Design and Simulation of a Control Model for the Energy-Saving Management of Buildings

[1]Shumaila Shaikh, [2]Abdul Ghafoor Memon, [3]Samiullah Qureshi, [4]Ghulam Yasin Shaikh

[1]Post Graduate Student, Department of Energy systems Engineering, Mehran U.E.T., Jamshoro, Sindh, Pakistan
[2]Professor, Department of Mechanical Engineering, Mehran U.E.T, Jamshoro, Sindh, Pakistan
[3]Lecturer, Department of Mechanical Engineering, Mehran U.E.T, Jamshoro, Sindh, Pakistan
[4]Professor, Department of Industrial Engineering, Mehran U.E.T, Jamshoro, Sindh, Pakistan

Abstract - **Increase in technology and population has created a necessity for further research on energy-saving so new techniques are applied and tested world-wide. Building automation system and Building Energy management system are one of them. A large amount of energy is wasted due to human behavior and it directly affects the energy usage. In educational institutes a lot of energy is wasted due to different human behavior which results in a lot of energy wastage and it is difficult to encourage occupants to use efficiently. A control model is made consisting of a air-conditioning system, heating system, lighting system and ventilation system. It also includes feed forward loop which is used with PIC controller to check data continuously and if threshold levels are crossed, certain decisions are taken accordingly. In order to assume the savings after applying automation, consumption patterns of a lab have been made with the help of timetable and occupancy level. Some conditions are assumed where a certain percent of appliances are turned for 8 hrs and then they are compared with consumption patterns in order to compare the difference and analyze and assume the results. After comparing it is estimated that in all conditions where human behavior vary a large amount of energy can be saved.**

Keywords: Building Automation system, Building Management System, Energy-saving Management, Consumption Patterns.

I. INTRODUCTION

With the growth in population and development in technology, there has been a rapid increase in energy consumption all around the globe. The growth of population has resulted in a dimension increase in indoor activities which has produced a need of advancement in installed systems in order to save electricity. Estimation is created in which it states that energy consumption of world would be increasing at the rate of 56% from 2010 to 2040. [1] As per statement from intergovernmental panel on climate change, a large amount of energy consumption is consumed by institutional

buildings worldwide [2,3]. According to research in the United States, around 13% of energy consumption of buildings is of university buildings, is on 4th ranking after retail buildings, office buildings, hotels and restaurants [4]. Most of the time mankind is occupied in buildings about 80-90% of time human spend time in buildings, which plays a huge part in increase in demand. Human comfort directly effects on the performance and in an educational institute it is necessary that comfort level should be prioritized as students as well as teacher can perform their job efficiently. Energy can be saved in two ways either equipments used should be energy efficient or energy usage should be managed properly [5,6].

1.1 Literature review

Many researchers have done different work in building automation system and building management system such as Carli has worked on controlling of illumination and temperature of room, a lab of university has been considered for identifying the benefits of control system and if it would be beneficial for adopting Many scholars have done different work related to this such as a BEMS had been tested on a test bed. The purpose of this study was to decrease energy consumption and increase the comfort level of occupants by applying building energy management. The system which was built by the author is for controlling of illumination and temperature of room with the help of genetic algorithm and fuzzy logic controller [7]. MPC is applied in cost function approach on BAS in an office building of Italy at the On-field tests were conducted in order to determine the performance of algorithm which is related to thermal comfort approach and is on thermostat. MPC algorithm is used for optimization of indoor thermal comfort and related energy consumption of buildings for thermal comfort index Fanger's predictive mean vote has been used [8]. A VA parallel (parallel fan-powered terminal units) FPTU's model is designed in Energy plus for developing building model for a performance approach. HVAC system is integrated with VA parallel FPTUs for energy management system and determining feasibility of the integrated system. This simulation is done on a five-zone small office proto-type building for determining the effect of

VA parallel FPTU's and constant air flow. And also system energy consumption is determined [9]. An air-conditioning laboratory is designed on experimental setup in MATLAB. This experiment was to make use of an old air-conditioning laboratory by using some different techniques. Different equations were used to consider and were compared to theoretical and simulation results fans speed is also considered [10]. A work on indoor comfort parameters while keeping in view university, Iraq. The parameters are set as ASHRAE standard-55 and are implemented to achieve energy savings [11]. An automatic ventilation system is developed by Kim for better indoor air quality regarding occupant's behavior. Data collected in paper was related to IEQ factors and the corresponding behavior of occupant over ventilation then an algorithm was made with the help of logistic regression [12]. Firstly data was collect with respect to IEQ factors and occupants behavior towards ventilation then an automatic ventilation algorithm was developed using logistic regression then data was evaluated through graph of receiver operating characteristic curve and performance was checked through standards and for decision criterion Youden's index was used. A model is created by Jain to reduce cost using a data-driven control algorithm which is based on neural networks. These control algorithms are validated on a two-story algorithm with controlled zones which is located in Italy. Dynamical energy consumption models and zone temperatures with high accuracy and demonstrate better comfort with less energy consumptions energy compared to the default system controller [13]. A hierarchical decomposition is proposed by camonogra which is to split the computation between a distributed component to a centralized component whose objective is to create flexibility in system and also to make a distributed computation. Bi level optimization, benders and Lagrange and decomposition are three methods which are used. Results are plotted by simulation in application to a building energy management system and numerical analysis of decomposition where a specific amount of chilled water is distributed among HVAC units [14]. A building control system has been designed which has a hybrid controller which includes Adaptive user interface, a history tracker of state and a state transition controller and its operation is to receive measurement and signals from sensors and also sends signals. The adaptive user interface generator represents the changes between states and also generates adaptive user interface. It also has a control that navigates the history and also provides access to select a operating state which is defined by state history. And its generator automatically updates the interference to provide an access to select operating state [15].

1.2 Research objectives

Parameters such as temperature, lighting, and ventilation can be controlled with efficient use of energy by adopting building automation systems and building management system. Most of the occupants complain about automatic room temperature control because the temperature set can be different from their comfort zone. So, in this research a feed-forward system is introduced for occupant to change the value according to his comfort zone.

