Design and Development of Energy audit and Load Management system

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***Abstract* – Under developed countries are mainly suffering from two basic problems in the energy sector i.e. load shedding and energy management. These problems continuously hit back to a country's economy and badly affect the performance of their industries. Therefore, the well-known industrialists are packing up their bags from these under developed countries and migrating towards countries like Bangladesh where an industry is given priority and is being facilitated. However, load shedding can be avoided by good administration and with the utilization of full resources available in a country, more over a collective effort is also required to overcome the problem of energy management. Energy management plays an important role in reducing energy requirements per unit of output. The goal of energy management can be achieved by performing energy audit that determines how and where energy is utilized and identifies the methods for energy savings. In this paper, a brief analysis of energy consumption, demand, losses and recommended necessary steps for the betterment of this energy crisis are discussed. Furthermore, a hardware device is designed and proposed to perform a fully atomized energy audit. This device can be connected to the main supply to analyze and notice the power consumed by each particular electrical appliance and to show their behavior on a monitor screen in form of graphical representation.**

Index Terms – Energy audit, Energy conservation, Load management, WAPDA, Generator.

I. INTRODUCTION

Energy is the basic need of our lives. In our daily routine continuous supply of energy is very important for our working and living. In all sectors of modern economics, energy is the key element. Our standard of economy and our daily life is maintained by the energy as it is continuously used at homes and at work. The most important type of energy is electrical energy. Electrical energy has a valuable status in the industry. When the industry of a country goes on the way of progress, then its economy gets strong. Electrical energy is very important for the economy of a country. Economy will be damaged and difficult to survive without electrical energy. According to the act of 2001, monitoring and analysis of energy consumption is referring as energy audit that includes the submission of technical reports, energy efficacy refinement recommendations and a proper program to lower down the consumption of energy. Basically energy audit is the detailed analysis of how and where energy is consumed and how it can be saved. For this purpose, different methods are considered. Greater opportunities lie in the use of renewable energy technologies. "Energy audit is an analysis of a building, campus or an industry which indicates how and where that building, campus or industry can reduce energy consumption and save energy cost." Energy audit Educates and creates awareness regarding energy usage and conservation opportunities. It also helps to protect the environment by reducing waste and pollution. In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

This research work proposes a hardware device that can save 20% to 30% of electricity by managing load and can perform a fully atomized energy audit that can also be used to analyze the load variation or segregation. The remaining contents of this paper are organized as follows: Section I reviews the related work in the field of energy management and audit. The methodology of the proposed system is presented in Section II. Section III presents the test models and different parameters measured using manual methods. Flow of proposed system is discussed in Section IV. Section V presents the results and discusses the performance of the proposed approach in a wider context. Finally, Section VI concludes the work and proposes the future research directions.

The demand for Energy is increasing day by day with the increase in population so to reduce the energy consumption, energy conservation is required. Energy conservation is done through the energy audit[1-3,10]. In [1], an energy audit of a building is performed to identify the flaws in its load consumption and energy conservation techniques are proposed for the financial analysis of energy conservation. It is concluded that more than 30% of energy can be saved through these energy conservation techniques. As compared to residential buildings, the energy audit is more important in large industrial buildings. An audit of lightning and the electric load of an industry is performed in [2]. Audit of thirteen different types of loads are carried out and it is concluded that the efficiency of industry can be improved by using the separate metering, by reducing the use of electricity during peak hours, by installing the demand controllers and Timers (time scheduling control system).

Some researchers work on energy audit done in textile industry so that the energy consumption of electric motors can be analyzed. It is observed from the results that most of the energy is consumed by the old rewound motors and energy can be saved by replacing the old rewound/faulty motors by the new motors [1]. The energy audit of a large industrial building of a famous car industry in Italy is presented in[10]. This work concluded that the energy audit analysis can achieve a 15% reduction in the gas per year. The energy audit of a department of a well-reputed university is also performed using smart power outlets [4]. Collected data is used to analyze the energy consumption and a few good

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practices are identified to reduce the total electricity footprint. Some researchers propose an advanced home energy management system(HEMS)for power scheduling [5] and an effective yet simple PIR sensor-based model is also proposed and applied to conserve the energy of a classroom by controlling the loads [6]. By reviewing the literature we come across other research work that include the energy audit of an office building that is performed through a GUI (Graphical user interface) based energy management system [7] [8] and model analysis of a building is done to study the energy consumption. The focus of this analysis was to study the variability of the cost and use of electricity and action required to reduce the billing cost [9]. An energy audit of one of the historical building of Italy is performed in a research by the analysis of energy consumption through billing and invoicing [11]

