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Design of an Alternative Energy Sources for A Four Bedroom Flat in Awka Anambra State Nigeria

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ABSTRACT

In this work, a comparative analysis of alternative energy sources has been carried out to ascertain their suitability in terms of availability, cost, advantages and disadvantages among other factors. The selected energy alternatives are solar and inverters. The case study-site was a four-bedroom flat in Awka, Anambra state Nigeria. Practical surveys and data collection were carried out for the selected site coupled with the energy auditing to obtain the total energy consumed. An energy sizing analysis helped in determining the energy specifications and installation-cost of the alternative energy sources in the surveyed site. The results obtained presented guiding principles among other solutions on how homes can be powered by applying the method of selective-loading to reduce energy cost.

Keywords: Alternative energy sources; cost-analysis; electricity; energy auditing, Nigeria

INTRODUCTION

Renewable energy simply refers to alternative source of energy that can be harnessed freely, which means you spend nothing or less to regenerate energy. The development of any society is anchored on the steady supply of power which is an elixir to manufacturing companies. It is therefore a matter of utmost importance to analyze other means of energy supplies in term of cost effectiveness, reliability, availability and environmental compatibility so as to alleviate the energy crisis prevalent in some developing countries. Alternative energy sources such as solar cells and battery-powered inverters as researched in this work have become increasingly popular subjects. Many of these results shows that global warming has rapidly increased from anthropogenic causes. Various energy resources are available in Nigeria. The hydro power resources which can be explored in Nigeria are over 11,000MW per annum (average capacity is more than 40,800GWh). The main sources of energy in Nigeria at present are mostly from Power Holding Company of Nigeria (PHCN). The installed capacity is 5296MW. However, about 99.5% of Nigeria power requirement come from the various power stations with 0.5% coming from other sources (Nwokoye, 2006). Thus, the 0.5% is purchased by private companies. Some of the problems faced by people in developing countries such as Nigeria which has been reported in this study and in earlier works (Akarakiri, 2002; Akin Iwayemi, 2008) include:

• Inadequate electricity supply to household, offices and industries: It is increasingly becoming difficult to get energy for domestic utilization. People now depend on generating set for their energy supply.

• Low industrial productivity: For many industries, technical changes are found to increase the shares relative to those from other inputs of production. Changes in electrical inputs contribute to notable alterations in output values. The unavailability of this crucial requirement of production has hampered production of goods and services.

• Pollution of the environment: Noise and air pollution caused by the use of generating sets as energy sources creates immeasurable level of health hazards to all forms of life in the environment.

• High cost of commodities: There is existing relationship between the price of commodities and energy. Energy is part of cost of production; exorbitant expenditure on energy will eventually lead to high cost of the product.

• Increase in overhead costs of production: Overhead cost is the money spent on rent, insurance, electricity and other things to keep the business running. Huge amount is spent of fuelling generating sets for production of goods and services, this tends to increase the overhead cost.

The general objective of this work is to minimize the adverse effects of over dependence on national electric energy generation which is unreliable in many developing countries. In attaining this general goal some specific objectives were considered. Namely; ascertaining the positive and negative aspects of alternative sources of energy; analyzing the effectiveness, feasibility and viability of other alternatives energy to electricity; determining cost-implication of choosing alternative sources; reducing dependence on PHCN electricity supply; discovering the possibility of powering a portion of a household with alternative energy sources; prescribing likely solution to energy crisis in Nigeria; giving the urban and rural dwellers in Nigeria an improved living standards for a better quality of life (Oladele, 2009).

THEORETICAL CONCEPT

Inverters and solar cells the inverter is the heart of all but the smallest power systems. It is an electronic device that converts direct current DC power from batteries or solar modules into alternating AC power to operate lights, appliances or anything that normally operates on power supplied by the utility grid. The electrically-rechargeable-battery-powered inverters which have been considered in this work come in many varieties, sizes and qualities and offer various features that specializes them for particular applications. There have been a large number of articles written concerning power conversion in recent years. This can be attributed in part to the rise in popularity of high voltage DC transmission systems and their integration with existing AC supply grids. There is also a consistent demand for high efficiency inverter devices for lower power applications like houses, caravans, UPS and developing countries of the world. The resulting AC converted by inverters can be at any required voltage and frequency with the use of appropriate transformers, switching and control circuits. Due to the higher operating frequencies, inverters yield higher, more economical output power. This increased power source efficiency translates to decreased utility costs. Virtually all the inverters used with alternative power systems are transistorized, solid state devices (Ezekoye & Ugha, 2007). Solid-state inverters are preferred for their higher efficiency, ease of maintenance, and infrequency of repair. Important output specifications to consider when searching for DC to AC inverters include maximum voltage, maximum steady state current, maximum power, and frequency range.

