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Assessment of Residential Electrical Energy Demand for Effective Load Management and Energy Conservation: Ikeja Electricity Distribution Company Network as a Case Study

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ABSTRACT: *One of the lingering crises faced by the Nigerian electricity sector is the wide supply-demand gap. The insufficient generated electricity has not been effectively and efficiently utilized to serve the ever-growing electrical energy demand. Therefore, the need for appropriate load management technique to conserve the available energy for improved electricity utilization by the consumers becomes highly imperative. This work assessed the electrical energy demand of a residential setting to a devise an effective load management and energy conservation strategy. Ikeja Electricity Distribution Company (IKEDC) Network controlled by Ikotun Business Unit, Lagos State, Nigeria was used as a case study. Electrical load audit of Diamond Estate, a residence community, within the network of IKEDC was carried out. The distribution patterns of the lighting load components were examined. The energy and equivalent cost equations were analysed and presented with 18 W energy saving compact fluorescent lamps (Cfls) as alternative to the existing 60 W incandescent lamps (Ils) used for lighting study area. The electrical energy consumed by both Ils and Cfls with the equivalent cost were determined. The saving in electrical energy consumption and cost from the use of Ils and Cfls were also estimated. The results from the analysis revealed that there was 70% saving in both energy consumption and cost of consumption annually from using Cfls in place of Ils by the estimated 300 consumers in Diamond Estate over the study period. The load management and energy conservation strategy proposed in this work efficiently improved the electrical energy utilization of study area.*

KEYWORDS: *Consumption Cost, Energy conservation, Lighting Load, Load Audit, Load management, Residential consumer*

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I. INTRODUCTION

Electrical energy is the major propelling force for the socio-economic and industrial development of any nation. The demand for electricity in the third world economy such as Nigeria far outstrips its supply. The imbalance was due to inadequate generated electrical energy coupled with the alarming rate of increase of population and industrialization, resulting in an enormous load demand from the consumers [1], [2]. It is, therefore, very crucial that the available generated electricity in Nigeria is efficiently managed to address the demand of the consumers through effective implementation of the right energy conservation schemes.

The Power Holding Company of Nigeria (PHCN), formerly called National Electric Power Authority (NEPA) was the utility company saddled with the responsibility of generating, transmitting, and distributing electrical power in Nigeria [3], [4], [5], [6]. The utility was a vertically integrated and monopolistic electricity market with poor operational and financial performance [2], [5], [7], [8], [9], [10]. The Nigerian Government resolve to tackle the challenges of her electricity market led to the unbundling of PHCN via Electric Power Sector Reform Act (EPSRA) of 2005 to six generation companies, a transmission company and eleven distribution companies with interest to promote competition by the involvement of private utilities to enhance service delivery [2], [4], [10].

The Nigerian deregulated electricity market, as with the practice during the pre-reform era, continues to experience electricity supply-demand inequality. The installed capacity of the Nigerian grid electricity is barely above 12,000 MW with an average availability of 4,000 MW [11] and an average demand of over 25,000 MW [12]. Hence, the need to put in place appropriate load management scheme in Nigeria to conserve the use of the available generated electrical energy especially at the distribution segment where majority of the loads is concentrated becomes highly imperative. Proper load management on the demand side, using the right energy conservation techniques, will facilitate maximum utilisation of the generated electrical energy by the consumers. This in effect will help to narrow the wide gap between electricity supply and demand in Nigeria.

Load management generally refers to the process by which electrical loads on power network are reduced during the period of peak demand. It could be implemented on both the electricity supply side and the demand side. However, the interest of this work was demand side management (DSM) since it influences the customers to help reshape the load demand curves for better utilisation of the available generated electricity [13], [14]. It is defined as the action taken on the customer's side to change the amount or timing of energy consumption. It involves planning, implementation and monitoring activities of electricity utility designed to encourage consumers to modify their level and pattern of electrical energy utilisation [13]. Therefore, the goal of this work was to assess the electrical energy demand of a residential setting for effective load management and energy conservation considering Ikeja Electricity Distribution Company (IKEDC), Ikotun Business Unit, Lagos State, Nigeria as a case study.

