Effective Energy Conservation System for Hostels

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***Abstract:-* In an attempt to lower the amount of energy consumed in order to make a significant savings in the cost of using electricity in students' hostels, a system that monitors, controls, and manages energy usage is of paramount importance. In this paper, excess usage of electrical energy has been identified in Mandela hostel, Sharda University, Greater Noida, India, and the automation system aims at conserving this wasted energy is proposed. The system involves the use of motion sensors, ultrasonic sensors, as well as hybrid sensors placed at strategic places in the building to monitor and control light loads such as lamps, ceiling fans, and, exhaust fans, Programmable Logic Controllers (PLC), connected to a Molded Case Circuit Breakers (MCCB) of the Distribution Boards (DBs) of each floor in the building to control Air Conditioners and Water Heaters, A SCADA system which runs on a Personal Computer located in a control room to monitor and control the PLCs at each DB through a Master PLC. The energy consumption of the Hostel before and after the implementation of the proposed automation system has been calculated. Based on the comparison made, 45% of the total amount of energy consumed before the automation can be conserved, this amount to huge savings and gross reduction in the wastage of the scarce resource of electricity.**

***Keywords*— Programmable Logic Controller, Molded Case Circuit Breakers, SCADA and Personal Computer**

I. INTRODUCTION

The International Energy Agency (IEA) has highlighted six factors that influence the building energy efficiency: climate, building envelope, Mechanical, and Electrical (M&E) Systems, indoor design criteria, operation and maintenance, and occupant behavior[1]. Several studies have revealed that a huge amount of energy is wasted when students refused/forgot to turn off electrical appliances while leaving their hostel rooms. The management of the institution is usually at the receiving end. The US department of energy reports that lighting accounts for 38% of the electricity used in commercial buildings, occupancy sensors are therefore considered effective in saving a significant amount of electricity consumed by lighting system [2]. These sensors detect when motion has stopped for a specified period in order to actuate a light extinguishing circuit[3]. The significance of utilizing occupancy networked sensors in curtailing the uncertainty in the occupancy determination of a single sensor in a space (room) has been demonstrated[4]. A programmable logic controller is also considered as one of the efficient and reliable tool utilized in building automation and energy conservation [5]. This paper combines both occupancy sensors and Programmable logic controllers in designing an automation plan aims at curtailing energy wastages in hostels.

II. OCCUPANCY SENSORS

Occupancy sensors automatically switch light ON or OFF. A person never has to enter a dark room and the light will never remain ON when a room is not occupied [2]. The most common technologies used by occupancy sensors are passive infrared (PIR), ultrasonic, and dual technology.

Passive Infrared

PIR sensors sense the difference in heat emitted by humans in motion from that of the background space. These sensors detect motion within a field of view that requires a line of sight; they cannot "see" through obstacles and have limited sensitivity to minor (hand) movement at distances typically greater than 15 feet. The sensor is most sensitive to movement laterally across the sensor's field of view, which can be adjusted[2].

Ultrasonic Sensors

Ultrasonic sensors can "see" around obstructions by giving out an inaudible sound pattern and then reading the reflection resulting from the transmitted sound. A break in the pattern is recognized as a motion in the area of coverage of the sensor. Ultrasonic sensors are the best to use for areas with cabinets and shelving, washrooms, and open areas requiring 360-degree coverage. Ultrasonic sensors use the Doppler principle to detect occupancy by emitting an ultrasonic high-frequency signal through space, it senses the frequency of the reflected signal and interprets the change in frequency as motion in the space. They are more effective for low motion activity, with high sensitivity to slight (hand) movement, typically up to 25 feet. Ultrasonic sensors typically have a larger coverage area than PIR sensors[2].

Dual-Technology

Dual technology sensors engage both PIR and ultrasonic technologies. It is triggered only when both technologies detect presence to avoid false detection and it requires either one of the two technologies to keep it activated. It is suitable for use in classrooms, conference rooms, and other places where a higher degree of detection may be desirable.

III. LAYOUT OF THE HOSTEL

Mandela Hostel is one of the international Hostels in Sharda University, Greater Noida; India. It is a 12-story building with 57 rooms on each floor. Figures 1, 2, and 3 show the layout of the ground floor, the floor plan, and the plan of some selected rooms in the hostel drawn with REVIT software. The ground floor of Mandela hostel consists of Mess (vegetarian and Non-vegetarian mess located opposite to each), the Managers Office, and the Wardens Office. The number of sensors to be utilized and the control strategy depend on the layout of an area.