There are two general types of inverters: True-sine wave and Modified-sine wave (square wave). Compared to the modified-sine wave, the true-sine wave inverters produce power that is either identical or sometimes slightly better to power from the public utility power grid system. The other divisions of inverters are:

(i) Off-Grid Inverters or standalone inverters: These are the types considered in this evaluation study and are available in sizes from 100watts, for powering notebooks computers and fax machines and cars, to 60kilowatts, for powering a commercial operation.

(ii) Grid-tie inverter: This is a sine wave inverter which has a higher cost, but can operate almost anything that can be operated on utility power. A grid-tie system uses an external utility company, in effect, as its storage battery. When more power is needed than the system can supply, the utility makes up the difference.

This type of system makes the most sense in most cases where there is utility power, because there are no batteries to maintain or replace. Unfortunately, if the utility power goes down, this type of inverter will go off, too.

These inverters are designed to run at voltages up to 600 VDC and faster to install, more efficient and allows the use of smaller gauge wire.

LOAD SELECTIONS AND INSTALLATION OF INVERTERS

A key consideration in the design and operation of inverters is how to achieve high efficiency with varying power output. It is necessary to maintain the inverter at or near full load in order to operate in the high efficiency region. However, this is not possible. Some installations would never reach their rated power due to deficient tilt, orientation or irradiation in the region. Inverters are very easy to install. Most of them are "plug and play" devices, especially smaller, low-wattage inverters. The selection of a location where the DC low voltage cable is the shortest possible distance to the battery is important as the longer a DC cable runs the greater the voltage loss. Ventilation is also an important factor to consider when installing inverter. Inverters generate a fair amount of heat, and therefore use cooling fans and heat dissipation fins to prevent overheating. More so, the unit must not be allowed to come in contact with any liquids or condensing humidity. Here in, the rules for choosing an inverter based on the load selection are discussed.

• The first step in selecting an inverter is to match the inverter to the voltage of the battery that will be used to power the system.

• The devices to be powered with the inverter must be determined. The wattage rating of the inverter must exceed the total wattage of all the devices to be run simultaneously. For instance, running a 600-watt deep freezer and a 600-watt coffee maker at the same time needs an inverter capable of a 1,200-watt output.

• It must be ascertained that the inverter's peak rating is higher than the peak wattage of the device you intend to power.

• The final specification to look for is the wave output of the inverter. If there is the need to power any of the equipment that is sensitive to square waves, an inverter with a "perfect sine" wave output should be used.

SOLAR ENERGY

Solar energy is energy generated from sunshine. It is renewable because the sun continue to shine on a daily bases for a period of 12 hours maximum, although during rainy season we may have lesser amount of sunshine. Solar energy can be used to generate power in two-way; solar-thermal conversion and solar electric (photovoltaic) conversion. Solar-Thermal is heating of fluids to produce steam to drive turbines for large-scale centralized generation. Solar-Electric which is considered in this study is the direct conversion of sunlight in to electricity through a photocell. This could be in a centralized or decentralized fashion. Energy payback time (EPBT) is the length of deployment required for a photovoltaic system to generate an amount of energy equal to the total energy that went into its production. Roof-mounted photovoltaic systems have impressively low energy payback times, as documented by recent engineering studies. The value of EPBT is dependent on three factors. Namely, the conversion efficiency of the photovoltaic system; the amount of illumination that the system receives (about 1700 kWh/m/yr average for southern Europe and about 1800 kWh/m/yr average for the United States); The manufacturing technology that was used to make the photovoltaic (solar) cells.

