Advanced and Innovative Automation Technique for Energy Conservation

(A Review, Recommendation and Experimentation)

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Abstract— **Energy wastage is a serious issue in industries and office buildings. Around 40% of energy is consumed for HVAC systems and 15% of energy is consumed for Lighting systems. Lighting is one area where energy can be conserved. But before that there arises a necessity to know the measures and policies and the need for the energy conservation. The main aim of the paper is to give an overall view of the process involved from setting the status, measures and policies to implementing the policies through audits and come out with one new methods to achieve an energy conservation for lighting systems. The paper also comes across the view of process through the design, management, conservation. By going through overall journey about the energy setting up measures and policies and implementing using audits, it would be useful for setting policies for the future and .**

Keywords—energy scenario, performance , conservation techniques.

I. INTRODUCTION

Around two fifth of the energy is being consumed by the buildings on a global scale[1]. There is a drastic increase in the energy consumption and out of which India alone consumed 11 % of total consumption in. Also when compared with other nations in terms of population and energy consumption, the energy consumption of India is very low with respect to population. This means many people in India do not have electricity. Many standards and policies are implemented for electrification of rural areas and energy conservation in urbanized areas. As per the present scenario a wide focus is given for the usage of renewable energy[15].

With the help of policies and standards, many methods and techniques are implemented to conserve the energy. The performance of these innovative techniques greatly influence in energy conservation[10]. A poor performance of the technique leads to excess energy wastage rather than conservation. An optimal power saving performance is important in cases where there is variation in the energy demand throughout the year.

Energy conservation can be done only if a detailed study of the entire building is carried out. For the detailed study, Energy auditing is carried out throughout the building to identify in which area there is energy wastage and how to conserve the energy wastage. If there is energy wastage in the lighting systems then the lighting auditing is carried out.

Energy management in lighting systems can be done by utilization of natural resources as well. By automating the buildings 15 % of the energy is spent on Lighting systems[13].Utilization of daylight into the buildings to meet the required illumination standards can save energy, cost, improves the comfort level and efficiency[2]. Daylight is the light received from the sun and it is classified into two parts solar illumination and skylight. The skylight is considered to be visually comfortable whereas the solar illumination leads to glare causing discomfort[3]. However in case of lack of daylight, artificial lights are required to supplement the daylight for energy efficient operation. Automatic on/off of lights play an important role in conserving the energy. Through this automatic on/off control we can save the unutilized light in the buildings and thereby we can save energy [4].

Sensors play an important role in automating the systems. But increase in the building area increases the number of sensors. With the increase in the number of sensors controlling the data from the sensors become complicated and there are other difficulties in transmission of signals from the sensors to the controllers. This increases the cost as well. An alternative approach is to provide a centralized device that can achieve the same objectives with multiple functionalities as the sensors used for visual comfort and conserving the energy. Image sensor or the cameras can be used as the centralized device for occupancy sensing through which energy can be conserved[5].

The window blinds, shades are used for avoiding the sun's direct component of light. By controlling the position of the blinds we can reduce the intensity of the sun's direct component. Using blinds for daylight linked with automatic on/off control is one of the smartest way to conserve the energy[6].

II. LITERATURE REVIEW

A wide literature review has been done to gather the Energy status, performance, management, and conservation. The main focus is done on the lighting systems

A. Energy status and current scenario

1) Energy policies:

Allouhi et al[17] has given an overview about the energy policies and measures in different countries and their energy conservation techniques. (Refer Fig 1)

The author analyzed the energy policies that were in the past and what is the current status of the energy policies and what would be the future trends. The standards that were adopted to reduce the carbon emission levels, which was one of the problem in industries were also discussed in it.

The author also discussed about the energy consumption in office buildings, residential buildings and commercial buildings. After discussing the energy consumption in the various buildings, energy efficiency in the buildings were discussed. A set of building regulations that were provided by different organizations like European Commission, ASHRAE and different journals supporting the regulations were discussed in detail.

