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Estimation of Future Energy Demands for Rural Off-Grid: A Methodology

Oladeji A.S.[1] and Akorede M.F.[2]
[1]National Centre for Hydropower Research and Development, University of Ilorin, Ilorin, Nigeria.
[2]Department of Electrical and Electronics Engineering, University of Ilorin, Ilorin, Nigeria.
Email: akinsun3k@yahoo.co.uk

Abstract
The economic viability of hybrid energy systems depends on accurate electrical load estimate and forecasts among other factors. Since, off-grid power system usually operates beyond ten years, it will not be normal to consider the static estimate of the total energy demand. This paper presents an approach for the formulation of hourly load profile using bottom up approach and long-term electric power load forecasting using end use model for off-grid rural communities. The study focuses precisely on the formulation of daily load profiles and forecasts by considering standby power consumption for rural off-grid which has not been considered when formulating load profiles for rural areas in the previous study. The formulated procedure is used to formulate load profiles and ten years' electrical energy forecast for a cluster of three rural communities located in Ifelodun Local Government Area of Kwara State, Nigeria. To study the shape of the load pattern for a typical rural household, FLUKE 434-SERIES II ENERGY ANALYZER was used to measure hourly energy consumption of a typical rural household that is connected to the grid for 8 days with a 1hour time step. Multiple regression analysis was carried out to investigate the various factors that can influence the increase in electricity consumption by a rural household using Pearson correlation and Minitab 18 statistical software. The results demonstrate successful ten-year load forecast with the annual maximum demand in the first year estimated as 54.12 kW and 63.90 kW in the tenth year.

Keywords: *Keywords: Bottom up, end use model, load forecasts, load profiles, rural off-grid*

1.0 Introduction

Availability of a reliable, affordable and efficient electrical energy is the basic need for the socio-economic and technological development of any country. Without electricity, many human daily activities will come to a stop. Likewise, the per capita consumption of electricity in any nation has a direct relationship with the standard of living. The higher the per capita consumption of energy in a country, the higher will be the standard of living and vice versa. "Energy poverty" must first be addressed if poverty is to be eradicated in rural areas of any nation**.** About 1.1 billion people around the world have no access to electricity in the world. (World Bank, 2015). The challenges of Electricity in Africa remain disheartening. For example, about 2% of Liberians enjoy uninterrupted supply of electricity. Moreover, one out of three developing countries suffers for at least 20 hours of power outages a month. The most efficient way of minimizing poverty and increase prosperity is Inclusive economic growth. Up till now, most economic activity is too difficult to embark upon due to lack of efficient, reliable and affordable competitively electrical energy (World Bank, 2015).

About 68.2% of people without access to electricity live in rural areas of developing countries (Mandelli *et al*. 2016). Electricity can be extended to these areas through campaign for the use of energy efficient appliances so that energy that is saved can be extended to these areas. Electricity can also be extended to these areas in a sustainable and environmentally manner by combining two or more renewable energy sources as integrated renewable energy sources (IRES) or microgrid for the generation of electricity to these areas. The design process of such systems (using renewable resources) requires special attention since it deals with unpredictable energy sources, unknown or uncertain electric consumption and it is a combined challenge of cost saving (affordability), appropriate sizing (reliability) and long term duration (sustainability) (*Mandelli et al.,* 2016). In addition, the situation in rural areas of developing countries remains complex due to lack of detailed information about both load profiles and available energy sources. Certainty, in most rural electrification activities, example experiences are rare to build the system design on. For the optimal sizing of hybrid renewable energy systems/microgrid/IRES for off-grid rural electrification, the electrical load profiles and forecast are of utmost importance in the design process. The knowledge of the load profile is required at the different stages of the design procedure.

Likewise, rural energy consumption will continue to increase along with population growth, Gross Domestic Product (GDP) growth, and electrical devices increase. The prediction of electrical power required to meet the short, medium and long term demand is called load forecasting. The electric load forecasting assists the utility companies in their day to day operation and management of the supply to satisfy their customers' electrical energy demand reliably and successfully. Most importantly, load forecasting is required by utility company to decide economic viability for electric power generation. Electric utility companies use load forecasts for system security, scheduling and maintenance and to make long-term investments in generation, among others. In addition, load forecasting assists the utility companies to decide the needed resources to operate the generating plants in conjunction to other resources that are required to guaranty uninterrupted, efficient and economical generation of the electric power to the consumers. It is sometimes difficult to accurately fit the numerous complex factors that affect demand for electricity into the forecasting models (Steven, 2016). In addition, it may not be easy to obtain an accurate demand forecast based on parameters such as change in temperature, humidity, and other factors that influence consumption. An extensive overestimation of load demand will result in substantial investment for the construction of excess power facilities while underestimation will result in customer discontentment (Al-Hamadi and Soliman, 2005) which will eventually lead to the shortage in the available spinning reserve of the system.

1.1 Review of Electrical Energy Load Forecasting Methods

Different methods of load forecasting, methods of load profile formulation and factors influencing in electrical energy consumption were briefly reviewed in this section. A lot of research works have been conducted on electric load forecasting with different research subject of discussions and with different purposes. Load forecasting can be defined as the domain of models able to provide data for setting the best planning and operating of electric grids (Mandelli *et al.*, 2016). Load forecasting can be divided into three groups namely: short term, medium term and long term forecasting. Short term load forecasting is used to predict electrical loads from 1 hour to a week ahead and is required to solve unit commitment and economic load dispatch problems. Artificial intelligence and varieties of statistical techniques have been developed for short term load forecasting method such as regression methods, time series and artificial neural network among others. Examples are exhibited in Patrick et al. (2014); Al-Hamadi and Soliman (2004); Liu *et al.,* (2014); Hippert *et al.,* (2001); Deihimi *et al.,* (2013); Gross and Galiana (1987).

Medium term load forecasting is used to predict weekly, monthly up to a year peak loads and is required for efficient grid operational planning. Example is in Lee and Hong (2015) which proposed hybrid dynamic and fuzzy time series model for mid-term power load forecasting. Long term load forecasting is used to predict loads up to 50 years ahead and is required for grid expansion planning. Examples are presented in Al-Hamadi and Soliman (2005); Jia *et al.,* (2001); Carpinteiro *et al.,* (2007).
The methods listed above for load forecasting are usually used when there is lack of information, or no information about the appliance stocks and details of consumers load profiles. Energy consumption modeling deals with energy consumptions by a country, a region or a sector (Mandelli *et al.,* 2016). The methods of estimating electricity profiles have been reviewed by Swan and Ugursal (2009) and grouped into two approaches namely bottom up and top down approaches. Bottom-up, which is used to model consumptions of each end-use and hence to identify areas for efficiency improvements at user level, and is based on statistical or engineering models. The basic idea of bottom-up model is to build up the total load from the rudimentary load components. The uniqueness of bottom-up approach is that it can analyze the effect of each appliance or user class on the overall load. Top-down, which is used to determine the effect on consumptions due to ongoing long-term changes to assess future supply requirements, and is based on econometric or technological models (Mandelli *et al.,* 2016. To the best of authors' knowledge, there is little works that precisely focus on the formulation of daily load profiles that considers standby power for rural off-grid systems. In addition, most of these published works focused on domestic or commercial electrical energy consumptions.

