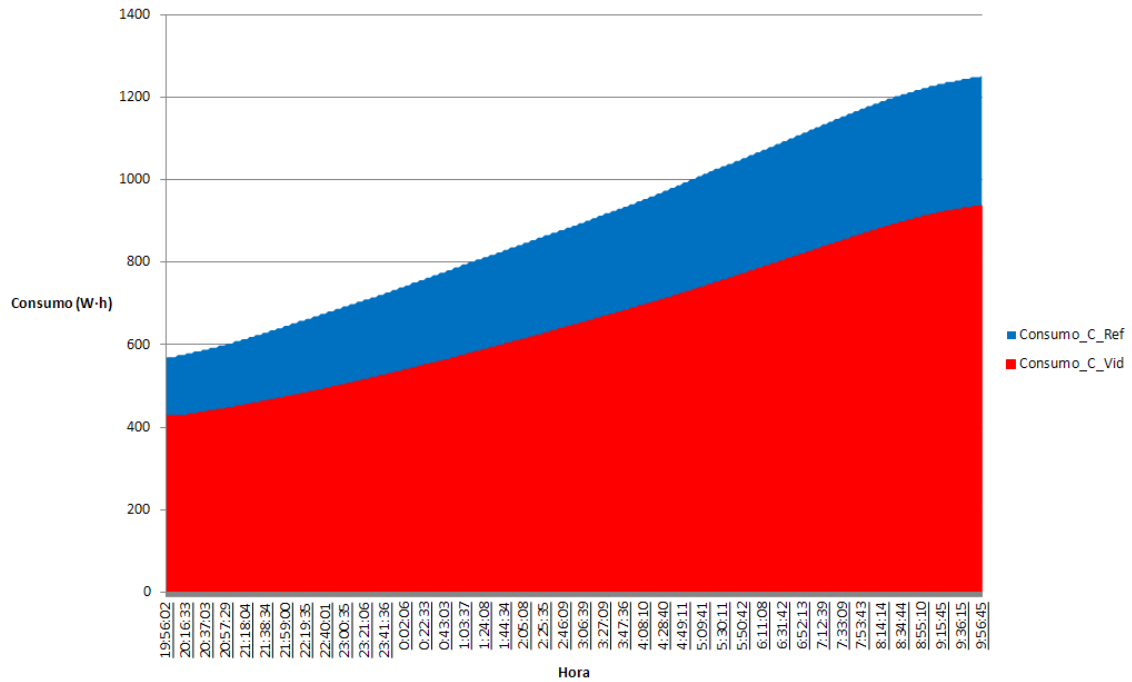


Figure 5 Test boxes energy consumption

Since networking capabilities can be easily added to the control system, for example by means of a LAN shield or 3G/4G modem shield, it could be connected to a commercial building home automation system and controlled from internet or any internal local area network. Owing to ADK version of the Arduino Mega board is used, the system could be managed by any compatible Android device when properly programmed.

6 CONCLUSIONS

A new home automation controller for a water-flow window, based on the inexpensive Arduino open hardware prototyping platform, has been designed and built from scratch. The described system has been tested in a test box equipped with a water-flow based window that reduces in 28% the heating energy consumption for a winter night. It owns continuously monitoring and managing capacities, so it is possible to optimize the energy efficiency of the facility taking advantage of solar energy with a certain delay of time, and without any manual operations.

Additionally, due to its programmable characteristics several control strategies could be evaluated by writing the corresponding programming code. The use of the ADK version of the Arduino board enables the system to be controlled from any Android device. On the other hand, by

adding an Arduino compatible network interface (LAN/3G-4G) the system could be controlled through a LAN or WAN network.

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