Also the building codes, different assessment tools that were used to measure the energy conservation and certify the building that are energy efficient. Leadership in Energy and Environmental Design (LEED) is one of the major building assessment tool. The author has discussed about many building assessment tools, their pros and cons as well. Finally a brief discussion on the impact of the energy policies and their barriers in the energy conservation pathway. The barriers like economical barrier, political barrier and social barriers greatly influence in the implementation of energy efficiency in buildings

2) Indian Energy Scenario:

Vijaykumar Kulkarni et al[15] has discussed about the Energy scenarios in India. A brief introduction was given on the energy consumption of India with respect to the population. It says that energy consumption of India is very low when compared to the population. The renewable energy like wind, small hydro power, bio power and solar power, their installed capacity and their contribution to the nation as of December 2014 has been reported. Finally the different energy schemes in India are briefed. Some of them are

a) Standards and Labelling Programme which describes the efficiency in terms of STAR ratings from 1 to 5

b) Energy Conservation Building Code which classifies the buildings into three different structures and setting the norms based on the structure

c) Bachat Lamp Yojana which replaces all the incandescent lamps with energy proficient lamps

d) State Energy Conservation Fund is setting up with subsidies for those who come up with energy conservation techniques.

Many such codes and regulations that were set as standards are discussed

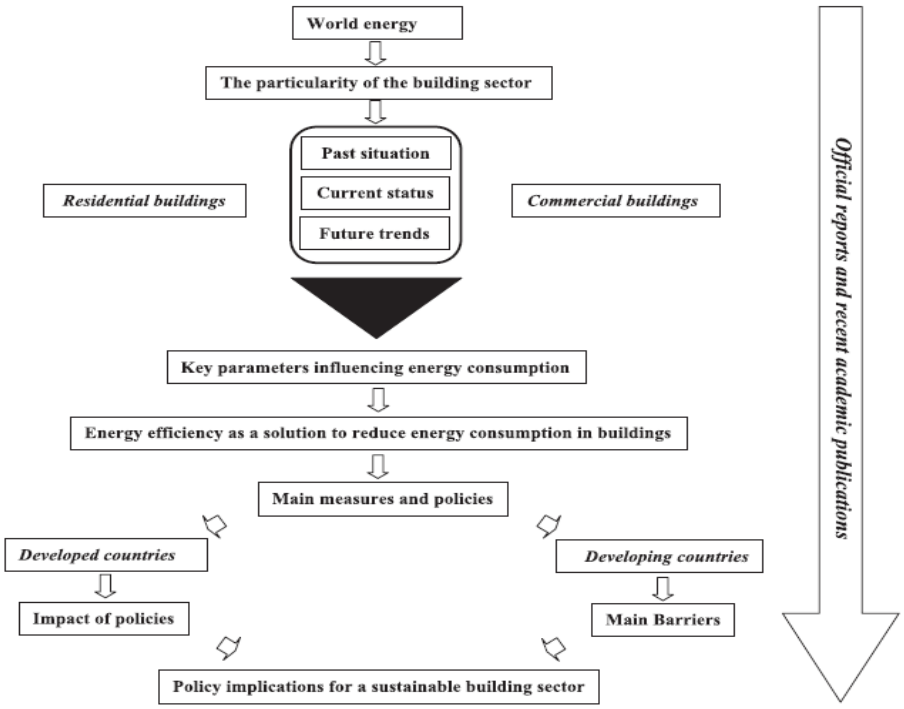

Fig 1 represents the procedure in which the review has been done by the author [17]

Country/ Regions	Population (millions)	GDP per capita (PPP-$2000)	TPES per capita	TPES/GDP	Electricity Consumption (kWh)	kWh/GDP
Post-Soviet	285	8996	3650	0.41	4660	0.52
Asia	3156	12324	2250	0.18	3190	0.26
India	1139.97	3781	540	0.14	566	0.15
Africa	984	2540	670	0.26	571	0.22
Latin America	462	8522	1240	0.15	1956	0.23
Middle East	199	8191	2990	0.37	3384	0.41
OECD	1190	27620	4560	0.17	8486	0.31
Non OECD Europe	53	10471	2010	0.19	3378	0.32
World	6688	9549	1803	0.19	2782	0.29

(Source: 2010 Key World Energy Statistics: IEA)

