

Online Energy Audit and Renewable Energy Management System

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Abstract- Energy conserved is energy generated. Energy plays a pivotal role in our life. The requisite for energy is soaring. The intensifying demand can be met either by furthering the energy generation or by conserving the usage of energy. Generation of energy is an expensive affair; hence it is very important to conserve energy. Electrical energy audit is the process of examining the patterns in consumption of electricity to discover opportunities to conserve energy. Energy audit is a labor-intensive task; therefore, automation is necessary. The Online Energy Audit and Renewable Energy Management System (OEAREMS) aims at introducing automation in the process of energy audit and implementation of distributed generation of energy. OEAREMS helps in establishing a better understanding of electrical energy usage tendencies and also create awareness about conservation of electrical energy.

Keywords- Energy Audit, Renewable Energy Management, Energy Conservation.

I. INTRODUCTION

According to the latest statistics India faces a base load energy deficit of 2.1% and peaking shortage of 2.6% respectively for 2015–16 fiscal year. This imbalance between the demand and supply ratio is challenging. This motivated us to conserve the usage of electrical energy and add to the electricity generation by installing distributed generation systems. Electrical energy audit as mentioned before is a cumbersome process.

Following steps are involved in a manual, generic electrical energy audit ^[1]:

- Collect the load details for electrical equipment with high electricity consumption.
- Calculate the usage load after designing the single line diagram by feeding the values in ETAP ^[A].
- Plot real time load curve by using the energy meter and measuring KwHR ^[B] for 20 days.
- Calculate the connected load with respect to single line diagram.
- Plot a graph between years and tariff.
- Identify and calculate the unnecessary usage and power wastage in the layout with graph.
- Draw the power utilization chart with respect to the layout.
- Calculate the daily utilization of power of all the equipment and convert them to a pie chart.
- Collect data of all the major equipment and find out the performance.
- Interaction about the energy usage with the concerned party along with suitable survey.
- Identify energy conservations opportunity, if any.
- Provide a report on suitable recommendation for existing appliances and suggestions for implementation of energy conservative measures.
- Plot Cost Benefit Analysis with Breakeven Chart
- Check the earth resistance and report on the status of earthing in that concern.
- Provide Awareness on Electrical Safety.
- Submission of Suitable Energy Audit Report with Breakeven Analysis and taking the benefits of renewable energy and simulating it in the ETAP software and provide the best recommendation to reduce electrical consumption by renewable sources.

Clearly the process of electrical energy audit is an exacting one. Hence introduction of automation could help in reducing a lot of man hours. An online system ensures the product reaches the maximum number of potential users. It also eliminates the cryptic jargons mentioned above and enables a layman to conduct an electrical energy audit and obtain the appropriate recommendations to conserve electrical energy.

The first step towards conserving electricity is conducting an electrical energy consumption survey. This helps us in understanding of the patterns in the usage of electrical energy. The second step in this process is conducting electrical energy audit. Here the user will feed the system with data relevant to their electrical usage such as: total energy consumption in watts, age of equipment and the time of usage per day etc. The third step here would be analyses of data. OEAREMS, once furnished with the required data will analyze it and generate information that will aid the recommendation system to chalk out the appropriate recommendations. The final step here will be providing the users with suitable recommendations.

A. Literary Investigation

Energy audit can be described as inspection, survey and analysis of energy flow for energy conservation in a building, process or a system to reduce the amount of energy input into the system without negatively affecting the output. In commercial and industrial real estate, an energy audit is the first step in identifying opportunities to reduce energy expense and carbon footprint^[2].

Energy audits initially became popular in response to the energy crisis of 1970 and later years. Interest in energy audits has recently increased as a result of growing understanding of human impact upon global warming and climate change. Energy audits are also popular due to financial incentives for homeowners.

Audits could further be classified as follows

1) *Home energy audit* - A home energy audit is a service where the energy efficiency of a house is evaluated by a person using professional equipment (such as blower doors and infrared cameras), with the aim to suggest the best ways to improve energy efficiency in heating, cooling and lighting the house. A home energy audit is often used to identify cost

effective ways to improve the comfort and efficiency of buildings. Recently, the improvement of computer & smartphone technology has enabled homeowners to perform relatively sophisticated energy audits of their own homes. This technique has been identified as a method to accelerate energy efficiency improvements.^[2]

2) *Industrial energy audits* - Increasingly in the last several decades, industrial energy audits have become widespread. The demand to lower increasingly expensive energy costs and move towards a sustainable future have made energy audits greatly important. Their importance is magnified since energy spending is a major expense to industrial companies (energy spending accounts for ~ 10% of the average manufacturer's expenses). This growing trend should only continue as energy costs continue to rise. While the overall concept is similar to a home or residential energy audit, industrial energy audits require a different skillset.^[2]

Energy audit is an evolving domain. There are few systems existing in this field and fewer systems with automation. A majority of these tasks are done manually. These procedures are incommensurate which drastically reduces the effectiveness of the process. Existing systems are either ineffective in analyzing the data efficiently or incompatible with the framework of the consumer. Thus a majority of people are deprived from obtaining the benefits from this system. Some existing energy audit system charge on monetary basis for their services. These are some of the setbacks with the existing systems.

