ARUNAI PUBLICATIONS

Asian Journal of Applied Research

DOI: http://dx.doi.org/10.20468/ajar.2018.10.07

Research Article

Industrial Energy Audit and Improve Power Quality in Solar Energy System

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ABSTRACT

An energy audit, or review, is an investigation of all facets of an organization's historical and current energy use with the objective of identifying and quantifying areas of energy wastage within the organization's activities. It is best carried out by an Accredited Energy Masters Auditor. An energy audit establishes the baseline for any improvements in an organization's energy use. It provides a comprehensive and systematic method for targeting cost-effective efficiency gains. There are many examples where clients have been able to make savings without requiring any significant capital investment. An auditor should work with their clients to ensure those savings are achieved and sustained in the long term. The objective is to have all identified improvement projects "payout" within 2–4 years, equivalent to a return on investment of between 25% and 50%. Anybody receiving an accredited energy audit should expect to receive recommendations for savings between 5% and 15% as a typical starting point. Due to the energy policies and the consequent transition to renewable energy sources, the amount of photovoltaic (PV) installations is continuously increasing in many countries. As PV inverters utilize power electronics, its impact on power quality is an important concern for manufacturers, planners, solar power operators, and utilities/network operators. The International Council on Large Electric Systems working group C4/C6.29 has studied many aspects related to PV installations and its impact on power quality. To incorporate the existing experiences with power quality issues related to solar power, an international survey has been conducted by the working group. The survey has found that there is a significant lack of information among utilities/network operators with respect to the possible impact of PV installations on power quality. It is recommended to intensify the monitoring of PV installations to obtain sufficient information for a reliable assessment of its impact on power quality.

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Keywords: Energy sources, Energy wastage, Planners, Renewable energy, Solar power operators, Utilities/network operators

Received: 05th February 2018
Accepted: 20th September 2018
Published: 13th October 2018

INTRODUCTION

An energy audit is an inspection survey an analysis of energy flows, for energy conservation in a building, process, or system to reduce the amount of energy input into the system without negatively affecting the output(s). In commercial and industrial real estate, an energy audit is the first step in identifying opportunities to reduce energy expense and carbon footprints.

Principle

When the object of study is an occupied building then reducing energy consumption while maintaining or improving human comfort, health and safety are of primary concern. Beyond simply identifying the sources of energy use, an energy audit seeks to prioritize the energy uses according to the greatest to least cost-effective opportunities for energy savings.

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 and cooling the house.

An energy audit of a home may involve recording various characteristics of the building envelope including the walls, ceilings, floors, doors, windows, and skylights. For each of these components, the area and resistance to heat flow (*R*-value) are measured or estimated. The leakage rate or infiltration of air through the building envelope is of concern, both of which are strongly affected by window construction and quality of door seals such as weather stripping. The goal of this exercise is to quantify the building's overall thermal performance. The audit may also assess the efficiency, physical condition, and programming of mechanical systems such as the heating, ventilation, air conditioning equipment, and thermostat.

A home energy audit may include a written report estimating energy use given local climate criteria, thermostat settings, roof overhang, and solar orientation. This could show energy use for a given time period, say a year, and the impact of any suggested improvements per year. The accuracy of

energy estimates is greatly improved when the homeowner's billing history is available showing the quantities of electricity, natural gas, fuel oil, or other energy sources consumed over a 1- or 2-year period.

Some of the greatest effects on energy use are user behavior, climate, and age of the home. An energy audit may, therefore, include an interview of the homeowners to understand their patterns of use over time. The energy billing history from the local utility company can be calibrated using heating degree day and cooling degree day data obtained from recent, local weather data in combination with the thermal energy model of the building. Advances in computer-based thermal modeling can take into account many variables affecting energy use.

A home energy audit is often used to identify cost-effective ways to improve the comfort and efficiency of buildings. In addition, homes may qualify for energy efficiency grants from central government. Recently, the improvement of 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.[1] In the United States, this kind of service can often be facilitated by public utility companies or their energy conservation department.

Independent, private sector companies such as energy services company, insulation contractor, or air sealing specialist in (US) State energy office. Utility companies may provide this service, as well as loans and other incentives to insulate. They also often provide incentives to switch, for example, if you are an oil customer considering switching to natural gas. Where to look for insulation recommendations: Local building inspector's office.

Local or state building codes. US Department of Energy. Your local Builders Association.

