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Electricity Demand Evaluation for Rural Electrification

A Case Study of Kikwe Village in Tanzania

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***Abstract*—The electricity demand for Kikwe village has been successfully assessed. Kikwe village is one of the villages located in remote areas of Tanzania. This village like many other villages in the remote areas has no access to electricity. Electricity demand in Kikwe village has been estimated and classified into residential load, community load, commercial load, and small-scale industrial load. Energy demand evaluation has been conducted by End-Use method. The total daily energy demand for each load category was determined to be 601.335 kWh, 54.425 kWh, 70.01 kWh, and 31.254 kWh for residential, community, commercial, and small-scale industrial load respectively. The total daily energy demand for the whole village was found to be 757.024 kWh. Daily peak load has been found to be 56 kW while lowest load is 5Kw per day. Daily average energy demand per small-scale house was approximated to 1.2 kWh, which is equivalent to a monthly average of 36 kWh units. Daily average energy demand for one customer for the entire village has been estimated to be 1.49 kWh which is equivalent to monthly average of 45 kWh units.**

Keywords—Electricity Demand; Load Classification; Daily Load Profile; Energy Forecasting

I. INTRODUCTION

Electric load in any distribution system changes with time and area. Energy generation and distribution systems react to customer's load demand instantly. As such, the electric supply should meet customer's electricity need without compromising the optimum cost. Load demand estimate is an important aspect in planning and successful implementation of energy generation, transmission, and distribution [1], [2]. Studies on electricity demand forecasting from electrical energy systems began in 20th century [1]. Before this period demand forecasting was not a major issue both in developing and developed countries due to low electricity demand. Although forecasting medium and long term electricity demand is now well established and approved in developed countries [1], forecasting electricity demand in a fast growing economy is still a big challenge due to the rapid changes in facilities. Electricity demand is determined by major factors such as gross domestic product (GDP) prices and population [1]. Methods like auto–regressive (AR) algorithm, moving average (MA) algorithm, auto–regressive moving average (ARMA) algorithm and auto–regressive integrated moving average (ARIMA) algorithms were produced[1],[3].

Tanzania population is estimated to be 46 million out of which about 80% live in rural areas while the reminder (20%) live in urban areas. The 80% living in rural areas is not connected to the national grid and thus has no access to electricity. The aggregated installed capacity in Tanzania is 1129 MW, 50% of which is from thermal power plants, 49% from hydro- electric power sources, and 1% from co–generation [4]. This capacity is not enough to serve both rural and urban population. Moreover, the total capacity of the national grid is limited by poor conditions of the power generation systems and long-standing drought [5], [6] compounded with the high consumption rate that has been report to be growing at a rate of 11 to 13% [7].

Most of the rural areas in Tanzania are sparsely populated and this makes national grid extension to these areas economically unviable [8]. Off grid electric systems based on renewable energy sources present a huge promise for these areas [9]. However, the deployed of any renewable energy system, for instance wind turbine, in any given area is informed by good electricity/energy demand data. Currently, there is little or no electricity demand data for most of the remote areas in Tanzania.

Kikwe village in Meru district was taken as the case study for it as one of the least electrified villages in Tanzania. The village is sparsely populated and therefore national grid extension is not economically viable even in the near future. The aim of this paper was to estimate electricity demand at Kikwe village. End –Use Method was used for the task [10].

II. AREA OF STUDY AND METHODOLOGY

A. *Area of Study*

Kikwe village is one of 26 the villages that constitute Meru District (Formerly Arumeru District) which is located at 3º24´S and 36º48´E, and is about 20 km East of Arusha City in Tanzania. Kikwe village has three sub–villages, namely, Malala, Huduma, and Luwaini. Kikwe village has a population of 2334, of which 1118 are men and 1216 are

women. According to the village executive office, Kikwe village has total area of 4800 acres out of which residential area covers 500 acres and 3500 acres are for agriculture activities. The remaining portion of 800 acres has been reserved for pastoralist purposes. Kikwe village has 483 households. The major income generating activities in this village are agriculture and livestock keeping. At present, villagers use kerosene lamps, disposable batteries; rechargeable batteries, candles, small single phase diesel generators and few small solar house systems for lighting. A few of these energy sources sometimes are used as power sources for entertainment and communication purposes. Traditional biomass such as firewood is used as a fuel for cooking.