Let us have a look at some of the recent developments in this domain. Some of the existing software of energy audit are EnergyGauge USA, National Energy Audit Tool (NEAT), Energy Performance Score (EPS), BEopt™ (Building Energy Optimization). These tools are extremely sophisticated. Most of them are incompatible with the framework of an Indian household.

A research^[3] suggests the presence of information gap between the auditors and the house owners. Not enough homeowners know about or understand audits, and the follow-through on recommendations after completion of audit is imperfect. This motivated us to create an awareness about energy audit and implementation of distributed generation and recommendations to conserve energy.

Another research [4] suggests methodologies to conserve energy in industrial plants by reducing the electrical energy consumed by lighting appliances.

One of the study [5] concludes with an audit of lighting equipment, motors and harmonic analysis, but fails to address concerns like cooling system, heavy machineries and other energy consuming factors. There are various techniques listed out by multiple research publications [6] to conserve electricity in a home as well as an industrial environment. But these techniques miss out on encompassing other household or industrial electrical appliances where there is a possible leakage of electrical energy. This encouraged us to design a comprehensive system encompassing various factors that might play a pivotal role in electricity consumption.

Further investigation elucidates that factors like accuracy of existing tools, their marketplace and their corresponding attributes such as climate etc., ease of usage and other similar aspects play an essential role in performing an efficient energy audit. OEAREMS is designed keeping in mind all the above listed issues. We have tried to address all the possible constraints in energy auditing procedure and have devised an all-inclusive system in OEAREMS.

II. PROPOSED SYSTEM

The proposed system will include an online survey. This survey contains a set of generic questions that the users are required to answer. This survey helps us analyze the electrical usage tendencies of the user of this system. It also furnishes us with the details regarding the patterns in usage of electricity and electrical appliances. This information could help us create a better understanding of energy usage trends.

The energy audit application will take an array of information such as total rating (electricity consumption in watts), age of equipment, time of usage and BEE [c] star rating concerning various electrical appliances that are present in a household. The application will calculate the amount of electricity consumed and the cost incurred by each and every electrical appliance. This information will act as an input to the recommendation system.

The recommendation system will provide the user with generic as well as specific recommendations. These recommendations may or may not involve investments. These recommendations are generated by taking into consideration the plethora information that

is acquired from the user specific audit as well as the generic survey. Our application allows the user to perform more than one audit. Users will also be able to access the details from previously performed audit(s) thus enabling them to compare the results from more than one audit. The further section will discuss in detail about the procedures involved in development and implementation of this system.

A. METHODOLOGY

Energy Audit involves the following procedures

1) *Statistical Data Collection*

Currently the collection of data for the system is done by a team of students who inspect the usage of electricity in a house manually. Collection of data involves the following steps.

- a) *Preparation of Power Distribution Single Line Diagram* - Collect all the load details for electrical equipment with high electricity consumption and calculate the usage load after single line diagram has been fed with load values.
- b) *Real time lode curve* - Plot real time load curve by taking the energy meter KWHR, for 20 days.
- c) *Real time power loss* - Identify and calculate the unnecessary usage and power wastage in the layout with graph.
- d) *Equipment Life Cycle Analysis* - Data collection of all the major equipment and find out their respective performance.

2) *Electrical Usage Investigation*

A survey will be conducted for obtaining the data to mine specific patterns in the electrical usage.

- a) *Interview with faculty members* - Interview with faculty members to understand the trends in electrical usage.
- b) *Study the Status of Earthing* - Check the earth resistance and report on the status of earthing in that concern.

3) *Statistical Data Calculation*

Calculation of these data is a difficult task. We aim to bring in automation in the process of calculation.

- a) *Load calculation of single line diagram* - Calculate the connected load with respect to single line diagram.
 - b) *Energy Meter Tariff Graph* - Plot a graph between years and tariff.
 - c) *Power utilization chart* - Draw the power utilization chart with respect to the layout.
- 4) *Statistical Data Analysis*
 Analysis involves analyzing the data for specific usage patterns. The following step is involved in the statistical data analysis.
- a) *Energy conservation opportunity* - Identify the energy conservation opportunities.

