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Design of Electrical Distribution Network for 500 Housing Units

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Abstract: *This work deals with the design of electrical distribution network for 500 housing units. The distribution system is designed to be overhead line, because it is cheap and tapping can be conveniently made at any time. A load estimation method was used for estimating an adequate transformer capacity with consideration of future expansion in load demand in the nearest future while the same transformer and other substation equipment will still be considered relevant and reliable. The overhead line accessories such as the pole, conductors, insulators, cross arms stay insulators and stay wives are also designed to suit the area. The transformer ratings are design to be four number of 500 KVA (11/415V). The system is also designed to carry the load imposed upon it without damage to the conductors. The system can also meet the load variations which are likely to arise in near future and provide continuity of supply.*

Key words: *load estimation, transformer rating and overhead line accessories*

1.0 INTRODUCTION

Electricity is the most convenient and useful form of energy. Without it the present social infrastructure cannot be feasible. The increasing per capital consumption of electricity throughout the world reflects a growing standard of living of people (Pablo, 2000) and the optimum utilization by society of this form of energy can be ensured by effective supply and distribution system. Distribution system differs from transmission system in several ways. Apart from voltage magnitude, the number of branches and source is much higher in distribution system and the general structure topology is different. Transmission is normality implied, the bulk transfers of power by high voltage between main load centers. Distribution on the other hand is mainly concerned with the conveyance of power of consumer by means of lower voltage network.

Due to expansion in the use of electricity, the demand on the distribution become greater and more complex.Therefore, the distribution network are designed to be able to carry the load imposed upon it without causing excessive heating in the consumers conductor and consequent damages to the insulator. The voltage drop through the network must be kept to minimum so as to maintain the voltage at the customer terminal within specified units (i.e 6% of the nominal value) whatever the loading conditions [NKPA electricity distribution manual 1977]. Electrical wiring is one of the major parts of building construction. Electrical wiring is the connection of electrical accessories such as:sockets, lamp holder, distribution boards, fuses or cutouts, ceiling rose, etc. with electrical wire or cable of the appropriate rating. According to Electrical Engineering Portal (EEP), wires used in electrical wiring are normally coded with colour codes for easy identification. In electrical wiring, current entered a circuit through the hot (live) wire (usually red color) and returned along neutral wire (Uguru, and Obukoeroro, 2020). An electrical circuit is a continuous loop, which carries electricity from the mains (e.g. distribution line), throughout the house, then returns it back to the mains. Switches and other electrical appliances are usually connected to a single electrical circuit (EEP, 2020). Electrical wiring are done by trained professionals, but in some countries like Nigeria, due to lack of skill workforce, people with informal education, commonly called “engineers” within the locality, are mainly employed to carry out the electrical wiring of buildings. The utilization of substandard electrical materials or wrong connection of the circuit is very dangerous, as it can lead to electrical fires or breakdown of the system. Electrical fires are fires comprising the potential energization of electrical appliances and accessories.Electrical fires are mainly caused by either over-loading of the circuit or short-circuiting the system (Fair, 2014). Safely of human lives and materials in residential, administrative or commercial buildings is of high priority to every country. Electrical fire has become a serious threat to the life and materials in residential and commercial buildings (Madueme, 1997).

The paper is aimed at designing an electrical distribution network for the newly completed 500 housing estate. Toward the development of the area, power demand is necessary. Consideration is given to the future expansion of the area, also the maximum load demand of the Varian load centers and the effective maximum demand (i.e the total maximum load demands required by the consumers) are conserved for successful.

2.0 Methodology

This chapter deals with how the electrical distribution network for 500 housing unit was designed, the distribution network was also designed to be overhead type which technically suit the area.The type of line support and their accessories are also designed to the technical standard. Distribution substation is also designed to receive energy from a higher voltage system, convert into a form suitable for local distribution.

2.1 LINE SUPPORTS

For the purpose of this project, a steel reinforced concrete pole was designed, the poles were designed to be 8.5m length for the low voltages and 10m length for the high voltage line.

The span length for the low voltage lines was designed to be 40m while that of high voltage line was designed to be 50m, this is to avoid the difficulties of terrains, urban development and natural hazards.