One of the limitations of bottom-up methods is a great need of detailed data about the consumers and their appliances. Since, some parts of the data may not be easily available for off-grid rural areas, the need for detailed data about the appliances is avoided by simply using a sample of representative data and statistical averages. Studies have shown that the daily electrical energy consumption on a yearly basis do usually depends on external factors or variables such as the average outside temperature and daily sunlight hours that typically follow related patterns over successive years, known as seasonal effect. As the pattern of daily temperature and sunlight hours' change, the daily electrical energy consumption on a yearly basis will also change. Depending on the climatic condition of the location, sometimes, the seasonal effect may not have significant effects on daily electrical energy consumption on a yearly basis.

In Nigeria, the seasonal effect has a significant effect on electrical energy consumption. Figure 1 shows the variation in monthly electric power consumption for idofian feeder and university of Ilorin feeder in Ilorin, Nigeria due to seasonal effect for the year 2016. The peak electricity load demand occurred in January for Idofian and December for University of Ilorin when the average temperature in the country is usually at the highest in the year. The lowest load demand was observed in June, July, August and September for both Idofian and University of Ilorin which coincidently happened to be the coldest period in the rainy season of the year. Also, the variation in the load demand between the peak and off peak part is 819.5MW for Idofian and 311.1MW for University of Ilorin which are considered as significant change. This shows that during dry since when temperature was high the load demand was also high as resented in Figure 1. Based on this fact, the seasonal effect is considered in this work.

Also, the hourly variation of electrical energy consumption can also be because of the combined effect of consumer availability and activity level. Furthermore, the consumption pattern can also be influenced by some factors such as public holidays to celebrate national events or festival, unexpected weather condition (that is variation in temperature) among other factors. These uncertain factors are not considered in this work. These will be considered in future works.

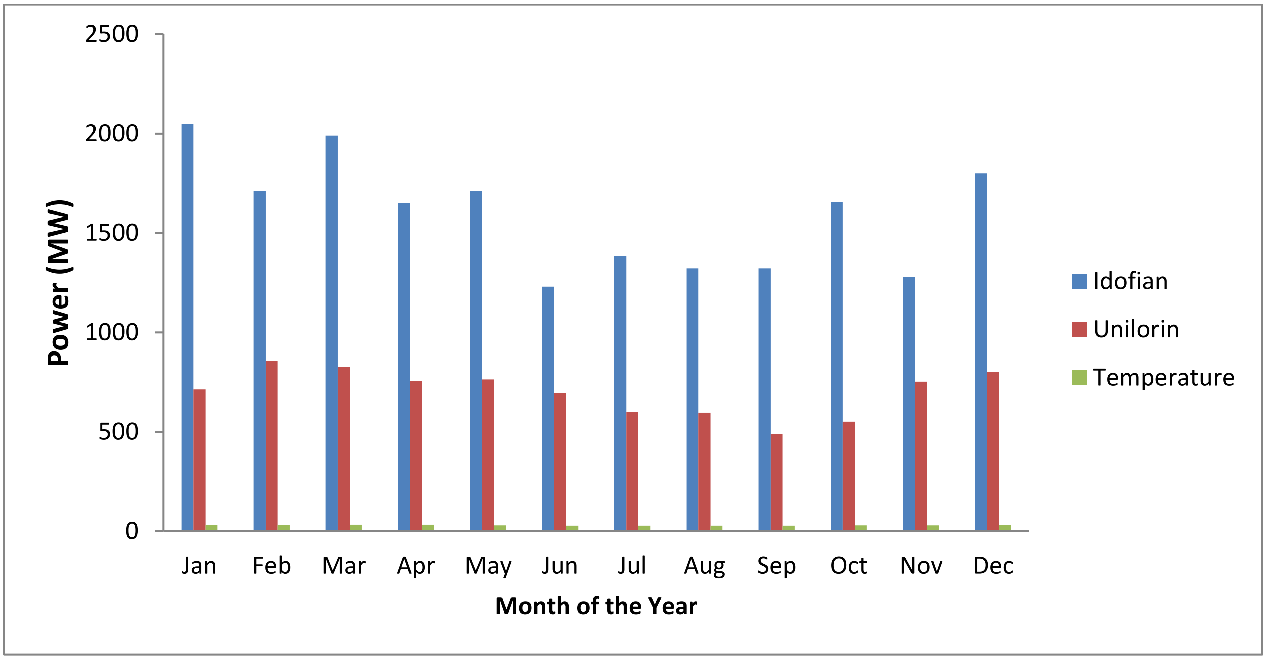

Figure 1: Monthly Electric Power Demand for Idofian and University of Ilorin, Ilorin, Nigeria, 2016 (IBEDC, 2017)

Mandelli et al., (2016) reported that researchers that have worked in the field of integrated renewable energy sources usually present daily electrical load consumption profiles in three manners:

1. Electrical load profiles are defined without any description about their source (Bala and Siddique, 2009; Nandi and Ghosh, 2010; Kanase-Patil et al., 2011).
2. Electrical load Profiles are deduced by employing other ones from related frameworks (Nfah and Ngundam, 2009, 2012; Phrakonkham et al., 2012; Semaoui et al., 2013; Sen and Bhattacharyya, 2014).
3. Electrical load profiles are prepared without any distinct method, but rather through assumptions on electric appliances functioning times or load factors, so as to shape up a coincidence actions (Al-Karaghouli and Kazmerski, 2010; Gupta et al., 2010; Bekele and Tadesse, 2012).