B. Methodology

The survey of the electricity demand for Kikwe village was based on the appliances possessed by households in the village. Primary data on energy requirement were obtained by structured interview from the stakeholders in the village like village executive officer, school leaders, religious leaders and other villagers. These data were also collected by visiting homes, schools, churches, shops, groceries, and small local bars. For good judgment on equipment installation requirement, secondary data such equipment ratings were obtained by searching in the internet, appliances owned by some customers, few were found by visiting few available existing solar house systems available at Kikwe village. Table 1 below indicates types of consumers that are available in the village.

Load analysis was performed by using End –Use Method [10]. The method was selected due to limitations of data availability. This method involves customer's appliances ownership application. This method entails power rating of the appliances and their time of operation. Load analysis may be obtained from Load = power rating of appliance (W) x Time (h).

Individual load was calculated based on the number of customers present in a category. Lighting points were classified according to the sizes of the premises. Conservation of energy was also considered by using energy saving lamps. Indoor lighting was assumed to operate for 5 h between 6 pm to 10 pm and 6 am to 7 am while outdoor lighting was considered to operate for 12 h starting from 6 pm to 6 am. In this study, lighting for street lights was neglected so as to reduce generation costs.

- Residential load

Load analysis in this particular category was performed by using common domestic appliances in rural communities that are used mainly for lighting, entertainment, and communication purposes. Appliances such as fluorescent tubes, energy saver lamps, TV sets, radio sets, mobile phone charger and iron boxes were considered in determining electricity demand for Kikwe village.

In order to establish the electricity demand for residential two assumptions were made: First, a small scale house for rural community was assumed to be a four roomed family house one for the parents the other two for children that is girls and boys the fourth one is for sitting room and all households were assumed to have same energy requirement. Secondly, all houses for the whole village were considered to be connected to energy supply.

- Community load

Community consumers included dispensary, village executive office, primary school, secondary school, churches, and mosque. Load assessment profile for individual consumer was established according to the size of the building and energy requirement by the prospective consumer.

- Commercial Load

Commercial consumers included grocery, bars, shops, saloon (female), and Barber shop (male). Load analysis of each establishment was also performed using appliance ownership method. The appliance ownership was based on size of the establishment.

- Small-scale industrial load

Small-scale industrial load in this study included a small size training workshop used by Kikwe Lutheran for the trades such as carpentry, electricity demand profile. Computer room was estimated to have a capacity of 20 students. Electrical laboratory had 1 testing bench, single-phase induction motor and one three-phase induction motor for experiments. On the other hand, the carpentry section of the workshop had 1 lathe machine and combined machine curving and cutting activities and other associated tools.

TABLE I. LOAD CLASSIFICATION AND NUMBER OF CONSUMERS AT KIKWE VILLAGE

Type of load	*Consumer*	*Quantity*
Residential	Small house	483
	Medium house	-
	Large house	-
Community load	Dispensary	1
	Village office	1
	Primary school	1
	Secondary school	1
	Churches	3
	Mosque	1
Commercial load	Grocery	4
	Bar	2
	Shop	4
	Female salon	3
	Barber shop (Male)	3
Small-scale industrial load.	Small workshop	1

III. RESULTS AND DISCUSSIONS

Fig. 1 shows that peak electricity demand of 56 kW occurred between 6 am and 7 am. During this time, residents of Kikwe village are awake and electric lights, television sets, refrigerators, radio sets and flat irons are turned on. Fig. 1 also indicates that 50 kW is demanded from 6 pm to 7 pm. This amount of power is less than peak value because during this time period, offices and business establishments are closed thus lighting and other power services are switched off. Lowest electricity demand of about 5 kW occurred between 11 am to 12 noon and from 5 pm to 6 pm at this period of time residential load is low because villagers are out for work. Daily energy demand for residential, community, commercial and small-scale industrial premises was found to be 601.335, 54.425, 70.01, and 31.254 kWh, correspondingly, see Table II.