This research aims

- To estimate the energy saving when a building automation system is applied to a lab of university.
- To develop control model on Protues which consists of temperature control, lighting and ventilation control system and also consists of feed-forward system
- To estimate energy savings consumption patterns are compared with different percent of full load.

II. METHODOLOGY

This study first considers the consumption of a lab in department of a university in Pakistan. The consumption table is made with the help of a timetable and the rating of appliances. After it a control model is made on Proteus which consists of heating, air-conditioning, ventilation and feed-forward system. Then for estimation that how much energy can be saved it is considered that energy utilization is highly dependent on human behavior so four scenarios are considered and compared with consumption patterns.

2.1 Consumption Patterns

A lab is considered for this research work. The timetable of lab is considered for calculating consumption patterns. Power rating of fans and lights has been considered while for Air-conditioners current is measured through clamp meter and actual power is calculated and used for calculation. Energy used in lab is determined by power consumption with respect to time.

2.2 Control Model

A control model is made on Proteus to represent the automation system for lab of department. First timetable was taken from department and then PIC is used for controlling the system and its code is programmed in C language and compiled on C compiler. Then the file is burnt in PIC. The control model consists of temperature, ventilation and lightning control and also it senses the humidity. Temperature is sensed by LM-35, when temperature would be more than the set values air-conditioners (which are represented as fan in the system)would be turned on and when it would be less than the set value heater would be turned on (which is represented as a lamp in the system). An occupant can be

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unsatisfied with the preset values of temperature so a Keypad and an LCD are provided for occupant to change the preset value to the desired value. Presence of an occupant is sensed by IR sensor and intensity of light is sensed. In lightning control system lights would be turned on when an occupant is sensed. According to number of occupants in room lights would be turned on. MQ-2 sensor is used for ventilation purpose if any type of harmful gas is sensed by MQ-2 sensor fan will be turned on.

2.3 Energy Saving Estimation

In order to estimate the energy savings, some conditions have been considered. Mostly building automation system is applied due to negligence of humans toward appliances which is known as human behavior and this behavior can vary from person to person. So, five conditions have been considered in which 60%, 70%, 80%, 90% and 100% of appliances are turned on for 8hrs and is then compared with consumption patterns to see the difference.

III. RESULTS AND DISCUSSIONS

The data of appliances for this research was obtained by power ratings for fans and light where as for air-conditioners current was measured through clamp meters and actual power was calculated. The occupancy was estimated according to the timetables. Control model was made on Protues and PIC controller was used as controller and the code was compiled in C language on C compiler and in order to show the operation of appliances and system virtual meter. Virtual meter's screen shows the operation of appliances and values of temperature, light intensity and humidity. Energy saving is estimated by consumption patterns and full load.

3.1 Consumption patterns

The data used in this study was based on appliances in lab and real time table of lab. Occupancy of students and teachers was considered according to time table. Working of appliances at timetable hours has been calculated in year. Due to seasons there is change in spring semester and fall semester consumption.
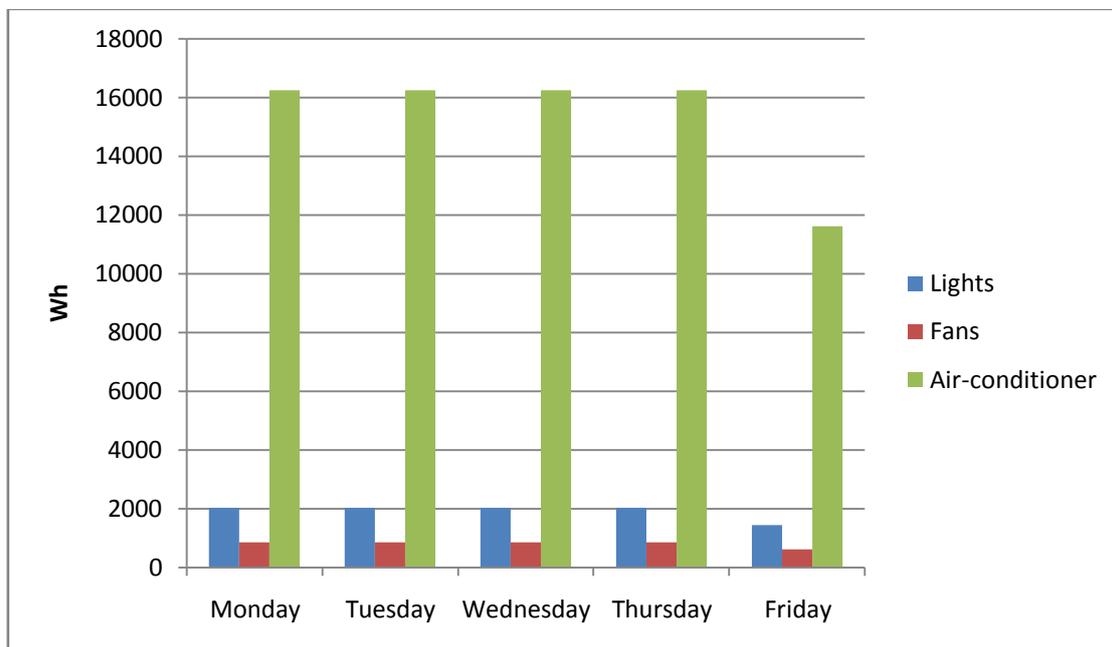

