Temperature Regulating Independent Smart Blinds

Juan David Franco, Saeed Jafarzadeh
Computer and Electrical Engineering
California State University Bakersfield
Bakaerfield, CA, USA
is-green@cs.csub.edu

***Abstract*—In this paper an independent implementation of temperature regulating smart blinds is introduced. The smart blinds main goals are to improve energy efficiency and temperature control especially on buildings with variable and asymmetrical thermodynamic characteristics that decreases the building's HVAC system to temperature regulation and energy efficiency.The smart blinds system is a fully independent system built in Arduino microcontrollers. Which provides high flexibility, scalability and retrofitting. Furthermore, the system is designed to balance the temperature and light requirements of the user based in the actual light intensity and temperature, providing optimal balance in changing conditions. Also, the system is fully capable of working with different motors and blinds without the need of modifying the system thanks to its intelligent calibration.**

Keywords—Intelligent; Blinds; Temperature; Regulation; Implementation; Energy Efficiency; Arduino; Simulink.

I. INTRODUCTION

Venetian blinds are the mainstream light control solution in commercial and residential buildings because of their stylish and simple design that offers control over the environmental light. In principle, blinds act like a controllable light source that can be set to let a percentage of the light enter the building. However, their ability to control the entrance of light has been also used to regulate temperature [1]. Light is an electromagnetic wave that carries a certain amount of energy that is proportional to its intensity and inversely proportional to its wavelength. Therefore, high intensity light sources like the sun can be used to regulate the energy delivered to the indoors of a building. Which then can be can be easily transformed into heat that can be used to warm the building during cold seasons, or can be blocked by the blinds to keep the temperature low during hot seasons.

Nowadays, blinds are used to reduce energy use for cooling, heating, and/or lighting. Blinds have been proved useful for regulating the thermal load of heating and cooling systems. Furthermore, carefully designed blinds have shown significant effect on the power load on both lighting and HVAC [1]. Calling for better and innovative solutions to maximize the thermal regulation and light control.

The use of automated blinds together with light and temperature sensors is a popular application in smart and ecofriendly residences and offices. Analytical approaches taking into account only geometrical variables like the sun position and slat angle have been developed to determine the reaching of the sunlight trough a window including curved slats [2] and [3]. Latera study successfully measures and collects data related with the relative position of the sun, thermal load, and position of the slats to optimize the slats algorithm thought fuzzy logic and genetic algorithms to improve energy use is described in [4]. [5] Developed an algorithm using the artificial neural networkmethod that controlled the slats usingilluminance data generated by EnergyPlus [4], which had higher simulation time than the traditional analytical model.

As the literature review reveals, many efforts have been done to control the entrance of light taking into account many global parameters like; relative position of the Sun, optical properties of the blinds and crystal, thermal load of the system, glare probability, and shape and form of the slats. Other systems applied a more adaptive and dynamic technologies in [5]. Measuring and controlling the actual light entrance over each one of the blinds have not been done in an individual scale, despising important environmental variables that can not be predicted or modeled; like possible obstructions of direct sunlight by buildings, trees or other environmental weather factors that affect only certain windows and not the system as a whole. This individual approach provides a much stronger control over the system as a whole and better regulation thanks to its flexibility. In this approach the system is capable of overcoming changing environmental parameters that can not be predicted or accurately modeled without recurring to intensive data processing applications and continuous micromanagement.

This paper presents an autonomous, efficient and highly adaptable motorized blind system that can measure and regulate temperature and light intensity in an individual scale, maximizing energy usage and light entrance in any situation. The remainder of the paper is organized as follows; in section

II the hardware and software implementation is presented and discussed; in section II the simulation method is explained; in section IV the simulation results are analyzed and discussed; finally, in section V presents the conclusions.

II. HARDWARE IMPLEMENTATION

Main Microcontroller

The system is based in the Arduino Prototyping platform series, which is a group of highly configurable and scalable open-source electronics platforms. These boards are capable of receiving analog and digital inputs, controlling light, motors and other actuators [6]. The Arduino platform was selected because of its unparalleled flexibility and scalability. This platform allowed new algorithms and sensors to be tested in times of 5 min. In this paper two specific models are used to develop the smart blind system; the Arduino MEGA 2560 R3 and the Arduino UNO R3.

