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Electrical Energy Saving and Management Initiatives: A Case Study of University Libraries in KPK, Pakistan

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ABSTRACT

Several recent studies show that a significant portion of the electrical energy consumption in educational institutes, residential and business buildings are due to the improper use of electrical appliances. The objective of this paper is to develop a cost effective automated power management system for the academic institutions to reduce the consumption of electrical energy. To this aim, a sensor-based intelligent system and decision making algorithm are proposed. As per algorithm, the system monitors the number of persons, intensity of light, temperature and accordingly controls the behavior of appliances. This paper includes a case study of two university libraries in KPK, Pakistan, namely, University of Engineering and Technology(UET), Peshawar, Abbottabad Campus and Hazara University Mansehra. The analysis of the experimental results concludes that the proposed energy saving system (PESS) is able to provide a significant energy savings.

1. Introduction

It is a known and relevant fact that the future progress and economic development of a country depends upon the availability of electrical energy. The continuous increase in population and industrial development rapidly accelerate the energy consumption rate. Approximately 41% of the overall world-wide energy consumption is covered by educational institutes, residential and business buildings [1]. The major cause of energy consumption in educational institutes are space heating, air cooler, air conditioning, lighting, the use of computers, printers and other electronic appliances [2]. Major part of energy consumption is due to the improper use of such appliances, especially the use of electrical appliances in standby mode which accounts 10% of the overall energy consumption [3]. According to several studies, the students play an important role in reducing the overall energy consumption in educational institutes. However, this can only happen if the students are made aware of the consequences of consuming too much energy. An effective solution to this problem would be an automated monitoring energy management system in addition to user cooperation. This paper explores the ongoing efforts in two higher university libraries for monitoring and controlling the power consumption of each appliance that is used by the libraries. The system proposed in this paper is a network of different sensors and a microcontroller that is able to check and control the behaviour of electrical appliances in a university library in order to minimize the overall energy consumption without affecting the comfort level of the users.

This work is organized as follows: Section 2 explains the related work. Section 3 describes the survey performed in different places, while section 4 presents the proposed work. Section 5 hosts the hardware description. Section 6 provides the system operating functions in details. Section 7, 8 and 9contain the results, cost analysis and conclusions, respectively.

2. Related Work

In the literature, many approaches are suggested for saving an electrical energy. In [4], the author developed and implement power saving system in classrooms. They focused only on the controlling of lights and fans and did not consider the total electrical appliances and devices in the classrooms. A distributed monitoring system based on AC power meters for reducing energy consumption in buildings is described in [5]. The same AC meter is also tried in another study on energy saving performed in the computer science department [6]. The aim of the study in [6], is to understand *how*, *where,* and *for whom* electricity is utilized. The same objective is also presented in [7, 8]. Monitoring electrical appliances in buildings is the purpose of [9], where the authors describe the energy consumed in various buildings and/or various floors within the same building in a university campus. In [10], the author discussed home automation system, where he concludes, that automatic energy saving system are being preferred over the manual system. In the same fashion, smart

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metering for energy audit is studied in [11]. All the previous papers mainly concentrated on energy monitoring, while this paper provides an overview of power management of electrical appliances and the rule of modern power electronics converters and PIC-microcontroller to decrease the energy consumption. The parameters used in this paper are presented in table 1.

Table 1: Nomenclature

Symbol	Description
θ	Firing angle
θ_{max}	Maximum firing angle =180°
V_i	AC input voltage = 220V
T_{max}	Maximum temperature set point
T_{min}	Minimum temperature set point
V_{in}	DC input voltage = 12V
y_b	Output of ADC
WAPDA	Water And Power Development Authority
ℵ	Temperature sensor resolution = 10mV/℃

3. Survey

To know about the power utilization, a detailed survey review has been completed in two different academic institutes.