A good place is chosen at home or certain cabin such that it is out of the way or main path of activity. It is on this basis that most people choose to mount on a roof, hence protection is ensured. There is a need to tap as much sunlight that can be reached. The more intensity of light received by the solar modules, the more power they will produce. The solar modules are kept away from shade between the prime hours of sunlight, 9.00 am to 3.00 p.m. shadows are known to reduce the module's output. Shadow cast by telephone lines, trees, buildings, electricity poles, parked vehicles all can affect the module's output. Another factor given rapt attention is the angle of tilt for maximum exposure. The modules are mounted at the best angles so as to get more sun. The best known tilt for a module is the one that puts it at right angles to the noontime sun.

MATERIALS AND METHODS

The research methodology of this study is presented in three stages, namely, (i) Site selection; (ii) Energy Auditing and AC Sizing (iii) Energy-Cost

ANALYSIS

The reasons for selecting the case study sites and performing energy audit for the site, the different types of cost analysis and phases of energy audits applied in the work are all discussed in this section.

SITE SELECTION

The site selected is a typical four-bedroom flat in the city of Awka. The flat is one of the flats in a one story building. The most important reasons for selecting these site is because the locations is in an area where energy consumption is frequent and mostly unavailable and hence the rate of diesel and fuel is on the high side due to the unsteady power supply. Energy auditing and Ac sizing Energy audits carried out at the site is for the following reasons:

(i) To ascertain the total energy consumed in the home

(ii) (ii) To discover the appliances that consumes most energy

(iii) (iii) To reduce avoidable expenses on energy.

Types of energy audits considered in this work were (i) preliminary audit (ii) general audit (iii) investment-grade audit.

The preliminary audit alternately 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 identify glaring areas of energy waste or inefficiency.

The general audit alternatively called mini-audit, site energy audit or complete site energy audit expands on the preliminary audit described above by collecting more detailed information about facility operation and performing a more detailed evaluation of energy conservation measures identified. Utility bills are collected for a 12 month-period to allow the auditor to evaluate the facility's energy/demand rate structures, and energy usage profiles. Additional metering of specific energy- consuming systems is often performed to supplement utility data. In-depth interviews with the facility operating personnel systems as well as insight into variations in daily and annual energy consumption and demand. This type of audit will be able to identify all energy conservation measure appropriate for the facility given its operating parameters. A detailed financial analysis is performed for each measure based on detailed implementation cost estimates; sites-specific operating cost savings, and the consumer's investment criteria.

INVESTMENT GRADE AUDIT

The investment-grade audit alternatively called a comprehensive audit, detailed audit, maxi-audit or technical analysis audit expands on the general audit described above by providing energy use characteristics of both the existing facility and all energy conservation measures identified. The building model is calibrated against actual utility data to provide a realistic baseline which is used to complete operating savings for proposed measures. In a comprehensive or investment- grade audit extensive attention is given to understanding not only the operating characteristics of all energy consuming systems but also situations that cause load profile variations on both an annual 6 and daily basis. Also existing utility data is supplemented with sub-metering of major energy consuming systems and monitoring of system operating characteristics.

PHASES OF ENERGY AUDIT

The Phases involved in the energy auditing were: (i) data collection (ii) data verification (iii) energy-saving opportunities (iv) energy conservation opportunities (v) executive summary. In data collection, visitation was done on the site studied. The results of the data gotten are below. The results shows the data collected for the four bedrooms flat. Data verification is the process of checking for the accuracy and adequacy of the data collected. This procedure is carried out due to challenges that might have been faced while performing the study. Energy saving opportunities technique aids the selection of load that were analyzed and presented in figures 2 below. It indicates how some bulbs can be replaced by energy saving bulbs. Energy saving opportunities identifies cutting energy consumption to bearable minimum. Energy conservation opportunities is an avenue to identify the ways energy can be conserved in the room through the usage of energy saving bulbs. This also involved reduction of the number of appliances being used. It identifies and eradicates energy wastage in the house. Executive summary is a report which indicates all the aforementioned. It defines the details of the audit; cost implication, energy saving opportunities etc. it is usually presented to the concerned organization on individual depending on the context. Shown in Fig. 1 is the frame work of the energy audits and AC sizing carried out in this work. As depicted in Fig. 1 complete energy audits were firstly carried out for the site and then followed by the Alternative Current (AC) sizing at each site for three different energy loadings, namely, (i) with complete load (ii) without heating equipment (iii) without heating and A/C. This procedure was adopted to minimize cost for the cases of solar power generation and Inverters. The results obtained such as Total Connected Load (TCL), Total Daily Load (TDL) and Total Amperes Needed (TAN) for the three cases and site were compared in Tables 1 and 2. As presented in Tables 1 and 2, the Connected Load (CL) and Daily Load (DL) were obtained using equations 1 and 2 respectively where IWL is the Instant Watts per Load; Q is the quantity of items or appliances present in the home or office and RT is the average hours the each equipment is run daily. Also, the Watts required With Loss (WRL);