The Arduino MEGA 2560 R3 is the central microcontroller of the system which is board based in the ATmega56 [7]. It can be directly connected and programed trough the Arduino programing software. The Arduino Mega was selected as the main microcontroller due to the ATmega56 larger number of inputs and dynamic memory pool compared with other products of the Arduino family. The MEGA's main functions in the system are; (i) supply power to the motor, sensors and LCD display; (ii) receive and process the signals given by the humidity, temperature and light sensors; (iii) control of the main motor; (iv) control and update the systems LCD display; (v) receive the inputs of the end user; (vi) regulate temperature.

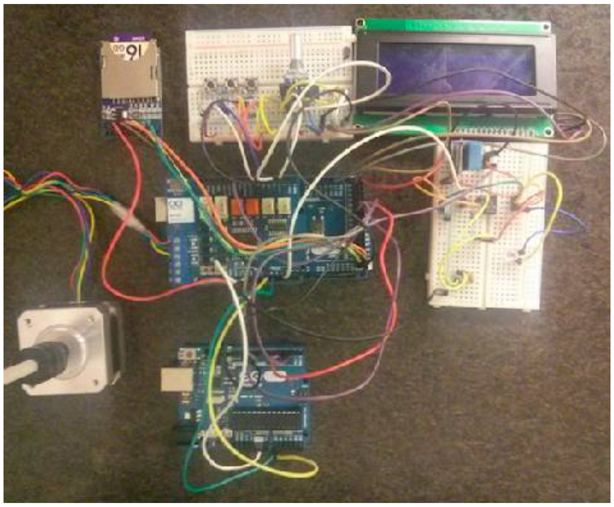

Fig.1 Hardware Implementation of the system.

Light Sensor

In order to accurately measure and determine the amount of energy that will be transferred to the room, a photoconductive light sensor was designed.The light Sensor is composed of a PDB-C139 blue enchanted photodiode [8], a LTC1050CN8 precision operational amplifier [9] and some capacitors to filter high frequency noise.In principle, the current that goes trough a photodiode operated in photoconductive (reverse bias) mode is directly proportional to the input optical power, which is determined by the spectrum sensibility, but operating in photoconductive mode causes the dark current (Leakage current which varies directly with temperature) to be higher, therefore inducing noise into the output current [10]. Taking into account that, The PDB-C139 blue enchanted photodiode by advanced photonics was chosen because of its wide spectrum sensibility (which is broad enough to sense the main frequencies that the sun emits), low dark current (30nA maximum), and low price.

So, because of the low voltage reverse bias applied to the photodiode (5V limited by the voltage source of the Arduino board), the current output of the photodiode is very low, requiring a resistor in series to scale the output to voltage and an operational amplifier to amplify it to 5 V (which is the maximum voltage that the Arduino board can sense) in order to obtain a better measurement resolution and to avoid undesired noise. Thus, the LTC1050CN8 zero-drift precision operational amplifier by linear technologies was chosen in order to guarantee low noise amplification due to its low offset voltage (0.5µV) and low temperature drift (0.01µV/°C).