Different energy conservation techniques were also proposed and to save energy by 21%[12]. An easy-to-use simulation based energy audit system is presented by some researchers [13]. An energy audit software based on quasi-steady-state method has been built to find the energy consumption in one of the oldest university building of Europe. [14] A new energy efficient product i-e solar panel is proposed in a research for effective usage of energy for commercial office[15].To overcome the shortfall of energy crises or demand and supply, a research paper presents the energy audit of a commercial building in Dhaka[16].

Similarly, in [17], the energy audit of a building identified that the inefficient lighting system needs to be replaced with the efficient lighting system to conserve energy. Different researchers focus on various levels of energy audit techniques that are discussed such as, walk through analysis, energy survey/analysis and capital-intensive modification as per guidelines of ASHRAE that is a global energy conservation and development society [18]. A case study is presented with a focus on energy performance standardization of educational buildings and energy audit techniques and practices are applied to lighting systems of a building.[19] [20].A Smart Energy Management System (EMS)to analyze the demand for total energy and provide a continuous power supply for the local load is proposed in [21].

A smart integrated energy audit system for the detection of malfunctions and identification of anomalies in a building/plant is presented in [22].

In [23], it is proposed to use the statistical methods for the energy audit to analyze the effects of the season and climate at daylight consumption of the electricity and the energy audit is also done to identify the inefficient electrical appliances And it is investigated that the 24 % total energy of the residential buildings are consumed by the air conditioner.[24]. A model based and modular approach is proposed and experimented in 280 companies across Europe that resulted not only with financial benefits but also in the reduction of greenhouse emissions.[25] Different cropping systems are chosen for the assessment of the energy requirement [26]. Another research has given the concept of Continuous Auditing which took energy auditing to the next level by analyzing the real-time data of a building for many months, detecting the energy loss and suggesting the Energy Conversion Measures [27] [28].

In this research paper, we proposed and designed a hardware device that can perform an atomized energy audit. This device is named as “atomized energy audit machine”. Our proposed device can be connected to the main supply to analyze the power consumed by each particular electrical appliance and visualizes their behavior on the monitor screen in the form of graphical representation. Another important feature of the proposed system is load segregation. The device can prioritize the load when the power supply turns over from the electric supply company (WAPDA in case of Pakistan) to the generator. The maximum designed allowable limit of the load is 10A on the generator, exceeding that limit will activate the prioritizing function. This feature is discussed in detail in section 3. We also performed the energy audit of our University campus and on the basis of that, a list of recommendation is proposed that can be helpful in the design of a new campus building for saving energy.

II. METHODOLOGY OF THE PROJECT

This section presents the comparison of old manual method of energy audit and proposed automated method:

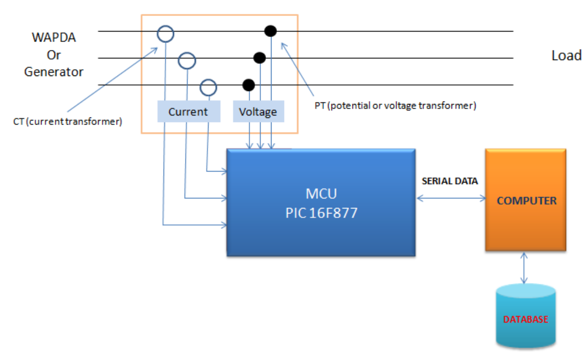

Fig. 1 Block Diagram of Modern Energy Audit System

A. *Manual Method*

The old method of energy audit involves the manual work of systematically study and analysis. Therefore, it is also known as the Manual Method. This method is non-accurate, cumbersome and time-consuming. The accuracy of this method is normally 70% due to random data collection and the manual work loses the 30% accuracy. This method is better for an energy audit of small buildings but not reliable for a large geographical area like a university, school and college campus or any huge industry.

The manual audit method requires following information:

1. Survey done by the concerned department about the energy consumption.
2. Material balance data (recycled and raw materials, final and intermediate products) Materials like dump waste products and the recycled products that can be used in Industries etc.

