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DESIGN OF A COST-EFFECTIVE GRID-BASED RURAL ELECTRIFICATION PLAN FOR EYINWA VILLAGE, ODOGBOLU LOCAL GOVERNMENT, OGUN STATE

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Abstract: Access to energy has been a challenge in many regions of Africa. This research employed grid-based technique to design and analyse rural electrification in Eyinwa Village, Odogbolu, Local Government, Ogun State, Nigeria. A fifteen years load growth was calculated for future expansion using a linear mathematical model based on household data of the area. Design equations were used to evaluate actual ratings and quantities of injection transformers, substation transformers (load points A, B, C), length and sizes of cable and other accessories that were required for the electrification design. The proposed electrical model design for the Village was implemented using ArcGis Software. The results showed that the electrical energy demand of Eyinwa Village was 1.35 MW and the calculated fifteen years load growth was 4.83 MW using a load factor of 0.4. The load analysis showed that 2.5 MVA injection transformer substation with a 60% loading capacity to feed three 500 kVA distribution transformers were needed for the electrification of the study area. The inter-township connection and township distribution network lengths were determined as 11.04 and 19 km, respectively. The voltage drop of the distribution transformer load points A, B and C were 3, 0.7 and 0.2%, respectively of the nominal voltage. With an assumed transformer loss of 1% of the nominal rating, the power losses estimated at these load points were 0.056MW, 0.008MW and 0.0016 MW, respectively. These results indicated that the electrification is feasible with minimal power loss and provides an implementable scheme for electrifying the area.

Keywords: Electrification, Grid-Based, Transformer, Network, ArcGis

1. Introduction

Electricity is of critical importance to human development, quality of life and welfare such as basic activities like lighting, refrigeration and running household appliances (Adeleke, 2022). Access to electricity can significantly aid in reducing poverty in rural areas. Unfortunately, ensuring that these services reach the people who need them most is still a huge challenge. It's especially difficult in developing countries, where a significant part of the rural population still lacks access to electricity (Lillo *et al*., 2021).Duer and Christensen (2010) as well as Kanagawa and Nakata, (2007) in their studies submitted that access to electricity is a key element in driving socio-economic development in a country. Every country's ability to thrive economically sustainably depends on having an adequate supply of energy. Without substantial access to energy, a nation cannot develop past the point of sustenance (Ohunakin 2010). Due to limited transmission lines, government efforts to electrify rural areas in Nigeria have stopped, leaving rural areas with an uneven distribution of electricity and a relatively low voltage profile. Future growth (social and economic) in rural areas has been hampered by inadequate access to and facilities for electricity. The country's poverty rate has therefore increased due to a lack of power in rural areas (Borhanazad *et al*., 2013; Nnaji *et al*., 2012).

Planning rural electrification is made easier by integrating basic geographic information using a Geographic Information System (GIS). Energy system tools are helpful because they can represent complex systems and aid extensive computations and analyses of the systems (Hiremath *et al*., 2007). Geographic information are considered in developing a geospatial information system to obtain the best possible electrification planning and strategies. Data like sunshine hour/irradiance, wind speed, slope, land use-land cover, protected areas, water bodies, forest, and towns are collected and analyzed (Taye *et al.*,2020). Many researchers viewed the concept of rural electrification from different perspectives. Corigliano *et al*. (2020) developed an iterative minimum path algorithm for mini-grid and existing national grid electrical networks connecting clusters with minimum cost. Their effort is termed holistic geospatial data-based procedure for electric network design and least-cost energy strategy.Thomas *et al*. (2020) worked on the effects of rural electrification in India. According to their research, legal electrification in the Bahraich district of Uttar Pradesh has a beneficial effect on household spending, adult household activities, and the ownership and use of equipment. This was found in an initial survey of 686 homes spread among 120 habitations. Nnaji *et al*. (2019) while modeling smart microgrid for rural electrification in sub-Saharan Africa: the case of Nigeria, investigated a smart microgrid's potential for Nigeria's off-grid rural electrification. A model was developed and an appropriate microgrid configuration was chosen by combining design thinking with a model-based design approach. The Simulink model was created for a system that included a diesel generator, batteries for energy storage, and a solar photovoltaic array. The model's performance was verified using data from ten rural villages in Nigeria, and demand management was also taken into account. The outcome showed that the case study communities' peak electricity usage was decreased from 42 to 76% when energy-efficient light bulbs were used. This research employs modern tools to draw up electrification plan for a rural community located in a developing country like Nigeria.

2. Materials and Method

2.1 Design Procedure

In designing an efficient grid–based rural electrification model for Eyinwa Village, the flow chart of activities making the methodology is represented in Figure 1. Each of the stages is described beginning with survey and analysis stages.

2.1.1 Survey and Analysis Stage

This stage of the research work, the community was visited to observe the conditions, which entails; checking their topographies, and determining the quantity and characteristics of consumers (household, agricultural, industrial or commercial users).