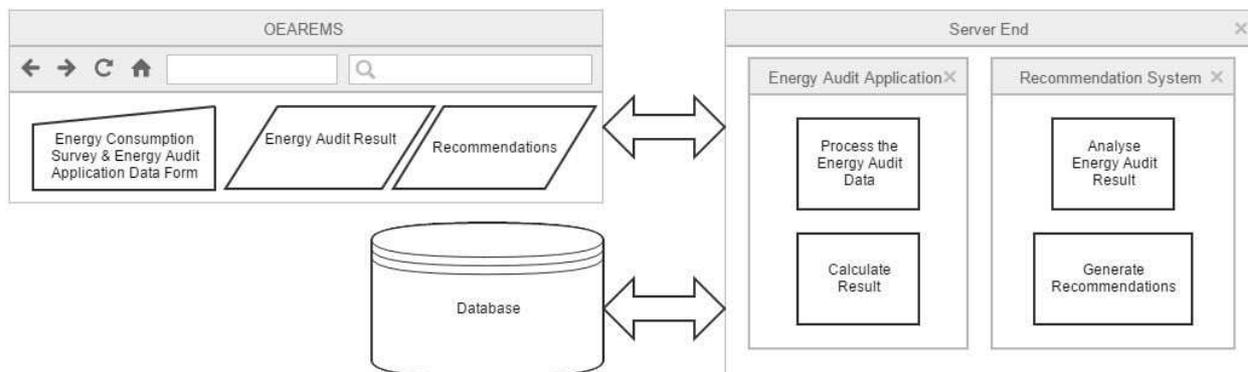


Fig 1. Architecture of Online Energy Audit and Renewable Energy Management System

5) Recommendation

Once the data is analyzed suitable recommendations are provided to the users. Following steps are involved in the process of recommendation.

- a) *Recommendation* – Provide a report on suitable recommendation for existing appliances and suggestions for implementation of energy conservative measures.
- b) *Cost benefits* - Plot cost benefit analysis with breakeven chart.
- c) *Awareness on Electrical Safety* - Provide awareness on electrical safety to the concerned users.

B. IMPLEMENTATION

OEAREMS aids most of the above mentioned process by introducing automation. OEAREMS can be divided into various submodules as listed below.

1) Online Survey

Online survey is a part of energy audit. Every time a user takes an audit, he is required to go through the survey. The survey consists of generic questions related to consumption of electricity and usage patterns of electronic appliances. These questions were designed by our peers in the department of electrical and electronic engineering. This survey makes us aware of the developments in usage of electrical energy and electronic appliances. Once a question is answered, the survey application instantaneously displays the results of the survey in graphical format.

2) Online Energy Audit Application

Online Energy Audit Application is a sophisticated, yet a user-friendly application. This application consists of a dynamic data collection sheet, where the user is required to feed data associated to electrical equipment. This data might be number of equipment, total rating (electricity consumption in watts), age of equipment, time of usage and BEE star rating, depending upon the attributes of the equipment. Once the data is fed into the system, the energy audit application calculates the amount of energy consumed by each equipment and the cost incurred by them. The formulae used in calculation of energy consumed and cost incurred are listed ahead.

$$(W)^T = (R)^T \times (T)^T$$

(W)^T = Total Number of Watts Consumed Per Day.
(R)^T = Total Rating.
(T)^T = Time of Usage.

(1)

$$(W)^{TY} = (W)^T \times 365$$

(W)^{TY} = Total Number of Watts Consumed Per Year
(W)^T = Total Number of Watts Consumed Per Day.

(2)

$$(U)^{TY} = \frac{(W)^{TY}}{1000}$$

(U)^{TY} = Total Number of Units Consumed Per Year
(W)^{TY} = Total Number of Watts Consumed Per Year

(3)

$$(C)^{TY} = (U)^{TY} \times (U)^C$$

(C)^{TY} = Total Cost Incurred Per Year
(U)^C = Cost Per Unit
(U)^{TY} = Total Number of Units Consumed Per Year

(4)

Equation (1) is used to calculate the total number of Watts consumed per day, Equation (2) involves calculation of total Watts consumed per year, while Equation (3) determines the units of electricity consumed per year the Equation (4) is used to estimate the cost incurred by the user over a period of one year.

3) Recommendation System

Recommendation system does out recommendation to conserve electrical energy. These recommendations would be generic as well as user specific. Recommendation system utilizes the data obtained from the energy audit application to chalk out the user specific recommendation.

Under following circumstances, the recommendation system will suggest replacement.