This study presents the formulation of hourly electrical load profiles and ten years' energy forecasts for off-grid rural communities using three rural communities namely Sangotayo, Budo Umoru and Idin Isin, Kwara State, Nigeria as case studies. The specific objectives of this study are to: identify and classify the types of electricity user class in rural areas; construct the aggregative load profile and validate the rural household model load profiles using measured data from on-grid rural areas; forecast the energy demand for ten years using end use modeling technique

2.0 METHODOLOGY

The survey was conducted for different users' class of electricity that are connected to the electric grid in the rural areas in Kwara State of Nigeria with aim to study the electricity consumption pattern. The sets of input data for the load profile formulation for the cluster of the three rural communities under study were obtained by gathering information about electrical appliances and consumption pattern of the rural dwellers in the similar rural communities that are connected to the grid by means of questionnaires and local surveys. Seasonal effects were observed during the survey as fans were not required during the rainy seasons. In addition, FLUKE 434 SERIES II energy analyzer was also used to study consumption pattern of a typical rural household. The bottom up model was first implemented to obtain the aggregate hourly load profile by summing up hourly consumption of each user class by appliance. The bottom-up model estimates the hourly electricity demand profile based on the behaviors of members in each user class and typical patterns of electrical appliances use. Multiple regression analysis was also used to investigate the effects of educational level, family composition and annual income on annual electrical energy consumption in rural areas of Nigeria. The annual rate of growth of each user class was also estimated from the ten years' demographic data obtained from the head of the community. Generally, there are two methods that can be used for medium and long term load forecasting which are end-use and econometric approaches. For off-grid rural areas load forecasting, end- use model is most appropriate. End use model was implemented to forecast annual electrical energy demand for ten years. Summary of the models implemented in this work is presented in Figure 2.

2.1 Description of Study Area

The study area is in Ifelodun Local Government area of Kwara State, North-Central Nigeria and comprises of three (3) rural communities namely: Sangotayo, Budo Umoru and Idi Isin. The study areas are completely off-grid locations. The features of each of the rural community are shown in Table 1. These data are based on the results of electrical load survey/resource assessment conducted on 19th July, 2017. The primary source of energy is fuel wood for cooking and secondary source is kerosene for lighting and security in all the three rural communities. The significant commercial activity in these communities is agriculture which involves crop production and animal husbandry. The main crops grown are corn, millet, yam, beans, groundnut and cassava. The study areas are rich in hydro, solar and wind renewable resources. The features of the locations are represented in Table 1.

Table 1: Features of the Study Area

Features	Sangotayo	Budo Umoru	Idi Isin
Number of Houses	14	63	9
Number of Shops	3	4	-
Number of Primary Schools (3 classrooms)	1 shared Primary School	1 shared Primary School	1 shared Primary School
Number of Mosque	1	3	-
Number of Church	-	-	2
Number of Households	28	126	18

2.2 Problem Formulation

The data on average daily, monthly and annual electrical energy consumption of a typical on-grid rural area that can be accessible from Nigerian Electricity Distribution Company (DISCO) is usually aggregated consumption of multiple commercial centres, rural health clinics, schools and households, without information about the events in individual user class. There is lack of data that could give information about consumption pattern of different appliances in each user class. In this section, the rural area load which comprises of seven different user classes is simulated. The bottom-up approach analysis method which builds up the total load for each user class, considering every piece of rural appliance in each user class, in a statistical average manner is used in this research work.

The basic assumption of end-use method is that demand for electricity is obtained from customer's load demand for refrigeration, space cooling, heating, security and so on. This approach also explains electrical energy demand in relation to number of available appliances in the market. Ideally, this approach is very accurate but, it is sensitive to the amount and quality of end use data (Feinberg and Ganethlion, 2005). The major factors considered for long term forecasting are previous load and weather data, user categories, the number of customers in each user class, the appliances in each user class and future energy demand forecasts. Features of end use method of forecasting are:

(i) It considers each electrical device such as fan, TV, fridge e.t.c.
(ii) It considers the number of each devices
(iii) It estimates the electricity usage of each electrical devices
(iv) It predicts the future number of each of the electrical devices