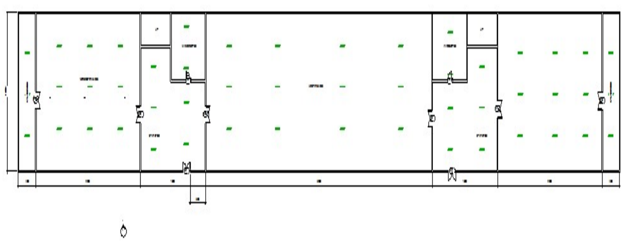

Figure 1 Layout of the ground floor

Figure 2 Floor plan of Mandela Hostel

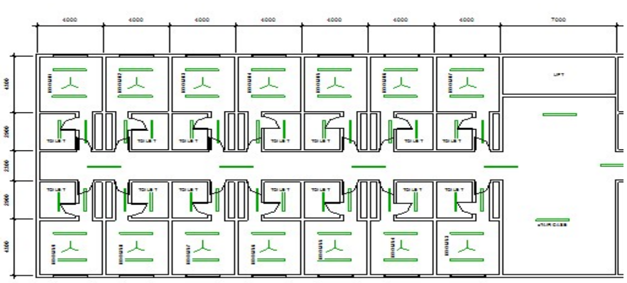

Figure 3 Selected rooms of the Hostel

IV. CONTROL STRATEGIES FOR MANDELA HOSTEL

Control strategy for students' room

As shown in figure 3, each room consists of the passage immediately after the entrance before the main room and a toilet attached to the passage. There is one lamp at the passage, two lamps in the main room, while the toilet has a lamp, a water heater, and an exhaust fan.

Students may sometimes enter the room to either use wardrobe or use the toilet without going inside the main room, as such the sensor controlling the passage lamp will be different from that of the main room. A ceiling-mounted PIR sensor is conveniently used to control the lamp. No delay time is added to the sensor operation, this is because whenever someone is present in that area, there must be some light.

The main room lamps will be controlled by a hybrid sensor that uses both PIR and Ultrasonic technology to operate. This is to avoid false ON/OFF when the students are not engaged in any form of motion such as reading. A 15-minute delay is set before OFF when the room seems no occupants. The toilet lamp and the exhaust fan will be controlled by the Ultrasonic sensor also to avoid false detection. A 30-minute delay shall be set to OFF the lamp and the exhaust fan when no one is sensed. The water heater in the toilet is controlled by a timer through a PLC.

Considering the temperature profile in the Northern region of India, the Fans and the ACs in the student rooms are controlled by a PLC using the inputs from temperature and PIR sensor. When the temperature in the room is below the set-point, the AC and the FAN should not be operated even if the PIR sensor detects human presence in the room.

Control strategies for the corridor

The corridor on each floor has 8 lamps. Two PIR sensors (with daylight feature) installed two-meters apart control 7 of the lamps; to avoid total darkness, 1 of the lamps will be controlled by a daylight sensor.

Control strategies for the Wardens office

There is one lamp, fan, and AC in the warden's office. Each of these will be controlled to minimize energy loss. A hybrid sensor will be used to control the lamp and the fan, to avoid false ON/OFF. The Same hybrid sensor will control the AC, and a 15-minute delay will be set before the AC is OFF when the office seems empty.

Control strategies for the Manager's office

The manager's office contains the same gadgets and patterns as the warden's office. All control strategies applied in the warden's office are also applied here.

Control strategies for the Mess

There are 9 lamps and 3 ACs in each of the vegetarian and Non-vegetarians mess. Three ultrasonic sensors are deployed to control the lamps. The AC will be remotely controlled by RTU (PLC). Thirty minutes before each mealtime; the ACs will be ON and will be OFF 30mins after the time of the meal. Table 1 summary of the type and number of sensors used as well as how it should be mounted (either ceiling mounted or wall-mounted).

Table 1 summary of sensors selected.