Residential energy auditors are accredited by the Building Performance Institute[2] or the Residential Energy Services Network.[3,4]

There are also some simplified tools available, with which a homeowner can quickly assess energy improvement potential. Often, these are supplied for free by state agencies or local utilities, who produce a report with estimates of usage by device/area (since they have usage information already). Examples include the Energy Trust of Oregon Program[5] and the Seattle home resource profile.[6] Such programs may also include free compact fluorescent lights.

A simple do-it-yourself home energy audit can be performed without using any specialized tools. With an attentive and planned assessment, a homeowner can spot many problems that cause energy losses and make decisions about possible energy efficiency upgrades. During a home energy audit, it is important to have a checklist[7] of areas that were inspected as well as problems identified. Once the audit is completed, a plan for suggested actions needs to be developed. In New York City, local laws such as Local Law 87 require buildings >50,000 square feet (4600 m^2) to have an energy audit once every 10 years, as assigned by its parcel number.[8] Energy auditors must be certified to perform this work, although there is no oversight to enforce the rule. Because Local Law 87 requires a licensed Professional Engineer to oversee the work, choosing a well-established engineering firm is the safest route.

These laws are the results of New York City's PlaNYC to reduce energy used by buildings, which is the greatest source of pollution in New York City.[9] Some engineering firms provide free energy audits for facilities committed to implementing the energy saving measures found.[10] In Lebanon, since 2002, The Lebanese Center for Energy Conservation (LCEC) initiated a nationwide program on energy audits for medium and large consuming facilities. By the end of 2008, LCEC has financed and supervised >100 audits.

LCEC launched an energy audit program to assist Lebanese energy consuming tertiary and public buildings and industrial plants in the management of their energy through this program.

The long-term objective of LCEC is to create a market for ESCOs, whereby any beneficiary can contact directly a specialized ESCO to conduct an energy audit, implement energy conservation measures (ECMs), and monitor energy saving program according to a standardized energy performance contract. At present, LCEC is helping in the funding of the energy audit study and thus is linking both the beneficiary and the energy audit firm. LCEC also targets the creation of a special fund used for the implementation of the ECMs resulting from the study. LCEC sets a minimum standard for the ESCOs qualifications in Lebanon and published a list of qualified ESCOs[11] on its website.

Industrial energy audits increasingly in the last several decades, industrial energy audits have exploded as the demand to lower increasingly expensive energy costs and move toward 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. Weatherproofing and insulating a house are the main focus of residential energy audits. For industrial applications, it is the HVAC, lighting, and production equipment that use the most energy and, hence, is the primary focus of energy audits.

TYPES OF ENERGY AUDIT

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through of a facility to identify major problem areas to a comprehensive analysis of the implications of alternative energy efficiency measures sufficient to satisfy the financial criteria of sophisticated investors. Numerous audit procedures have been developed for non-residential (tertiary) buildings (ASHRAE; IEA-EBC Annex 11; Krarti, 2000). Audit is required to identify the most efficient and cost-effective energy conservation opportunities (ECOs) or ECMs. ECOs (or ECMs) can consist in more efficient use or of partial or global replacement of the existing installation.

When looking to the existing audit methodologies developed in IEA EBC Annex 11, by ASHRAE and by Krarti (2000), it appears that the main issues of an audit process are as follows:

The analysis of building and utility data including study of the installed equipment and analysis of energy bills; the survey of the real operating conditions; the understanding of the building behavior and of the interactions with weather, occupancy, and operating schedules.

The selection and the evaluation of ECMs; the estimation of energy saving potential; and the identification of customer concerns and needs. Common types/levels of energy audits are distinguished below, although the actual tasks performed and level of effort may vary with the consultant providing services under these broad headings. The only way to ensure that a proposed audit will meet your specific needs is to spell out those requirements in a detailed scope of work. Taking the time to prepare a formal solicitation will also assure the building owner of receiving competitive and comparable proposals. In general, four levels of analysis can be outlined (ASHRAE): Level 0 - Benchmarking: This first analysis consists in a preliminary whole building energy use analysis based on the analysis of the historic utility use and costs and the comparison of the performances of the buildings to those of similar buildings. This benchmarking of the studied installation allows determining if further analysis is required.

Level I

Walk-through audit

Preliminary analysis made to assess building energy efficiency to identify not only simple and low-cost improvements but also a list of ECMs (ECMs or ECOs) to orient the future detailed audit. This inspection is based on visual verifications, study of installed equipment, and operating data and detailed analysis of recorded energy consumption collected during the benchmarking phase.