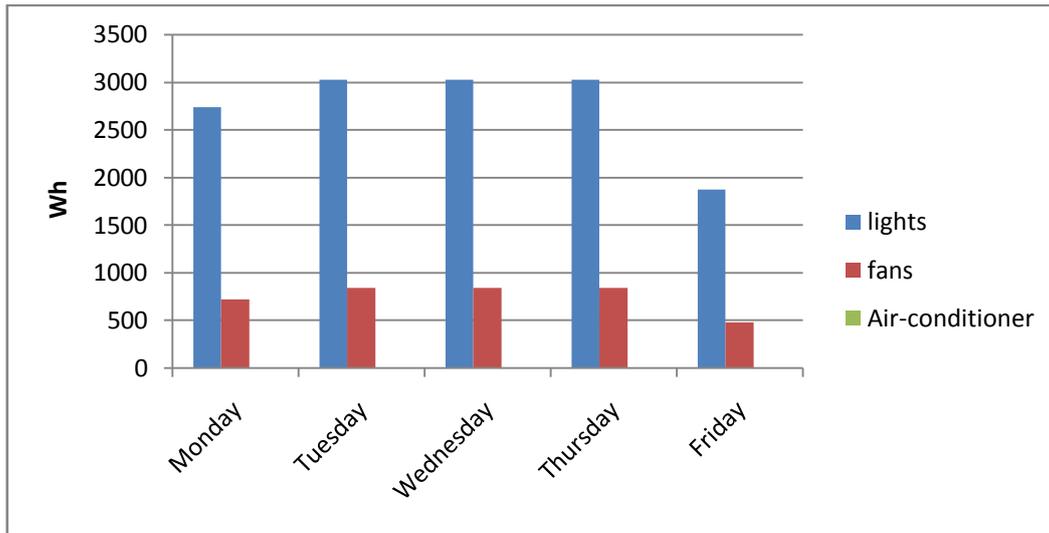**Figure 1: Spring semester daily consumption**
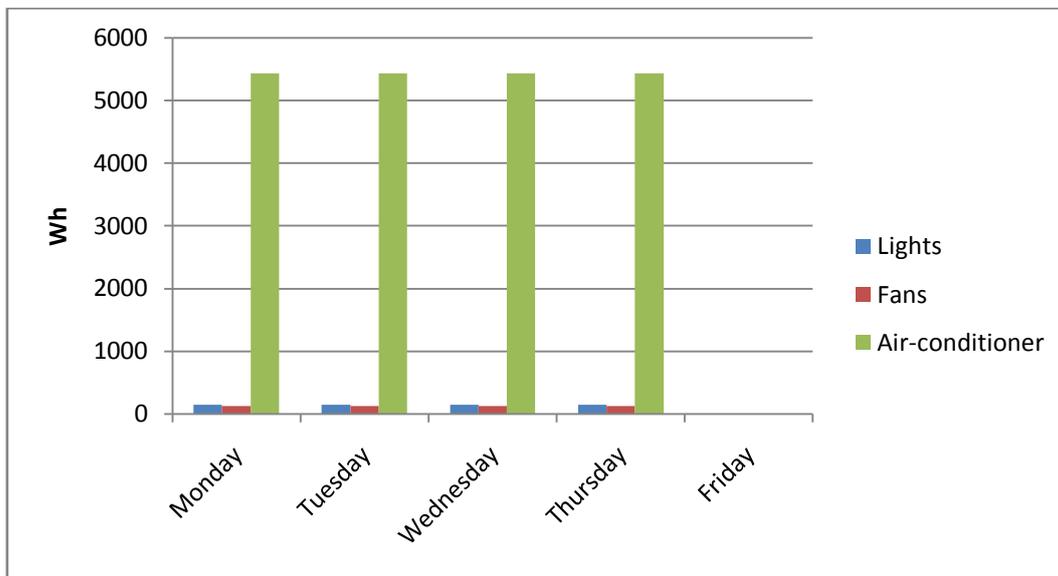
Figure 2: Fall semester daily consumption

Figure 3: Fall and spring semester final exam daily consumption
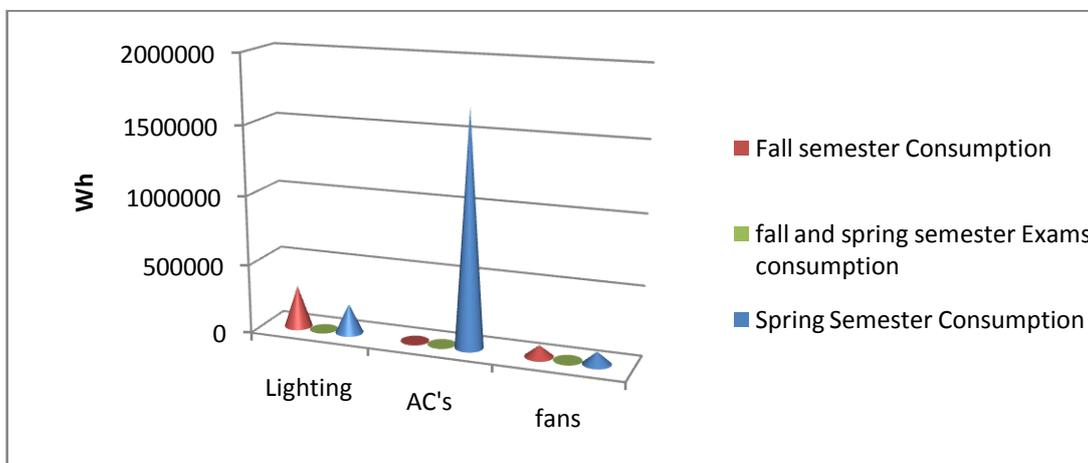

Figure 4: Overall consumption

3.2 Control Model

The control system is made on Proteus in order to control the temperature, lightning and ventilation. The same system also provides a feed-forward system through which occupant can feed the new values in the control system through keypad. Virtual terminal is connected to PIC in order to show the working of sub-systems and appliances