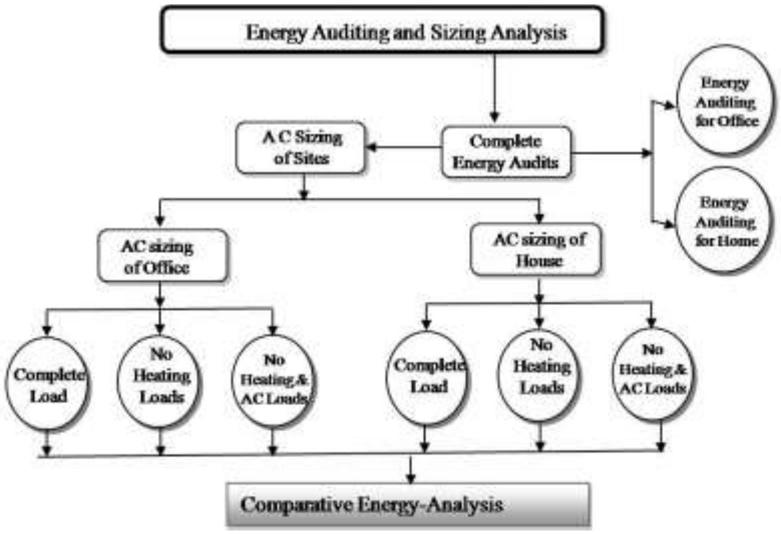

Figure 1: Energy auditing and sizing analysis

ENERGY COST ANALYSIS

There are several cost analysis methods that have been propounded such as: (i) Cost-of-illness analysis (ii) Cost-minimization analysis (iii) Cost-effectiveness analysis (CEA) (iv) Cost-utility analysis (CUA) (v) Cost-consequence analysis (vi) Cost-benefit analysis (CBA). Cost-of-illness analysis is a determination of the economic impact of an illness or condition (typically on a given population, region, or country) e.g., of smoking, arthritis or bedsores, including associated treatment costs. Cost-minimization analysis is a determination of the least costly among alternative interventions that are assumed to produce equivalent outcomes. Cost effectiveness analysis (CEA) is a comparison of costs in monetary units with outcomes in quantitative non-monetary units, e.g., reduced mortality or morbidity. Cost- utility analysis (CUA) is a form of cost-effectiveness analysis that compares costs in monetary units with outcomes in terms of their utility, usually to the patient, measured. Cost-consequence analysis is a form of cost-effectiveness analysis that presents costs and outcomes in discrete categories, without aggregating or weighting them. Cost-benefit analysis (CBA) compares costs and benefits, both of which are quantified in common monetary units. The suitability of any of these methods depend upon the purpose of the assessment the availability of data and other resources.