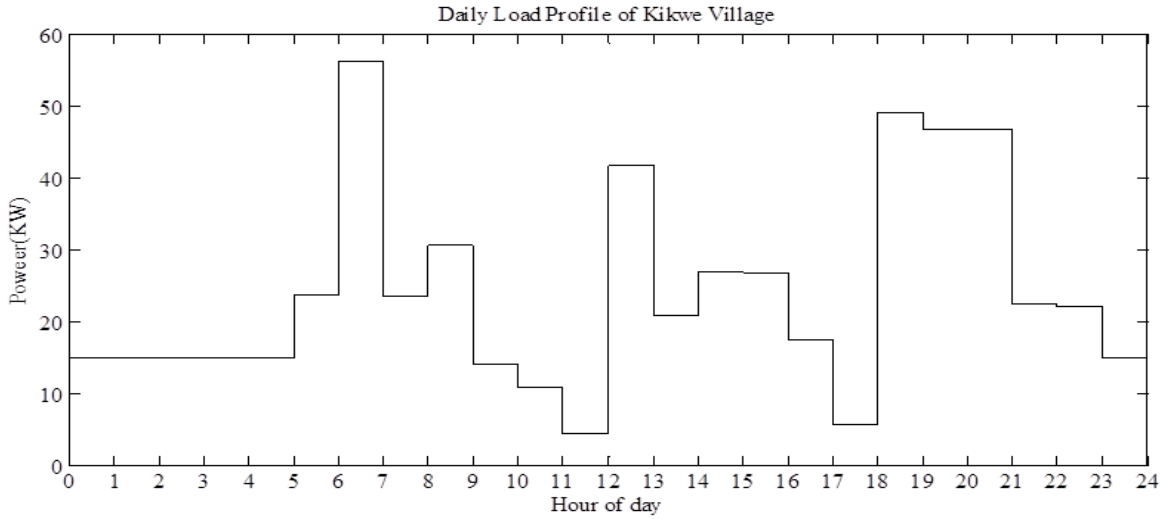

Fig. 1. Daily load profile for Kikwe village

TABLE II. SUMMARY OF DAILY ENERGY DEMAND ACCORDING TO LOAD CLASSIFICATION AT KIKWE VILLAGE

Load classification		
	Daily energy demand (kWh)	Daily demand in percentage (% of total daily energy demand)
Residential	601.335	79.4
Community	54.425	7.2
Commercial	70.01	9.34
Small-scale industrial	31.254	4.1
Total	757.022	100

Residential load, which consisted of 483 households, was estimated to be 601.335 kWh. This translated to a daily average load demand per household of 1.2 kWh that is equivalent to a monthly average 36 kWh units. Table III shows that energy requirement for the household load was the highest while the total electricity demand for public load was found to be 54.425 kWh. This category comprises customers such as 1 dispensary, 1 village executive office, 1 primary school, 1 secondary school, 3 churches and 1 mosque. Secondary school was found to be the largest consumer with daily energy requirement of 36480 kWh while the least consumer was the village executive office with daily energy consumption of 370 kWh. Energy demand for commercial load was estimated to be 70.010 kWh.

Commercial load consisted of 4 groceries, 2 local small bar, 3 female salons, 3 male salons and 4 small shops. It was observed that small shops were the largest consumers in this load category with daily consumption of 23.64 kWh while the lowest consumer was the male salons with daily energy consumption of 4.32 kWh.

Small industrial load, which included 1 computer class, 1 electrical laboratory, and 1 small carpentry workshop, had daily energy consumption of 31.254 kWh. In this category, electrical laboratory showed the highest (14.13 kWh) daily energy consumption while carpentry workshop was the lowest (7.59 kWh).

Carpentry workshop showed the lowest consumption since most of work was done manually. Total energy demand for the whole village was estimated to be 757.022 kWh. From Table 1, there are 508 total customers in the village (483 household customers, 8 community customers, 16 commercial customers and 1 small-scale industrial customer). This translates to an average daily energy demand per customer of 1.49 kWh units. This amount is equivalent to a monthly average energy demand of 45 kWh units per consumer. The total electricity demand did not include power losses.