2.1.2 Load Estimation Stage

In this stage, the consumers' loads were estimated and analysed through the use of tools such as personal contact that is oral interview. These buildings were grouped in clusters after which load estimations and calculations in turn is used in determining the energy consumption (in watts) of the community. An estimated energy requirement was considered to cater for future expansions know as load growth expressed in percentage.

2.1.3. System Configuration Stage

In this phase of the project, the supply system (three phase system 33 kV or 11 kV) needed to supply community is given a thorough consideration. At this stage, transformer point locations as well as the characteristics of primary lines and route design were determined. Also, voltage drop which is one of the important considerations in optimal electricity design was given consideration to obtain the temporary electrical design model of the community. More so, the supporting structures locations for the distribution line route was selected based on where: easy access for maintenance, firm and stable soil condition. free land acquisition, no adverse effect on buildings, trees, etc., shortest distribution route.

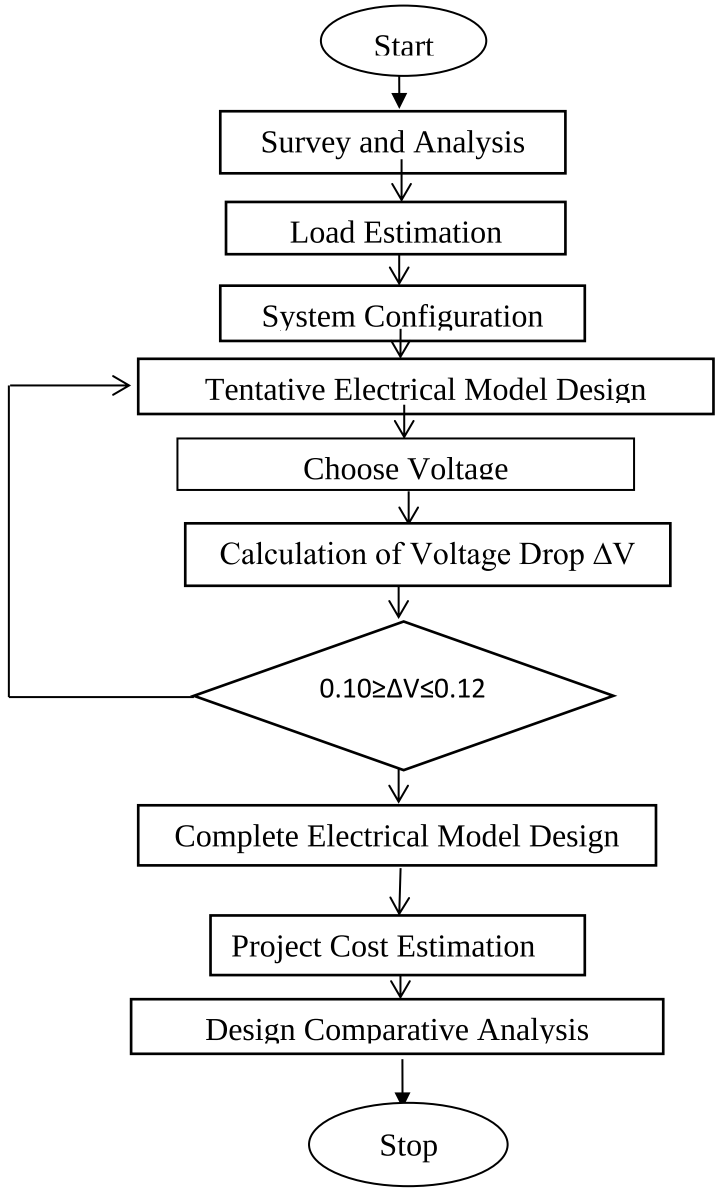

Figure 1: Flow of activities involve in the design of electrification plan

2.1.4. Tentative electrical model Design

This stage involved the selection of voltage, appropriate resistance and reactance of a conductor. This is dependent on the current carrying capability of the conductor. A conductor's resistance is inversely proportional with its cross-sectional area and directly proportionate to its length. Power transmission is done at high voltage but moderate current to minimize transmission losses, particularly over long distances.

2.1.5. Complete Electrical Model Design Stage

This stage entails the development of the complete electrical design models of the rural community based on the total estimated load capacity and the considered supply system with all it auxiliaries. This stage leverage on tentative model designs.

2.1.6. Implementation of computer model

This stage involved the use of the computer model which serve as a decision support tool for the evaluation of the cost of components needed for the optimal implementation of the electrification design plan for the community, based on the current market prices of these components. All other overhead costs apart from components costs were also considered. The model computes precise demand estimates for the community in a dataset by combining data on population, other socioeconomic factors, and geographic information.

2.1.7. Design Analysis Stage

This stage of the research work involved drawing of conclusion on the electrification plan for the community in terms of the cost of rural electrification implementation to provide useful suggestions on the relative ease of electrifying Eyinwa.

2.2. Design Equations

This section presents essential equations employed for designing Eyinwa village electrification plan. Taking into account the estimated load demand of every residence in the Village.