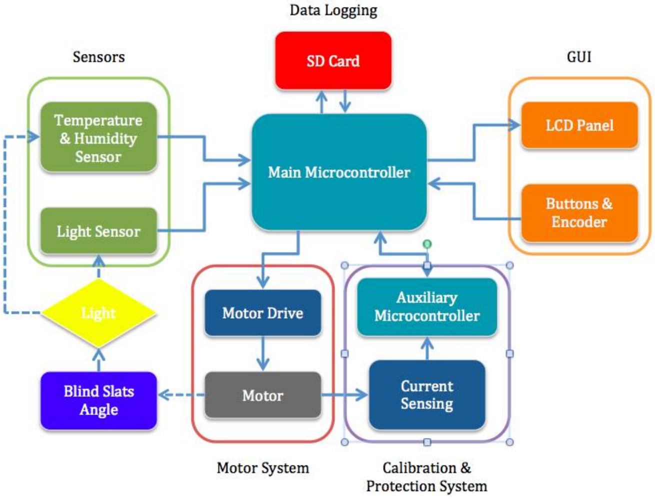

Fig.2 System architecture color coded flow chart ,where the blocks are color coded in relation its main function characteristic; green means it is a sensor,orange means it is part of the user interface,red means it is a data storage item,light blue means that is part of the main algorithm,dark blue means it is part of the calibration system, gray means it is the motor, deep blue means it is part of the physical blinds, yellow means it is a radiometric energy source.

Humidity and Temperature Sensor

Since it is necessary to accurately measure temperature and relative humidity in order to determine the actual heat sensation that the persons feel, a humidity and temperature package was chosen to speed up the development process and provide a reliable solution. The chosen package is the digital output DHT11 relative humidity and temperature sensor. This low power temperature sensor can sense between 20-90%RH and 0-50 ℃ with an error of ±5% and a ±2℃ respectively [11]. The DHT11 senses humidity thought a polymer humidity capacitor. Meaning that as the polymer absorbs water, the dielectric constant changes proportionally to the relative humidity of the surrounding environment. Therefore, monitoring the capacitance the relative humidity can be determined [12]. Also, to sense temperature the package uses DS18B20programmable resolution 1-wire digital thermometer. Which measures temperature thought a set of didoes which current vary proportionally to the temperature [13]. The digital output of the DHT11 package is fully compatible with Arduino's digital inputs. Thus, guaranteeing a reliable and accurate constant measurement of humidity and temperature.

Motor and Motor Drive

To effectively control the tilting of the slats the MERCURY MOTOR SM-42BYG011-25 stepper motor was chosen due to its high precision and torque at low speed operation, in comparison with other DC motors []. This motor has a step angle of 1.8° ±5% and a holding torque of 0.23Nm, which is crucial to operate medium to heavy weight blinds under normal conditions. For instance, its high precision step guarantees reliable performance and enough control to actively regulate the entrance of light. To operate the motor the system uses the Arduino Motor Shield, which is based on the L298 Dual Full Bridge Driver. This shield is designed to dirve inductive loads such as relays, solenoids, DC and stepper motors [14] and it is able to produce high efficiency pulse modulation in order to control the motor.

LCD Display and System Input Interface

The system also comes equipped with set of buttons, a rotary encoder and a 4-row LCD screen to provide easy and real time management of the blinds. It was found that 3 buttons and an encoder yield the most intuitive and effective control of the blinds. Furthermore, the system can be easily expanded and retrofitted to accommodate more buttons or screens if needed.

Auxiliary Microcontroller

In this case the Arduino UNO is used an auxiliary microcontroller that it's in charge of the motor calibration and system protection. It is based on the ATmega328. The protection system main functions are; (i) Motor calibration and current sensing; (ii) system protection. Due to the impossibility of the Arduino Mega to measure and process information while it is operating the motor, an external microcontroller was needed to perform the motor current sensing and calibration. This task required high-speed sampling rates and data processing to successfully measure and process the data. Therefore, the Arduino Uno board was chosen. Its comparable clock speed made possible to measure the current that goes trough the motors while it communicates in real time with the Arduino Mega allowing bidirectional communication and synchronization in order to calibrate and protect the system from stalling and over currents.

III. SOFTWARE IMPLEMENTATION

All the code and algorithms were developed using the Arduino software [15]. Which is fully compatible with the Ardiunos used in the system. Each one of the microcontrollers has its own code according to the tasks it must perform. All the code were developed in house and in the case of the encoder and the LCD display, open source libraries where used to enhance compatibility and reduce development time. In Fig.3 a general overview of the algorithm is provided.

Window Controller

The algorithm used to control the blinds is has the following main tasks: (i) read the local sensors data and user input; (ii) save data in the microSD; (iii) apply control algorithm; (iv) actuate based in the control; (v) check protection system; (vi) Sleep for 1 second.