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3. Process flow and material flow diagrams
4. Generation and distribution of site services (e.g. compressed air, steam).
5. Energy supply sources (e.g. electricity generation from the grid or self-generation)
6. Usage of cogeneration systems and fuel substitution and process modifications (combined heat and power generation).
7. Once the manual process is completed results are conclusions are discussed.

B. *Automated Method*

In this research work, an automated energy audit system is proposed, and a hardware device is designed that can automatically perform the energy audit. This device can be connected to the main supply to analyze/monitor the power consumed by each particular electrical appliance and to show their behavior on the monitor screen in the form of graphical representation. This graphical monitoring shows us live load variation in form of readings and graph. These variations are also stored in the database from where a report can be generated at the end of the month. The proposed system can also segregate the load. Block diagram of the proposed modern energy audit system is shown in Figure 1.

The proposed system is tested in the main campus of "University of Central Punjab, Lahore, Pakistan". This university has two sources of power supply, one is from the national electric supply company that is WAPDA in Pakistan and the second source is Generator.

With the increasing prices of fuel, it's very difficult to run the heavy load on generators, because the generated unit is very costly. A generator usually produces three units by consuming one-liter fuel. It means that the generated power's unit cost is 30 Rupees/Unit. This cost per unit is two times the unit cost of the national electric supply company.
So, the proposed device controls the load automatically when the main power supply is not available, and the load is on the generators supply.

Following priorities are defined in the proposed device:

TABLE 1 PRIORITY LIST OF DIFFERENT LOADS

Priority Number 1	Computer and projector
Priority Number 2	Lights
Priority Number 3	Fan
Priority Number 4	Air Conditioner

This table elaborates the priority list explaining which load will remain active even if the main supply is off. If the load increases from 10A, the air conditioners will be off followed by fans and light respectively. But computer and projectors will always remain ON even on generator source. This segregation and prioritization of load adds innovation to the proposed system. When the load is on to the main supply, then the whole load would be in running condition. If the load is on generator, then it will not be allowed to drive load more than 10A.

III. SURVEY WORK AND ANALYSIS

First of all, the required data is collected manually, and a database of the collected data is created that can be analyzed on the software. Following are the steps of the survey work

- Visual inspection and data collection
- Observations of the general condition of the facility, equipment and quantification
- Identification /verification of energy consumption and other parameters by measurements
- Detailed calculations, analysis and assumptions
- Validation
- Potential energy saving opportunities
- Implementation

To collect this data, a team of three persons is formed. The team started survey from basements and then move up to fourth floor. In this survey, team noticed and calculated the whole load (Lighting Load, Fan Load, Air Conditioner Load, Computer Lab Load) of university.
Data of every floor of the university is collected and managed according to power consumption. The details of the collected data are as under:

A. *Survey of Basements:*

Basement No 01:

TABLE 2 POWER CONSUMPTION OF TUBES & ENERGY SAVERS OF BASEMENT 01

Tubes Power Consumption	12.3KW
Energy Savers Power Consumption	90W

Basement No: 02:

TABLE 3 POWER CONSUMPTION OF BASEMENT 02

Tubes Power Consumption	12.3KW
Energy Savers Power Consumption	90W
Fans Power Consumption	460W

B. *Ground Floor Survey:*

Survey Report:

Analysis:

TABLE 4 POWER CONSUMPTION ANALYSIS OF DIFFERENT APPLIANCES OF GROUND FLOOR

Appliances	1.5 TON AC	2 TON AC	Tube Panels	Energy savers	Fans
Numbers	9	50	303	372	138
consumption	25 KW	175 KW	29.3 KW	5.1 KW	20.7 KW

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Graphical Representation:

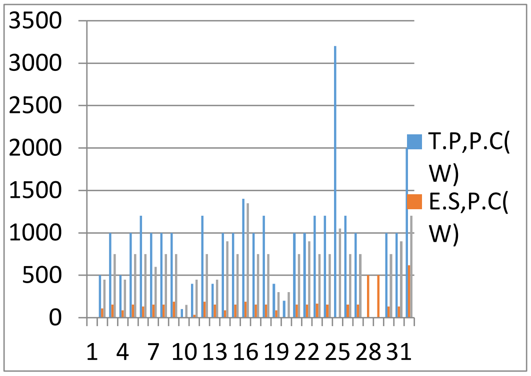

Fig. 2 Graphical Representation of Power Consumption of T.P, E.S and Fan

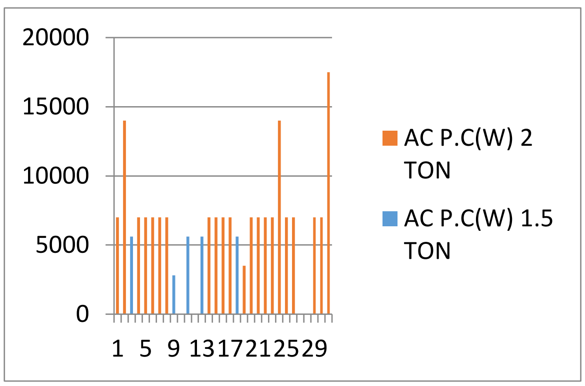

Fig. 3 Power Consumption of 2 Ton Ac and 1.5 Ton Ac

C. First Floor Survey
Survey Report:

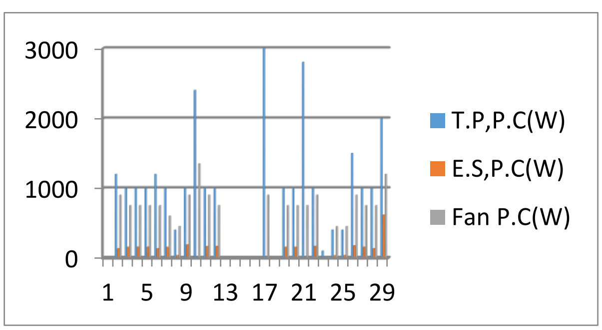

Fig. 4 Power Consumption of T.P, E.S and Fan of First Floor

D. Second Floor Survey:
Survey Report

Analysis:

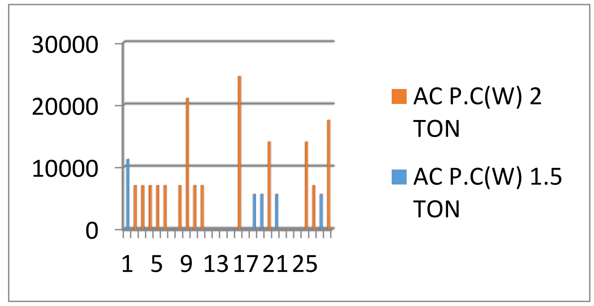

Fig. 5 Power Consumption of 2 Ton Ac and 1.5 Ton Ac of First Floor

TABLE 6 POWER CONSUMPTION ANALYSIS OF DIFFERENT APPLIANCES OF SECOND FLOOR

Appliances	1.5 TON AC	2 TON AC	Tube Panels	Energy savers	Fans
Numbers	14	44	274	487	116
consumption	33 KW	154 KW	27 KW	5 KW	17 KW

TABLE 7 POWER CONSUMPTION ANALYSIS OF DIFFERENT APPLIANCES OF THIRD FLOOR

Appliances	1.5 TON AC	2 TON AC	Tube Panels	Energy savers	Fans
Numbers	12	46	293	543	138
consumption	33.6 KW	161 KW	29.3 KW	5.9 KW	20 KW

NOTE:

AC 1.5 TON	2800	W
AC 2 TON	3500	W
T.PANEL	100	W
E.SAVER	11	W
FAN	150	W

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Graphical Representation:

