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Design Of 3phase 50hz 500kva 33/0.4kv Distribution Substation

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ABSTRACT: *The benefit of a good electricity power delivery is dependent on a well designed and installed distribution substation. This project is geared towards designing a 3-phase, 50Hz, 500kva 33/0.4kv distribution substation to improve on the voltage supplied by Port-Harcourt Electricity Distribution Company (PHED) Rumuola, Port-Harcourt to the Port Harcourt Polytechnic. The study deployed an Electrical Transient Analyzer Program (ETAP) a computer software tool which was used for the simulation. The software was implemented in the computation of the electrical equipment and accessories, load flow and short circuit analysis. The result obtained from the analysis demonstrated a comprehensive single line diagram for easy implementation. Other results obtained include unbalanced load report, cable short-circuit withstanding current. The implementation of this design, will greatly enhance power distribution in Port Harcourt Polytechnic as well as reduce the frequent power outages experienced here as a result of low voltage, equipment breakdown and system failure.*
Keywords: *Substation; Load Flow; Single Line Diagram; Load Report; Low Voltage; ETAP*

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I. Introduction

A substation is a part of an electrical generation, transmission and distribution system. Generally substations are basically used for transforming voltage levels from high to low and vice-versa and also to perform other several functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels according to [1].

Substation serves as a source of supply of electrical energy in an area in which it is located. While some substations serves as a switching station where various transmission lines connected without transforming the voltage, others are either to convert A.C to D.C or vice-versa or converts frequent from higher to lower or vice-versa. Substations may be owned and operated by an electrical utility, or may be owned by a large industrial or commercial customer [2].

Substations generally have switching, protection &control equipment, and transformers. In an injection substation, circuit breakers are used to interrupt any short circuits or overload currents that may occur on the network.

In [3][4], the design of a distribution substation, transformers plays a central role. It takes place in several stages in sequence, starting at the generating plant where the voltage is increased for transmission purposes and is progressively reduced in the substation for distribution to household or industrial uses.

According to [1, 5], A distribution substation uses circuit breakers or fuses for protection of distribution circuits. Substations themselves do not usually have generators, although a power plant may have a substation nearby. Other devices such as capacitors and voltage regulators may also be located at a substation.

Substations may be on the surface, fenced enclosures, underground, or located in special-purpose buildings. High-rise buildings may have several indoor substations. Indoor substations are usually found in urban areas to reduce the noise from the transformers, for reasons of appearance, or to protect switch gear from extreme climate or pollution conditions.

Where a substation has a metallic fence, it must be properly grounded to protect people from high voltages that may occur during a fault in the network. Earth faults at a substation can cause a ground potential rise. Currents flowing in the Earth's surface during a fault can cause metal objects to have a significantly different voltage than the ground under a person's feet; this touch potential presents a hazard of electrocution.

Other safety devices like isolator, circuit breakers, surge protection, fuses are also necessary to interrupt any short-circuit or overload currents that may occur on the system.

II. History Of Port Harcourt Polytechnic (Ph Poly): Case Study

Port Harcourt Polytechnic, Rumuola is one of the Polytechnics in Rivers State, the Polytechnic was established in 1977 as a School of Basic studies to offer Higher School Certificate/Advanced level GCE, Interim Joint Matriculation Board Examination (IJMBE) moderated by Ahmadu Bello University, Matriculation

Examination Programme (MEP) moderated by Rivers State University of Science and Technology and the Remedial Programmes, UTME, JAMB/GCE preparatory classes.

In 1992 due to its success and educational relevance the School of Basic Studies was converted to Rivers State College of Arts and Science to award College Diploma and Certificates in addition to its original programmes. This conversion provided the opportunities to those who otherwise would have been denied access to tertiary education.

In 2006 the National Board for Technical Education (NBTE) accredited four programmes thereby elevating the College to a Polytechnic status.

In 2010 the National Board for Technical Education (NBTE) granted accreditation to three (3) additional programmes at National Diploma (ND) and Higher National Diploma (HND) levels. Following this development Rivers State Government responded to infrastructural challenges/needs of the institution; according to [6].

In 2016, the Executive Governor of Rivers State, Chief (Barr.) Ezenwo Wike changed the name of the institution to Port Harcourt Polytechnic to fit its status.

Thus, PH Poly as one of the polytechnic founded by Rivers State government lack a reliable power supply, since it is connected to low tension network from neighbouring community distribution transformer. This polytechnic is chosen by the author for the case study because of his first-hand knowledge and accessibility of the area [6].

III. Design Methodology

A. Methodology

This methodology contains the details of how the design of the 500KVA, 33/0.4KV distribution substation for Port Harcourt Polytechnic was achieved.

In this design, the 500KVA, 33/0.4KV distribution substation is simulated by ETAP software. In addition some electrical standard are the design criteria. Some big companies' manual such as ABB Ltd. is used as references.