First of all, when the microcontroller wake up (after being reset), it will automatically perform the motor calibration tests to determine the motor and blind characteristics; which is described in more depth in its dedicated section. So, after the calibration algorithm is performed the system will begin its regular duties. First, the system will read and store the measurements in the SD the card. This will provide the system with valuable information, which can be easily read, used and expanded in the control algorithm to determine the window light characteristics and how efficient is the current control algorithm in changing the room temperature. This data will give valuable information to determine the impact of the system and the control algorithm. Then, after the information is stored the control algorithm will be applied; the algorithm will process and weight the information according to the user preferences and motor, blind, and light characteristics. Once the computation is finished the system will actuate if necessary according to the control algorithm results, which are the number of steps that the slats should tilt in order to achieve the user input preferences, while the motor is running the system will check after each step if the motor is stalled. Finally, the system will sleep for 1 second to save energy.

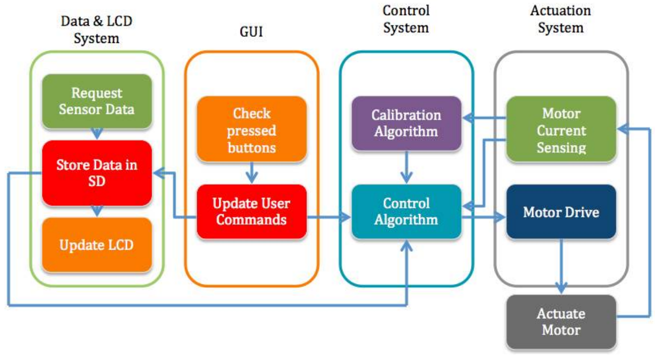

Fig.3 Main algorithm color coded flow chart, the color code is explaned in Fig.1 with the exception of purple, which means it is part of the calibration algorithm.

System Protection and Calibration

The system protection and calibration device determines trough a set of scripted tests the nominal current of operation of the stepper motor to define the limits of normal operation and to determine when the system is stalled or having an overcurrent. This system is critical to guarantee optimal operation of the blinds and enables the system to work with other stepper motors and changing conditions without the need of changing the code. Without it the blinds could not determine the relative position of the slats or the motor. At first, the system was devised to be implemented in the main microcontroller, but due to the high sampling rate and high response time required in order to detect spikes in the stepper current the code had to be implemented in a microcontroller that must run in parallel with the main system.

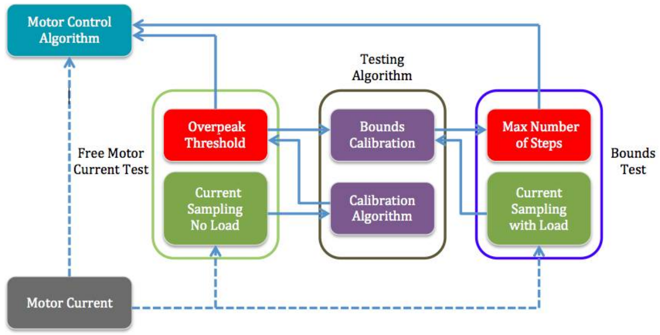

Fig.4 Testing and calibration color coded algorithm flow chart.

As seen in Fig.4 the system is composed of two independent algorithms; the calibration and motor testing algorithm and the current monitoring and protection algorithm. The motor testing and calibration algorithm is performed only when the system is restarted. However, periodic motor testing is performed when the system detects recurrent stalling in order to guarantee long time reliability of the system. To achieve that the two microcontrollers communicate between them and synchronize to perform the tests, during the first test the algorithm performs the following tasks: (i) check if the main microcontroller began the test; (ii) read the sensor data; (iii) check if the test had finished; (iv) apply calibration algorithm. This algorithm is repeated two times (both directions) to determine the stalling current. Then, the second test determines the amount of steps that the motor is able to move in each direction by moving the motor in each direction until it stalls while it measures the amount of steps it performed. The second test is performed three times to make sure the measuring's are consistent to avoid false measurements.