The reinforced concrete pole have the advantage of longer life, shattering tendency when hit by vehicles and can be used in areas that have high humidity

2.2 ACCESSORIES OF OVERHEAD LINES DESIGNED FOR THESE PROJECT ARE:

i. CROSS-ARM

A hot dip galvanized cross - arms are designed for the project, the length of the cross - arm should be 1.63m long and, the bolts and nuts of 5mc and 8mc respectively should be used.

The hot dip galvanized has the following advantages:

a. It has longer life.

b. They cannot be attack by termites

c. They are stronger than the wood types.

ii. INSULATORS

For the insulation of the distribution lines, use shall be made of porcelain insulators as specified in B.S. 137.

The Disc type insulator of approximately 254mm in diameter, 6.3kg In weight and mechanical failing load of 10.6KN should be used for the high voltage lines.

Also for the low - voltages a single groove type shackle insulator of 76mm in diameter, 0.4kg in weight with a mechanical failing land of 19KIM should be used.

iii. CONDUCTORS

Conductors used are aluminum conductors (AAC), conductors shall be $50mm^2$ and $100mm^2$ in size for the high voltage and the low voltage respectively. Base conductors shall be used in normal conditions, conductors shall be hard-drawn aluminum twisted wires made of aluminum for electric purposes. However, it major advantage is that it is cheaper than copper.

2.3 Design of Electrical Installation for Buildings

The total load was used to determine the actual size of the transformer required for the area.

According to IEE Regulation A30 - 36, that the cables supplying lighting load need only be rated for 50% of the full load current.

The diversity factor is taken into consideration due to the fact that the likely-hood of all the domestic installation been ON at the same time is remote, hence it reduces imbalance in the lighting loads. (George G. 1975).

Finally, the diversity factors suggested in the I.E.E regulations A27 & A28 are:

1. Lighting circuit is 65%
2. 13A socket outlet is 65%
3. 15A socket outlet is 80%

4. Electric Cooker is 65%

The breakdowns of the load demand are as follows:-

The total lumens is given by

θ = E x A/n x p (1)

Where E = is the illumination in Im/m^2

A = is the Area of working plane to be illuminated in m^2

p = Maintenance factor

n = utilization factor.

Using the standard table of installation (T. G. Francis 5th edition).

P = 0.8 for bedrooms and living room.

n = 0.5 for bed rooms and living room.

E = 40lm/m^2 for Bedrooms and living room. Lumen/watt for (4 x 4)m^2 size = 10lm/w.

Now, for Bedrooms;

a) Two Bedrooms Flat: There are 350 two bedroom flats, the load demand of single 2-bedroom was calculated and multiplied by 350 to give the total load demand of the flats.

i. For the bedroom with size (3.5 x 3.5)m^2, the following standard were obtained using electrical installation IEE standard table (M. A. Laughton, 2003). As stated in (A) above.

P = 0.7

n = 0.5

E = 40lm/m^2

$$\theta = \frac{E \times A}{n \times p} = \frac{40 \times (3.5 \times 3.5)}{0.5 \times 0.7} = 1400 lm$$

The total watt required = 1400lm/12lm/w = 116.7w

Therefore, 116.7/60 = 1.9 = 2 lamps of 60w for each bedroom

ii. For the living room with size (4.5 x 4.5)m^2, it has the following data. Lumen/watt = 13lm/w, n = 0.5, E = 40lm/m^2, p=0.7

$$\theta = \frac{E \times A}{n \times p} = \frac{40 \times (4.5 \times 4.5)}{0.5 \times 0.8} = 2314 lm$$

The total wattage required = 2314.3lm/13lm/w = 178w

Therefore, 178/60 = 3 lamps of 60w.

iii. For the kitchen, toilet, Veranda and security light, eight numbers of lamps was designed. That is, totaling to 15 lamps.

iv. Six number of 13A socket, each of 100w was designed.

v. Two number of ISA socket, each of 1500w was designed.

vi. Three number of ceiling fan, each of 80w was designed.

vii. One number of electric cooker with 1200w rating.

viii. One number of water heaters with 8000w rating.

b) **One Bedroom Flat**: there are 150 one bedroom flats, the load demand of single one bedroom was calculated and multiplied by 150 to give the total load demand of the all flats.

i. For the bedroom with size (3.5 x 3.5)m2, the total number of wattage required was the same with that of two bedroom, since they have same size, hence the same illumination was required.

ii. Therefore, two lamps of 60w each was designed.

ii. For the living room; with size $(4.2 \times 4.2)m^2$, the following data's were extracted from the standard installation table.