S/N	TYPE OF SENSOR	PLACE USED	QUANTITY USED
1.	Ultrasonic sensor	Toilet	1 in each toilet (ceiling mounted)
		Mess(both)	3 in each mess (ceiling mounted)
2.	Hybrid (Ultrasonic + PIR)	Manager's Office	1(ceiling mounted)
		Students' Rooms	1 in each room (wall mounted)
		Warden Office	1(ceiling mounted)
3.	Passive Infrared (PIR) sensor	Corridor	3 in each block (ceiling mounted)
		Staircase	1 in each staircase (ceiling mounted)
5.	PIR + Daylight sensor	Corridor	1 at the middle of each corridor (ceiling mounted)

V. DESIGN OF AUTOMATION SYSTEMS FOR MANDELA HOSTEL

The automation system consists of a Workstation (PC), Master PLC, Distribution board (DB), Molded case circuit breakers (MCCBs), Remote terminal Unit (RTU) based PLC, Ethernet LAN, Ethernet Hub and temperature sensors as depicted by figure 4.

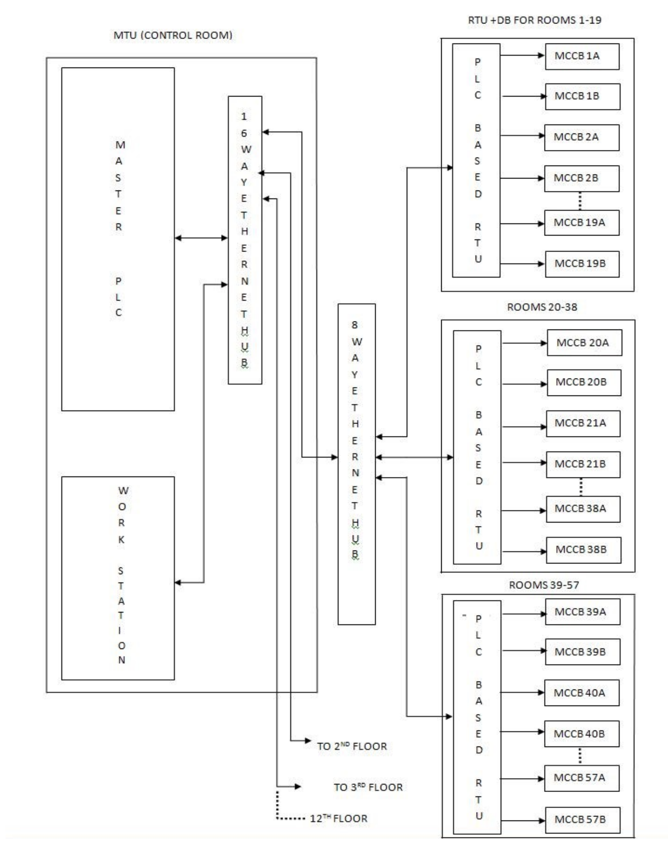

Figure 4 Automation Plan for Mandela Hostel

PC/Workstation

The PC is being located at the Manager's office (control room) to monitor and control various devices and equipment in the facility. The SCADA software which is installed on the PC has an interface for easy interaction with the user and the PC is connected to the other automation equipment through the communication cables.

Master PLC

A programmable logic controller (PLC) is a special form of microprocessor-based controller that is designed to be operated by engineers with limited knowledge of computers and programming languages. The designers of a PLC have programmed it so that the control program can be entered using simple logic[6]. In this project, a PLC is utilized as the main controller for the implementation of a control algorithm for efficient energy conservation in the hostel. The communication interface of the master PLC is capable of receiving and transmitting data on the communication networks from or to all the remote PLCs (RTU), it can also be expanded when the need to expand the building arises. The PLC which is located at the manager's office is connected to all the RTUs through a 16 way Ethernet hub as shown in figure 4.

A distribution board (DB)

A DB is a component of an electricity supply system which divides an electrical power feed into subsidiary circuits or final outlets. The final outlets of the electrical system in a building are lighting points, socket outlets, and fixed equipment. The wiring to each of these comes from an excess current protection device (fuse or circuit breaker) in a distribution board, but one fuse or CB can serve several outlets. If the circuit supplies current using equipment, wiring from one fuse or CB is known as the final circuit, and all the outlets fed from the same fuse or CB are on the same final circuit [7].

To control the equipment in the building, the RTU is connected to the MCCBs in the DB. The ground floor of Mandela hostel contains 2 DBs while each other floor contains 3 DBs. The Warden office and the Non-vegetarians mess are connected to one of the DBs on the ground floor while the Mangers office and vegetarians mess are connected to the other DB. 19 students' rooms are connected to each of the 3 DB on the other floors.

Molded case circuit breakers

These are devices that provide overload and short circuit protection for all circuit elements. It is placed on the distribution board. The RTU based PLC is connected to the MCCBs at the DB to control the AC and WH which have their separate circuits directly from the various rooms to the DB. The control is a time based; in which RTU automatically trips the MCCBs to ON/OFF the connections to the ACs and WHs.