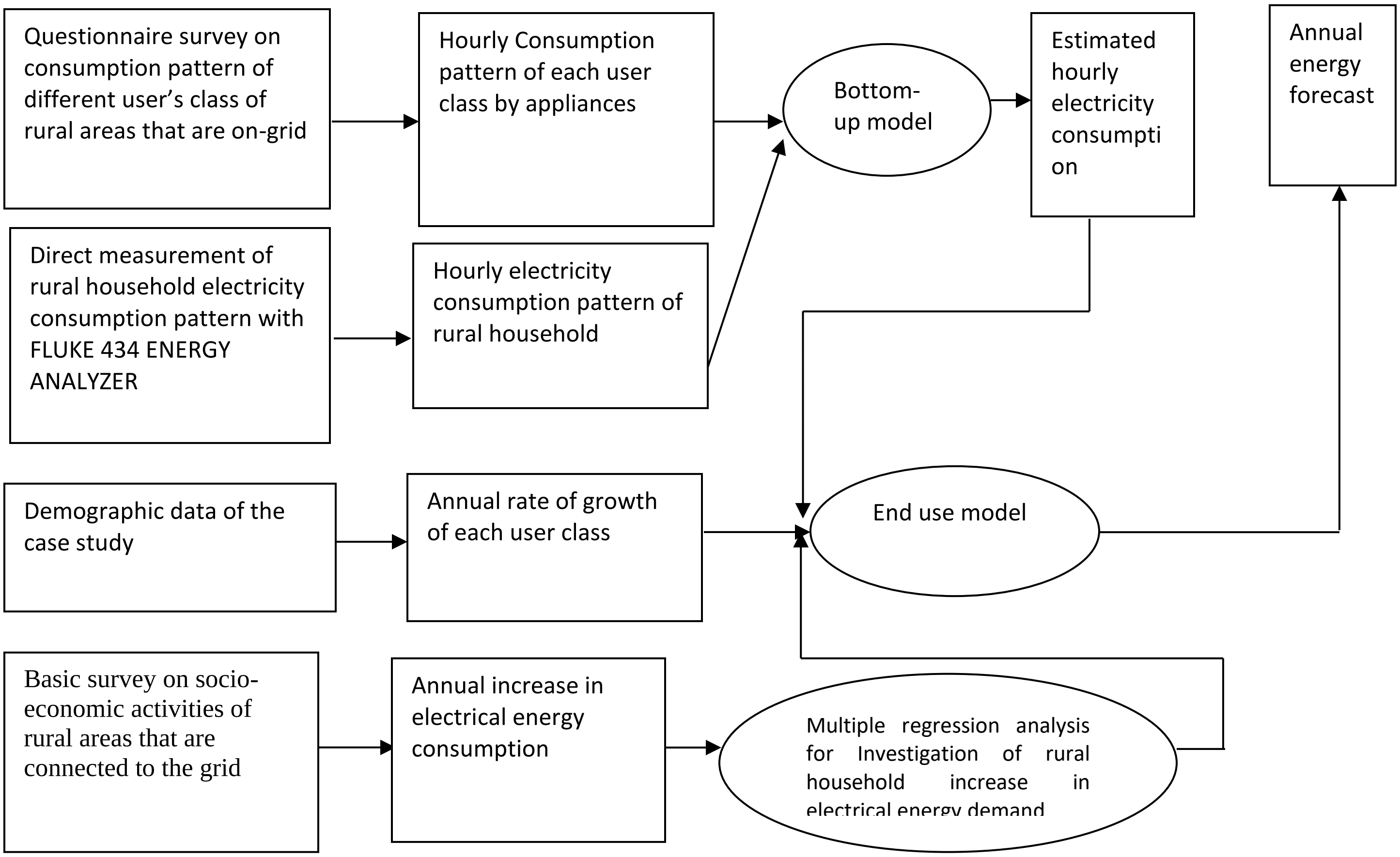

Figure 2: Block Representation of the Models Implemented in the Work

2.2.1 Mathematical Model for the Rural Electrical Energy Consumption and Forecast

For this methodology, the electricity consumers in the rural areas are grouped into different user classes (seven cases) to formulate a daily load profile for the hourly total electrical energy consumption for the rural consumers with different electrical appliances. The features considered for the design of seasonal daily load profiles for the selected un-electrified rural areas are:

(i) Classification of user classes and electrical appliances in addition to number of users and appliances which is bottom up approach
(ii) The rated and standby power would be required for the modeling of each appliances
(iii) The functioning time of each appliance that is, the total time each appliance is ON per day.
(iv) The period(s) each appliance is ON daily that is, the functioning windows.
(v) Standby time
(vi) One hour time-step.

The above features are necessary to formulate a daily load profile and forecasts for group of electrical energy consumers in rural areas. They can be assumed through local surveys which are done in this work. Appliances' functioning times and functioning windows are the meaningful data since they decide the daily electricity consumption and the coincidence performance of the appliances, respectively. This can be engaged to formulate different load profiles for the same affected group of users based on seasonal change, working days/weekends, etc (Mandelli *et al.*, 2016). For this work, six types of electrical load would be considered as given below:

(i) Household load demand: lighting, television set, electric fan and miscellaneous loads
(i) Commercial load demand for small shops: lighting load, fridge and miscellaneous loads
(ii) Primary health centre load demand: lighting, fan, TV, fridge, centrifuge, miscellaneous loads
(iii) Street lighting load demand: LED fitting with good luminous efficacy
(iv) School load demand: lighting loads
(v) Religion houses load demand (church and moaque power demand): lighting, sound reinforcement system (microphones, amplifiers and loud speakers)

Note: Miscellaneous loads are phone and radio chargers. The electrical power demand of the loads can be expressed as:

$$P_t^L = P_t^{HD} + P_t^{CM} + P_t^{HC} + P_t^{SL} + P_t^{SC} + P_t^{RH} \tag{1}$$

where P_t^L is the total hourly power demand at time t, P_t^{HD} is hourly household power demand at time t, P_t^{CM} hourly commercial power demand at time t, P_t^{HC} is hourly health centre power demand at time t, P_t^{SL} is hourly streetlight power demand at time t, P_t^{SC} is school power demand at time t, P_t^{RH} is the religion houses demand at time t (church and mosque power demand at time t).

Likewise, the energy demand of the loads can be expressed as:

$$E_t^L = E_t^{HD} + E_t^{CM} + E_t^{HC} + E_t^{SL} + E_t^{SC} + E_t^{RH} \tag{2}$$

Where E_t^L is total electrical energy demand at time t, E_t^{HD} is hourly household energy demand at time t, E_t^{CM} is hourly commercial energy demand at time t, E_t^{HC} is hourly health centre energy demand at time t, E_t^{SL} is hourly streetlight energy demand at time t, E_t^{SC} is school energy demand at time t, E_t^{RH} is hourly religion houses energy demand at time t.

The standby power consumption for computer, television and refrigerator studied by (Ajay et al., 2009; Mustafa et al., 2012) are incorporated in this study for the load profile formulation for rural off-grid areas. Nowadays electrical and electronic appliances plus those with on/off switches, consume power for standby functions (Ajay et al., 2009). The number of electrical appliances with standby power consumption is increasing daily in numbers and varieties. Numerous electrical appliances have no standby structures but are furnished with exterior power supply unit called wall-pack. Still, when they are not in operation, a small quantity of electrical energy will be lost due to low voltage power supplies, mostly because of the common transformers that usually have high core losses. The residential and office electrical appliances like TVs, video and audio players, telephone answering and facsimile machines, computers, printers and photocopiers among others, usually contribute to this standby power loss which is low, ranges from 0.5 to 25W.

By defining the kind of electrical appliances, different user classes, the number of users per user class, the number of appliances, the rated and standby powers of the appliances, functioning time and standby time, the hourly (E_t^L) and daily (E_d) electrical energy consumption can be computed using equations (3) and (4) as follows:

$$E_t^L = \sum_{q}^{u} N_q \times (\sum_{r=1}^{S}[(P_{qr} \times n_{qr} \times t) + (P_{qr-sby} \times n_{qr-sby} \times t)]) \tag{3}$$

$$E_d = \sum_{q}^{u} N_q \times (\sum_{r=1}^{S}[(P_{qr} \times n_{qr} \times t_{qr}) + (P_{qr-sby} \times n_{qr-sby} \times t_{qr-sby})]) \tag{4}$$

Moreover, the annual energy consumption (E_i^{AEC}) for each year is calculated as given in equation (5).

$$E_i^{AEC} = \sum_{m=1}^{M}\left(\sum_{d=1}^{D} E_{d,m}\right) \tag{5}$$

Also, the annual load factor (L_i^{f-AEC}) is calculated using equation (6)

$$L_i^{f-AEC} = \frac{E^{AEC}}{24 \times 365 \times P_l} \tag{6}$$

The total annual demand P_i^{tot} for each year is calculated using equation (7)

$$P_i^{tot} = \frac{E^{AEC}}{L_i^{f-AEC} \times 8760} \tag{7}$$

Where P_{qr} is power consumed by appliance r in user class q, n_{qr} is number of devices of appliance r in user class q, S is the number of electric appliance used, , t_{qr} is hour of usage of appliance r in user class q, P_{qr-sby} is the standby power consumed by appliance r in user class q, $t_{qr-stby}$ is the hour of usage of appliance r in user class q on standby mode, M is total number of months per year, D is the total number of days in a particular month, $E_{d,m}$ is the total daily energy in a particular day of the month, P_l is the power peak.

The mathematical models are simulated based on the following assumptions:

(i) The hourly behavior of household members, commercial, school, streetlight, community health centre, church, mosque is assumed and fitted per the results of the local survey conducted from the similar rural communities that are connected to the grid.