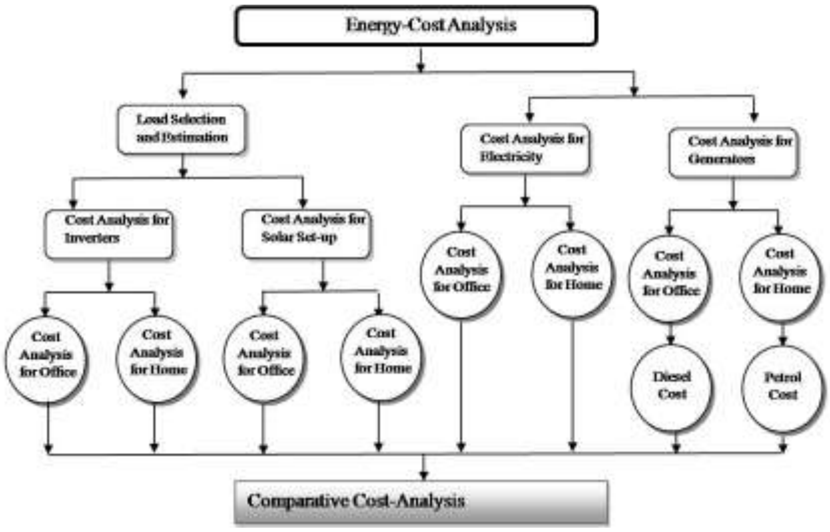

Figure 2: Energy cost analysis

Table1. Alternative current sizing for a 4 bedroom flat

ITEMS	Q	L(w)	TL(W)	CL(W)	RT(WH)	EF%
Fan	5	100	500	12	6000	15
Light	30	5	150	10	1500	15
Tv	5	100	500	8	4000	15
Water dispenser	1	30	30	1	30	15
Freezer	1	600	600	12	7200	15
Fridge	1	300	300	12	3600	15
Radio	1	300	300	8	2400	15
A.C	2	1500	1500	12	18000	15

DESIGN OF THE INVERTER

For a setting like this without air condition total consumption will be 1880w and the total consumption with AC is put at 2500w for the 4-bedroom flat. Therefore, since there is possibility that there could be some addition of load in future and the fact that some appliance takes almost double of the power to start like fridge and freezers and also other loses that may be associated with powering the device there is need to increase the power of the inverter. For this work I designed an inverter of 3000w based on the calculated load and to accommodate for any excess as the case may be. We cannot go lower than this because it could damage the inverter if more loads are drawn from it beyond its capacity.

BATTERY SELECTION

In selecting the battery, we consider the time hour of electricity that is needed. In this case we are proposing a 24 hours power supply every day. The number of batteries or battery bank needed to supply power of 3000w when there is no sun for about 12 hours is calculated below P= IV (1)

Where: P = power, I = current V = voltage

In case we are using a battery of 12v 200Amp P= 200x12 =2400 Power discharged by 200Amp 12V battery in an hour is 2400. Therefore, for the load of 3000 is given as

2400/3000 =0.8hr

It requires 0.8 hrs for one battery to discharge a battery of 200Amh12V. Therefore about 15 batteries are needed for 12 hours.

PANEL SIZING

Next is to obtain the number of panels needed for this design. Since we are considering a load of 3000watts, let us consider a panel of 300watts. Therefore 10 pieces of 300watts is required. It is known that the panel is needed to charge the battery while the sun is up and during the time the sun is up the load is been used therefore the battery is charging and at same time discharging during the day. In other to set up a balanced system we would have to double the quantity of solar panel so as to make up for the lost current during usage during the day. Furthermore, we will need an additional 3000 watts making it 6000 watts of solar panel.

DESIGN OPTIMAIZATION

In order to virtually observe the energy consumption rate of the load units considered in the design of a four-bedroom flat apartment, figures 3 and 4 shows the gradual energy drop per 0.8 hours for the rated 3000W load design and 6000W panel design. MatLab 2017a was used for the design optimization.

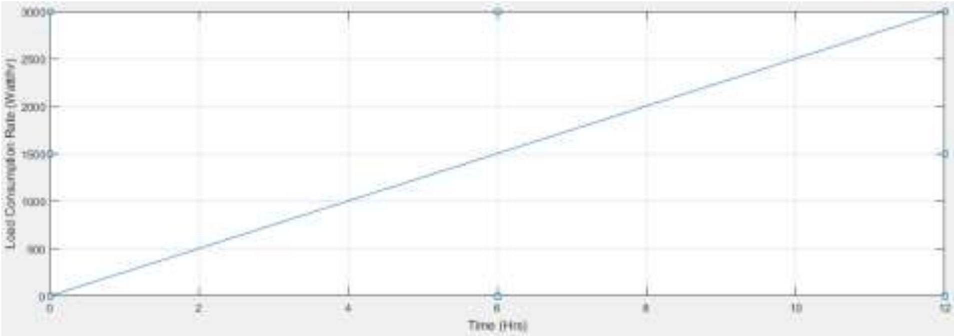

Figure 3: Load consumption rate per 0.8 hours

From figure 3, using a design basis of 200W energy consumption per 0.8 hours for a load design of 3000W, a linear relationship between the load consumption rate and time is noted. As the load increases, the time increases until 12 hours when 3000W load is maximized.