Finally, after the tests are performed the system will keep acting as a protection system; monitoring the current and notifying the main microcontroller to stop when it senses an overcurrent.performing the following loop: (i) check if the motor is energized; (ii) apply current sensor read algorithm ;(iii) check if the system is having and overcurrent (iv) sleep for 1s. Where the system will only measure the current and check the current if the motor is energized, keeping the power usage low.

GUI

As said before the interface of the blinds is consists of a 4 row LCD panel and a set of buttons and an encoder, all of which where programed and implemented taking into account the requirements and capabilities of the system. Also, in order to speed up the process and get a better implementation, `two open source libraries where used; the first one to allow the communication with the LCD panel trough the ISP pins of the Arduino Mega and the second one two accurately detect the ticks of the mechanical encoder when it is rotated.

Basically, the LCD display updates and shows the current and desired values of relative humidity, temperature (degrees Fahrenheit), and light intensity (Lux). But, because of updating the LCD display is a very taxing for the limited resources of the Arduino Mega.The screen is refreshed and the values updated every second in order to keep the system responsive to user inputs. Therefore, as the encoder is rotated or the buttons pushed to select and save the desired values of temperature and light, the values are refreshed in real time giving the user a feeling of responsiveness and interactivity that couldn't be possible if the screen where refreshed at higher speeds. That said, the desired values and the system status can be modified and set trough the buttons and encoder, there is no need for any auxiliary software and the system is fully autonomous.

IV. SIMULATION

We programmed and tested the blind tilt control and the temperature regulation in Matlab. A basic thermodynamic model was designed to emulate the system performance and capabilities. This system takes into account the most influential parameters that are related with the system. Like, variable environmental temperature and the solar energy delivered per hour.Also, a HVAC system was modeled to emulate the operation of the blinds in real conditions. In order to give a better understanding of the system the simulation will be presented trough the following sections; (i) Room thermodynamic subsystem (ii) HVAC subsystem (iii) Blinds subsystem.

Room Thermodinamic subsystem

Theroom subsystem takes into consideration the heat flow form the HVAC, the blinds subsystem and the heat losses from the environment.All this parameters are modeled using Newton's law of heating and the heat equation [16].

In principle,we use Newton's law of heating (eqt 1) to model the room's thermodynamic system. Newton's law of heating is a first order differential equation that allows us to model the temperature of a building as a function of the exterior temperature, the heat generated by the heater and the heat controlled by the blinds. In its basic from it establishes that the rate of temperature change is equal to the between the exterior temperature and the interior temperature multiplied by a constant that is represents the physic properties of the building;

$$\frac{dT_{room}}{dt} = K(T(t)_{interior} - T(t)_{exterior}) + C(1)$$

were$K$ is dimensionless, all the temperatures are measured in degrees Celsius, and C is the initial temperature of the system.

Or, in the case of the room, the difference between the exterior (outside) temperature and the room (interior) temperature multiplied by the inverse of the equivalent thermic resistance of the room:

$$\frac{dT_{room}}{dt} = \frac{1}{R_{eq1}}(T(t)_{room} - T(t)_{out}) + C \qquad (2)$$

But, we can use the heat equation (eq3) to represent the change of temperature as a function of its physical qualities (mass density and specific heat) and the rate of change of the energy:

$$\frac{dQ}{dt} = \rho c_p \frac{dT}{dt} \qquad (3)$$

Where Q is the energy applied to the system in Joules, c_p is the specific heat capacity, and ρ is the mass density of the material.So, representing the change of temperature of the room as a function of the energy and solving for the change of energy we have:

$$\frac{dQ}{dt} = \frac{\rho c_p}{R_{eq}}(T(t)_{room} - T(t)_{out}) + C \qquad (4)$$

Finally, we can include the specific heat and the mass density of the air in the thermic resistance of the room in order to obtain the total resistance of the thermodynamic system $(1/R_{eq2})$ and get the first equation that describes the room energy losses of the room in function of the room and the outside temperature.