II. MATERIALSAND METHODS

2.1. Load Audit

An electrical energy or load audit is a process employed usually employed to determine the electrical energy demand of the appliances in a home or a community as the case may require. This process aims to identify specific energy efficiency measures appropriate to reduce the energy bills of the setting under consideration. In this work, a load audit was performed using IKEDC Ikotun Business Unit. The load profile information including a one-line diagram of the electrical distribution network and the communities covered within the network was collected. The total electrical energy imported into the network and the actual quantity invoiced/consumed from 2007 to 2012 which was study period, were obtained. The lighting load analysis of Diamond Estate, Igando which was the residence community of interest in the electrical network of IKEDC Ikotun Business Unit was carried out.

2.2. Mathematical Models Used for Energy Consumption and Cost Computations

The equations presented in this section of the work aided the analysis of the audited loads in terms of the energy and cost saved in using the alternative load or alternative consumption pattern which primarily includes the use of compact fluorescent lamps (Cfls) as alternative to incandescent lamps (Ils) within the network under consideration.

The daily electrical energy consumed by any of the lighting loads was determined using equation (1) while the saving in energy consumption arising from the use of Ils and Cfls was obtained from equation (2):

$$E = PtN_c \quad (1)$$

$$ES = E_{Il} - E_{Cfls} \quad (2)$$

where E is the electrical energy in kWh consumed by the consumer(s) in the considered time frame, P is the electrical power in W consumed by the 60 W incandescent light (Il) bulb or the 18 W Osram Cfls, t is the time of the use of the lighting loads considered which was assumed to be 5 h per day, Nc is the number of consumers considered, ES is the energy saved in kWh, E_Ilis the energy used with incandescent lamps in kWh and E_Cfls is the energy used with Cfls in kWh.

The daily cost equivalent of the energy consumed any of the lighting loads was estimated using equation (3) with cost saving involving the use of use of Ils and Cfls determined from equation (4):

C=E×R (3)

CS=C_Il-C_Cfl (4)

where C is the cost electrical energy consumed by any of the lighting loads in ₦ in the considered time frame, R is the cost of a kWh energy consumed charged by IKEDC as at the period of study, CS is the cost of energy saved in ₦ from using Ils and Cfls, C_Ilis the cost of energy in ₦ from using Ils and C_Cfls is the cost of energy in ₦ from using Cfls.

The annual saving in electrical energy consumption and the cost of consumption were determined respectively from equations (5) and (6):

$$AES = ES \times 365 \quad (5)$$

$$ACS = CS \times 365 \quad (6)$$

Where AES and ACS respectively denote annual saving in electrical energy consumed and cost of consumption.

2.3. Case Study

The IKEDC Ikotun Business Unit considered as a case study in this work is the administrative arm of IKEDC in Ikotun that controls electrical power distribution to areas of Oke-Afa, Ejigbo, Ikotun, Abaranje, Isheri-Oshun, Igando, Akesan, Egan, Idimu, Jakande low cost housing, Egbe, and Ilamoshe. The distribution network covers many towns of old Alimosho LGA and parts of Oshodi-Isolo Local Government Areas of Lagos State. IKEDC, being a very large distribution network serving many areas as earlier mentioned, experiences frequent system failures in the areas served due the fact that the network was over-stressed from the rising load demand of the consumes [15]. Therefore, the implementation of appropriate load management strategy by the IKEDC Ikotun Business Unit becomes a right step in the right direction to conserve the available electrical energy to mitigate the frequent service interruption being experienced by the areas served.

III. RESULTS AND DISCUSSION

3.1. Electrical Energy Invoiced by IKEDC Ikotun Business Unit for the Study Period (2007 – 2012)

The electrical energy imported from the grid and the actual quantity invoiced between years 2007 to 2012 by IKEDC Business Unit is shown Table 1 while the number of consumers of different categories in the Business Unit and the comparison of energy imports with peak energy demand from all customers in the Business Unit are presented respectively in Table 2 and Figure 2. Table 1 revealed that the minimum and maximum energy invoiced by IKEDC Business Unit were 238,825,773 and 308,770,272 kWh which occurred in the years 2007 and 2012, respectively. The average loss in energy distributed over the study period was 12.16%. Table 2 showed that the main customers of the IKEDC Business Unit are the residential consumers whose number amounts to 60,538. Figure 1 revealed that the electrical energy invoiced to the consumers in each year of the study period was far less than the peak energy demand, an indication of the need for effective load management to ensure maximum utilisation of the available electrical energy by the consumers.