Figure below shows that when the temperature is sensed by LM-35 and temperature is low then the set value for heating system in PIC, heater (lamp) is turned on in heating system.
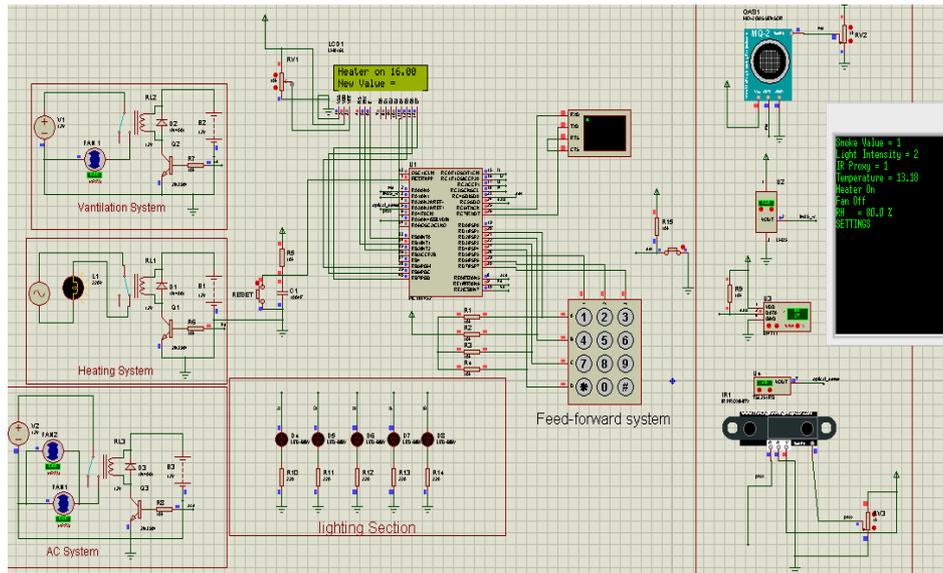
Figure 5: Temperature Control System, Heater is turned on

When LM-35 sensor senses temperature and the temperature is high then the set value of air-conditioning then Air-conditioner (fan) is turned on in air-conditioning system.
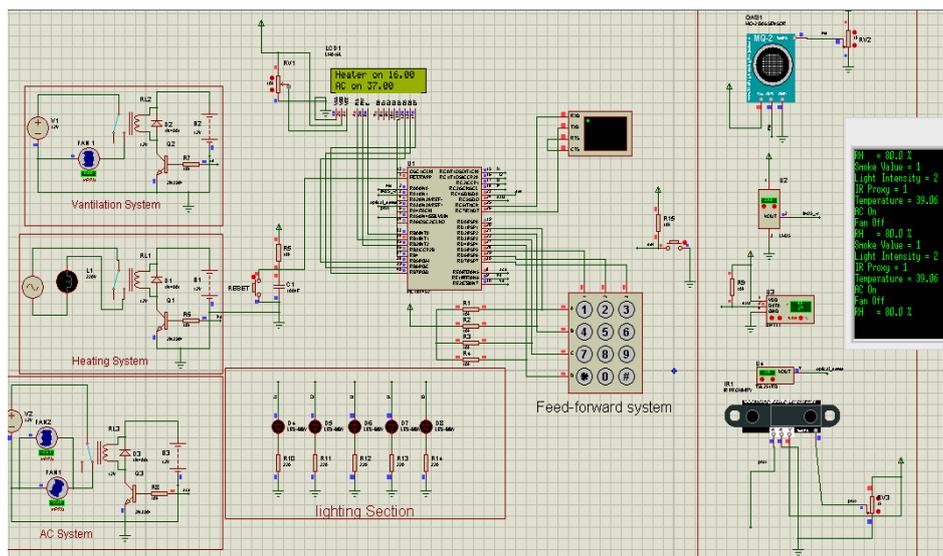
Figure 6: Temperature Control system, Air-conditioner is turned on

When MQ-2 sensor senses smoke, carbon-mono-oxide or another gas then fan of ventilation system is turned on and hence ventilation is provided.
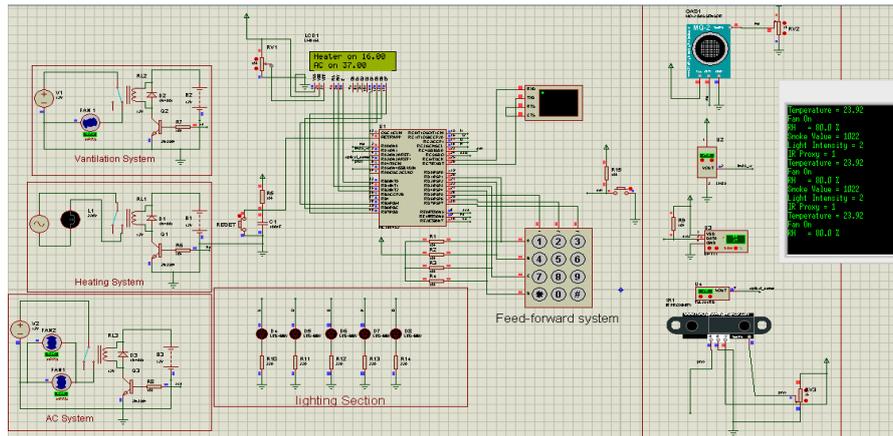
Figure 7: Ventilation system, Fan is turned on

When IR sensor senses presence of a human body it turns on a LED in lighting system in this we are providing the input with variable switch.
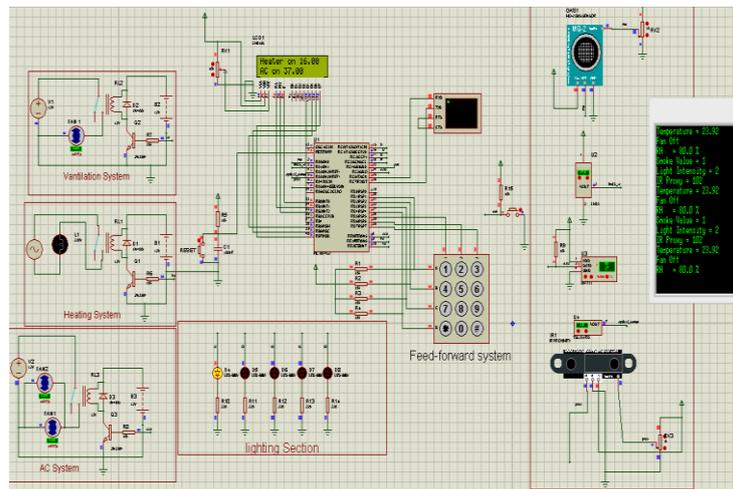