3.1. Analytical Survey

The academic institutes of New Zealand, Canada and America spent an average of $1.10 per square foot on electrical energy [12]. According to the Survey report, university class room building and lighting accounts 31 %, while space heating records for 28 % of total power use. The percentage shows that these places are the best target for energy savings [13]. In Asian countries, such as India, China and Pakistan space cooling is done normally through ceiling fans or air conditioners. In order to collect the statistical data, we measure the energy consumption of each device provided by PEPCO (Pakistan Electric Power Company) as shown in table 1 [14].

3.2. Actual Field Survey

A random survey is conducted through the working day at different times (e.g. study hours, tea breaks and lunch breaks) in two libraries of two different universities. The survey was first conducted at the UET Peshawar, Abbottabad Campus & than the survey was conducted in Hazara University, Mansehra.

Table 2: Electrical load

Type of Appliance	Watts
Tube light (Ordinary Choke)	40
Tube Light (Electronic Choke)	70
Ceiling Fan	70
Table Fan	60
GLS Bulb	100

3.3. Survey Analysis and Observation

The following observations were made from conducting the survey.

1. Both the libraries are fully occupied and all electrical appliances and devices are turned ON.
2. Both the libraries are not fully occupied and all electrical appliances and devices are turned ON.
3. Both the libraries are fully un-occupied and all electrical appliances and devices are turned ON.

The first observation describes a very normal situation and there were no problems found. The second observation indicates the occupancy during tea breaks and the third observation provides the status of appliances when no one is present in the library. Since, the second and third observations concluded that there exists a tremendous possibility to save energy in the libraries. This can be done by using the appliances as per the authentic requirement of the students.

4. Proposed Work

An innovative approach is followed to save the power consumption of electrical appliances normally used in the library such as ceiling fans and lighting bulbs. For this, a proper power management system (PMS) is needed. PMS is designed to control one ceiling fan and light per student and working on the following two observations.

1. Chair in the cabin is free
2. Chair in the cabin is not free

5. System Hardware Description

The proposed system is developed by combining a module of light sensor, temperature sensor, electronics components and pressure switch. The interfacing of the resulted module through PMS is shown in Fig. 1 and hardware setup of each PESS is shown in Figs. 2 and 3.

6. System Operating Functions

The block diagram is shown in Fig. 1 describes the proposed system control units.