Compact Fluorescent Lamp = Time of Usage > 7 hours & Total Rating > 18W

Recommendation- Replacement of CFL with energy efficient LED lamp.

Equipment	Total Rating	Hours per day	Watts consumed Annually	Units consumed Annually	Cost Annually	Units Saved Annually	Money Saved Annually
Florescent Tube Light	55	5	100375	100.375	301.125	73	219
LED	15	5	27375	27.375	82.125		
Payback Period							
(Investment cost (Cost of LED) / Annual saving) * 12 months = (700/219) *12 = 38.3 Months							

Table 1. Result of Implementation of Recommendations.

Tube Light = Time of Usage > 2 hours & Total Rating > 40W

Recommendation- Replacement of Tube Light with energy efficient LED lamp.

Air Conditioner = Time of Usage > 5 hours & Bee Star Rating < 3 star & Age of Equipment > 3 years

Recommendation- Replacement of AC with energy efficient BEE Star Rated AC.

Fan = Time of Usage > 5 hours & Total Rating > 60W

Recommendation- Replacement of fan with energy efficient BEE Star Rated fan.

Refrigerator = Bee Star Rating < 3 stars & Age of Equipment > 3 years

Recommendation- Replacement of refrigerator with energy efficient BEE Star Rated refrigerator.

Equipments	No	Recommendation	Before Replace	After Replace	Watt's Saved	Money's Saved
Ceiling Fan	2	Replace the fan with star rated fan	219	91.25	127.75	383.25
TubeLight	1	Replace the Light With LED Light	109.5	43.8	65.7	197.1

Fig 2. A Sample Recommendation Generated for a Dining Hall

Implementation of these recommendations could lead to energy conservation. The recommendation system also provides you with the energy consumption details and monitory savings detail, before and after replacement.

III. RESULTS

The table below illustrates the cost benefit incurred from replacing a 55W Florescent Tube light with 15W LED. LEDs have a general life expectancy

of 50 000 hrs. If you use your lights for 10 hours a day, this should be 13.7 years, taking this into account every time you use a LED light after its payback period it adds up as profit earned. Implementation of Energy audit not only helps in conservation of energy but also has economic benefits attached to it.

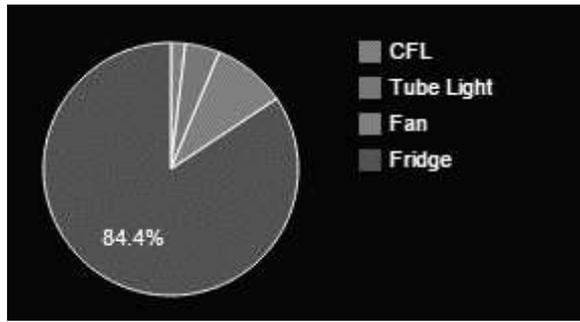


Fig 3. A Sample Survey Result Depicting the Energy consumption in a kitchen

The result above illustrates that changing a Florescent Tube Light with LED could help you save around 73 units annually, roughly translating it into a saving of ₹219 considering a unit of electricity costs ₹3. This implies that within a period of 3 years we would get our investment back. Any amount saved after that period could be considered as profit. All this just by replacing one Florescent Tube Light. Replacing multiple electrical appliances could further aid the energy conservation process and result in environmental as well as financial benefits over a period of time.

IV. CONCLUSION

Online energy audit and renewable energy management system provides the public with a platform to conduct electrical energy audit and obtain measures to conserve energy with minimal effort. This system provides abstraction to the user from internal complexities of energy audit process thus making it more accessible to the wider sections of our society. As it was said, 'prevention is better than cure', the same way 'conservation is better than generation'. With the staggering increase in the demand for electrical energy OEAREMS provides a pathway to conserve electricity and aid the implementation process for distributed generation.

Monitory benefits itself can act as a great motivator in encouraging people to adopt energy conservative methods. Apart from that energy conservation also eases the disparity prevalent in the availability of electrical energy. It also lessens the toll

it takes on our nature and natural resources to generate electricity, hence helping our environment. Hence it is vital that we conserve energy and act as a responsible predecessor for our future generations.

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GLOSSARY

- [A] ETAP - ETAP electrical engineering software is a power systems analysis solution that includes analytical software modules for load flow, arc flash, load flow, short circuit, transient stability, relay coordination, cable ampacity, optimal power flow etc.
- [B] KwHR - The kilowatt hour is a derived unit of energy equal to 3.6 mega joules. If the energy is being transmitted or used at a constant rate (power) over a period of time, the total energy in kilowatt-hours is the product of the power in kilowatts and the time in hours.
- [C] BEE - Bureau of Energy Efficiency.