3.2. Results of Load Analyses of Sampled Houses in Diamond Estate, IKEDC Business Unit

The lighting loads audited for the 12 houses randomly selected in Diamond Estate area of the IKEDC Business Unit with each house comprising 3-bedroom flat are presented in Table 3. As reflected in Table 3, some of the houses audited used both Ils and Cfls while some used only Ils for lighting purposes. It further revealed that a common trend in Diamond Estate involves the use of 60 W Ils. Using an estimated 27 units of 60 W Il per 3-bedroom flat of a consumer, the total power consumed was 1620 W which translated to 540 W or 0.54 kW per phase with an assumed balanced 3-phase connection. A further assumption of 5 hours daily use of the lamps resulted into the energy consumed per day by a consumer in Diamond Estate being 2.7 kWh. In a month of 30 days, the consumption by a consumer was computed as 81 kWh. For a considered 300 consumers in Diamond Estate, the total electrical consumption per month was 24,300 kWh and was equivalent to 291,600 kWh annually. Using the IKEDC Ikotun Business Unit tariff of ₦21.80k as at 2013 for residential consumers, the cost of this annual consumption was ₦6,356,880 for the 300 consumers of Diamond Estate.

The replacement of the 60 W Ils in Diamond Estate with 18 W Cfls, using the same 27 units of lighting points per consumer resulted into a total consumption of 486 W which translated to 162 W or 0.162 kW per phase with an assumption of a balanced and desired 3-phase distribution of lighting loads. The same 5 hours utilization time of lighting loads produced energy consumption of 0.81 kWh per day which became 24.3 kWh in a month of 30 days. For the 300 Diamond Estate consumers, the total electrical consumption per month was 7,290 kWh which was equivalent to 87,480 kWh annually. Using the ₦21.80k tariff, the cost of this annual consumption was N1,907,064 for the 300 consumers.

The analysis of the energy consumed by 60 W Ils and 18 W cfls revealed that the energy saved by a consumer in Diamond Estate was 56.7 kWh monthly and for the estimated 300 consumers, the energy saved annually was 204,120 kWh which was equivalent to an annual cost saving of ₦4,449,816. These results showed there was a 70% saving in electrical energy supplied to Diamond Estate and cost of consumption with the application of Cfls instead of Ils. These results are indications that IKEDC Ikotun Business Unit would have more spares of electrical energy to distribute to its customers if they are encouraged to embark on the use of the load management strategy proposed in this work which involved the adoption of the energy saving Cfls in place of the Ils for lighting purposes. The utilisation of the Cfls would not only facilitate effective distribution of electricity to consumers by IKEDC Ikotun Business Unit but also would assist the consumers to cut down the cost of electrical energy consumed in sharp contrast to the use of Ils for lighting functions.

Table 1: Electrical energy imports and the invoiced electrical energy for the years 2007 – 2012 [15]

Year	Electrical energy imported(KWh)	Electrical energy invoiced(KWh)	Losses (KWh)	Losses percentage
2007	284,316,397	238,825,773	45,490,624	16%
2008	298,483,542	256,695,846	41,787,696	14%
2009	300,493,734	264,434,486	36,059,248	12%
2010	273,819,324	246,437,392	27,381,932	10%
2011	339,734,192	302,363,431	37,370,761	11%
2012	343,078,080	308,770,272	34,307,808	10%

Table 2: Number of Consumers in different Consumers' Categories in IKEDC Business Unit as at year 2012 [15]

S/No	Consumer Type	Number
1	Residential	60,538
2	Commercial	12,341
3	Industrial	52
4	Street-lighting points	672
5	Government offices	119