(ii) Estimation of electricity usage for each appliance based on appliance usage, unit power consumption and standby power consumption

(iii) Weekdays and weekends consumption are not differentiated but are averaged to obtain a mean hourly profile.

(iv)The consumption patterns are not influenced by the hour-of-energy use tariff system, since time of used tariff is not currently practiced in Nigeria.

Equations (8) and (9) are used to estimate the rate of annual growth in electricity consumption for each user class.

$$R_q = R_{oq}(1+x)^n \tag{8}$$

$$x = \left(\frac{R_q}{R_{oq}} \right)^{1/n} - 1 \quad (9)$$

where R_q , R_{oq} are final and initial number of each user class, x is the rate of annual growth, n is the number of years.

The annual growth rate used for each user class was calculated per the results of local survey on ten years' demographic data for the number of rural household, shops, students in primary school, number of houses, number of mosques and number churches as shown in Table 2. The year-by-year projection of the total number of users in each user class can be calculated using annual growth rates as expressed in equation (10):

$$P_q^{k+1} = P_q^k \left(1 + x_q\right) \quad (10)$$

where, P_q^{k+1} , P_q^k are projected and initial total number of users in each user class in year k+1 and k, x_q is user's class annual rate of growth.

Table 2: Ten years historical (Demographics) data realized from the local survey

S/N.	Year	Rural household Population	Number of shops	Number of students in school	Number of classrooms	Number of mosque	Number of church	Number of houses
1.	2008	150	1	30	3	2	1	64
2.	2009	154	1	32	3	3	1	66
3.	2010	155	1	35	3	3	1	70
4.	2011	159	1	38	3	3	1	72
5.	2012	160	2	40	3	3	1	76
6.	2013	163	2	40	3	3	1	78
7.	2014	165	2	45	3	4	2	78
8.	2015	167	3	50	3	4	2	80
9.	2016	170	5	58	3	4	2	84
10.	2017	172	7	65	3	4	2	86

2.3 Investigation of Rural Household increase in Electrical Energy Demand

The various factors that can influence the increase in electricity consumption by a rural dweller have been studied. A local survey was carried out in four rural communities that are connected to the electricitiy grid in Kwara and Oyo State (Ahun, and Jimba Oja in Kwara State; Ahileke and Abduka in Oyo State) by administered a questionnaire for 80 rural households by means of stratified random sampling. Pre-paid metering and billing systems are not currently available in nearly all rural areas of the country. The usual practice is payment of a fixed amount monthly regardless of unit of electrical energy consumed. Based on this fact, the questionnaire was prepared such that is to provides information on number of electrical appliances owned each year since last four year (N_r) (rather than annual kWh consumed), annual income from the sales of agricultural produce since last four year (A_{in}), family composition (F_{co}), highest education level attained by the head of the rural household (E_{le}).

Minitab 18 statistical software was used to carry out multiple regression analysis between independent variables (change in annual income, highest education of the head of the family and family composition) and dependent variable (variation in number of electrical appliances). The results revealed that the rural household annual income, family size and the highest qualification of the rural household cannot explain the variation in number of electrical appliances significantly. The percentage increase in annual electricity consumption of a rural household is almost negligible if and only if the basic electrical appliances (TV, Radio, DVD Player, Fan, bulbs and Miscellaneous that is, phone and transistor radio chargers) for rural household have been acquired.

3.0 RESULTS AND DISCUSSION

3.1 Results

The results of the hourly, daily, monthly load demand plus annual load forecast are presented in this section using bottom up and end use approaches.

3.1.1 Bottom up model

The estimated hourly, daily and monthly electricity profile by bottom up model method for the base year (year 0) is shown in Table 3, which shows the mean monthly estimated hourly electricity profiles for the three rural communities which comprise of 172 rural households, 7 small commercial shops, 1 primary school with 3 classrooms, 4 mosques, 2 churches and 1 community health centre as presented in Table 1. Peak demands usually occurring in the evening, and are reproduced. In dry season, the electricity consumption increases by 0.16 kWh per hour from 7:00 to 17:00; 13.36 kWh per hour from 6:00 to 18:00; 13.52 kWh per hour from 18:00 to19:00. In this work, we measured and monitored the hourly energy consumption of a typical rural household that is connected to the grid by using FLUKE 434-SERIES II ENERGY ANALYZER for 8 days with a 1hour time step.

The purpose of the direct measurements is to study the hourly electricity consumption pattern of a typical rural household. The average daily profile from the measured data is plotted as shown in Figure 3. The observed variation between the estimated and the monitored profiles looks small. The little error might be as a result of inclusion of appliances miscellaneous demand which might not be orderly considered from the real-time measurements. The total daily energy demand is estimated as 569.44kWh in dry and 402.3958kWh in rainy season with annual energy demand of 176713.32 kWh in the base year (year 0).

3.1.2 End use model

The results of the load forecast for ten years using end use model are presented in Table 3. For briefness purpose, the daily (dry and rainy seasons) and monthly load profile for ten year are presented in Figures (4)-(6) respectively. The total daily energy demand is estimated as 569.44kWh in dry and 402.3958kWh in rainy season with annual energy demand of 176713.32 kWh in the first year and daily energy of 721.8292 kWh in dry and 534.5429 kWh in rainy with annual energy demand of 229008.138 kWh in the tenth year. Also, the total annual demand in the first year is estimated as 54.12 kW and 63.90 kW in the tenth year.