$$\frac{dQ_{losses}}{dt} = \frac{1}{R_{eqt}}(T(t)_{room} - T(t)_{out}) + C \qquad (5)$$

Now, that we established the change of energy of the system in function of the outside temperature we need to model the Heater and blinds heat gaineffects on the temperature of the room. This can be easily done by replacing the energy gain and losses in the heat equation and solving for the rate of change of the temperature:

$$\frac{dT_{room}}{dt} = \frac{1}{\rho c_p}\left(\frac{dQ_{heater}}{dt} + \frac{dQ_{blinds}}{dt} - \frac{dQ_{losses}}{dt}\right) \quad (6)$$

Where the energy injected in the room by the heater and the blinds is considered positive and the energy taken by the environment is considered negative.

With equation 5 and equation 6 we can accurately simulate the room's thermodynamic system in Simulink using an integrator with a negative feedback in order solve the differential equation.

Heater subsystem

The heater subsystem acts as an injector of energy in function of the amount of hot airthat it blows (T_{heater}set at 122 degrees Fahrenheit by default), the current temperature of the room (T_{room}), and the constant flow rate (M_{heater} set at 1kg/hr by default). This model can be easily represent using the heat equation by multiplying the mass density by the mass we want to blow:

$$\frac{dQ_{heater}}{dt} = Mc_p(T_{heater} - T_{room}) \qquad (7)$$

Therefore, this system that injects thermal energy in the house subsystem can be modeled in Simulink as a heat gain that positively feeds the house loop. It is important to note that the heater is activated by a relay that is labeled as a thermostat. The relay values vary between 1 and 0 depending in the interval defined. The relay output value is multiplied by the total heat gain of the heater, so when the relay is activated the heat gain is added to the house subsystem loop, and when it is deactivated it makes the heater gain zero. Thus, functioning as a switch that accurately simulates the heater thermostat.

Blinds subsystem

The blinds subsystem takes into consideration solar radiation, the solar gain factors of the multiple materials and geometric factors of a window, the coefficient of heat transmission of the glass, the shade coefficients, the room temperature, and the outside temperature in order to determine the net heat gain due to the solar radiation. In other words,this system allows us to link the total sunlight that goes trough the windows of the building with its effect on the room temperature trough the thermal energy gain.

All these parameters are modeled in Simulink using the heat transfer equation to determine the total heat gain for exposed glass areas. This equation is a first order differential equation that allow us to model the heat gain due to solar radiation as a function of the solar radiation, and the window characteristics like the coefficient of heat transmission, the solar gain factor and more importantly the shade coefficients. Because these shade coefficients are the ones that the blind can control to allow or restrict the entry of thermal energy to the house, as we can see in the equation:

$$\frac{dQ_{Sunlight}}{dt} = \left(SC(t)\right)\left(SHGF(t)\right) + U\left(T(t)_{room} - T(t)_{out}\right) \qquad (8)$$

WhereSC is the multiplication of all the shade coefficients of the window (Dimensionless), $SHGF$ is the solar heat gain factor (in British thermal units per hour per square foot), U is the heat transition of vertical windows (in hour per square foot per degree Fahrenheit), and the outside and inside temperatures are (in degrees Fahrenheit).

The blinds affect the system by allowing or restricting the entrance sunlight (and then heat) to the room. Physically, This can be modeled as a change of one of the shade coefficients of the system. Which are dimensionless quantities that represent the geometrical and refractive properties of materials that affect the entrance of sunlight, but are not the glass itself. So, in this case the as the tilt of the blinds vary the entrance of light varies too. The ASHRAE handbook of HVAC systems estimates that this tilting variation changes the blinds shade coefficient between 0.5 and 0.9, meaning that venetian blinds block between 10% and 50% of the total heat received by solarradiation [17].

V. MEASUREMENTS AND DATA ANALISIS

The system performance was only simulated in Simulink due to the time constrains. All the code development, hardware implementation, and system simulation were done during a time interval of 90 days. Limiting the system performance measurementto the blinds-heater simulation, but the obtained results can be interpolated to cooling systems, thanks to the ability of the blinds to allow or limit the entrance of light.