2.2.1. Load Estimation

The total amount of energy needed for Eyinwa Village, P_{erv} in kilowatt (kW) of the village was calculated using equation 1 (Oyejide *et al.*, 2014).

$$P_{erv} = n \times P_h \quad (1)$$

where

$P_h is$ the kilowatt (kW) energy requirements of a household

$nisthen$umber of households (with other energy consumers) in the given village

A modification is made to equation (1) because there is an expected increase in load over the years known as load growth. Thus, a total of 30 % allowance is provided for load growth, the energy requirement, P_{er} in kW is given by equation (2).

$$P_{er} = 1.3\sum_i^N P_{ervi} \quad (2)$$

Equation (2) was further broken down to make provision for three phases of load growth with percentage growth of 15, 10 and 5% respectively, catering for the first, second and third growth periods. Consequently equation (2) was modified as equations (3) to (5) (Oyejide *et al.*, 2014):

$$P_{er1} = 1.15\sum_i^N P_{ervi} \quad (3)$$

For the first phase of 15 % growth

$$P_{er2} = 1.10\sum_i^N P_{ervi} \quad (4)$$

For the second phase of 10 % growth

$$P_{er3} = 1.05\sum_i^N P_{ervi} \quad (5)$$

For the third phase of 5 % growth

2.2.2 Sizing of Distribution Transformer

Equation (6) was utilized to determine the distribution transformer's size in order to service N houses existing in the village (Gupta, 2011).

$$S = \frac{P_{ergp}}{cos\Phi} \quad (6)$$

Where

S is the kVA rating equivalent of the energy demand

P_{ergp} is the total load demand at a given growth period and $\cos\emptyset$ is the Power factor

The ratio of average demand to the maximum demand during a certain period of time which could be a day, month or year is the load factor.It is typically much lower than unity and quite low for rural communities. It is expressed by equation (7) (Gupta, 2011):

$$\text{Load Factor} = \frac{\mathrm{D_{ave}}}{\mathrm{D_{max}}} \quad (7)$$

where, D_{ave} is average demand in kW and D_{max} is Maximum load also in kW

2.2.3 Sizing of Cable

The rated current, I, of the primary and secondary sides in amperes of each distribution transformer to service the village is determined with the following equations (8) and (9) (Gupta, 2011):

$$I_p = \frac{kVA}{\sqrt{3}V_p} \quad (8)$$

$$I_s = \frac{kVA}{\sqrt{3}V_s} \quad (9)$$

where, I_p , I_s are primary and secondary currents respectively;
V_p and V_s are corresponding voltages respectively.

The feeder pillar unit rating was determined after the transformer current rating was known. The secondary current output of the transformer was used in determining this.For the purpose of ascertaining reliability and quality of the distribution model that was proposed, voltage drop was determined. at various load points. In determining that mathematical equations were used,which were presented in the following section.

2.2.4 Determination of Voltage Drop

Voltage drop,V_D in a distribution line in per unit (p.u.) is dependent on the length of the conductor and resistance among others. It is determined by the equation (10) (Lakervi and Holmes 1995);

$$V_D = \frac{P_{erv}R + Q_{erv}X}{V^2} \quad (10)$$

where V_D is Voltage of the distribution in Per unit (p.u);Q_{erv} is Overall reactive energy requirement of a given village (kVAR); R is resistance of the selected conductor size for the distribution line in Ω/km; X is reactance of the selected conductor size for the distribution line in Ω/km; L is length of the distribution line which corresponds to the distance of a village from serving substation in kmandV is base value of the voltage of supply system in kV.

P_{erv}, Q_{erv} and S_{erv}, which are the kVA equivalent of the energy requirement of a village are related by equations (11) and (12):

$$P_{erv} = S_{erv}\cos\emptyset \quad (11)$$

$$Q_{erv} = S_{erv}\sin\emptyset \quad (12)$$

With the use of equations (10), (11) and (12), highlights of the steps for the determination of voltage drop are as follows:

i. Assume, the power network has no loss and choose a voltage level 11 kV
ii. Determine the voltage drops at the load point.
iii. Compare the value of V_D with the 10-12 % of the chosen 11 kV. If higher choose 33 kV voltage level and re-compute V_D, otherwise go to the next step.
iv. Compute V_D for all lines and ensure compliance of less than 10-12 % of nominal voltage level chosen.
v. Determine the actual voltage drop on the network as well as power loss.

2.2.5 Determination of Power loss

Power loss was determined after the distribution lines satisfy the condition of having values of voltage drop that is less than 10-12 % of nominal voltage supply.