RTU based PLC

An RTU is a small PLC which usually has less processing power and fewer ports than a PLC. This is because an RTU is built for a specific task and is dimensioned accordingly[8].

One RTU is placed at every DB and connected to the MCCBs to take care of the ON/OFF of the AC and water heater (WH). Each RTU is programmed to carry out the tripping on its own i.e. to ON/OFF the AC or WH, it will be done automatically. Programming of RTU is done using Allen Bradley software. The ladder diagram of the program is shown in figure 5. while the simulation is shown directly in the software.

However, the ladder diagram consists of the START/STOP switch to ON/OFF the program respectively. It also contains a latched switch that keeps it ON even after releasing the button. A timer is also initiated to record the timing of the whole program. A limit switch has been used also to select the exact time to ON/OFF the ACs and the WH. At last, the timer is reset to keep the program repeating itself every 24hrs.

Moreover, for the purpose of demonstration, the timer has been programmed for 24 seconds in the simulation, but during real implementation, it will be changed to hours

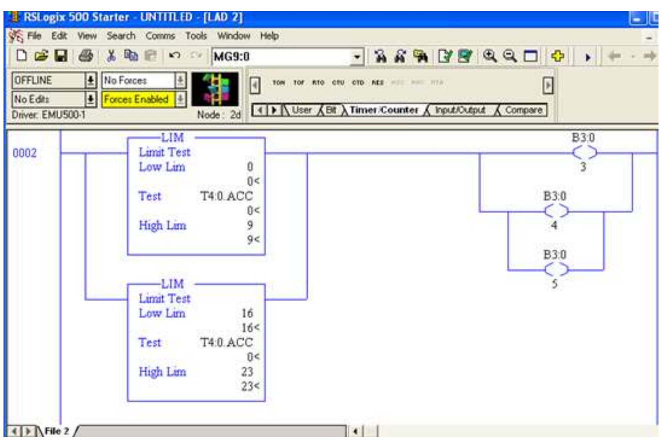

Figure 5 Snapshots of PLC program

Ethernet LAN

Ethernet LAN is the most widely used communication protocol. It uses a principle called CSMA/CD (Carrier Sense Multiple Access/Collision Detection). All devices monitor the transmission medium and wait until the medium is free before transmitting. If some other nodes have already transmitted on the medium, the device will wait and try again when the line is free. When two devices attempt to transmit at the same instant, a collision occurs. In that case, each device then backs off and waits a random amount of time before attempting to retransmit. With this access method, it is normal to have collisions. However, the delay caused by collisions and retransmitting is very small and does not normally affect the speed of transmission on the network. The Ethernet protocol allows for linear bus, star, or tree topologies. Data can be transmitted over wireless access points, twisted pair, coaxial, or fiber optic cable at a speed of 10 Mbps up to 1000 Mbps. All communications throughout the automation system the Ethernet protocol. Ethernet LAN has been selected because of the following reasons:

i. Low-cost components
ii. Easy to install
iii. Noise Immunity
iv. Presence of already existing Ethernet connection in the Hostel

Ethernet Hub

A hub is a device that joins or connects multiple devices together and usually supports Ethernet protocol. In this work, two types of hubs have been used; a 16 way and 8 ways. Each floor of the hostel contains an 8 way Ethernet hub in which all RTUs are connected. The 16 way will be at the manager's office which connects the master PLC, the PC, and each hub from the floors.

SCADA Program

SCADA in full means "Supervisory Control and Data Acquisition". It is mainly used to monitor and control equipment in buildings. It can be operated in a manual or automatic mode. The manual mode requires the operator to initiate the commands [9]. A factory talk view has been used to design the SCADA program in this project. The Factory talk view of machine edition (ME) software is a human-machine interface application that offers a solution for machine-level operator interface devices. It provides superior graphics, runtime user management, language switching, and faster commissioning time to Rockwell Automation terminal- or PC-based applications. The designed SCADA program consists of the following parts:

Start/Stop switch:

Start/stop switches are used to switch ON/OFF the PLC program. The same address has been assigned to these switches in both the PLC and the SCADA program

Numerical display:

The timing of the ON/OFF of the whole SCADA program shall be displayed numerically on the screen of the PC that is located in the Manager's office.