Lumen/watt = 17im/w, n = 0.5, E = 40lm/m2, P = 0.8,

A = (4.2 x 4.2)m2.

From:

$$\theta = \frac{E \times A}{n \times p} = \frac{40 \times (14.2 \times 4.3)}{0.8 \times 0.5} = 1764 lm$$

The total wattage required = 1764lm/17lm/w = 103.76w

Therefore, 103.76w/60 = 3 lamps.

Hence, the living room was designed with two lamps of 60w each for it illumination.

iii. For the kitchen, toilet, veranda and security lights, the number of lamps designed was 8 lamps of 60w each.

iv. Five number of 13A socket outlet, each of 100w was designed.

v. One number of 15A socket outlets, each of 1500w was designed.

vi. Two number of ceiling fan, each of 80w was designed.

vii. One number of electric cooker, rating 8000w was designed.

viii. One number of water heater ratings.

2.4 Design of Distribution Transformer

The distribution transformer were design based on the load demand of the area and the breakdown of the load demand are presented below.

Table 1: Maximum required for single two bedrooms.

Load	Wattage (W)	Total (Kw)	Diversity factors (%)	Maximum load Demand (KW)
Lightings	15 x60	0.9	65	0,59
13A socket outlets	6 x 100	0.6	65	0.3
15A socket outlets	2 x 1500	3.0	80	2.4
Ceiling Fan	3 x 80	0.24	-	0.24
Cooker	1 x 8000	8.0	65	5.2
Water heater	1 x 1200	1.2	-	1.2

Maximum load = 9.9kw

Therefore, the total maximum load demand for the 350 two bedroom flats will be; 9.9 x 626 = 3465kw.

Sub-total (1): 3465kw

Table 2: Maximum required for single one bedrooms.

Load	Wattage (W)	Total (Kw)	Diversity factors (%)	Maximum load demand (KW)
Lightings	13 x 60	0.78	65	0.51
13A socket outlets	5 x 100	0.5	65	0.325

ISA socket outlets	1 x 1500	1.5	80	1.2
Ceiling Fan	2 x80	0.16	-	0.16
Cooker	1 x 8000	8.0	65	5.2
Water heater	1 x 1200	1.2	-	1.2

Maximum demand = 8.595kw.

Therefore, the total maximum load demand for the 150 one bedroom flats will be;

8.595 x 150 = 1288.5kW

Sub-total (2) =1288.5kW

c) Load Requirement of the Other Building

v. For the primary school, the required maximum load is 7.5kw i.e **subtotal (3) = 7.5kw**.

vi. For the Boreholes, the required maximum load is 180kw. i.e **subtotal (4) = 180kw.**

vii. For the street light the required maximum load is 15kw. i.e **sub-total (5) = 15kw.**

vii. For the fire-service office, the required maximum demand is 2.5kw.**sub-total (6) = 2.5kw**

Therefore, the total maximum demand of the whole units will be total maximum demand of all load centres, i.e Total maximum demand of sub (1) + sub (2) + Sub (3) + Sub (4) + Sub (5) + Sub (6) = **3465kw + 1288.5kw + 7.5kw + 180kw + 15kw + 2.5kw = 11220.47kw.**

Grand total = 4958.5kw.

Now, power = 3VI Cos θ where θ is the power factor and is taken as 0.85.

$$\text{Therefore, IV} = \frac{\text{Total Power in kw}}{3\,\theta} \qquad (2)$$

VI = 4958.5/3×0.85 = 1944.51kw

Where VI, is the KVA which determines the sizes of transformers to be used.

The total KVA = 1944.51kw. Now, it is designed to use **4 x 500KVA** transformers.

2.5 TRANSFORMER LOCATION AND ITS LOADING CONDITION.

Distribution transformers are output rated, then can deliver their rated KVA without exceeding temperature rise limits when following condition are applied (ABB, 1995).

a. The secondary voltage should not exceed 105% of rating.

b. The load factor should be > 80%.

c. The frequency should not be > 95% of rating. Transformers are to he located at the centre of load so as to minimized the looses and maintained quality supply to a consumer.