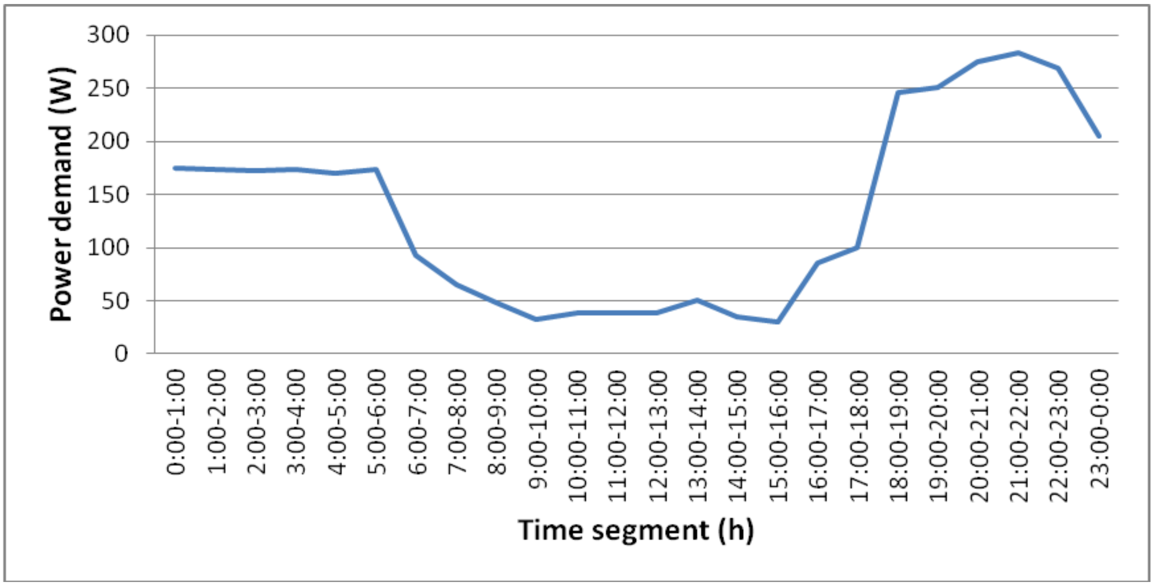

Figure 3: Average Daily Load Profile from the Measured Data

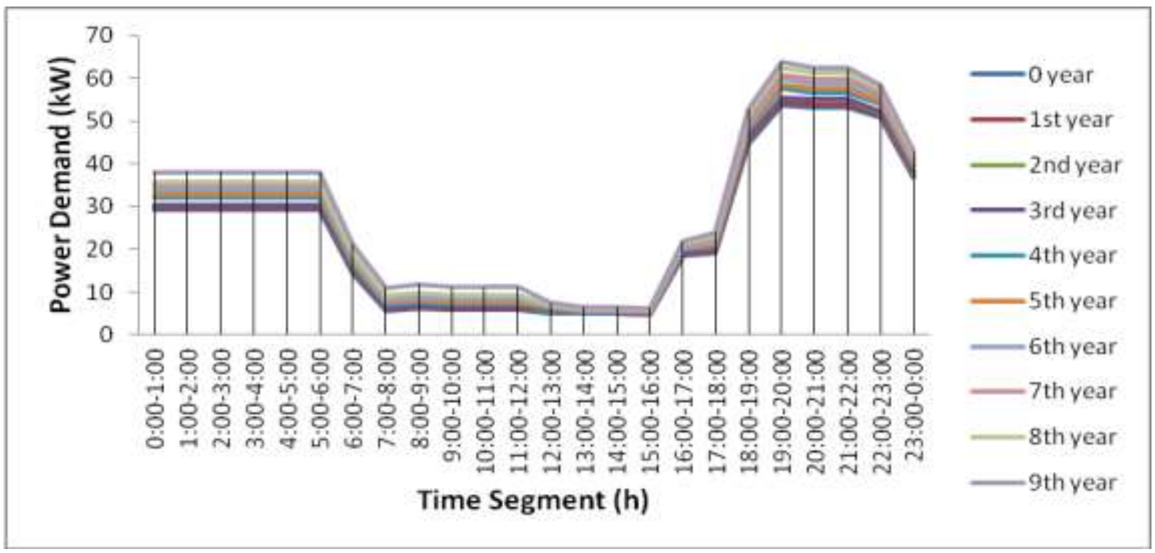

Figure 4: Dry season daily load profile forecast for ten years

Table 3: The results of the bottom up model for the base year

Time Range (Hours)	Elecrical load (kWh)																				Total hourly Electrical Load Demand (kWh) Dry/Rainy
	Household Load					Commercial Load			Primary Health Centre Load					Basic School		Streetlight	Church Load		Mosque Load		
	Bulb	DVD	TV	Fan Dry/Rainy	Misc.	Fridge	Bulb	Misc.	Fan Dry/Rainy	Bulb	Misc.	Fridge	Centrifuge	Bulb	Misc.	LED fittings	Bulb	SRS	Bulb	SRS	
0:00-1:00	8.6	0.4644	0.3784	13.76 /0	3.44	0.875	0.175			0.05		0.125				1.044	0.1		0.2		29.2118/15.4518
1:00-2:00	8.6	0.4644	0.3784	13.76 /0	3.44	0.875	0.175			0.05		0.125				1.044	0.1		0.2		29.2118/15.4518
2:00-3:00	8.6	0.4644	0.3784	13.76 /0	3.44	0.875	0.175			0.05		0.125				1.044	0.1		0.2		29.2118/15.4518
3:00-4:00	8.6	0.4644	0.3784	13.76 /0	3.44	0.875	0.175			0.05		0.125				1.044	0.1		0.2		29.2118/15.4518
4:00-5:00	8.6	0.4644	0.3784	13.76 /0	3.44	0.875	0.175			0.05		0.125				1.044	0.1		0.2		29.2118/15.4518
5:00-6:00	8.6	0.4644	0.3784	13.76 /0	3.44	0.875	0.175			0.05		0.125				1.044	0.1		0.2		29.2118/15.4518
6:00-7:00	8.6	0.4644	0.3784		3.44	0.875	0.175			0.05		0.125					0.1		0.2		14.4078/14.4078
7:00-8:00		0.4644	0.3784		3.44	0.875		0.14	0.16 /0		0.04	0.125	0.12								5.743/5.583
8:00-9:00		0.4644	0.3784		3.44	0.875		0.14	0.16 /0		0.04	0.125		0.15	0.06			0.3			6.1328/5.9728
9:00-10:00		0.4644	0.3784		3.44	0.875		0.14	0.16 /0		0.04	0.125		0.15	0.06						5.8328/5.6728
10:00-11:00		0.4644	0.3784		3.44	0.875		0.14	0.16 /0		0.04	0.125		0.15	0.06						5.8328/5.6728
11:00-12:00		0.4644	0.3784		3.44	0.875		0.14	0.16 /0		0.04	0.125		0.15	0.06						5.8328/5.6728
12:00-13:00		0.4644	0.3784		3.44	0.07		0.14	0.16 /0		0.04	0.01		0.15	0.06					0.6	4.9128/4.7528
13:00-14:00		0.4644	0.3784		3.44	0.07		0.14	0.16 /0		0.04	0.01		0.15	0.06						4.9128/4.7528
14:00-15:00		0.4644	0.3784		3.44	0.07		0.14	0.16 /0		0.04	0.01		0.15	0.06						4.9128/4.7528
15:00-16:00		0.4644	0.3784		3.44	0.07		0.14	0.16 /0		0.04	0.01			0.06						4.7628/4.6028
16:00-17:00		0.4644	14.276		3.44	0.07		0.14	0.16 /0		0.04	0.01			0.06						18.6604/18.5004
17:00-18:00		0.4644	14.276		3.44	0.07	0.35	0.14	0.16 /0	0.1	0.04	0.01			0.06						19.1104/18.9504
18:00-19:00	8.6	2.58	14.276	13.76 /0	3.44	0.07	0.35	0.14	0.16 /0	0.1	0.04	0.01	0.12			1.044					44.72/30.8
19:00-20:00	17.2	2.58	14.276	13.76 /0	3.44	0.07	0.35	0.14		0.05		0.01				1.044	0.1		0.2	0.6	53.82/40.06
20:00-21:00	17.2	2.58	14.276	13.76 /0	3.44	0.07	0.35	0.14		0.05		0.01				1.044	0.1		0.2		53.22/39.46
21:00-22:00	17.2	2.58	14.276	13.76 /0	3.44	0.07	0.35	0.14		0.05		0.01				1.044	0.1		0.2		53.22/39.46
22:00-23:00	17.2	0.4644	14.276	13.76 /0	3.44	0.07	0.175			0.05		0.01				1.044	0.1		0.2		50.7894/37.0294
23:00-0:00	17.2	0.4644	0.3784	13.76 /0	3.44	0.07	0.175			0.05		0.01				1.044	0.1		0.2		36.8918/23.1318