Output Symbols:

These are symbols representing the ACs and WHs, they are assigned the same address in both the PLC and SCADA programs. As the PLC program runs, these symbols change color to indicate their status (ON or OFF). A green color indicates ON while a red color shows that the output is OFF. Figures 6 shows the snapshot of the SCADA program

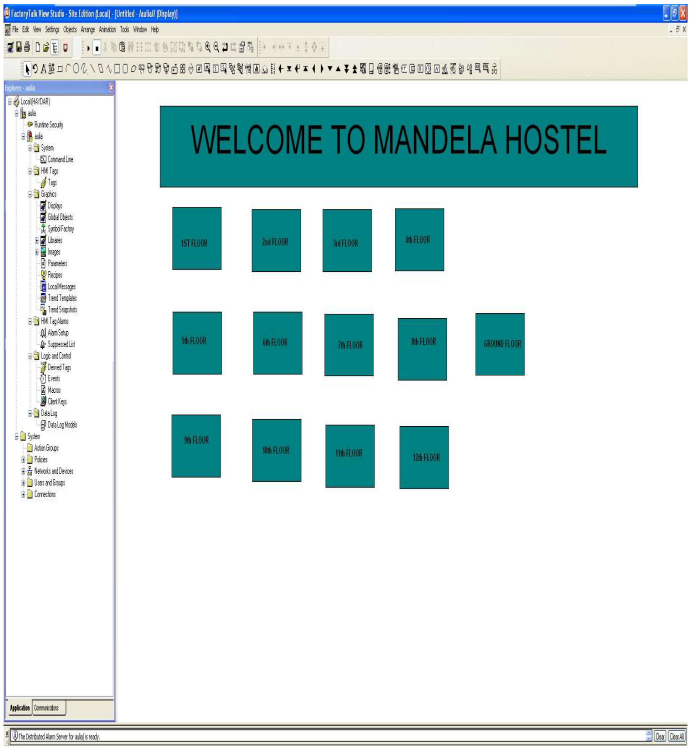

Figure 6

VI. ENERGY CALCULATIONS BEFORE AND AFTER AUTOMATION

The main aim of this research paper is to conserve energy; as such a thorough calculation of how energy is consumed before and after the implementation of the automation has been illustrated to determine whether the aim has been achieved or not. All calculations have been summarized in an excel spreadsheet.

Example of how the calculations have been made is illustrated below:

Energy consumed by a gadget per day = power rating of the gadget × Number of hours used in a day

Energy consumed by a gadget per Month = power × Number of hours used in a day × Number of days in a Month.

Energy consumed by a gadget per annum = power × Number of hours used in a day × Number of days in a Month × number of months in a year.

The number of hours used in a day has been assumed by experience and through a verbal interview with the students in the hostel.

Comparison between energy consumed before and after automation

Tables 2 and 3 show the summary of the energy consumed in Mandela hostel before and after automation respectively.

Table 2 Summary of energy consumed in Mandela hostel without automation

SUMMARY OF ENERGY CONSUMPTION WITHOUT AUTOMATION						
	AC's	LAMPS	WH	FANS	EFAN	TOTAL
JAN	0.00	30696.20	254448.00	0.00	20415.36	305559.56
FEB	0.00	28715.80	238032.00	3580.92	19098.24	289426.96
MAR	159203.60	30681.32	254448.00	3831.60	20415.36	468579.88
APRIL	572649.00	27099.60	246240.00	4942.80	19756.80	870688.20
MAY	591737.30	28000.44	254448.00	5107.56	20415.36	899708.66
JUNE	572649.00	27097.20	246240.00	6174.00	19756.80	871917.00
JULY	473940.40	28000.44	254448.00	6379.80	20415.36	783184.00
AUG	473940.40	28015.32	254448.00	5107.56	20415.36	781926.64
SEPT	306748.50	29576.40	246240.00	3704.40	19756.80	606026.10
OCT	277057.85	30562.28	254448.00	3827.88	20415.36	586311.37
NOV	192085.50	29691.60	246240.00	2469.60	19756.80	490243.50
DEC	0.00	30696.20	254448.00	0.00	20415.36	305559.56
TOTAL	3620011.55	348832.80	3004128.00	45126.12	241032.96	**7259131.43**