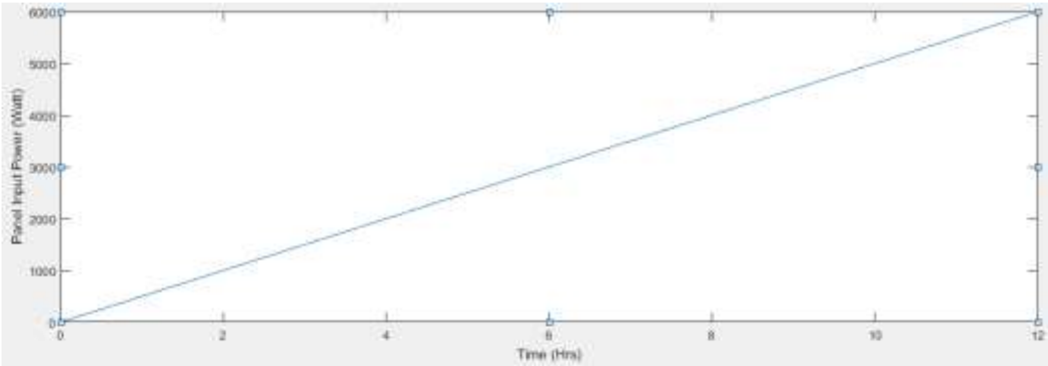

Figure 4: Plot of panel input power against time

For the panel design, for every 0.8 hours, the panel is expected to supply 400W of power to the apartment in order to drive the load units. For this design, to maximize the power supply from the panels, not all the load units should be powered on, this is to avoid failure in the system.

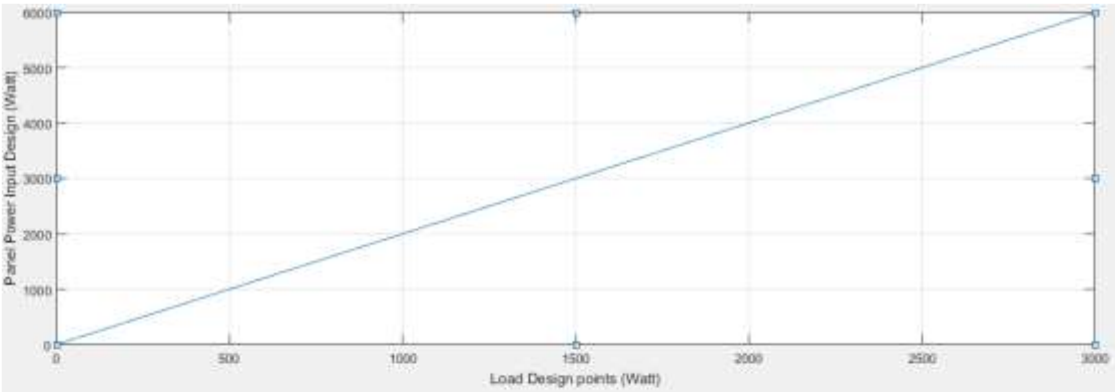

Figure 5: Load curve design

RESULT AND DISCUSSION

In addition, a total of 6000W power supply is expected at the 12th hour for maximum load support design. Also, the linear relationship between the load design points and panel input power design is shown in figure 5. From figure 5, for a load design of 200W, a power of 400W is supplied. The excess of 200W is to serve as a safety factor in events of excess load demands and human errors. It can be deduced that as the load design increases, the power input requirement increases as well.

CONCLUSION

The design of an alternative energy system performed in this paper employed a solar panel concept that supplies a total of 6000W of energy to drive a total load of 3000W. The design optimization that was carried out revealed that for a power input of 400W, a 200W load design point is required. Also, the design showed that within 0.8 hours, a total panel power of 400W is supplied to drive 200W of load units. Therefore, the design is suitable for commercial application.

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