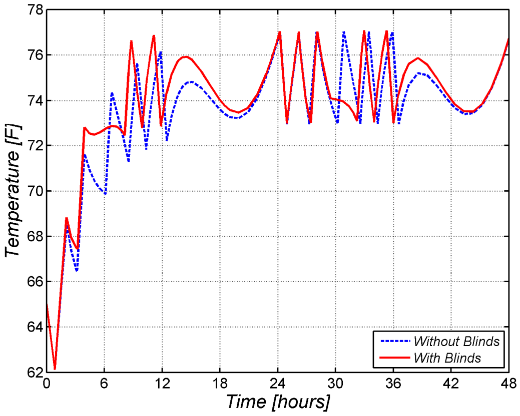

Fig.5 Temperature in Fahrenheit vs time in hours of the cold room of the building with smart blinds (and the building with regular blinds.

So, in order to obtain the accurate measurements in the simulation, various parameters like the specific heat of the air and the insulation and size of the windows were determined based on its physic or building characteristics. In this case two identical buildings composed of 6 rooms were compared;the first building used the designed smart blind system and the second one used regular blinds. In both cases the rooms have a volume of 20 square meters. The initial temperatures of all but the “cold room” (which initial temperature is set at 60 F) were set at 80 F. Also, the desired temperature was set at 75 F and the outside temperature was set at 45 F with a sinusoidal variation of ±15 F to emulate the day and night effects on temperature.

The solar heat gain factor is emulated by a taking only the positive value of a sinusoidal function with amplitude of 82.13 British thermal units per hour per square foot. This value was obtained using the ASHRAE handbook table of heat gain factors. It is important to note that this value is determined by the day, month, and relative position of the window and the latitude where the building is built.

Normally the heater system will begin to act when the average temperature of the building is below the desired temperature by 1.8 F. So, if the majority of the rooms are over the desired temperature and only a few are below it the heater will not act until the temperature of the majority of the rooms is low enough to send the average below the desired temperature. This, represents an issue for the below the average room temperatures because they are the minority. This situation was modeled to show the advantages in both energy savings and temperature regulation of the smart blinds system.

As seen in Fig.5 and Fig.6 the thermal regulation and energy efficiency of the smart blinds system is higher than its counterpart. Fig.3 shows that the room with smart blinds keeps the desired temperature skipping the activation the heater at hours 8 and 31, reducing the thermal energy delivered to the system by the heater approximately 6%. Representing considerable energy savings to the building.Also, building using smart blinds system achieves the desired temperature (75 F) 2 hours faster than the other system. This traduces into better regulation and more effective noise response of the system.

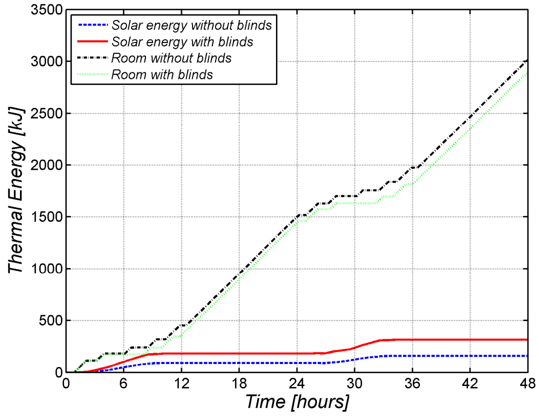

Fig.6 Heater thermal energy in kJ vs time in hours delivered to the“cold room”with smart blinds and room with regular blinds and the respective controlled by the blinds.

VI. CONCLUSIONS

Smart blinds is a full in house developed scalable project which unites several scientific areas to incresase the energy efficiency in comercial and residential buldings.