Fig 2 represents the table showing the energy scenario of India with the World [15]

B. Energy Performance

1) Interior Lighting systems

Giuseppe Praise et al[10] has discussed about the energy performance on Interior Lighting Systems. He came up with four new parameters for optimizing the energy performance and also certifying the luminaires. The four new parameters are

a) $EP_{Luminaire}$ - The Luminaire Energy Performance is used to certify the luminaires based on their efficiency. Many factors like Lamp Survival Factor, Maintenance Factor etc. are taken into consideration while calculating the $EP_{Luminaire}$

b) EP_{System}- The System energy performance is to calculate the energy performance of the total lighting systems. It is calculated from the actual power density and reference illuminance value

c) $EP_{Control}$- This indicator helps to find the control strategy that is implemented in the lighting system like occupancy or automatic on/off control

d) EP_{Global}- Global energy performance indicator is used to provide the overall efficiency of the system. It is the product of all the other indicators

Based on these indicators energy certification for the luminaires is done. They are classified into different classes based on the indicator values Finally the author carried out a case study for a 4x7 room to calculate the four parameters and their impact on the energy performance.

2) Road Lighting Systems:

Jan Zalesak et al [18] came up with the energy performance evaluation for exterior lighting systems that is for the road. The author discussed about the various lamps that are used for road lighting and the luminous efficacy of the lamps that were used. This paper mainly focused on the comfort for the human eye. The author came up with the parameter relating the photopic vision and scotopic vision in terms of luminous efficacy of the different lamps. Based on this parameter one can conclude which lap would comfort the human eyes with more energy efficient operation when used for exterior lighting. The author also assessed the vision with respect to mesopic conditions. An evaluation was done for calculating the illuminance at photopic condition and scotopic condition through various parameters. After the calculation of those parameters, the operating efficiency of the luminaires and energy performance of light loads that were installed for about one kilometer were determined. The author concluded that only the real scenario of the evaluation was done and also there were no exact results supporting the energy performance and conservation.

3) Lighting Control systems in buildings

Giuseppe Praise et al [19] came up with a procedure to improve the energy performance using lighting control techniques as per the EN15193 (European Standard). The author has discussed about the various control strategies that were available for the control of the lighting systems. The author classifies the entire process required for the control of lighting system into five different categories. They are

a) The techniques that are used for the controlling. ex. switching, dimming

b) By what means the control technique is implemented. Whether using a PLC or a relay etc.

c) modes for the control. Whether it is a manual mode or automatic mode

d) The strategy that is used for the control action

e) The control is done separately or for a part of the lighting system

Taking all these into account the energy consumed by the installed light loads were calculated. Many new indicators were introduced to analyze and evaluate the best control for the lighting systems in a building as per the standards of EN15193. From these we can come to know what control technique would be profitable, how much daylight should be allowed. Finally a case study was done implementing the procedure in real time and the various new indicators that were formulated are calculated to know its impact on energy performance.

4) Performance analysis in terms of economics- A case study

Siva Sakthi Velan et al[20] took a major initiative in by replacing the incandescent lamps with LED's and conducted a case study to analyze the energy performance in terms of economics. A two floor building is taken for the case study and all the basic parameters like amount of power consumption for a day, cost for each unit are found. A detailed financial analysis from the investment on the LED till the payback period were calculated for each LED that were to be replaced. Also if the replacement is done, then what would be the net savings were also reported. Along with that a proper design for the placement of the lighting systems is done to improve the energy performance. This is done using the room index, number of lamps, spacing between the lamps etc. The thermal performance and power quality analysis between the LED and FTL's are done to highlight the importance of LED

C. Enery Management

1) Buildings- Integrated control of Lighting and HVAC systems:

Biao Sun et al[13]came up with a new and effective method by combining roll out technique and scholastic dynamic programming for the HVAC systems and Lighting systems. This paper integrates the problems in the HVAC and lighting systems and proposes a common control and thus effectively manages the energy. The HVAC systems and the lighting systems are modelled for the study purpose and the problem is formulated from the modelled system. Decision models, decision variables, state variables and system dynamics are found with the help of various assumptions. Utilization of blinds and its impact also taken for the consideration. Solving the problem takes a lot of computation time, so the author comes out with a technique to reduce the computation time, that is the Roll out technique. The author also comes out with the relation between the outdoor and the indoor temperature. An effective method is thus proposed with cost savings by an integrated control of the HVAC systems and the lighting systems