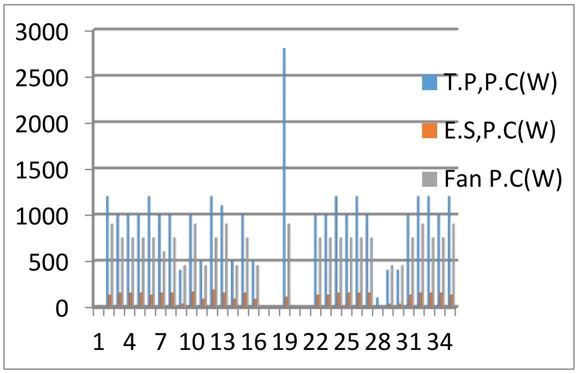

Fig. 6 Power Consumption of T.P, E.S and Fan of Second Floor

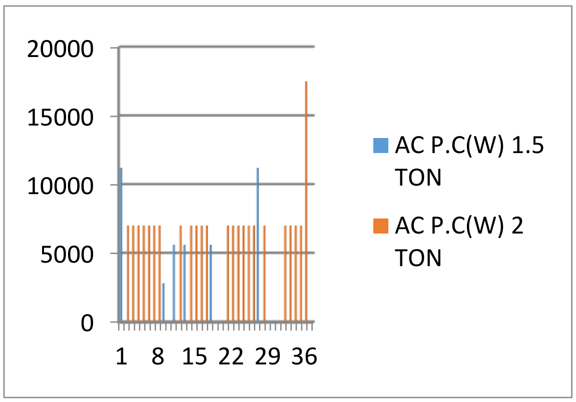

Fig. 7 Power Consumption of 2 Ton Ac and 1.5 Ton Ac of Second Floor

D. Third Floor Survey

Survey Report

Analysis:

NOTE:

AC 1.5 TON	2800 W
AC 2 TON	3500 W
T.PANEL	100 W
E.SAVER	11 W
FAN	150W

Graphical Representation:

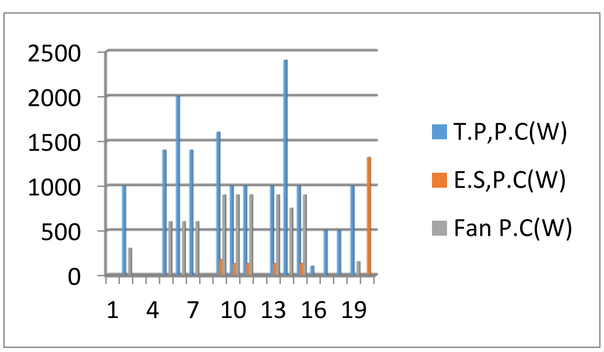

Fig. 8 Power Consumption Graph of T.P, E.S and Fan of Third Floor

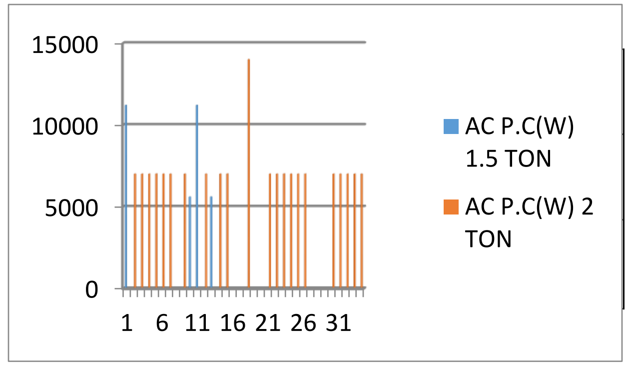

Fig. 9 Power Consumption of 2 Ton Ac and 1.5 Ton Ac of Third Floor

E. Fourth Floor Survey:

Survey Report:

Analysis:

NOTE:

AC 1.5 TON	2800 W
AC 2 TON	3500 W
T.PANEL	100 W
E.SAVER	11 W
FAN	150W

TABLE 8 POWER CONSUMPTION ANALYSIS OF DIFFERENT APPLIANCES OF FOURTH FLOOR

Appliances	1.5 TON AC	2 TON AC	Tube Panels	Energy savers	Fans
Numbers	4	22	159	184	51
consumption	11.2 KW	77 KW	15.9 KW	2 KW	7.5 KW

Graphical Representation:

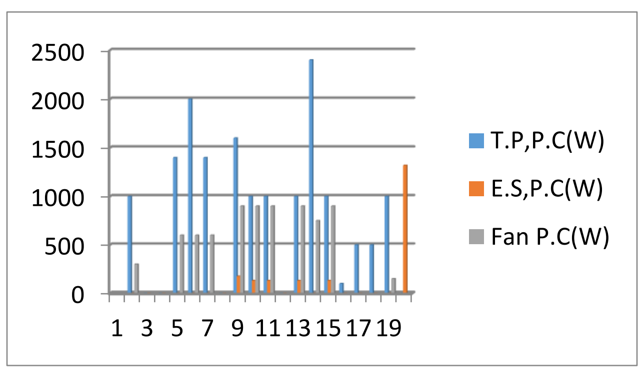

Fig. 10 Power Consumption Graph of T.P, E.S and Fan of Fourth Floor

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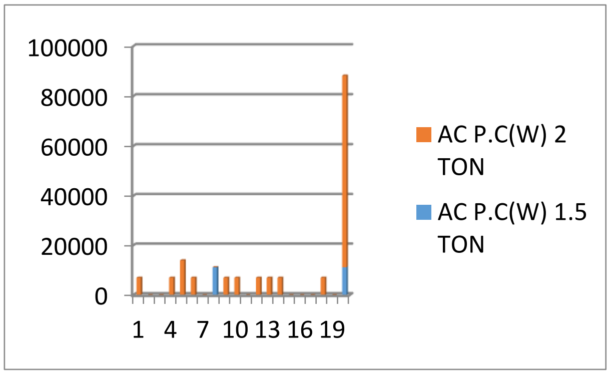