Power loss, $\Delta S = /I/^2 \times /Z/ \times L$ (kVA) (13)

While $\Delta P = /I/^2 \times R,$ (14)

$\Delta Q = /I/^2 \times X$ (15)

But $/I/ = \frac{/S/}{/V/}$ (16)

$$\Delta S = \left[\frac{/S/}{/V/}\right]^2 \times /Z/ \times L \quad (17)$$

Assume transform losses to be 1% of normal rating

$$\Delta S_T = 1\% \quad (18)$$

2.4 Design Configuration

An optimal design ensures the supply of service under adequate technical conditions and at minimum cost. In distribution design there exist two feeder system of load distribution namely the radial and loop. The radial system is considered in this research as it is the simplest and cost-effective system of power distribution. Figure 2 is the diagram of a typical radial system.

2.4.1 Design Considerations for Injection Substation Elements

In this study, the substation of concern is that of injection and distribution substations. An injection substation steps down a high voltage to a low voltage especially for transmission in densely populated area. The transformers involved in the injection substation is usually in the MVA range so that the output can serve a large consumer while a distribution substation is a power system subsidiary station whose purpose is to receive energy transmitted at high voltage from the transmission stations, reduce the voltage to a value appropriate for local distribution and provide facilities for switching (Gupta, 2011). A substation is required to be located at the load centre to reduce energy loss during distribution. The soil texture where a substation is to be erected should be critically studied to ensure firm erection of the substations poles. The ground area for the substations must of a level plain. This is because the substation should not be sited where it is prone to

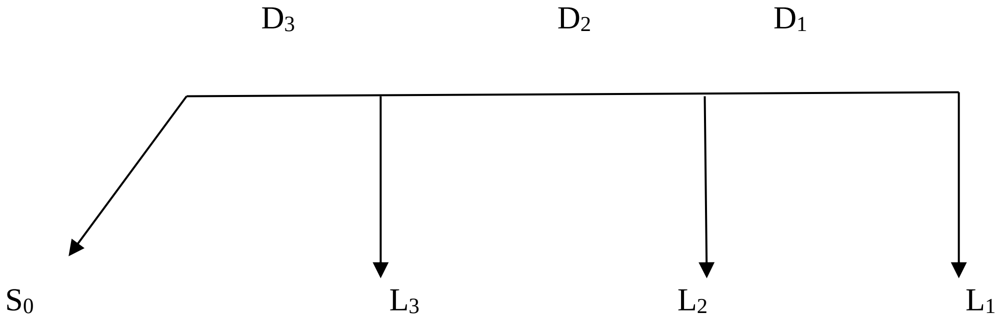

Figure 2: A Typical Radial Line Distribution System Configuration

NOTE: S_0 is Transformer rating of source (MVA)
L_1, L_2, L_3 is the distribution transformer load points (kVA) and D_1, D_2, D_3 is Distances between transformers (km)

3. Results and Discussion

3.1 Collected Data

Data was collected to facilitate the estimation of the load demand in Eyinwa, many factors were considered and these included mainly the type of buildings, usage and peculiarity. For all the building types, lighting and power loads were given priority. Table 1 show the total number of structures in Eyinwa village.

Table 1: Total Number of Structures in Eyinwa village

S/N	Category of Buildings	Numbers
1	Bungalows	260
2	Shops	25
3	Nursery /Primary School	4
4	Churches	4
5	Mosques	2
6	Mini Industries	5
	TOTAL	300

3.2 Results

The Rural electrification plan of Eyinwa village was carried out using ArcGIS. Part of ARCGIS tools entails getting the population density of a community, Figure 3 gives the UN-adjusted population density for Nigeria in person per km^2 as obtained from ESRI (ARCGIS) database. This data can then be used for rural electrification purpose, if the population of a community is known; hence, estimation of the energy demand becomes easy.

Highway data is therefore required for network planning to extend the grid to new electrification areas. The dataset captured through ARCGIS for road mapping of Eyinwa village is given in Figure 4 and 5. Proper planning is essential for electrification projects, of which overhead line routes are one of the most important components.

Figure 3: The ARCGIS GPWv4 UN-Adjusted Population Density 2015 for Nigeria.

Figure 4: The ARCGIS Topographic View of Eyinwa Village

Figure 5: Map of Road View of Eyinwa Vilage

3.3. Choice of Network

Household placements, land cover, slope, and proximity to highways are the four variables that need to be taken into account when routing a new network. Utilizing a raster based on these four criteria allowed for the computation of a cost-weighted route from the network and the shortest path from the closest accessible grid. As seen from the distance triangulation in Figure 6, from Ikenne 33 kV feeder to Eyinwa village, the shortest path is 14.85km but it is not cost effective. This triangulated distance and land cover if used will require a lot of trees cutting and path grading as it is not close to road route. The road route network from Ikene to Eyinwa village, the road map is given in Figure 7. The distance from Ikene transmission station to Eyinwa village is

18. 34km.The proposed Injection station is fed from the existing 33kV feeder from Ikene which passes through Aiyepe in Odogbolu local government. The inter- township connection between Aiyepe and Eyinwa is at distance 11. 07km.The 33 kV feeder were stepped down to 11 kV at the outskirt of Eyinwa after it met the voltage drop requirement.