Figure 8: Lighting system, lights are turned on

When more occupants are sensed more lights are opened in lighting system.
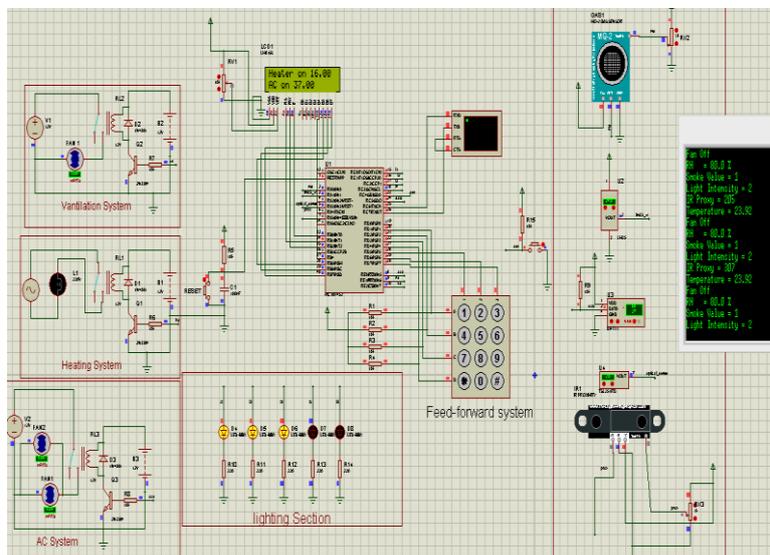

Figure 9: lighting system, more lights are turned on

Light intensity is also measured and compared and according it lights would be opened.
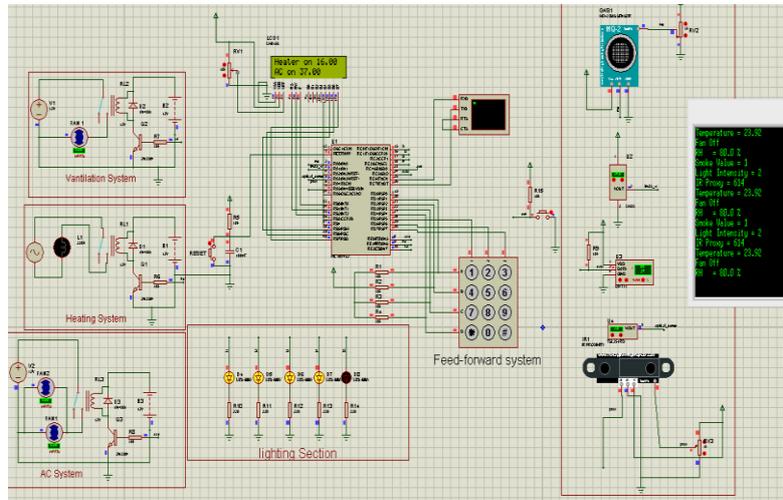

Figure 10: Light intensity is measured

When an occupant isn't comfortable with the present value he can change the values by clicking * settings will be opened and value can be entered for heating system first on which human wants that heating system should turn on the heater.
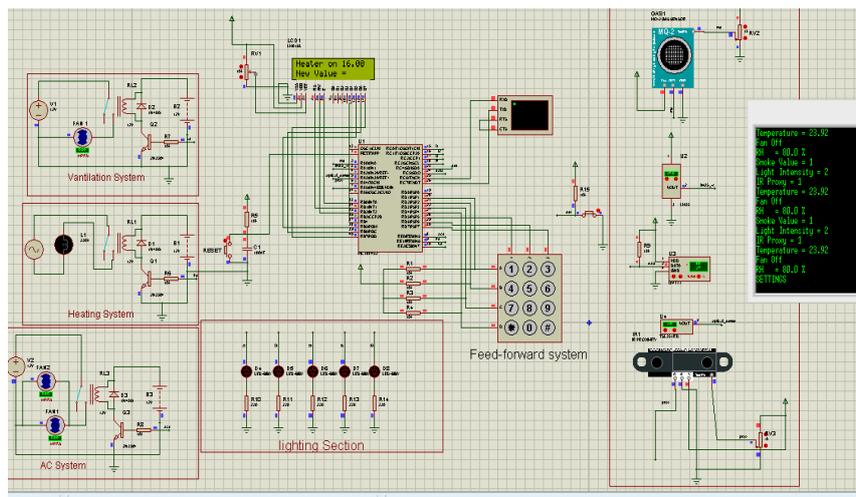

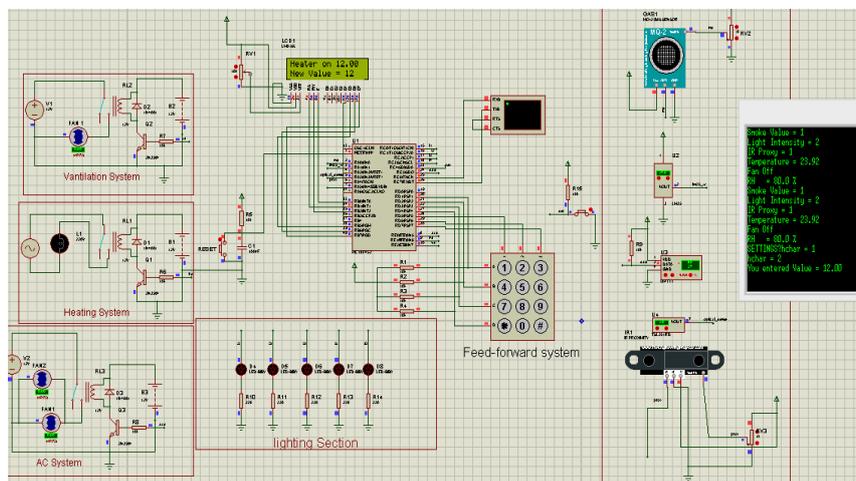**Figure 11: Feed-forward system, heating value fed**