Fig. 11 Power Consumption Graph of 2 Ton Ac and 1.5 Ton Ac of Fourth Floor

F. *Survey of Auditorium:*

TABLE 9 POWER CONSUMPTION OF AUDITORIUM

Appliances	5 TON AC	Energy savers	Fans
Numbers	4	40	34
consumption	32 KW	0.44 KW	5.12 KW

G. *Survey of Cafeteria:*

TABLE 10 POWER CONSUMPTION OF CAFETERIA

Appliances	5 TON AC	Energy savers
Numbers	9	70
consumption	45 KW	0.78 w

H. *Survey of University Substation*

Generator:

TABLE 11 UNIVERSITY GENERATOR SPECIFICATIONS

635 KVA	2
500 KVA	1
V OUT	400V
SPEED	1500rpm
EXCITOR	24v
TEMP	110C
P.F	0.8

Transformer:

TABLE 12 UNIVERSITY TRANSFORMER SPECIFICATIONS

1250 KVA	V1 PRIM	V2 SEC	CONNECTIONS
2	11 KV	400 V	STAR

It is clear from survey, analysis and graphical representation that the total load of university is 1.7 MW. The load of second floor is greater as compared to the other floors. The reason is that second floor has three distribution boxes. Lighting and Fan Distribution Box, Air Conditioner Distribution Box and Computer Lab Distribution Box. Ground, First, Third and Fourth has only two distribution boxes of Lighting and Fan Distribution Box and Air Conditioner Distribution Box.

IV. FLOW OF PROPOSED SYSTEM

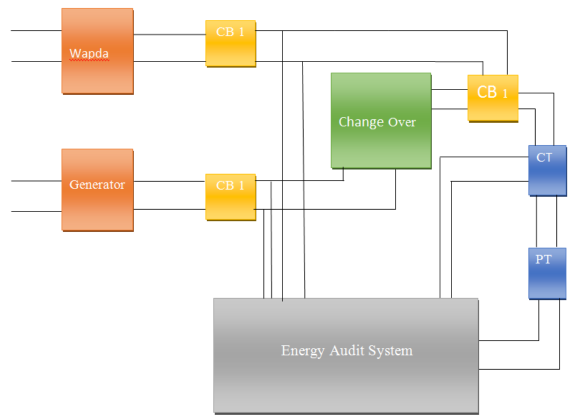

Fig. 12 Proposed System for Energy Management System

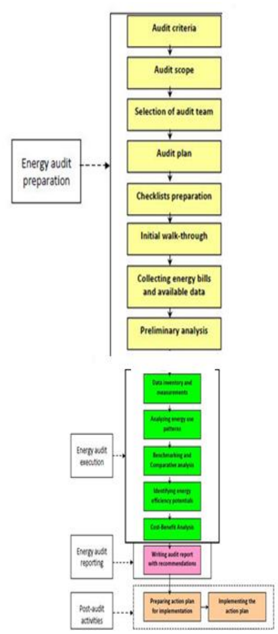

Fig. 13 Process Flow Diagram

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Figure 12 shows the schematic and hardware blocks of the proposed system. The Circuit is supplied with two types of supplies one is the main power supply and other is the generator. There are total six relays connected to the input side and four to the load side. Current and potential transformers are connected to CT and PT that gives an output of 5v which is fed to the controller as shown in Figure 12. In the proposed automated system, the PIC microcontroller **16f877** is used to monitor the parameters and segregate the load. The proposed system is designed to switch ON all the relays when the supply is from the main power station that means that the entire load will be ON. If the supply is a generator source, the proposed system will perform the function of segregation of load. It will prioritize the load, in case if load exceeds 10Aas shown in Table 1. The proposed automated system is designed in such ways that if load increases 10A, relay 1 will be tripped off simultaneously. Then it will check the load again and if found it again more than 10A, R2 and R3 will be tripped off respectively. Only the critical load R4 will always remain ON in every condition. The variation that occurs in the load throughout that time period will be continuously displayed on to the monitor screen connected with the circuit. Figure 14 shows the flow diagram of the energy audit system through which the energy audit is taken out.