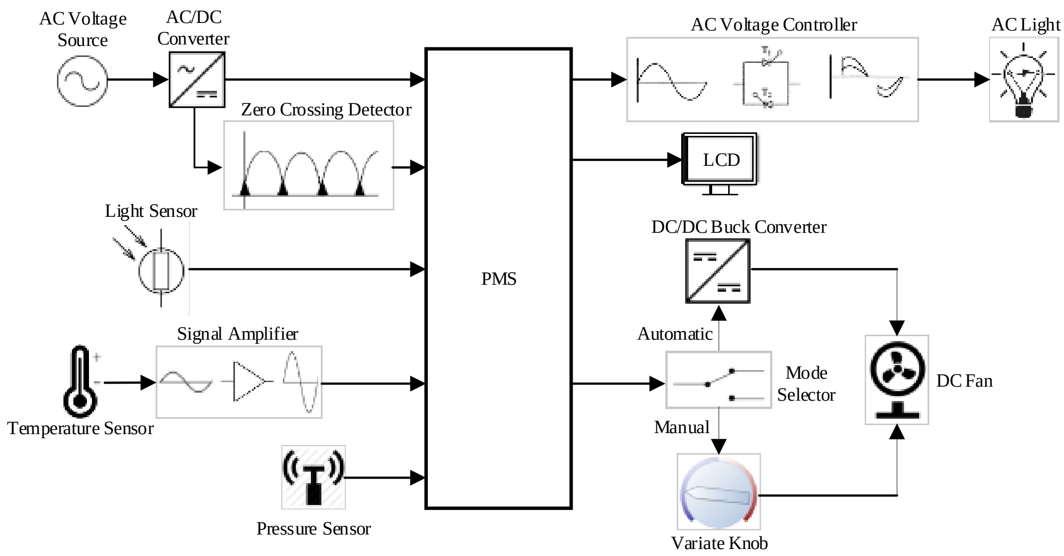

Fig. 1: Block diagram of proposed system

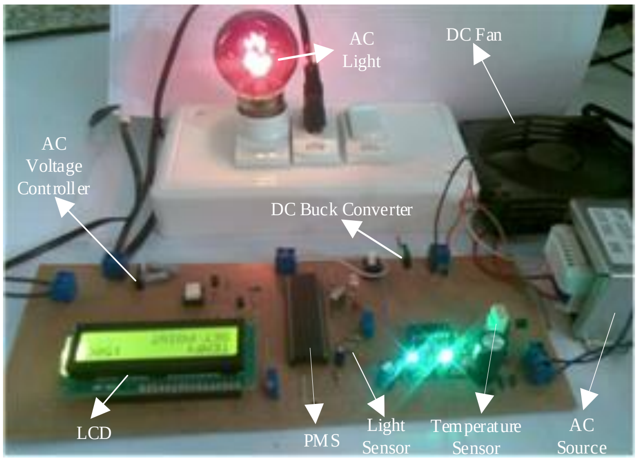

Fig. 2: Hardware test bed of PESS

Fig. 3: Test bed installed in the library

6.1 Control System for Lighting

For lighting control system the LDR is used, which sense the intensity of light inside the cabin and changes its resistance (R_{LDR}) accordingly. The relationship between R_{LDR} and the output voltage is given by (1). Fig. 4 shows the complete block diagram of the lighting control system. V_{LDR} is fed to the ADC (Analog to Digital Converter) pin of the microcontroller (MCU) which provides the PWM signal accordingly. Here, a single phase bi-directional controlled inverter is used. The relationship between V_{LDR} and V_{light} is given by (4) and (5). The working voltage and power of AC load is 50Hz 220V 100W.

$$V_{LDR} = \frac{R_{LDR}}{R_{LDR} + 10k} \times 5 \text{ (Volts)} \quad (1)$$

6.2. Control System for Ceiling Fan

Control System for ceiling fan is working in two modes, automatic and manual. In automatic mode, LM35 is used, which sense any small variations in temperature to give the output voltage. LM35 sensor can detect a voltage of 1.5V, but the ADC pin of microcontroller work on 5V. Since, an amplifier is used with desire gain to amplify the input to the required level and then dc to dc converter is used to regulate the fan speed according to the PWM signal sent by the MCU as shown in Fig. 5 (a). Similarly, in manual mode, the speed of ceiling fan is manually controlled via regulator according to the user's rules as shown in Fig. 5 (b).