Figure 12: Feed-forward system, new value fed

After entering heating system value, we can feed air-conditioning value and then type # to leave the settings. And then the settings are changed in accordance to the comfort level of occupant.
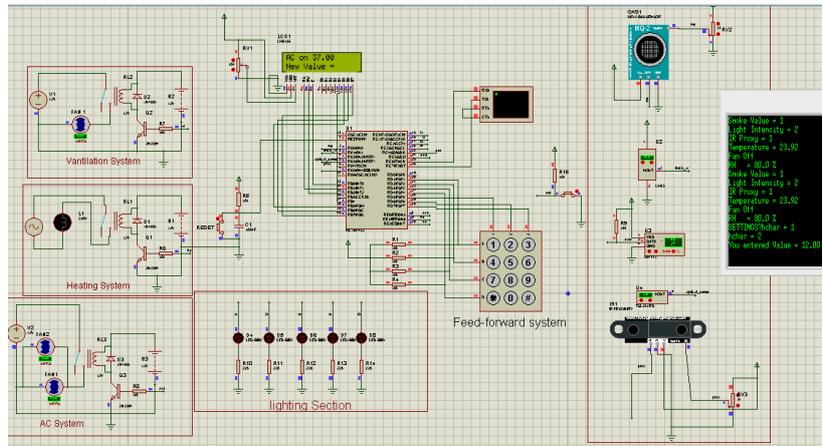

Figure 13: Feed-forwards system, air-conditioner value fed

3.3 Energy Saving Estimation

Human behavior can vary from person to person due to which five scenarios are made in which consumption patterns are compared with different percent of full load of the lab. Here, it is consider that when automation system would be applied the appliances would be working only when lab is occupied and they would be turned on according to the level of occupancy which is same as consumption patterns. So through this energy savings are estimated

3.3.1 When 60% of full load is turned on

It is estimated that about 60% of full load is turned on for 8hrs and then it is compared with consumption patterns of the lab to estimate the energy savings which is 6838210 Wh.
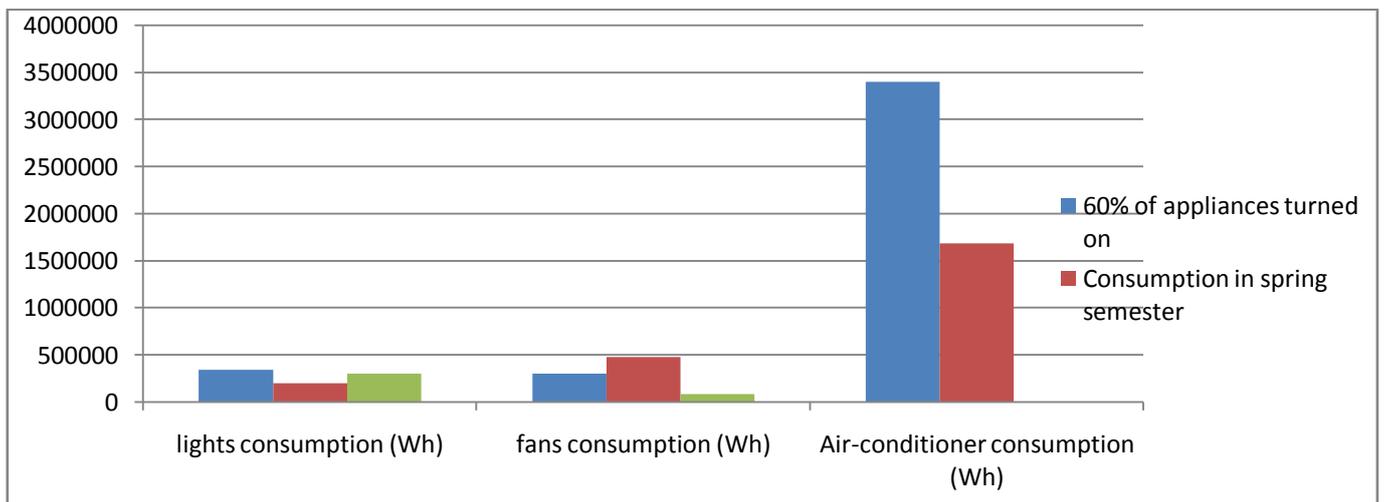

Figure 14: when 60% of appliances are turned on

3.3.2 When 70% of full load is turned on

It is estimated that 70% of full load is turned on for 8hrs and is then compared with consumption patterns so the energy saved is 6664715.98 Wh.
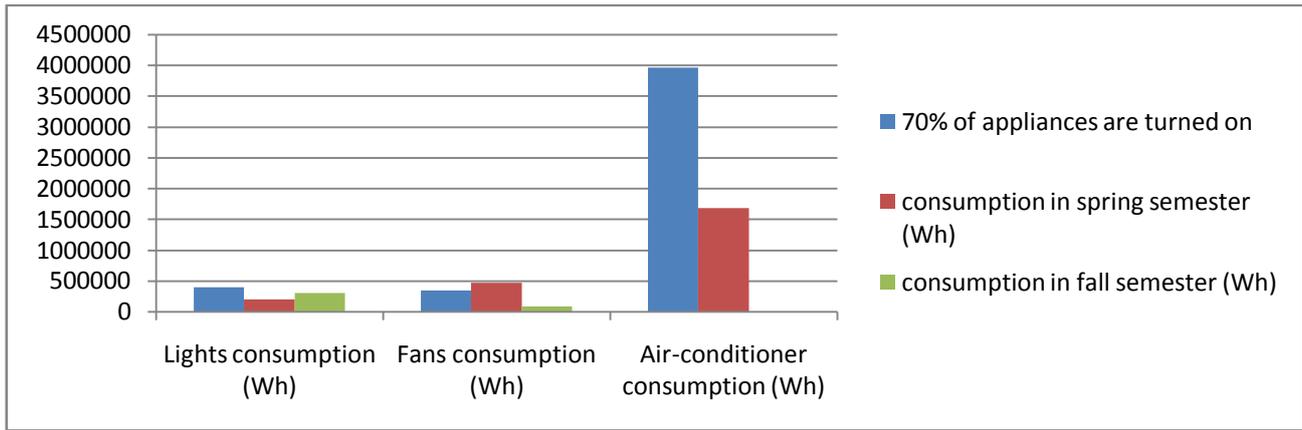
Figure 15: when 70% of appliances are turned on