TABLE III. AGGREGATED MAXIMUM DAILY LOAD DEMAND ESTIMATE FOR KIKWE VILLAGE

Load classification	Type of customer	Number of customers	Wattage per customer (W)	Energy per customer (Wh)	Total wattage (w)	Total energy (Wh)
Residential Load	Small-scale households	483	1160	1245	560280	601335
Public Load	Dispensary	1	1500	5600	1500	5150
	Village executive office	1	115	370	115	370
	Primary school	1	785	1935	785	3035
	Secondary school	1	1875	36480	1875	36480
	Churches	3	4075	5480	4075	5480
	Mosque	1	1635	3910	1635	3910
Commercial Load	Grocery	4	545	5810	2180	23240
	Local small bar	2	595	6000	1190	12000
	Female salon	3	250	2270	750	6810
	Barber shop	3	185	1440	555	4320
	Small shop	4	530	5910	2120	23640
Small- Industrial Load	Computer class	1	1360	9530	1360	9530
	Electrical laboratory	1	12035	14130	12035	14130
	Carpentry small workshop	1	2572	7594	2,572	7594
	Total					757022

IV. CONCLUSION

End–Use Method has been used successfully to estimate the electricity demand for Kikwe village for the year 2014. The method has taken into account several aspects such as type and number of consumers, equipment and expected time of operation for the appliance. Daily electricity demand for Kikwe village was found to be 757.024 kWh. Peak electrical load demand of 56 kW occurred between 6 am and 7 am while lowest load demand of 5 kW occurred between 11 am to 12 noon and from 5 pm to 6 pm. Lack of recorded data on energy requirement especially in rural areas is among of the challenges of rural off-grid electrification in Tanzania. Thus, availability of this information is important for rural off-grid electrification programs at Kikwe village. Residential premises were found to have the highest electricity consumption, taking 79.4% of the total estimated daily energy demand. Small-scale industrial energy requirement is the lowest 4.1% of total daily energy demand. Monthly average energy per household customer is 36 kWh units while monthly average for all customers in the village is 45 kWh units.

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REFERENCES

[1] B. Q .Lin and P. F. Quising, “Electricity demand in the People's Republic of China investment requrement and environmental impact “, Asian Development Bank, vol.37, 2003.

[2] A. Seppälä, “ Load research and load estimation in electricity distribution”: Technical Research Centre of Finland, 1996.

[3] L. A Greening ,D.L. Greene and C.Difiglio , “ Energy efficiency and consumption—the rebound effect—a survey”, Energy policy, vol 28, no 6, pp.389-401,2000.

[4] S. Kihwele, K. Hur and A. Kyaruzi, “Visions, scenarios and action plans towards next generation Tanzania power system”. Energies, vol.5,no.10,pp 3908-3927, 2012.

[5] F.Gwang’ombe and N. Mwihava, “Renewables in Tanzania, Status and Prospects of Biomass-based Cogeneration and Geothermal Technologies”, Afrepren Occasional Paper, 2005.

[6] J. Ondraczek, “The Sun Rises in the East (of Africa): The Development and Status of the Solar Energy Markets in Kenya and Tanzania”. Paper presented at the 2nd Symposium Small PV-Applications, Ulm, June, 2011.

[7] M Msyani,” Current status of energy sector in Tanzania: Executive exchange of developing an ancillary service market”, from http://www.google.com, Feb-March 2013.

[8] G. Kassenga, “The status and constraints of solar photovoltaic energy development in Tanzania”. Energy Sources, Part B,vol.3, no.4,pp.420-432, 2008.

[9] K.T.Kabaka and F. Gwang’ombe, “Challenges in small hydropower development in Tanzania: rural electrification perspective”. Paper presented at the International Conference on Small Hydropower–Hydro. Sri Lanka, 2007.

[10] R.Banerjee, R.Pandey, Bhure, A., and S. Phulluke, “Electricity demand estimation for village electrification”. Paper presented at the Proceedings of National Renewable Energy Conference, IIT Bombay, Nov 2000.