$$V_t = \aleph T_{room} \text{ (Volts)} \quad (2)$$

$$V_{temp} = 3.33 V_t \text{ (Volts)} \quad (3)$$

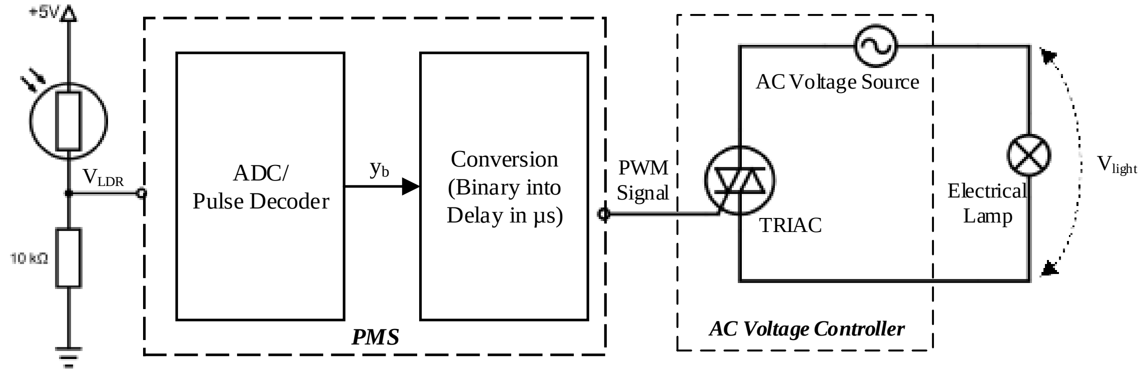

Fig. 4: Block diagram of lighting system

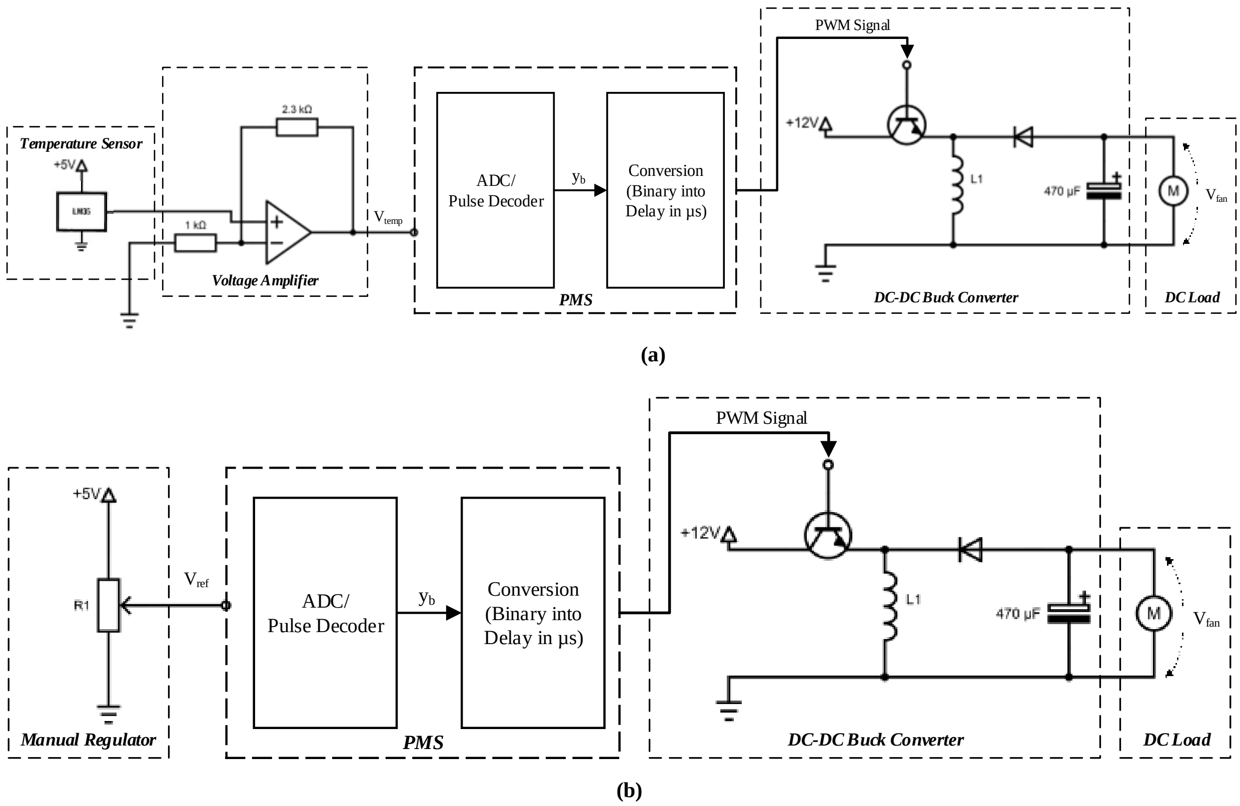

Fig. 5: Block diagram of fan control system (a) automatic (b) manual

6.3. Student Detection System

The student in a chair is detected using a pressure sensor. The Ultra-Fire remote pressure switch is used as a sensor. This pressure sensor contains four switches which are fixed on the chair. These switches are connected in parallel combination. These sensors activate when a student sits on the chair. These sensors are connected to interrupt pin of the microcontroller.