IV. RESULTS AND CALCULATIONS

This section presents the results obtained by proposed automated system for energy audit. Table 13 lists the results of current transformer. It's cleared from the results that 2.64A current is at 1.68V volts.so, for 1V the current is 1.57A. By this ratio, it can be set that for 5V voltage, the value of current would be 7.85A.

TABLE 13 CURRENT TRANSFORMER RESULTS

WATTAGE	CURRENT	VOLTAGE
100	0.41	0.16
200	0.87	0.46
300	1.30	0.77
400	1.75	1.07
500	2.19	1.37
600	2.64	1.68

Table 14 presents the reading of current transformer for 10A where the wire is rape three times. When a wire is raped three turns then the voltage enhances at the stage 400W. So, 1.3V can be achieved at 600W when 2.7A current is flowing. So, the ratio is set for 1V, at this ratio the current is 1.97A and for 5V it reaches up to 9.8A.

TABLE 14 CURRENT TRANSFORMER RESULTS

WATTAGE	CURRENT	VOLTAGE
100	0.87	0.45
200	1.23	0.8
300	1.7	0.97
400	1.9	1.08
500	2.4	1.24
600	2.7	1.37

Table 15 lists the reading of potential transformer. A simple potential transformer circuit is used to realized proposed system. The 220V AC voltages are applied to a step-down transformer and 8.5V AC output is achieved. These 5V are then rectified and dropped up to the 5V. Then the capacitor is used to stable output. This output also be kept stable for 250V by varying the 10k variable resistor.

TABLE 15 POTENTIAL TRANSFORMER RESULTS

INPUT	OUTPUT	RECTIFIED	VARIABLE	DIVIDER
250V	9.5V	6.8V	4.7k	5V
240V	9V	6.5V	4.3K	4.7V
220V	8.5V	6.1V	4K	4V
180V	5.4V	5.4V	3.7K	3.7V
150V	4.8V	4.8V	3.5K	3.5V
125V	3.9V	3.9V	3K	3V
100V	3.4V	3.4V	2.5K	2.5V
75V	3.5V	2.3V	2.3K	2V
50V	2.4V	1V	2.15K	1.5V

The results presented in Table 16 are measured when the load is on the generator supply. Results show that as load increases from 10A, relays start to trip and maintain critical load. This critical load is less than 10A.

TABLE 16 ENERGY AUDIT SYSTEM RESULTS

VOLTAGE	**CURRENT**	**WATTAGE**	**TRIP STATUS**
230	0.43	100	NO
235	0.85	200	NO
235	1.27	300	NO
240	1.66	400	NO
245	2.0	500	NO
230	2.6	600	NO
230	3.0	700	NO
220	4.5	1000	NO
220	5.45	1200	NO
223	6.8	1500	NO
220	7.7	1700	NO

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205	8.5	1750	NO
202	8.7	1775	NO
200	9	1800	NO
205	8.9	1825	NO
202	9.1	1850	NO
205	9.2	1900	NO
190	10.2	1950	YES
180	11.11	2000	YES

The proposed system has several benefits as well as applications. These applications are on the industrial or domestic level.

- Basically, proposed hardware can perform load management through which 20 to 30% electricity can be saved by managing the load in safe side especially when the load is on the generator.
- It also provides protection of the generator as well as the substation.
- Economically, this hardware design can reduce the expenditure of fuel, because fuel is major expense in generator supply.
- A monthly or weekly energy audit report can be generated.
- This report will be able to show the load variation or segregation on computer and store in the database**.**

V. CONCLUSION

It is very serious issue in the university that when there is no class or meeting held in the rooms, even then some load of the room is in running condition. Sometimes the person is not available to switch off the load. Due to this the load is ON unnecessary. This situation is also a cause of the electricity waste. To overcome this problem, an automatic energy audit device is proposed solution that is based on electrical circuits. These circuits cover the load management of a single room as well as the multiple rooms. The proposed system manages the load according to the nature of available power source and reduces the fuel consumption of an alternative source “Generator” significantly.

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