With the presented results it is safe to assute that the smart blinds system providesa significaly imporved energy efficieny and superior temperature control and regulation.Altought, because of time constrains, all this results are based on the designed simulation and thermal models. Also, the developed system microcontroller choice , Arduino, makes the system a hihgly modificable and scalable system that can be expanded or retorfitted wihtout the need of replacing any component.

As future work, the prototype system will be tested in real ecenarios. Also , the data logging system will be expanded to give the system a more robust control and calibration.Taking into account the sunlight and temperature frecuencies to predict and determine enviromental factors that are very hard to model like mountains or buildings that block sunlight during certain daylight hours.

ACKNOWLEDGMENT

The presented study is supported in part by Pacific Gas and Electric (PG&E) company. The authors would like to thank PG&E’s support. We are also grateful for CSUB California Energy Research Center’s help.

REFERENCES

[1] Mukherjee, S., Birru, D., Cavalcanti, D., Shen, E., Patel, M., 2010. *Closedloop integrated lighting and daylighting control for low energybuildings*. In: Proceedings of 2010 ACEEE Summer Study on EnergyEfficiency in Buildings, pp. 252–269.

[2] S. Zhanga, D. Birru, *An open-loop venetian blind control to avoid direct sunlight andenhance daylight utilization*,I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol.

[3] O’Neil, B., Tzempelikos, A., Athienitis, A., 2007. *Daylight and luminairecontrol in a perimeter zone using an automated Venetian blind*. In:Proceedings of the 2nd Canadian Solar Buildings Conference, pp. 1–10.R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.

[4] EnergyPlus, 2007. EnergyPlus Engineering Reference -The reference forEnergyPlus calculations. Lawrence Berkeley National Laboratory(LBNL).

[5] V. Congradac, M. Prica, M. Paspalj, D. Bojanic , D. Capko, *Algorithm for blinds control based on the optimization of blind tilt angle using a genetic algorithm and fuzzy logic* ,

[6] J. Hu, S. Olbina, *Illuminance-based slat angle selection model for automated control of split blinds*,

[7] B. Evans, *Beginning Arduino Programming Technology in action series*, 1sth ed. New York City,NY: Apress, 2011,ch. 1.

[8] Atmel, “8-bit Microcontroller with 4/8/16/32K Bytes In-System Programmable Flash,” ATmega328P datasheet, November 2009.

[9] Advanced Photonics, “Plastic Photodiode Package with Leads,” PDB-C139 datasheet, November 2009.

[10] Linear Technology, “Precision Zero-Drift Operational Amplifier with Internal Capacitors,” LTC1050CN8 datasheet, November 2009.

[11] OSI Optoelectronics, Appl. Note 1,pp-1-6.

[12] AOSONG electronics, “Temperature and humidity module,” DHT11 datasheet, November 2009.

[13] Texas Instruments, Appl. Note 216.pp-2-4.

[14] Texas Instruments,Appl. Note 267.pp-3-4.

[15] ST, “Dual Bridge Driver,” L298 Datasheet, January 2000.

[16] Arduino, Arduino Software(IDE),(Online). Arduino.cc, 2015.

[17] R. Nagle, E. Saff, and A. Snider, *Fundamentals of Differential Equations*, 8th ed. New York City, NY: Pearson, 2011.

[18] ASHRAE technical staff, *2013 ASHARAE Handbook-Fundamentals*, ASHRAE, 2013.

Juan Francois a senior student working on probabilistic power flow problem. His research goal is to implement a variety on Unscented Transforms and investigate their performance.

Dr. Saeed Jafarzadeh is an Assistant Professor at CSUB since 2012. He received a Ph.D. at the University of Nevada, Reno. His research interests include power systems, smart grid, renewable energy systems, energy markets, and energy conversion. His current research focus is on interdisciplinary aspects of energy industry such as stability analysis of energy markets, forecasting renewable energy resources, quantification of smart grid policies, optimization of energy conversion systems, and power systems dynamic state estimation. He has more than 30 publications in prestigious IEEE journals and international conferences. He provides leadership in directing the Power Systems Laboratory and IS-GREENto serve the students in the Electrical Engineering program(www.cs.csub.edu/~is-green).