3.3.3 When 80% of full load is turned on

Consumption patterns are compared with 80% of full load and energy saved is 8007112 Wh.
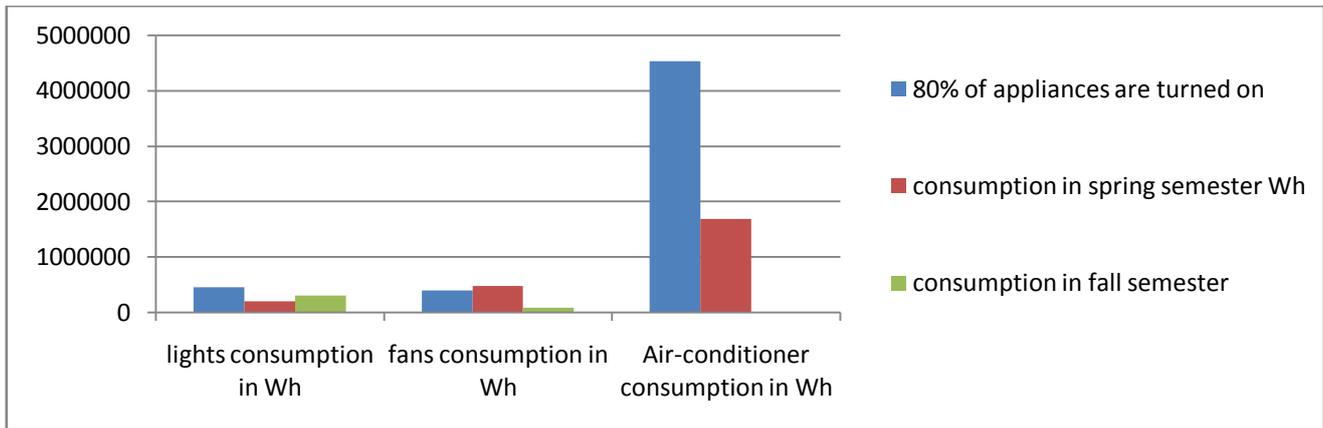

Figure 16: when 80% of appliances are turned on

3.3.4 When 90% of full load is turned on

Consumption patterns are compared with 90% of full load and energy saved is about 3851562 Wh.
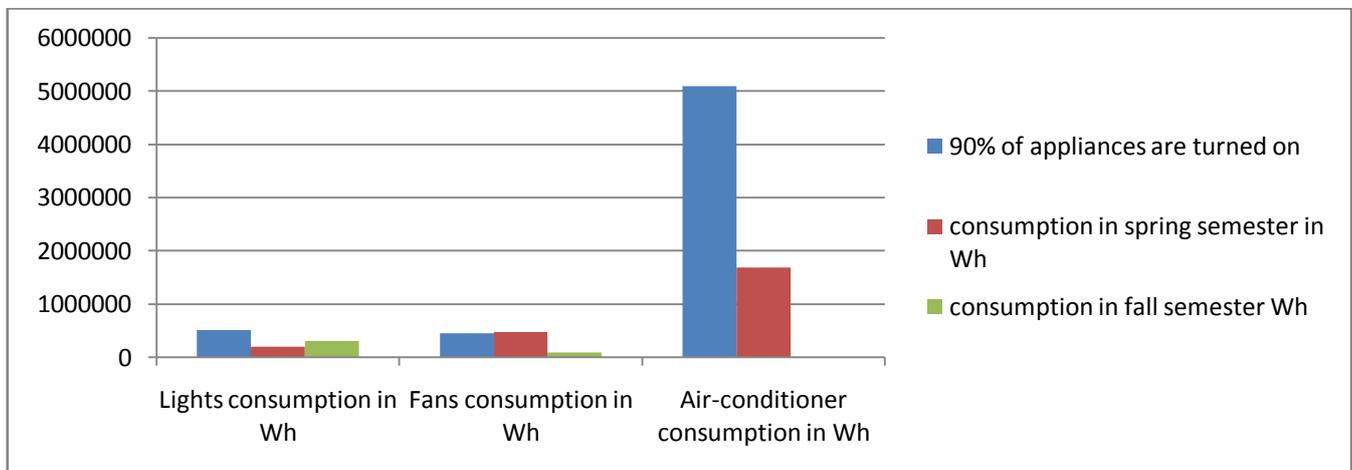