2) Building management on energy performance of lighting systems

Giuseppe Parise et al [12] discusses about the appropriate automation and control strategy for the lighting systems in the buildings. This paper mentions the goals of the lighting under the standards EN12464-1 which focuses on the lighting requirements in the work places and the standard EN15193-1 which certifies the efficiency of the luminaire using the LENI indicator. Also considering the daylight factor, occupancy factor and constant illuminance factor an appropriate control strategy is proposed and a case study has been conducted for the adopting a control strategy for the buildings to reduce the energy wastage and costs.

D. Energy Conservation

1) Automatic Lighting systems

Payal Rodi et al[21] discussed about utilizing the solar energy for storage during the daytime and use the stored energy to operate the street lights in the night time using the three different sensors. LDR sensor for the light intensity variation, PIR sensors to monitor the traffic movement, and rain sensor

2) Top up control of Natural Lighting for energy conservation

Chaichana Wangkadilok et al [22] discussed the reduction in utilizing artificial light source during the daytime instead using the artificial light sources to supplement the daylight for maintaining the standard illuminance levels. The author collected the data of the natural illuminance using LDR sensor. A detailed analysis is done by placing the sensor at different positions of a room taken for study during the February month to May month and noted its value at different positions. Illuminance control is done based on the appropriate LDR and the cost savings are analysed

3) Fuzzy control of LED tunnel lighting

Hong Zeng et al [23] proposed a new fuzzy control algorithm for the tunnel lighting using LED's. The author discusses about the inclusion of daylight and measuring it using sensors, monitors the traffic using the LASER transmitter and receiver which is not affected even in the change in climatic conditons. The author uses the fuzzy control algorithm to vary the illuminance levels depending upon the natural illuminance and the traffic. The author has designed a fuzzy control response table to vary the illuminance level inside the tunnel based on the natural illuminace available, traffic movement and the climatic conditions. A central control module is designed to collect the data from the controller and analyse for the energy conservation. Based on this technique a three year electricity charges are reported

4) Lighting Audit

Muhammad Usman Khalid et al [16] conducted a lighting audit for conserving the energy. The data from the Transformer Business Unit of Siemens in Pakisthan is taken as their case study for their lighting audit. The author conducted the survey throughout the site and noted the various lamps that were present and their energy consumption and proposed a new lighting scheme by designing task lighting for certain places and replacement of energy efficient lamps, re-lamping etc. . The identification of areas where cost can be saved and based on that a new maintenance plan was proposed and the payback period and cost savings were reported.

III. RECOMMENDED TECHNIQUES

Based on the literature survey few drawbacks are found. For instance usage of the sensors for large office buildings increases the cost on investment rather than saving the cost.

Similarly instead of the usage of the sensors for small spaces optimized load scheduling of the lighting systems can be done to save the cost

A. Optimized scheduling of lighting system loads

This method uses some user interface like smart phones or tablet for scheduling the lighting loads at different load conditions wirelessly based on the requirement of standard illuminance levels and conserving the energy with comfort

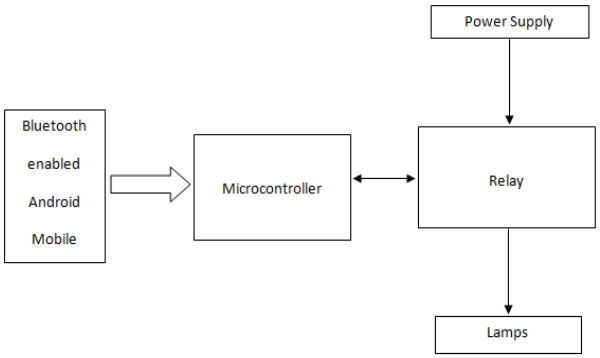

Fig 3. Block diagram showing Wireless Control

A predefined set of load conditions are programmed in the microcontroller. When the signal from the mobile is given to turn the specified number of loads instead of turning all the lighting loads, energy would be spent only on that particular load