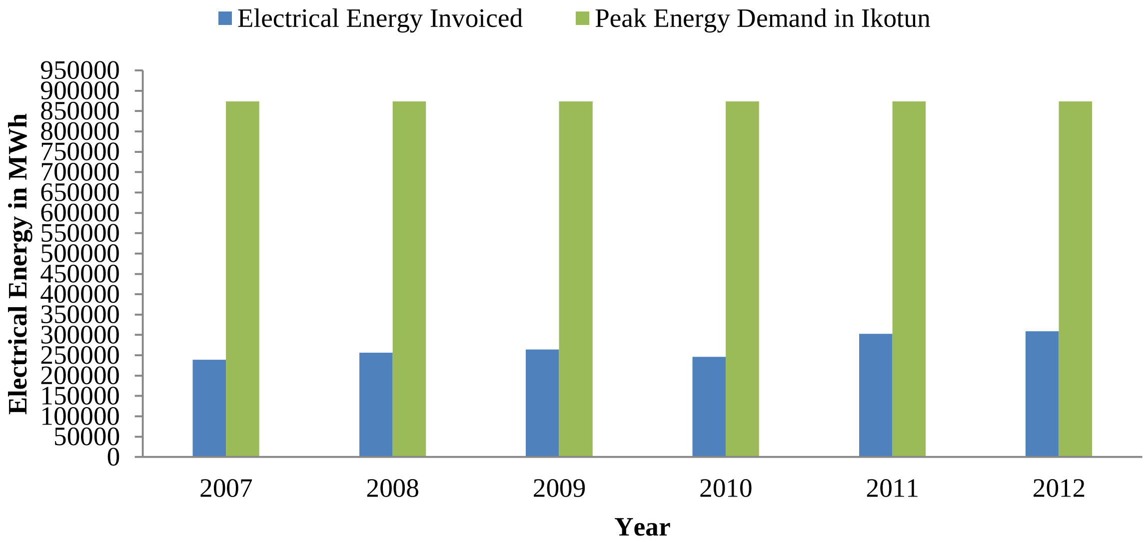

Fig. 1. Energy consumption chart in IKEDC Ikotun Business Unit compared to peak demand by consumers from 2007 to 2012 [15]

Table 3: Lighting loads in selected houses in Diamond Estate within IKEDC Ikotun Business Unit

Location	Sampled Houses	No of Lighting Points	No of Incandescent Lamps and Size (Watts) Mostly Used	No of Compact Fluorescent Lamps and Size (Watts) Mostly Used
Diamond estate, Igando (3-bedroom flats)	House 1	29	25 pieces; 60 W	-
	House 2	30	20 pieces; 60 W	10 pieces; 18 W
	House 3	29	29 pieces; 60 W	-
	House 4	29	23 pieces; 100 W	4 pieces; 18 W
	House 5	30	29 pieces; 60 W	-
	House 6	27	25 pieces; 60 W	2 pieces; 18 W
	House 7	29	27 pieces; 60 W	2 pieces; 18 W

House 8	27	27 pieces; 60 W	-
House 9	28	26 pieces; 60 W	2 pieces; 18 W
House 10	27	27 pieces; 60 W	-
House 11	29	27 pieces; 60 W	-
House 12	30	25 pieces; 60 W	5 pieces; 18 W

The results of work aligned with the findings from the work of [16] and [17]. The work of [16] showed that the use of energy-efficient lamps produced 83.3% cost savings compared energy-consuming lamps while [17] found out that compact fluorescent lamps saved about 75 to 80% supplied electrical energy in comparison to incandescent lamps. These submissions tallied with the results of this work signify the use of Cfls as an appropriate load management strategy that could be deployed with the electrical distribution network of IKEDC Ikotun Business Unit.

IV. CONCLUSION

This work assessed the lighting load demand of Diamond Estate, a residence community in the electrical distribution network of IKEDC Business Unit as a means towards implementing an appropriate electrical energy consumption strategy to conserve usage of energy in the network. The use of 18 W energy saving Cfls was found to minimise the annual energy consumption of the study area by 70% compared to the use 60 W Ils very popular in the area and also the cost of energy consumption by 70%. The conserved energy resulting from the use of energy saving Cfls serves as spare energy for distribution to other load centres in the network. The load management technique explored in this study will be very helpful if the consumers are encouraged to adopt its use for the improvement of energy utilization within the network of IKEDC Ikotun Business Unit in the face of steadily growing demand and dwindling supply of electricity. Further research is ongoing to assess impact of developing communal microgrid for the study in place of isolated generators commonly as a means to facilitate more robust distribution of electricity for the area.

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