6.4. Power Management System

The overall control strategy of PESS is shown in Fig. 6. Initially the PMS senses the room temperature (T_{room}) and intensity of light (V_{LDR}) in the cabin. The PMS continuously monitor the interrupt signal provided by pressure switch for detection of student. When a student is detected the PMS set the firing angle of the AC voltage controller to its maximum value (θ_{max}) and light will OFF. If V_{LDR} is at its maximum value i.e. 5V, PMS set firing

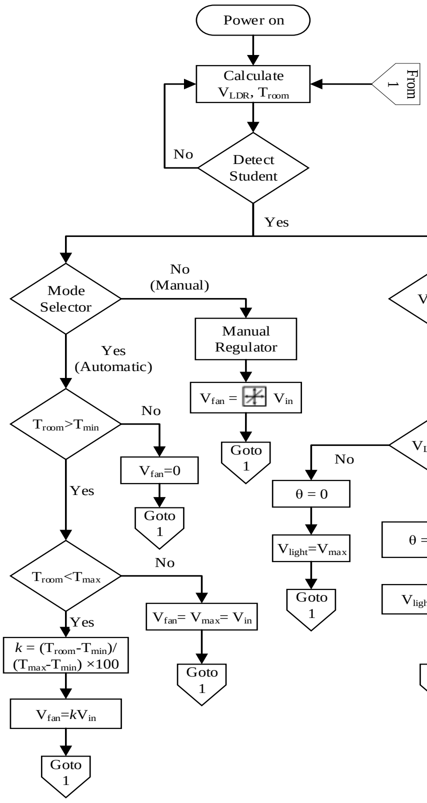

Fig. 6: Flow chart of power management system

angle to zero and light glows with its maximum brightness. If V_{LDR} is in between 0V and 5V, the V_{light} follows the relationship given in (4) and (5).

$$\theta = 36V_{LDR} \tag{4}$$

$$V_{light} = V_i \left[\frac{1}{\pi} \left(\pi - \theta + \frac{\sin 2\theta}{2} \right) \right]^{1/2} \tag{5}$$

Similarly, upon detection of a student, the PMS examines the operating mode. If a student has defined the manual mode, then PMS generates PWM signal independent of room temperature. It simply generates an output voltage (V_{fan}) accordingly to the reference voltage generated by the manual regulator (knob). Likewise, if a student has defined the automatic operating mode, then PMS adjusts the fan speed according to the room temperature. The duty cycle (k) of generated PWM is given by

$$k = \frac{T_{room} - T_{min}}{T_{max} - T_{min}} \times 100 \tag{6}$$

Where T_{max} and T_{min} are as taken 40ºC and 25ºC respectively. When $T_{room}>T_{max}$, the fan operates on its maximum speed and for $T_{room}<T_{max}$, the fan does not run.

7. Results and Discussions

The energy consumption of different electrical appliances is calculated in table 2. Tables 3 & 4, explain the hourly based power consumption calculated for both conventional system (WAPDA) and PESS. UET library's contains 22 cabins while Hazara University library's has 32 cabins. The energy usage of each cabin in standby mode is 4Wh. Now consider two cases for comparison of energy consumption.

Case 1 (No student in the cabin)

Consider the morning time e.g. 8-9 am from table 3 when there is no one inside the cabin, the energy consumption per hour in this case is calculated as 22×4=88Wh.

Case 2 (student is present in the cabin):

When the cabin is occupied, the energy consumption of cabin varies from 60Wh to 80Wh, depending upon the light intensity and temperature. Thus, the average energy consumption is taken as 70Wh. For WAPDA system, all the 14 tube-lights are ON for one hour, the energy consumption is 14×40=560Wh. Now from table 4, 8-9am, no one inside the library, the energy consumption per hour will be 32×4=128Wh.

The energy consumption per day for both universities is given in tables 5 and 6. From table 5, the energy consumption for Monday is 6125Wh.