Each transformer is designed to carry 440.0184 KVA, therefore it should be placed at the load centre even though the loads are not evenly distributed.

2.6 SUBSTATION

i. TRANSFORMER

A step-down transformers of ground mounted outdoor type was designed. The high voltage sides and low voltage side of the transformers shall be fitted with cable boxes in accordance to B.S 2562 part equipment.

They shall allow connection of 50mm^2 paper insulated copper cables on high voltage side and 150mm^2 PVC insulated copper cables on low voltage side.

The Cable size was designed considering the rating of the transformer. According to IEE regulation 7M, 50mm^2 copper cables should be connected on the high voltage side and 150mm2 copper cables should be connected on the low voltage side.

ii. LIGHTING ARRESTERS

For each transformer, there lighting arresters shall be installed in order to protect the system from high voltage surge due to lighting.

They should be attached to the high voltage side of this transformer and these arrangement will send any over voltage which falls on the system due to lighting to the ground directly.

iii. DROPOUT FUSES

The dropout fuses shall be of cross arm mounted type with such construction as shall allow opening and closing operation of the contact safely by an operating rod. Its construction shall be such that after this operation of the fuses shall construct as shall allow opening and closing operating of the contract safely by an operating after the operation of the fuses, the primary and secondary will be disconnected from each other and complete insulation will be maintained. Fuse intended for the dropout fuse switch shall be mounted on the switch and shall meet the rating capacity of 100MVA in the case of short circuit failing on the transformer side.

iv. EARTHING:

According to (Anthony J., 2006), the neutral conductors of low voltage shall be earthed at the supply point and each and every terminal as well as at interval of 250m along the distribution line route.The ear thing shall be covered copper conductor and it cross-section shall be less than 25mm earthing rods shall be used to serve as earthing electrode, each ear thing rod 2.5cm in diameter and 1.8m in length.

v. FEEDER PILLAR REQUIRED FOR THE LOW VOLTAGE LINE

Four feeders shall be provided for the four low voltage line. The feeder pillars should be water proved and installed. Each pillar should contain:

i. 3-fuse set, 3-phases and a neutral for overhead line feeders,
ii. 1-fuse set, 3-phases and a neutral for input cable from transformer.

According to (Frigsby L. L. 2001), the incoming and outgoing cable should allow connection to 150mm copper cables on the transformer side and 70mm copper cable on the side feeder side. Therefore, each transformer shall be provided with it feeder pillar.

2.7 CONSTRUCTION OF SUBSTATION

According to (NEPA Manual, 1977), the foundation which the transformer is to be installed shall be composed of an upper concrete base 20 to 25cm in thickness and wider than the transformer bottom by 10cm, reinforced by the steel wire 10mm in diameter placed cross-wise at a depth of 5mm below the surface.

A lower concrete base wider than the upper one by 10cm shall be constructed, there under a layer of stones of 150 to 200mm in diameter, 30cm thickness shall also be placed. Substation shall be constructed away from any such places;

i. Along heavy traffic road where motor cars are likely to collide.

ii. Where the soil is soft,

iii. Where people are frequent,

iv. As is likely to be flooded.

2.8 PROTECTION REQUIREMENTS

(i) According to I.E.E Regulation A8-A10, every consumers installation supplied from a external source shall be adequately controlled by protection equipment accessible to consumer, the protection equipment should incorporate:

i. Means of Isolation

ii. Means of excess current protection.

Circuit breakers was designed for the protection of excess current every conductor in the installation is to be protected by a circuit breakers fitted at the origin of the circuit.

The current rating of the circuit breaker should not exceed the current rating of the lowest rated conductor in the protected circuit.

(ii) Earthing: According to IEE Regulation D1, every conductor shall be prevented from giving rise to earth leakage current by earthing of exposed metal parts. For this purpose of this project, it was designed that all conductor are earth to ground using earth electrode.

3.0 Results and discussion

Based on the design of this project, the following results were obtained.

Table 2: Results for overhead line Design

S/N	ITEM	TYPE	SPECIFICATION
1	Line Support	Concrete Poles	10m long -H.T 8.5m long - LT.
2	Cross-Arm	Hot-Dip Galvanized Cross-arm	1.63m Long
3	Insulator	Disc Insulator Shackle insulator	254mm diam. 76mm diam.
4	Conductor	AAC	$50mm^2$ - H. T. $100mm^2$ - L. T.