Daily Load	**154.8**	**19.608**	**106.365**	**165.12/0**	**82.56**	**11.34**	**3.325**	**2.1**	**1.92/0**	**0.8**	**0.48**	**1.62**	**0.24**	**1.05**	**0.6**	**12.528**	**1.2**	**0.3**	**2.4**	**1.2**	**569.44/402.3958**
Nov. Load	**4644**	**588.24**	**3190.8**	**4953.6**	**2476.8**	**340.2**	**99.75**	**63**	**57.6**	**24**	**14.4**	**48.6**	**7.2**	**31.5**	**18**	**375.84**	**36**	**9**	**36**	**36**	**17050.53**
Dec. Load	**4798.8**	**607.91**	**3297.16**	**5118.72**	**2559.36**	**351.54**	**103.075**	**65.1**	**59.52**	**24.8**	**14.88**	**50.22**	**7.44**	**32.55**	**18.6**	**388.368**	**37.2**	**9.3**	**37.2**	**37.2**	**17618.943**
Jan. Load	**4798.8**	**607.91**	**3297.16**	**5118.72**	**2559.36**	**351.54**	**103.075**	**65.1**	**59.52**	**24.8**	**14.88**	**50.22**	**7.44**	**32.55**	**18.6**	**388.368**	**37.2**	**9.3**	**37.2**	**37.2**	**17618.943**
Feb. Load	**4334.4**	**549.024**	**2978.22**	**4623.36**	**2311.68**	**317.52**	**93.1**	**58.8**	**53.76**	**22.4**	**13.44**	**45.36**	**6.72**	**29.4**	**16.8**	**350.784**	**33.6**	**8.4**	**33.6**	**33.6**	**15913.968**
March Load	**4798.8**	**607.91**	**3297.16**	**5118.72**	**2559.36**	**351.54**	**103.075**	**65.1**	**59.52**	**24.8**	**14.88**	**50.22**	**7.44**	**32.55**	**18.6**	**388.368**	**37.2**	**9.3**	**37.2**	**37.2**	**17618.943**
April Load	**4644**	**588.24**	**3190.8**	**4953.6**	**2476.8**	**340.2**	**99.75**	**63**	**57.6**	**24**	**14.4**	**48.6**	**7.2**	**31.5**	**18**	**375.84**	**36**	**9**	**36**	**36**	**17050.53**
May Load	**4798.8**	**607.91**	**3297.16**	**0**	**2559.36**	**351.54**	**103.075**	**65.1**	**0**	**24.8**	**14.88**	**50.22**	**7.44**	**32.55**	**18.6**	**388.368**	**37.2**	**9.3**	**37.2**	**37.2**	**12440.703**
June Load	**4644**	**588.24**	**3190.8**	**0**	**2476.8**	**340.2**	**99.75**	**63**	**0**	**24**	**14.4**	**48.6**	**7.2**	**31.5**	**18**	**375.84**	**36**	**9**	**36**	**36**	**12039.33**
July Load	**4798.8**	**607.91**	**3297.16**	**0**	**2559.36**	**351.54**	**103.075**	**65.1**	**0**	**24.8**	**14.88**	**50.22**	**7.44**	**32.55**	**18.6**	**388.368**	**37.2**	**9.3**	**37.2**	**37.2**	**12440.703**
Aug. Load	**4798.8**	**607.91**	**3297.16**	**0**	**2559.36**	**351.54**	**103.075**	**65.1**	**0**	**24.8**	**14.88**	**50.22**	**7.44**	**32.55**	**18.6**	**388.368**	**37.2**	**9.3**	**37.2**	**37.2**	**12440.703**
Sep. Load	**4644**	**588.24**	**3190.8**	**0**	**2476.8**	**340.2**	**99.75**	**63**	**0**	**24**	**14.4**	**48.6**	**7.2**	**31.5**	**18**	**375.84**	**36**	**9**	**36**	**36**	**12039.33**
Oct. Load	**4798.8**	**607.91**	**3297.16**	**0**	**2559.36**	**351.54**	**103.075**	**65.1**	**0**	**24.8**	**14.88**	**50.22**	**7.44**	**32.55**	**18.6**	**388.368**	**37.2**	**9.3**	**37.2**	**37.2**	**12440.703**
Annual Load	**56502**	**7157.35**	**38821.5**	**29886.7**	**30134.4**	**4139.1**	**1213.63**	**704**	**347.52**	**292**	**175.2**	**592.9**	**87.6**	**383.3**	**219**	**4572.72**	**438**	**109.5**	**438**	**438**	**176713.32**