Figure 6: ARCGIS Distance triangulation from Ikenne to Eyinwa Village

Figure 7: Road Route Map from the Nearest Available grid network

3.4 Load Estimation Stage

An estimated energy requirement was considered to cater for future expansion known as load growth expressed in percentage. Since Eyinwa village consists of two hundred and sixty households, two churches, two mosques, four nursery and primary schools and five mini-industries coupled with the fact that the dwellers are peasant traders and farmers. Consequently, determining the maximum demand would be the first step in estimating load; given an installation or system, the total of all demands that have surfaced within the allotted time span is the maximum demand (Gonen, 2014). The peak load period would be between 5pm to 9pm after which the traders and farmers are back home from their respective activities in order to consume electric power. The estimation of the load is for 260 households; Figure 8 gives the building clusters with ARCGIS. The estimated loads are given in Tables 2. Because the village is situated in a rural area, energy savings bulb might not be used as the level of energy savings consumption awareness might be lower.

Figure 8: ArcGIS generated Building Cluster of Eyinwa Village

Table 2: Total load demand of Eyinwa

S/N	Category of buildings	Number of buildings	Estimated consumption per category of buildings (kW)	Initial total load demand per category of buildings (kW)
1	Bungalow	260	4.77	1,240.2
2	Shop	25	1.30	32.5
3	Nursery/Primary school	4	3.9	15.6
4	Church	4	6.00	24.0
5	Mosque	2	3.7	7.4
6	Mini industry	5	5.36	26.8
	Total			1,346.5

3.5 Load growth

The future load consumption in fifteen (15) years of the community was estimated based on the calculated initial total load demand of Eyinwa with a 30% allowance. It was determined that the community will see a 5% increase in load throughout the years 11 through 15. The fifteen (15) years load growth is presented in Table 3.

Table 3: 15 years load growth of Eyinwa Village

Period (yrs)	Percent (%) increase in the load demand	Expected load demand (kW)
1		1,346.5
3	15%	1,779.5
7		2,844.5
8	10%	3,128.5
9		3,440.5
10		3,789.5
13	5%	4,379.5
14		4,597.5
15		4,826.5

In this study, a load factor of 0.4 was used to cover for unforeseen circumstances. An average load demand of Eyinwa Village was determined as 1930.6 kW.Therefore, the estimated apparent power for the determination of injection substation transformer capacity was calculated using equation 6 as:

$$Average\ load\ demand\ of\ Eyinwa\ in\ kVA = \frac{1{,}930.6}{0.8}\ kVA$$
$$= 2{,}413.25\ kVA$$

Where value of power factor of 0.8 is adopted.

3.6. Estimated elements of the Injection substation

Based on the load data calculated the transformer chosen was an outdoor transformer. The village is rocky and naturally cool and will enhance the transformer performance. As a consequence, a 2.5MVA; 33/11KV outdoor type design was proposed. The primary and secondary current of the injection substation were estimated as 43.74A and 131.23A respectively.The estimated elements of the injection substation are shown table 4 below:

Table 4: Estimated Injection Substation Elements

S/N	ELEMENTS	RATINGS
1	Rated primary current Rated secondary current	43.74A 131.23A
2	Lightning arrestor	330V
3	Rating of Isolator	43.74A

4	High tension fuse	43.74A
5	11kV Voltage circuit breaker 33kV Voltage circuit breaker	163.03A 54.67A
6	AAC HV Cable rating	43.67A
7	Earth conductor rating	21.87A
8	Control panel size	164.03A

3.6.1 Transformer and Feeder Pillar Sizing

The load demand in kVA was determined as three 500 kVA distribution transformers for Eyinwa village. The rated primary and secondary currents for the 500kVA transformer were calculated as 26.24A and 695.60 A, respectively. Given that the 500kVA transformers rated secondary current outputs is 696A, this research recommends an 800A feeder pillar with 4-way distribution units.

3.6.2 Conductor and Cable Selection

Based on the calculated rated primary and secondary currents for 500 kVA transformer, it is recommended that 70mm^2 AAC conductor (all aluminium conductor) be chosen as the conductor for distribution and transmission, so as to reduce transmission losses especially over a long distance. The recommended cables that connect the secondary sides of the transformer 500 kVA to the feeder pillar, is 500mm^2 cable since the rated secondary current is 696 A. Also, for the connection of the feeder pillar to the low-tension line (up-riser), it is also recommended that 4 x 185mm^2 insulated PVC sheathed 4 core-armoured cables be chosen since the current per unit of the feeder pillar for 500 kVA transformer is 174 A.

3.6.3 Consideration of Substation Components

The summaries of the estimated number of components and cost analysis (BEME) required for the transformer injection substations, 11 kV high tension lines and 400V low tension lines for the electrification of Eyinwa is presented in Tables 5 while figure 9 shows the map of Eyinwa village with the transformer distribution.

3.6.4 Other Accessories: Consideration was also given to accessories such as the lightning arrester, J & P fuse of D –Fuse, and gang isolator. These accessories are needed at the substation and their ratings must be with 11 kV since the voltage level in this research study is 11 kV.