Table 3: Power consumption (W) per hour of UET Library

Day/ Time	Monday		Tuesday		Wednesday		Thursday		Friday	
	WAPDA	PESS	WAPDA	PESS	WAPDA	PESS	WAPDA	PESS	WAPDA	PESS
8-9 AM	560	88	560	88	560	88	560	88	560	88
9-10 AM	980	352	560	88	910	550	840	484	560	88
10-11AM	770	286	1050	550	1120	1012	770	682	770	418
11-12PM	980	748	980	682	980	748	980	418	840	616
12-1 PM	910	682	910	682	700	352	840	484	560	88
1-2 PM	455	209	735	737	350	110	420	209	0	0
2-3 PM	770	286	770	418	770	286	630	88	630	220
3-4 PM	700	220	520	220	630	88	630	88	630	154

Table 4: Power consumption (W) per hour of Hazara University Library

Day/ Time	Monday		Tuesday		Wednesday		Thursday		Friday	
	WAPDA	PESS	WAPDA	PESS	WAPDA	PESS	WAPDA	PESS	WAPDA	PESS
8-9 AM	840	128	840	128	840	128	840	128	840	1258
9-10 AM	1310	656	840	194	1700	1052	1450	920	840	128
10-11AM	1130	524	1910	1052	2310	1976	1530	1316	1380	788
11-12PM	1810	1448	1670	1316	1880	1448	1520	788	1560	1184
12-1 PM	1630	1250	1670	1316	1240	656	1520	920	840	128
1-2 PM	690	394	1190	1054	560	196	725	394	0	0
2-3 PM	1090	524	1380	788	1200	524	840	128	1020	392
3-4 PM	980	392	980	392	910	128	840	128	910	260

Table 5: Energyconsumption per day in UET Library

Days	WAPDA (Wh)	PESS(Wh)
Monday	6125	2871
Tuesday	6085	3465
Wednesday	6020	3234
Thursday	5670	2541
Friday	4550	1584
Total	28459Wh 28.4 kWh	13695Wh 13.6 kWh

WAPDA system and PESS energy consumption comparison are shown in Figs. 7 and 8. In these figures, the x-axis represents the day of the week and the y-axis represents the energy consumption in Wh. As shown in these figures the load on Friday is quiet less than other days because of the prayer break. During prayer break, the library is closed, i.e. no appliance is ON.

Table 6: Energyconsumption per weekof Hazara University Library

Days	WAPDA (Wh)	PESS(Wh)
Monday	9660	5316
Tuesday	10480	6240
Wednesday	10640	6017
Thursday	9265	4722
Friday	7390	3008
Total	47435Wh 47.4 KWh	25303Wh 25.3 KWh

For more accurate results, this survey is prolonged to one month (i.e. May 2014). The complete comparison using line graph is shown in Figs. 9 and 10.

Figs. 9 and 10 describe a repeated pattern in a week during an entire month. There is a slight deviation in the pattern, this is depended upon the number of students in the library.

After one month of analysis, the overall energy consumption for an entire month is shown in Fig. 11. At Hazara University using WAPDA it is nearly 206kWh while having PESS it is 108kWh. In the same manner for UET, WAPDA system has 123kWh energy consumption