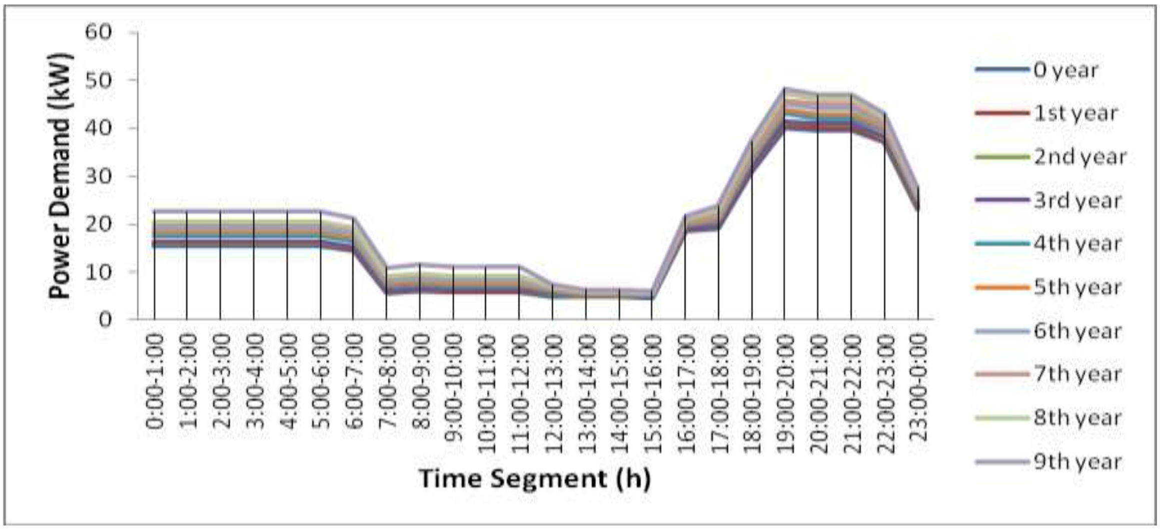

Figure 5: Rainy season daily load profile forecast for ten years

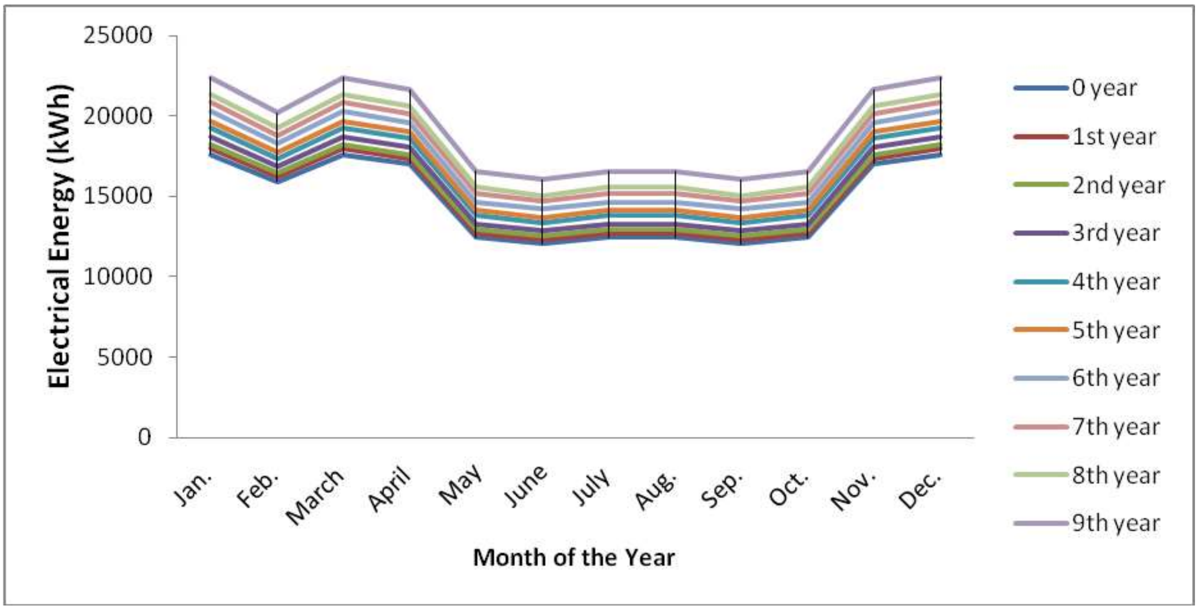

Figure 6: Monthly electrical energy forecast for ten years

3.1Discussions

Results of this study are briefly discussed as follows.

(i) Seven users class were considered for the clusters of three rural communities.

(ii)The measured hourly load profile of a typical rural household that is connected to the grid similar quite well with the simulated hourly load profile. The validation was carried out to study the hourly electrical energy consumption pattern of a typical rural household. This is because detailed information about hourly energy consumption profile for a typical rural household in Nigeria is always unavailable from Distribution Company of Nigeria (DISCO).

(iii)The peak load is usually between 18:00 to 23:00 daily. This is usually because in rural areas farmers do go to farm early in the morning and evening time. The activities that involve active electricity usage (watching films, listening to radio, fan usage) in rural areas are usually between the 18:00 to 23:00.

(iv)It is a common knowledge that as the pattern of the daily temperature and hours of the daylight varies, the hourly, daily and monthly electrical energy consumption on an annually basis will also change. In view of this the seasonal variation was observed in the load profiling as fans are not required in the rainy season of the year.

(v) Usually, there are other external factors that can influence electrical energy demand apart from seasonal factor which are income, educational level, family size among others. Multiple regression analysis was used to investigate various factors that can influence the increase in electricity consumption by a rural household using Minitab 18 statistical software. The results revealed that the rural household annual income, family size and the highest qualification of the rural household cannot explain the variation in number of electrical appliances significantly. The annual increase in electrical energy consumption per rural household was not considered in annual load forecast.
(vi) Unknowing factors which are not certain like local or international events, strange weather condition was not considered. These will be considered in the future works.
(vii)Bottom up mathematical technique is used to simulate the user class load profile. Bottom up model makes use of statistical data for the simulation of electricity consumption. Based on this approach, the overall load demand for the cluster of the three villages is built up from the fundamental load components i.e. the single piece of appliance. The bottom-up method is used to analyze every individual appliance's effect on the overall load demand, which can be of help in the study of smart grid in future.
(viii) End use model was used to make annual energy forecast for ten years. The annual growth rate used for each user class was calculated using the results of local survey on ten years' demographic data for the number of rural households, shops, students in primary school, number of houses, number of mosques and churches.

4.0 CONCLUSION

This paper presented procedure to estimate hourly and daily load profiles using bottom up approach and annual load demand forecast using end use model for rural off-grid dwellers in developing countries. The input data are based on the results of local survey obtained from the similar rural areas that are connected to the nation's electric grid. The procedure is used to estimate load profiles and ten (10) years electrical energy forecast for a cluster of three rural communities located in Ifelodun Local Government Area of Kwara State, Nigeria and the household user class simulated consumption was also validated by comparing the resulting profiles with the measured hourly energy consumption of a typical rural household that is connected to the grid by using FLUKE 434-SERIES II ENERGY ANALYZER for 8 days with a 1hour time step. The annual growth rate used for each user class was estimated based on the result of local survey on ten years' demographic data for the number of rural households, shops, students in primary school, number of houses, number of mosques and churches. The various factors that can influence the increase in electricity consumption by a rural household were also investigated using Minitab 18 statistical software. Additional work needed to be carried out in the future to analyze the uncertainty effects in hourly and daily load profiles on the sizing of off-grid hybrid energy systems.

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