3.7 Consideration of Voltage Drop and Power Loss

This is of utmost importance in a research study of this kind since it helps in determining the optimum location of the transformer substation. However, a vivid observation of the village distribution network connections revealed that Eyinwa is extremely short lines and voltage would not significantly impact on the electricity supply to the village. The estimated Voltage drop which help in determining the use of 11kV supply for Eyinwa was calculated at load points C, B and A to be 0.2%, 0.7% and 3% respectively. Since $V_D < 12\%$, hence, the 11 kV is quite feasible and viable in the rural electrification design of Eyinwa village.

3.7.1 Calculation of Power loss in the system

For substation C, S=0.5MVA, L=1.5km,

$$\Delta S_C = \left[\frac{0.505}{11}\right]^2 \times 0.502 \times 1.5$$

Power loss at C,

$$\Delta S_c = 0.0015MVA = 1.5KVA \approx 2kVA$$

For substation B, S=0.5MVA, L=2.5km

$$\Delta S = \left[\frac{1.0115}{11}\right]^2 \times 0.502 \times 2.5$$

Power loss at B,

$$\Delta S_B = 0.0106\ MVA = 10\ kVA$$

For substation A, S=0.5MVA, L=7.27km

To compensate for losses, substation A should be 1.59MVA

$$\Delta S = \left[\frac{1.526}{11}\right]^2 \times 0.502 \times 7.27$$

Power Loss at A,

$$\Delta S_A = 0.07MVA = 70\ kVA$$

Power losses are expressed in terms of useful power, thus, the calculated power loss at load points A, B, C with the consideration of 0.8 power factor are 0.056 MW, 0.08 MW and 0.0016 MW respectively.

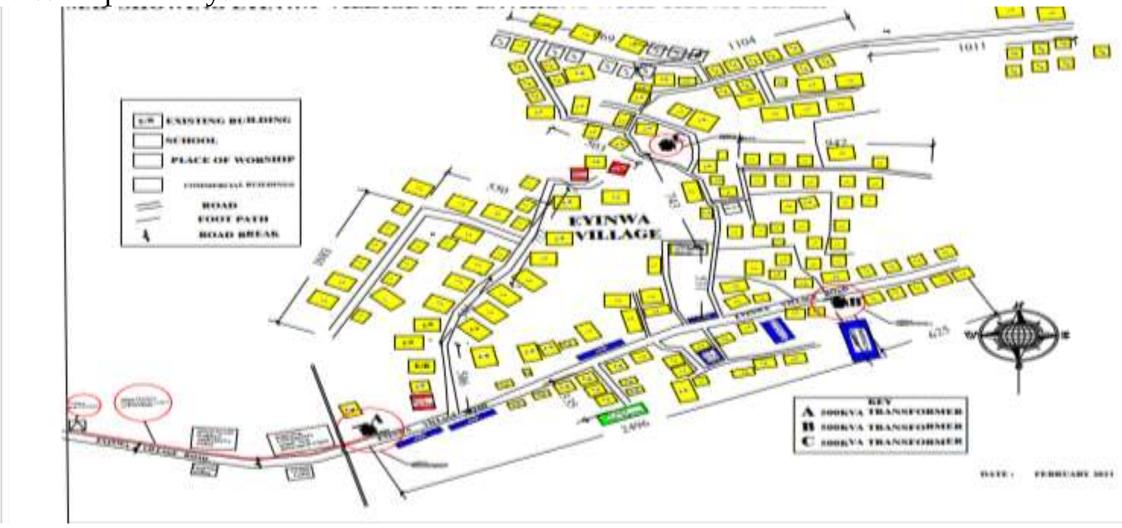

Figure 9: Map Showing Eyinwa Village and Environs with Transformer Distribution

Table 5: Bill Of Engineering Measurement and Evaluation (BEME) Of Rural Electrification Components For Eyinwa Community As At January, 2024.

S/N	Material Description	Quantity	Unitprice(₦)	Amount(₦)
1	2.5 MVA POWER TRANSFORMER	1	7,500,000.00	7,500,000.00
2	33 kV SF6 / Vacuum Meter clad switch gear	1	5,940,000	5,940,000.00
3	Transformer/feeder control panel with circuit breaker	1	5,050,000	5,050,000.00
4	100 kVA 33/0.415 kV outdoor transformer	1	2,850,000	2,850,000.00
5	11 kV SF6 Vaccum Metal clad switchgear	1	4,600,000	4,600,000.00
6	Comprising 1200 A incoming mains circuit breaker	2	5,450,000	10,900,000.00
7	1200 A Bus section circuit breaker	1	4,500,000	4,500,000.00
8	1200 A Metering section panel	1	4,000,000	4,000,000.00
9	600 A Outgoing circuit breaker	4	5,000,800	20,003,200.00
10	150 mm^2×3core 11kV XLPE Insulated 2Cable as feeder	100	9,500	950,000
11	300 mm^2×1core 11kV XLPE Insulated Cable	150	10,500	1,575.000.00
12	150 mm^2×3core 11kV XLPE Insulated Cable as feeder from 11 kv panels to main overhead line	100	9,500	950,000.00
13	300 mm^2×4core 600/1000V SWA/PVC cable	300	10,500	1,575,000.00
14	2.5 mm^2×19core pilot cable	100	8,950	895,000.00
15	2.5 mm^2×12core pilot cable	100	3,500	350,000.00
16	4 mm^2×4core pilot cable	60	2,850	171,000.00
17	2.5 mm^2×2core pilot cable	100	2,400	144,000.00
18	150 mm^2×3core 11kV XLPE Insulated Cable	100	10,800	1,080,000.00
19	185-300 mm^2 Single core 11kV Term. Kit	6	10,600	63,600.00