From table 2 above, it can be seen that concrete poles were designed for the project, wooden poles are rather short in service life because they are inapplicable in place that have higher humidity and liable to be affected by insects or animals. It can be concluded that concrete poles have advantage over wooden poles.

Although pin type insulators are also available but because of it low level of insulation, disc type was used as specified by B.S 137.

All aluminium conductors of $50mm^2$ were designed for the high voltage line while $100mm^2$ was designed for the low voltage line. Aluminium was used because of it cheaperness and easy to machine handle.

Standard cross-arms shall have a size of either 1.63 or 2.24m. for places that require span length size cross-arm will be used, but for the purpose of this project which the span length is not more 80m, 1.63 size was designed.

Table 3: Maximum load demand for whole unit.

S/N	BEDROOM FLAT/OTHER	TOTAL LOAD DEMAND (KW)
3.	Two Bedrooms	3465
4.	One Bedrooms	2388.5

5.	Primary school	7.5
6.	Boreholes	180
7.	Street light	1.5
8.	Fire services	2.5
9.	Transformer Designed	***4 x 500KVA***

The total load demand for each unit was calculated in table 1.6 above. This load demand was added to have maximum load demand for the whole unit. The transformers designed for the whole unit was obtained by considering this maximum load demand of the area. It can be concluded that ten number of 500KVA transformers was designed for the purpose of this project.

CONCLUSION

The objective of the design is to provide electrical power supply to 500 housing units, because the optimum utilization by society of electrical energy can be ensured by effective supply and distribution systems.Also, electricity is the most convenient and useful from of energy, without it the present social infrastructure cannot be feasible, hence there is a need to electrify the area.

The designed network of the area can carry the load imposed upon it without excessive heating in the conductor and consequently damages to the insulation. The voltage at the consumer terminal is kept within the specified limit (i.e 6% of the nominal value). (NEPA Manual, 1975)

The system as designed can meet the load variations which are likely to arise in near future and provide continuity of supply and should a fault occur on the system, interruption in the supply to the consumers should last for a shortest possible time.The system is very simple to maintain and operate and routine maintenance should be carried out with minimum interruption to power supply.

From the above results, it can be concluded that the system is quite reliable. Since the reliability of any good designed system depends on efficient control equipment such as circuit breakers, lighting arresters, fuses etc., hence it becomes necessary to incorporate in this design to obtain reliable system. The overhead lines distribution and the electrical installation designed for this project will suite the area, because it is cheaper and easy to maintain.

REFERENCES

ABB, (1995), "distribution transformer guide" 6th edition page 101-115.

Anthony J. Pansiri, (2006), "electrical power Distribution System; 6th edition page 164-168

Anthony J., (2006), "Distribution Transformer" 6th edition, page 201 - 203.

Clapp A. L, (1999), "Elect. Installation Code", vol. 4 page 41-48 George G. (1975), "Electrical Installation" 5th edition page 14 -16.

Electrical Engineering Portal –EEP (2020).The Complete Guide to Electrical Wiring. Available online at:https://electrical-engineering-portal.com/downloadcenter/books-and guides/electrical engineering/electrical-wiring retrieved on January,2020.

Fair M (2014). Garret fire displaces family. Available online at: http://www.nj.com. retrieved on January, 2020

Grigsby L. L., (2001), "Electrical power". 5th edition, page 21- 23

IEE Regulation, (1970), "Regulation for Building" 14th edition, page 148 - 149.

Laughton M. A., (2003), "Elect. Engrs Ref Book 2". 6th edition page 204-209,

Madueme TC (1997) Minimizing electric fire outbreaks in residential houses in Nigeria: A case study of eastern states. *Conference: Electric Power Engineering Conference (EPEC)*At: Nsukka, Nigeria, I-8

NEPA (1977), "Electricity Distribution manual". Vol. 1 pg 50-61.

NEPA Manual, (1975), "General Specification on Distribution System". Vol. 2, page 42 – 5

Uguru, H. E. and Obukoeroro John,(2020) A Survey of Residential and Mini-industrial Wiring Systemsin Nigeria: A Case Study of Bayelsa State, Southern Nigeria, Direct Research *Journal of Engineering and Information Technology* Vol. 7(7), pp. 148-154, December 2020