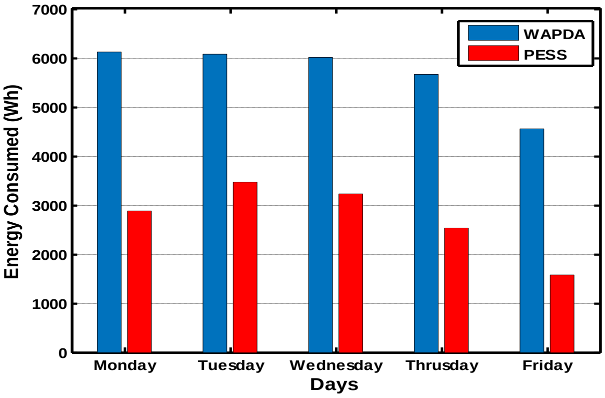

Fig. 7: Energy consumption per day in UET Library

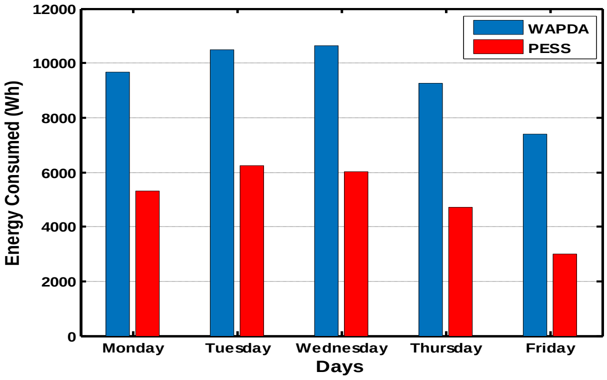

Fig. 8: Energy consumption per day of Hazara University library

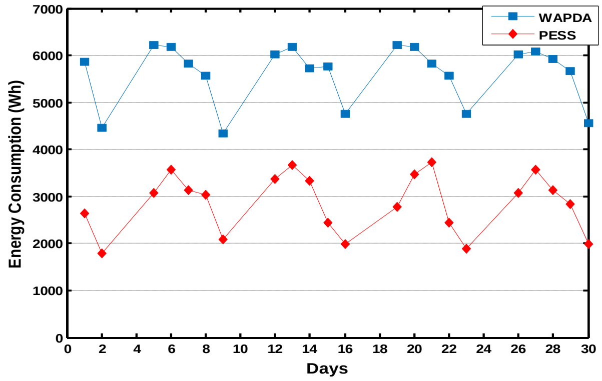

Fig. 9: Energy consumption for entire month of UET library

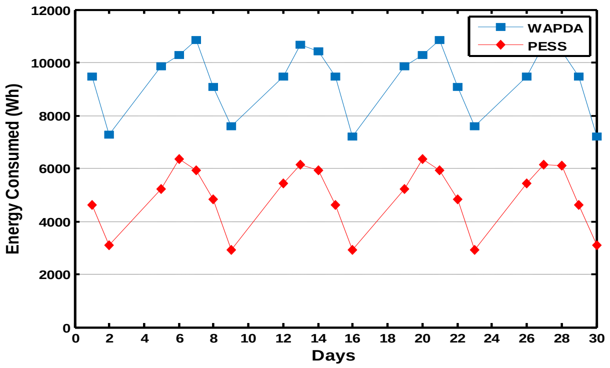

Fig. 10: Energy consumption for entire month of Hazara University library

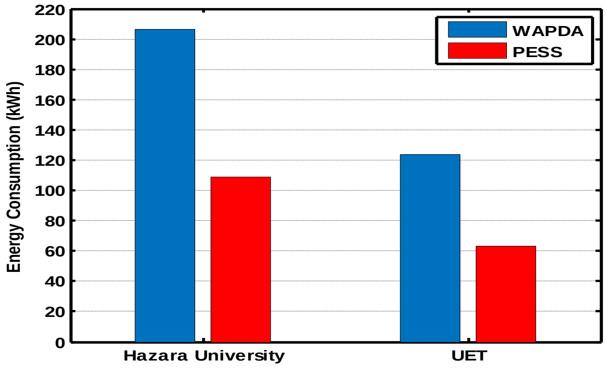

Fig. 11: Overall energy consumption

while PESS has 63kWh. The overall percentage of energy saved is given by

$$\text{Energy Saved} = \frac{E_{WAPDA} - E_{PESS}}{E_{WAPDA}} \times 100\% \quad (7)$$

Using (7), the energy saved in Hazara University is about 47.43% and in UET it is 49.07%. The variations in the percentage of energy saved depends upon many factors, e.g. number of cabins, occurrence ratios of the three scenarios, un-occasional holiday etc. In this work, we consider the effect of the number of cabins on energy consumption.