20	150-185 mm^2 Single core 11kV Term. Kit	4	11,500	46,000.00
21	150-185 mm^2 Single core 33 kV Term. Kit	6	13,000	78,000.00
22	1200,10way copper earth bar	6	35,000	210,000
23	16 mm×1200 mm copper earth rod	36	85,000	3,060,000
24	70 mm^{2}hard drawn copper conductor	380	8,300	3,154,000
25	300 mm^{2}PVC covered hard drawn copper conductor	35	9,500	332,500
26	5/8/9galvanisede earth rod complete with clamps and couplers	24	45,000	1,080,000
27	4″×4″×21″angle Ironpoles	48	21,000	1,008,000
28	3″×3″×21″Gal.tie angle Ironpoles	36	18,000	648,000.00
29	70mm^2 channel Iron	18	21,500	387,000.00
30	150 mm^2 Aluminium Conductor	100	20,500	2,050,000.00
31	Pin Insulator	896	7,232	6,480,000.00
32	Adaptor socket Tongue	162	940	152,280.00
33	Adaptor socket clevis	54	420	22,680.00
34	-Bolt clamp	54	2,400	129,600.00
35	5/8×4″Galvanised bolt and nuts	54	1,800	97,200.00
36	5/8×6″Galvanised bolt and nuts	54	1,500	81,000.00
37	33 skV Gang Isolator	6	105,000	630,000.00
38	Lighning arrestor	6	85,000	510,000.00
39	Laying of incoming upraiser cables		120,000	120,000.00
40	Termination of power cables		250,000	250,000.00
41	Laying of control tables		200,000	200,000.00
42	Wiring of protection cables		500,000	500,000.00
43	Earthing		2,500,000.000	2,500,000.00
44	Gantry Works Construction and fabrication of gantry structures	Lot	1,000,000.00	1,000,000.00
45	Civil works	Lot	12,000,000.00	12,000,0000.00
46	Electromechanical Works	Lot	10,000,000.00	10,000,000.00
			SUBTOTAL	120,903,060.00

Distribution Transformer Substations

S/N	Material description and specification	Quantity	Unit Price (₦)	Total Price (₦)
1	500 kVA, 33/0.415 kV Distribution Transformer	3	5,850,000	17,550,000.00
2	4-way feeder pillar	3	700,000	2,100,000.00
3	11 kV Lightning Arrester	3	60,500	181,000.00
4	11 kV J & P fuses	3	55,000	165,000.00
5	Earthing of substation	3	300,000	900,000.00
6	Line Taps	48	3,500	168,000.00
7	Plinth	3	140,000	420,000.00
8	Fencing of Substation	3	350,000	1,050,000.00
9	500 mm^2 single core PVC SWA/PVC cable (in meters)	72	15,500	1,116,000.00
10	35 mm^2 single core XPLE cable	180	4,500	810,000.00
11	4 x 185 mm^2 PVC/SWA/PVC cable (up-riser)	180	10,800	1,944,000.00
12	Cable sealing ends	3	150,000	450,000.00
	SUB-TOTAL			**27,304,000.00**

11kV High Tension Lines

S/N	Material description and specification	Quantity	Unit Price (#)	Total Price (#)