Wireless control through bluetooth would be more efficient but only for the small spaces. HC-05 bluetooth module is used for interfacing the android mobile to the lighting control system's microcontroller. For a large workspace this won't work because the connectivity holds good within 10 metres of distance

Using PIR sensors and LDR sensor for the daylight utilization and occupancy utilization would increase the performance but there would be some delay for turning the lights on. But vacancy detection can be useful much more than the occupancy detection and also it would be comfortable.

B. Sensor less lighting control

This method focuses on automating the lighting systems in office buildings to conserve light energy without sacrificing the visual comfort. Hence automation is provided to turn off of the lights automatically based on the absence of the person in the workspace. For utilization of daylight windows are available. But whenever the work plane or the workspace is exposed to glare due to the sun automation is provided to close the blinds. All these are monitored using the camera sensor instead of using multiple sensors like PIR for occupancy detection and LDR for light intensity detection. The block diagram explains well about it

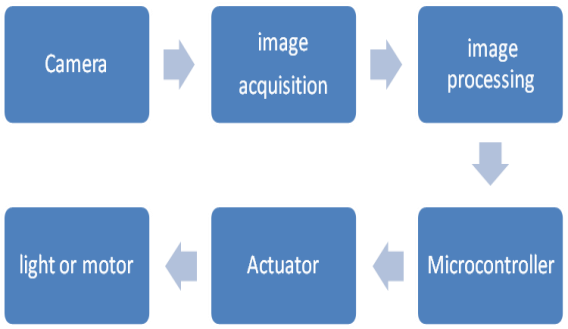

Fig 4. Block diagram showing the steps involve in automating the lighting systems

The process can be done in two different software namely MATLAB/SIMULINK and LabVIEW but the concept remains the same. The methodology for the MATLAB/SIMULINK is explained in detail below

1) Camera

In conventional methods PIR sensors are used for detecting the presence of a person and data is sent for automating . We can also detect the presence of a person from camera and use it for the automating. From the cameras that are used for the surveillance systems, image data of the office workspace is taken for processing. The cameras that can be used are DCAM compatible fire wire cams, GenTL, GigE Vision. These camera are supported by the image acquisition tool box in the MATLAB.

2) Image Acquisition

Image acquisition is an important step in the process. Once the supported hardware (camera) is connected we can collect the data in terms of frames. But a Graphic User Interface, is needed for acquisition. In MATLAB image acquisition tool box is used for it. Now we select the Region of interest as where the windows are present so that it should detect whether there is a glare because of the sun. By selecting the frame rate the process is carried out.

3) Image Processing

Image represents the 2D array of values of light intensity. Based on the intensity values we get from the image, we can detect the glare from the windows and also by comparing two frames we can detect the presence of a person with the reference frame being the office workspace without any humans. The image frames are converted into gray-scale initially and then processed for finding the intensity in terms of each pixel. A particular area where the windows are present(region of interest) is focused for measuring its intensity values. And also a database is created for the reference frames. A threshold value is set based on the reference frames. Image subtraction is used to find the variation between the images.

4) Microcontroller and actuator

Arduino UNO with ATMEGA 328 controller is used for the control process. Instead of coding in the Arduino IDE as a traditional way, Arduino support package for the MATLAB is used so that interfacing between the image processing blocks and the arduino control block becomes easy. The currently captured frame is compared with the reference frame and it is given as the signal to the microcontroller in terms of digital signal 0's and 1's. From the signal the controller gives signal to the relay to actuate the corresponding process, whether to turn the blinds or to off the lights.