Figure 17: when 90% of appliances are turned on

3.3.5 When 100% of full load is turned on

Consumption patterns are compared with 100% of full load and energy saved is about 10691904 Wh.
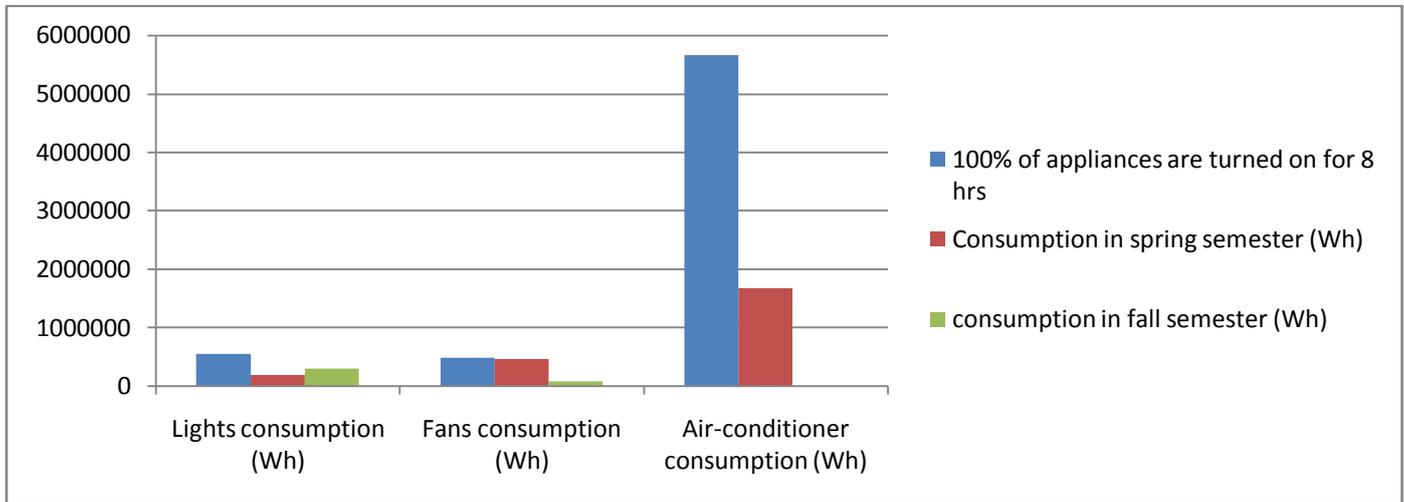

Figure 18: when 100% of appliances are turned on

IV. CONCLUSION

This era is technology period and increase in technology has increased the consumption of energy. Fossil fuels are decaying day by day and the exhaust of harmful gases is well-known by everyone, and renewable is a solution but it's better to adopt the systems through which we use energy efficiently. Large amount of energy is wasted in buildings due to negligence of human beings toward the operation of appliance. Human behavior highly affects the usage of energy and to encourage them to use energy efficiently is quite difficult specially places such as institutions where different people with different background behavior and aim gather. Energy can be saved if building automation system and building management system are applied. Most of the surveys show us that people aren't comfortable with automatic temperature control system and reason of that is that every individual has it's own comfort zone temperature so in order to make occupant satisfied a feed-forward system has been also introduced in this research In this research paper, consumption patterns were calculated with the help of timetable and power consumption of appliances then a control model was made which consists of automatic heating system, automatic cooling system, ventilation system and feed-forward system. Through feed-forward system the occupant can change the preset values according to his comfort zone. In this research we estimated the energy saving in order to analyze that how much energy is saved if building automation system is applied. The difference in values shows that a large amount of energy can be saved if automation system is applied. Hence, it is identified that after applying building automation system the energy which is wasted due to human behavior can be saved in large portion.

REFERENCES

[1] International Energy Outlook 2013 (IEO2013).

[2] IPCC Working Group I, Contribution to the IPCC Fifth Assessment Report Climate Change, IPCC, Geneva, 2013.

[3] Y. Allab, M. Pellegrino, X.F. Guo, E. Nefzaoui, A. Kindinis, Energy and comfort assessment in educational building: case study in a French university campus, Energy Build. 143 (2017) 202–219, https://doi.org/10.1016/j. enbuild.2016.11.028

[4] P.-L. Luis, J. Ortiz, C. Pout, A review on buildings energy consumption information, Energy Build. 40 (3) (2008) 394–398, https://doi.org/10.1016/j. enbuild.2007.03.007

[5] L. Dias Pereira, D. Raimondo, S.P. Corgnati, M. Gameiro da Silva, Energy consumption in schools-a review paper, Renew. Sustain. Energy Rev. 40 (2014) 911–922, https://doi.org/10.1016/j.rser.2014.08.010

[6] K. Song, S. Kim, M. Park, H.-S. Lee, Energy efficiency-based course timetabling for university buildings, Energy 139 (2017) 394–405, https://doi.org/10.1016/j. energy.2017.07.176.

[7] X. Luo, Y.F. Liu, A multiple-coalition-based energy trading scheme of hierarchical integrated energy systems, Sustain. Cities Soc. 64 (2021), https://doi.org/10.1016/ j.scs.2020.102518

[8] SOETEDJO, A., NAKHODA, Y.I. AND SALEH, C., 2019a. An Embedded Platform for Testbed Implementation of Multi-Agent System in Building Energy Management System. Energies, ,, 12(19), p.3655.

[9] CARLI, R., CAVONE, G., DOTOLI, M., EPICOCO, N. AND SCARABAGGIO, P 2019. Model predictive control for thermal comfort optimization in building energy management systems. IEEE International Conference on Systems, Man and Cybernetics (SMC) (pp. 2608-2613.

[10] SARDOUEINASAB, Z., YIN, P. AND O'NEAL, D., 2020. Energy modeling and analysis of variable airflow parallel fan-powered terminal units using Energy Management System (EMS) in EnergyPlus. Journal of Building Performance Simulation,, 13(1), , pp.1-12.

[11] KOÇYIĞIT, N. A. Ş., M.E. 2017. Design of a laboratory unit air-conditioning system with Matlab/Simulink software. Acta Phys Pol A, 132, pp.839-842.

[12] ALI, B. M. A. Ç., A.K., 2020. Energy Management and Saving Strategy using HVAC System in University Building. Journal of Engineering and Applied Sciences, 15(6), , pp.1306-1310.

[13] KIM, H., HONG, T. AND KIM, J., 2019. Automatic ventilation control algorithm considering the indoor environmental quality factors and occupant ventilation behavior using a logistic regression model. Building and Environment,, 153, pp.46-59.

[14] JAIN, A., SMARRA, F., RETICCIOLI, E., D'INNOCENZO, A. AND MORARI, M., 2020. NeurOpt: Neural network based optimization for building energy management and climate control. arXiv preprint arXiv:2001.07831

[15] CAMPONOGARA, E., SCHERER, H., BIEGLER, L., & GROSSMANN3, I. 2020.

[16] DREES, K. H. 2020. Building control system with adaptive user interface. U.S. Patent 10.

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