13	10.06 metres concrete poles	147	70,000	10,290,000.00
14	Steel cross arm	371	3,291	1,221,000.00
15	Tie straps	444	900	399,600.00
16	Pin insulators and spindle	441	8.313	3,663,000.00
17	Socket, tongue, tension clamp, J-Hook	45	3,200	144,000.00
18	Disc Insulator	270	6,900	1,863,000.00
19	Bolt and nuts of various sizes	1567	500	783,500.00
20	Stay complete	133	8,000	1,064,000.00
21	Pole earthing	3	9,500	28,500.00
22	Bush clearing/metre	1640	100,000	164,400.00
23	70 mm^{2}Aluminum conductor	37,000	800	29,600,000.00
24	Pole and stay hole	154	4,500	693,000.00
25	Stringing of lines	1,640	600	1,200,000.00
26	Design, line tracing and pegging	1,640	300	492,000.00
27	Anti-climbing devices /D plate	60	4,500	270,000.00
	SUBTOTAL			59,346,000.00
400 V Low Tension Lines				
S/N	Material description and specification	Quantity	Unit Price (#)	Total Price (#)
28	8.54 metres concrete poles	224	70,000	15,232,000.00
29	Bolts and Nuts of various sizes5/8 x7;5/8 x10, 5/8 x 8	1,000	500	500,000.00
30	Stay complete	36	8,000	288,000.00
31	D-iron A complete set Comprises of D-iron, shackle insulator and spindle	1,520	700	1,064,000.00
32	Pole and stay holes	154	4,500	693,000.00
33	Stringing of lines	6560	400	2,624,000.00
34	70 mm^{2}Aluminum conductor	84,000	800	67,200,280.00
35	Bush clearing (in km)	3km	100,000	300,000.00
			SUBTOTAL	80,836,500.00
Testing and Commissioning				
36	Statutory charges/ fees Testing and commissioning	4	1,000,000	4,000,000.00
Summary of Costs				
37	TRANSFORMER SUBSTATIONS			27,304,000.00
38	HIGH TENSION LINE			59,346,000.00
39	INJECTION SUBSTATION			120,903,060.00
40	LOW TENSION LINE			80,836,500.00
41	TESTING AND COMMISSIONING			4,000,000.00
	TOTAL			265,085,560.00

3.7.2. Discussion

The survey conducted in this research study revealed that, less than 20,000 people are currently living in Eyinwa. The survey revealed further that there were over 260-300 structures and most of the occupants of this community belong to middle class. The majority of the occupants of Eyinwa incur a lot of expenses on fuelling of generator for electrification since they suffer lack of access to the grid supply. The load audits carried out on Eyinwa showed that the current load demand is 1,346.5kW. The load growth for a period of fifteen (15) years considered in this research study showed that by the fifteenth (15^{th}) year, the load demand of Eyinwa would have been 4,826.5 kW. The simple reason for this is that there would be an influx of people from the urban centres of Ogun State into the village since they are still part of the State and as a result, the growth rate of the community would be quite rapid within a very short period. As aforementioned, one crucial merit discovered during the course of developing the electrical design models of Eyinwa was that the effect of voltage drop on the lines is negligible because the lengths of network connections of the village was well below 80 km. Hence, the village is in the category of extremely short lines. The effect of the voltage drop being negligible offered the advantage of strategically placing the transformer substations at locations where the buildings in their vicinities could be optimally served and this is very obvious in electrical design layout of the community. As can be observed from the electrical design layout the 33kV feeder from Ikene transmission station passes through Aiyepe Odogbolu local government to a Chinese company at the outskirt of Eyinwa where a tee-off exists. An injection substation which steps down this 33 kV to 11 kV were created haven met the voltage drop criteria of being less than 10-12% of the nominal voltage. This 11 kV line was used as supply to Eyinwa Village. The Voltage drop of the load points A, B and C calculated were 3, 0.7 and 0.2%, of the nominal voltage respectively. The distances between these load points were 7.27, 2.5 and 1.5 km, respectively. This provided important information for the subsequent calculation of the power flow losses which were 0.056, 0.08 and 0.0016 MW, respectively. These values mean a minimal power loss exists as such indicates that the design will ensure the optimum use of the electrical energy supplied. The electrification of Eyinwa would require an estimated cost of two hundred and two hundred and sixty five million,eighty five thousand, five hundred and sixty Naira (₦265,085,560.00). The inter-township network connection (ITC) and township distribution network (TDN) lengths of Eyinwa were estimated at distance 11.04 km and 19.043 km respectively. For the implementation of the developed electrical design layout for Eyinwa in this study, the calculation performed to determine the number of required components revealed that an injection substation with a power transformer of capacity 2.5 MVA its components and three 500 kVA distribution transformers, three feeder pillars, to mention a few were needed.

4. Conclusion

In this study, an optimal design and implementation of rural electrification for Eyinwa of Odogbolu local government of Ogun State had been presented. Despite the nearness of this village to an existing functional grid and their location in a State regarded as one of the commercial centres in Nigeria, they still suffer a lack of access to electric power supply. In order to assess the viability of electrifying this village and the cost implication of such electrification, an electrical design model was developed. The estimated load demand of Eyinwa is 1,346.5 kW, with a 15 years load growth of 4,826.5 kW. A 2.5 MVA transformer with a 60% loading capacity and three numbers of 500 kVA transformers were designed to cater for Eyinwa. The Voltage drop of the load were 3%, 0.7% and 0.2% of the nominal voltage and power loss subsequently calculated shows that the electrification of Eyinwa is feasible with minimal Loss. The components required for the implementation of the electrical design model, the size and number of such components were determined using appropriate design equations.

5. Recommendation

This study had focused primarily on grid extension as a method adopted for electrifying Eyinwa. It will, therefore, be recommended that further study be conducted on the use of other technologies (off-grid methods) for electrifying Eyinwa, with the cost implication of such technologies weighed with that of the grid.

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