IV. Case Studies for the Recommended Techniques

A. *Experimentation 1*

As a case study for the optimized scheduling of the lighting loads . In real time the room taken under consideration is the classroom in Energy System Simulation lab in MIT, Manipal. The class room having nine luminaires. Each luminaire consists of two FTL's each of 36 W. For wireless control via bluetooth we take four possible situations of this nine luminaires, being on and their respective power consumption

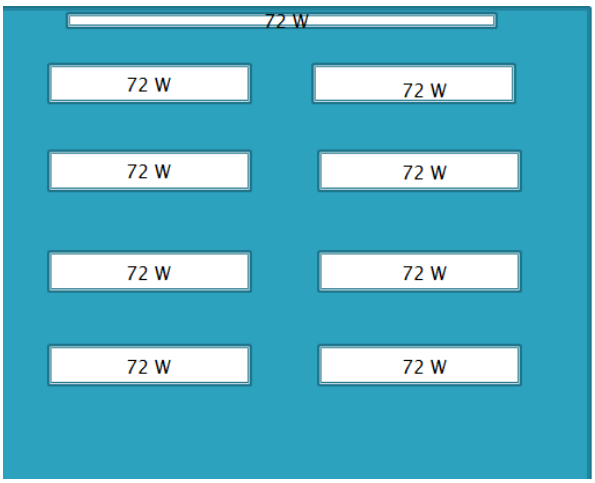

Fig 5. Room under consideration with their luminaires

	White Board Teaching	Projector Teaching
PE& ESM	A=648 W/h	B=432 W/h
Only ESM	C=504 W/h	D=288 W/h

Fig 6. Table representing the power consumed by switching different light loads

Where

A= All luminaires on

B= Luminaires near the board and first row luminaires are off and rest are on

C= Luminaires in the last two rows are off and rest are on

D= Luminaires near the board and the last two rows are off and rest are on

	M	Tu	Wed	Th	Fri	Sa	Total Hours
A	-	1	1	-	-	1	3
B	1	-	1	1	-	1	4
C	1	1	-	1	1	-	4
D	1	2	1	-	2	1	7

Fig 7. Table representing the different light load patterns in a week

Total Power Consumed by all possible combinations of the luminaires for different hours in a week can be represented as 3A+4B+4C+7D

a) Without Control:

When all the luminaires are on for 4 hours of the day and so for all the four working weeks, then the power consumed would be

Total power consumed in a month of 24 working days = 648*4*24 (Excluding Sundays)

= 62208 W/h

= 62.208 kW/h

= 62 units (approx)

Cost of 1 unit is 6 Rs. Therefore cost of 62 units is 372 Rs

b) With Control:

Total power Consumed in a week = 3A+4B+4C+7D

= 3(648)+4(432)+4(504)+7(288)

= 7704

Total power consumed in a month = 7704*4 = 30816 W/h

= 30.816 kW/h

= 31 units (approx)

Cost of 1 unit is 6 Rs. Therefore cost of 31 units is Rs 186

c) Returns :

- ✓ Total cost i.e. unit cost and the investment cost for the Blue tooth wireless control in the first month is 186+1615 =Rs.1801 whereas for the conventional one the cost would be Rs.372
- ✓ After 9 months the cost of wireless control would be Rs 3289 whereas conventional one costs around Rs 3348
- ✓ We will get a return of the investment within 9 months
- ✓ The payback time period is 9 months because we take only 4 hours of a day into consideration.
- ✓ Profit of Rs 186 can be gained every month after 9 months

B. *Experimentation 2*

As a case study for the sensor less control lighting control, two rooms of Manipal Institute of technology was taken. One of the rooms for the window blind automation and the other for vacancy detection for turning off of lights. Initially automation for glare detection and glare avoidance using window blinds were focused and input is in the form of images and not form the cameras of the surveillance systems. During the mid evening time windows in room1 where the blinds are present have a direct impact with sun's glare.

The images are processed for finding its light intensity There was a variation in the intensity level due to the glare. If the variation level is more than the threshold range then it actuates the blinds with the help of the motor.

Fig 2 showing two different images of the same window without and with glare due to sun

Fig 3. Showing the various positions of the blinds at 45° right and left to reduce the daylight penetration

Fig 4. Showing the fully closed position of the blind to avoid the glare when the sun's intensity is more

The arduino control is checked comparing two normal images instead of two frames. This comparison is changed is then changed in terms of the digital signal. This digital signal is sent to the four channel or eight channel 5V relay which is connected as the switch for the 230 V AC supply

For the arduino control to take work in the MATLAB Arduino support package for interfacing the arduino into MATLAB was installed in the MATLAB software. This is available in the add one and have to be downloaded from the MathWorks

After installing opening the Simulink model and use the Arduino IO setup to interface

The system is modelled in SIMULINK. Only a part of the model is done and interfaced successfully.