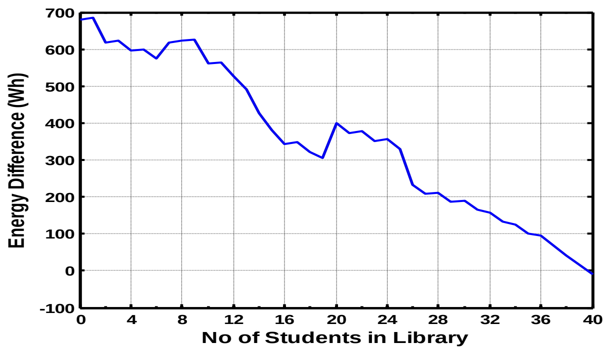

Fig. 12: Energy difference between WAPDA and PESS

By increasing the number of cabins (i.e. number of students) will decrease the amount of energy savings. From Fig. 12, 700Wh energy is saved for 1 cabin using the PESS. In addition, this figure also represents that as the number of students increases the energy saved difference decreases. For 38 students, the WAPDA system will dominate on PESS. Here, 38 students mean that all the 38 cabins are filled for one complete hour, thus the energy saving in that particular hour is zero. But, in the actual field the results are quite different, because, all the scenarios are possible at any time of the day (described in section 3).

8. Cost Analysis

The cost analysis is carried out for the period of 5 years. At Hazara division universities, the semester consists of 5 months. Therefore, one year embraces of one spring and one fall semester (5 months of each). In Pakistan, the electricity demand in winters is half of that of summers. So, considering the above facts and observations, the total power consumptions for both universities for a duration of a year is calculated and given in table 7 and 8 respectively.

Table 7: Energy consumption per year of UET Library

	WAPDA (kWh)		PESS (kWh)	
Duration	Spring	Fall	Spring	Fall
1 Month	123	61.5	63	46.8
5 Months	615	308	315	234
Total consumption (i.e Spring + Fall)	923		549	

Table 8: Energy consumption per year of Hazara University Library

	WAPDA (kWh)		PESS (kWh)	
Duration	Spring	Fall	Spring	Fall
1 Month	206	103	108	79.3
5 Months	1030	515	540	396
Total consumption (i.e Spring + Fall)	1545		936	

The average commercial unit price of electricity isconsideredRs32/unit. At UET library, the total electricity bill for the duration of 5 years using WAPDA is 923×5×32 = Rs 1,47,680 while using PESS it will be 549×5×32 = Rs 87,840. Similarly, in Hazara University library using WAPDA system electricity bill will be 1545×5×32 = Rs 2,47,200, while using PESS it will be 936×5×32 = Rs 1,49,760.

The overall initial cost per unit of PESS is Rs 750 [15]. Hence the overall cost of all the PESS units of UET library is 750×22 (cabins) = Rs 16,500 whereas Hazara University library is 750×32 = Rs 24,000. The total amount of money saved is calculated using (8).

The amount saved = $C_{WAPDA} – (C_{PESS} + ICC)$ (8)

Where C_{WAPDA}, C_{PESS} and ICC represents the cost of electricity using WAPDA system, cost of electricity using PESS system and the initial capital cost of all units respectively.

For UET Library

The amount saved = 1,47,680 – (87,840 + 16,500)
= Rs 43,340 (Pak Rupee)

For Hazara University Library

The amount saved = 2,47,200 – (1,49,760 + 24,000)
= Rs 73,440(Pak Rupee)

Using the above statistics, it is concluded that the overall reduction in cost is 29.34% for UET and 29.70% of Hazara University libraries respectively.

9. Conclusion

The paper presented the energy saving strategy in libraries using the power electronics converters and microcontroller. From the results, it is concluded that the proposed energy saving system is cost effective. This analysis is done only in the library. Thus, introducing the same concept in all lecturer rooms in the university, we can save innumerable amount of energy. Now, it's the responsibility of the Pakistani government to introduce this type of system in all educational institutes across Pakistan.

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