Table 3. Summary of energy consumed in Mandela hostel with automation

SUMMARY OF ENERGY CONSUMPTION WITH AUTOMATION						
	AC's	LAMPS	WH	FANS	EFAN	TOTAL
JAN	0.00	24492.48	106020.00	0.00	12762.08	143274.56
FEB	0.00	22912.32	99180.00	3577.44	11142.96	136812.72
MAR	120607.10	19391.12	106020.00	3827.88	11060.80	260906.90
APRIL	382617.00	18748.80	102600.00	3708.00	10716.00	518389.80
MAY	395026.80	19373.76	106020.00	3831.60	12769.52	537021.68
JUNE	382284.00	18734.40	102600.00	4939.20	9897.60	518455.20
JULY	316572.00	19105.92	106020.00	3827.88	9374.40	454900.20
AUG	316916.10	19120.80	106020.00	5103.84	10222.56	457383.30
SEPT	154512.00	18489.60	102600.00	3704.40	11536.80	290842.80
OCT	159203.60	21903.36	106020.00	3827.88	11070.72	302025.56
NOV	115995.00	21312.00	102600.00	2469.60	11539.20	253915.80
DEC	0.00	24462.72	106020.00	0.00	12772.00	143254.72
TOTAL	2343734.00	248047.30	1251720.00	38817.72	134864.64	**4017183.66**

Based on the comparison made, the calculation of the percentage of energy-saving with automation is as follows:

Percentage of energy saving with automation = {(Energy consumption before automation – energy consumption after automation) / (energy consumption before automation)} × 100

= ({7259131.43 - 4017183.66)/ (7259131.43)} ×

100= 45%

Figure 7 and 8 show the pie charts of the energy consumption before and after automation.

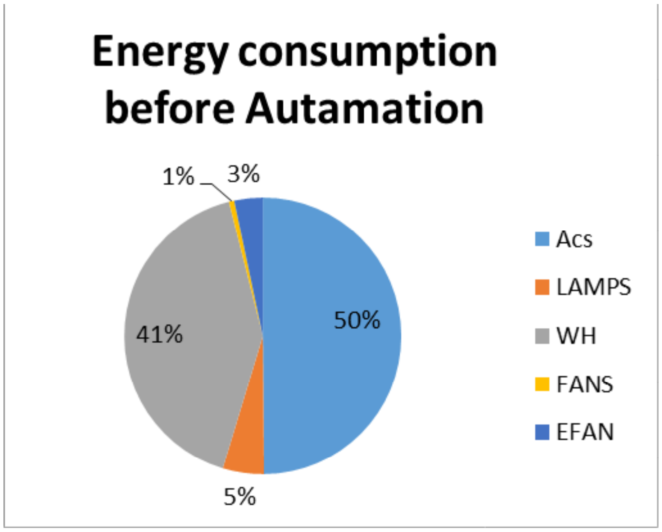

Figure 7

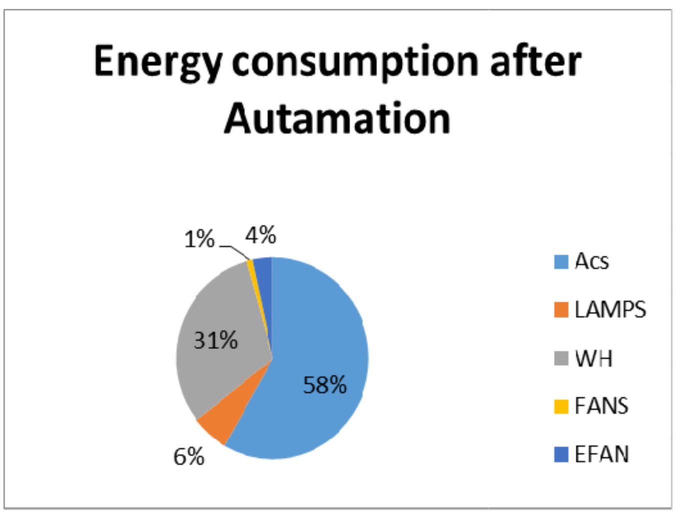

Figure 8.

VII. CONCLUSIONS

An economically viable Automation system for energy conservation is designed for Mandela Hostel of Sharda University. Ultrasonic sensors, PIR sensors as well as dual technology sensors have been used for detecting and controlling of thamps, fans, exhaust fan, etc. PLC-based RTU is programmed to control the AC and water heaters on time bases through the MCCBs. The energy consumption of the whole building has been calculated before and after the automation design. Based on the comparison made, 45% amount of energy can be conserved. This study shows that there can be a substantial savings of energy through automation.

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