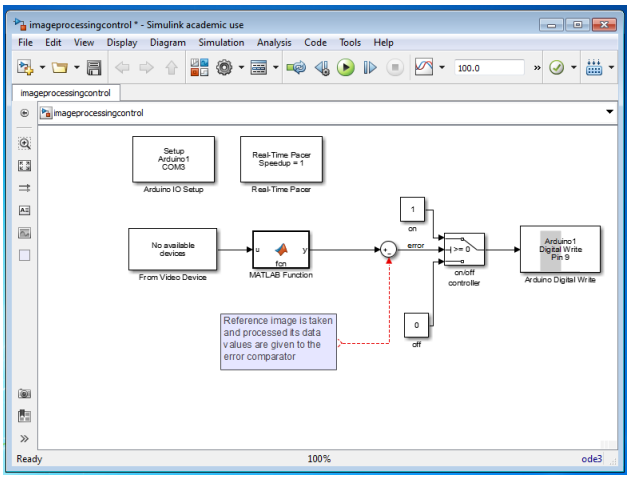

Fig 5.showing the modeled system for processing and controlling

. The camera that is supported for MATLAB is interfaced using 'From Video Device' block. Code for processing the image is written in the MATLAB Function block.

Based on the comparison between the reference frames and the acquired frame the values are converted in terms of digital signal and is sent to the arduinothrough which the light or the motor gets actuated.

V. RESULTS

Payback period of 9 months with a profit of Rs. 186 can be achieved if control through experimentation 1 is done.

Experimentation 2 is on process and many work needs to be done. But from the graphs there we can conclude that there is a hope for the conservation without the sensors

The two different intensity values were obtained.

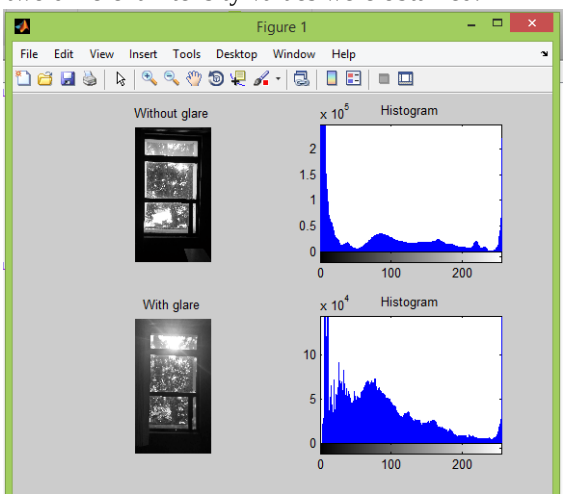

Fig 5. Graphs showing the intensity values of the images without and with glare

The X axis represents the pixel count from 0 to 255 and the Y axis represents the intensity values

Based on the variation a range of threshold values are set to design the reference frame

VI. FUTURE WORK AND FUTURE SCOPE

- A video device needs to be interfaced
- The reference frame needs to be processed and to be given as the second input to the comparator
- Performing the automation operation at various conditions
- The same can be done with the help of the LabVIEW software. But for that we need a DAQ card from the National Instruments and IMAQ VISION tool helps in the image acquisitioning part

The light intensity is the raw data that is obtained from the image it can be use to process or control other parameters that are influenced by light. A wide scope is available for conservation of energy through this sensor less technique

VII. CONCLUSION

This paper reviews the Energy policies, measures, the current status, energy performance of the controls in the lighting systems, energy management, and some common energy conservation techniques in lighting systems and suggests two new control techniques along with their methodology for energy conservation. Two experiments were carried out for the suggested techniques and one was successfully implemented with the cost savings of Rs. 186. The other technique is on process. The work has been carried out till image acquisitioning and control based on the comparison of two normal images

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