Level II

Detailed/general energy audit

Based on the results of the preaudit, this type of energy audit consists in energy use survey to provide a comprehensive analysis of the studied installation, a more detailed analysis of the facility, a breakdown of the energy use, and a first quantitative evaluation of the ECOs/ECMs selected to correct the defects or improve the existing installation. This level of analysis can involve advanced on-site measurements and sophisticated computer-based simulation tools to evaluate precisely the selected energy retrofits.

Level III

Investment-grade audit

Detailed analysis of capital-intensive modifications focuses on potential costly ECOs requiring rigorous engineering study.

Benchmarking the impossibility of describing all possible situations that might be encountered during an audit means that it is necessary to find a way of describing what constitutes good, average, and bad energy performance across a range of situations. The aim of benchmarking is to answer this question. Benchmarking mainly consists in comparing the measured consumption with reference consumption of other similar buildings or generated by simulation tools to identify excessive or unacceptable running costs. As mentioned before, benchmarking is also necessary to identify buildings presenting interesting energy saving potential. An important issue in benchmarking is the use of performance indexes to characterize the building.

These indexes can be comfort indexes, comparing the actual comfort conditions to the comfort requirements; energy indexes, consisting in energy demands divided by heated/conditioned area, allowing comparison with reference values of the indexes coming from regulation or similar buildings; energy demands, directly compared to "reference;" and energy demands generated by means of simulation tools.

Typically, benchmarks are established based on the energy outlets (loads) within the building and are then further parsed into "baseloads" and "weather sensitive loads." These are established through a simple regression analysis of energy consumption and demand (if metered) correlated to weather (temperature and degree - day) data during the period for which utility data are available. Aggregate baseloads will represent as the intercept of this regression and the slope will typically represent the combination of building envelope conduction and infiltration losses less losses or gains from the baseloads themselves. For example, while lighting is typically a baseload, the heat generated from that lighting must be subtracted from the weather-sensitive cooling load derived from the slope to gain an accurate picture of the true contribution of the building envelope on cooling energy use and demand. Walk-through (or) preliminary audit (alternatively called a simple audit, screening audit, or walk-through audit) is the simplest and quickest type of audit. It involves minimal interviews with site-operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.

Typically, only major problem areas will be covered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided. A list of ECMs (ECMs or ECOs) requiring further consideration is also provided. This level of detail, while not sufficient for reaching a final decision on implementing proposed measure, is adequate to prioritize energy efficiency projects and to determine the need for a more detailed audit.

GENERAL AUDIT

The general audit (alternatively called a miniaudit, site energy audit or detailed energy audit, or complete site energy audit) expands on the preliminary audit described above by collecting more detailed information about facility operation and by performing a more detailed evaluation of ECMs. Utility bills are collected for a 12–36-month period to allow the auditor to evaluate the facility's energy demand rate structures and energy usage profiles. If interval meter data are available, the detailed energy profiles that such data make possible will typically be analyzed for signs of energy waste. Additional metering of specific energy-consuming systems is often performed to supplement utility data. In-depth interviews with facility operating personnel are conducted to provide a better understanding of major energy consuming systems and

to gain insight into short- and long-term energy consumption patterns. This type of audit will be able to identify all ECMs appropriate for the facility, given its operating parameters. A detailed financial analysis is performed for each measure based on detailed implementation cost estimates, site-specific operating cost savings, and the customer's investment criteria. Sufficient detail is provided to justify project implementation. The evolution of cloud-based energy auditing software platforms is enabling the managers of commercial buildings to collaborate with general and specialty trades contractors in performing general and energy system-specific audits. The benefit of software-enabled collaboration is the ability to identify the full range of energy efficiency options that may be applicable to the specific building under study with "live time" cost and benefit estimates supplied by local contractors.

Investment-grade Audit

In most corporate settings, upgrades to a facility's energy infrastructure must compete for capital funding with non-energy-related investments. Both energy and non-energy investments are rated on a single set of financial criteria that generally stress the expected return on investment. The projected operating savings from the implementation of energy projects must be developed such that they provide a high level of confidence. In fact, investors often demand guaranteed savings. The investment-grade audit expands on the detailed audit described above and relies on a complete engineering study to detail technical and economical issues necessary to justify the investment related to the transformations.

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Cite this article: Sivakumar S, Venkatanarayanan S, Kannan S. Industrial Energy Audit and Improve Power Quality in Solar Energy System. Asian J Appl Res 2018;4(4):29-32.

Source of Support: Nil, **Conflict of Interest:** None declared.