To have a better overall understanding on how a distribution substation is designed, the ABB Electrical power supply procedure is shown in the following page; [15]

- **LOCATION OF AVAILABLE GRID SYSTEM**

In designing an efficient and reliable electricity supply system, the first step of the project design phase is to locate the nearest available grid system within the area of interest. This polytechnic administrative block is located some meters away from the existing 33Kv Grid system.

- **LOAD SURVEY AND ANALYSIS**

The polytechnic consists mainly of staff quarters (residential building), lecture Halls, offices, departmental workshops, conference hall, computer studio and market or Shops. Maximum demand will occur in the evening when all equipment is in operation. The basic loads have been divided into the following groups.

1. Dwelling houses,
2. Offices, workshop, computer studio
3. Lecture Hall, Market/Shops and conference hall

Each of the above group of loads differs from one another in term of simultaneous operation.

- **DWELLING HOUSES**

The estimated dwelling houses that will connect to the national grid in completion of the distribution substation project

Table 1: ESTIMATED LOAD FOR THE DWELLING HOUSES (CATEGORY A)

ITEM NO	DESCRIPTION OF ITEMS	NO.OF POINTS	NO. OF HOUSES	POWER RATING (HP/W)	TOTAL POWER (KW)
A.	**4Bedroom Boys Quarter**				
1.	Lighting Points; a. Internal Light b. External	 17 8	 8	 60W 100W	 8.16 6.4
2.	Fans	5	8	120W	4.8
3.	Refrigerator	2	8	320W	5.12
4.	Pressing iron	2	8	1000W	16

5.	Immersion Heater	2	8	1000W	16
6.	Air Conditioner	2	8	1.5HP	17.9
7.	Cooker	1	8	4500W	36
	TOTAL LOAD (KW)				**110.38**

Table 2: ESTIMATED LOAD FOR THE DWELLING HOUSES (CATEGORY B)

ITEM NO	**DESCRIPTION OF ITEMS**	**NO. OF POINTS**	**NO. OF HOUSES**	**POWER RATING (HP/W)**	**TOTAL POWER (KW)**
B.	**3Bedroom Flat**				
1.	Lighting Points; a. Internal Light b. External c. Street light on pole	 15 8 10	 8 8 0	 60W 100W 250W	 7.2 6.4 2.5
2.	Fans	4	8	120W	3.84
3.	Refrigerator	1	8	320W	2.56
4.	Pressing iron	1	8	1000W	8
5.	Water Heater	3	8	1000W	24
6.	Air Conditioner	2	8	1.5HP	17.9
7.	Cooker	1	8	4500W	36
	TOTAL LOAD (KW)				**108.76**

Table 3: ESTIMATED LOAD FOR THE WORKSHOPS (CATEGORY C)

ITEM NO	**ITEM DESCRIPTION**	**NO. OF POINTS**	**POWER RATING (HP/KW)**	**TOTAL POWER (KW)**
1.	Lighting Points	30	60w	1.8
2.	Security Lighting Points	6	250W	1.5
3.	Electric motors for Lath machines	4	5HP	14.92
4.	Table top drilling machine	4	1.5HP	4.48
5.	Electric motor for bore hole	1	5HP	3.7
6.	Electric motor for grinding machine	2	3HP	4.48
TOTAL LOAD (KW)				**31.07**

Note: 1 HP =746W

- **SHOPS, OFFICES, LECTURE HALLS**

Estimated power requirement in a day for Shops, Offices, and Lecture Hall may amount to a total load of 60KW.

- **FUTURE LOAD DEMAND**

Considering the size of the polytechnic and the above estimated load for dwelling, workshop, Shops, offices and lecture halls, an allowance of 30% of the known load is allowed for future load demand.

- **LOAD SUMMARY AND ANALYSIS**

1. Dwelling House Load = 219.14kW. (1)
2. Workshops = 31.07kW. (2)
3. Shops, Offices, and Lecture Halls = 40kW. (3)

Total Load = 290.21Kw (4)

Plus Future Load Demand (FLD) 30% of total load = 30/100 x 290.21 (5)

Therefore, FLD = 87.063kw (6)

Grand Total Load = 290.21+87.063 = 377.27kW. (7)

From the above, polytechnic estimated maximum load = 377.27Kw (8)

Let us recall the formula for power given as;

$P = \sqrt{3} VICos\,\Theta$ (9)

Where P = Power in Kilowatts

V = Voltage in Volts or Kilovolts

I = Current in Ampere

Cos Θ = Power factor (P.F)

Therefore, the KVA rating of the above load is given as;

KVA rating = KW/P.F (10)

= 377.27/0.8 (11)

= 471.59KVA (12)

Thus, the approximate KVA size of distribution transformer is 500KVA, 33/0.4KV dedicated for the polytechnic and the location of the substation should be such that the line losses for the O-H Lines and network will not have adverse effect on the quality of supply to the consumers located far away from the source of supply. The load center is taken into considering the location of the substation.

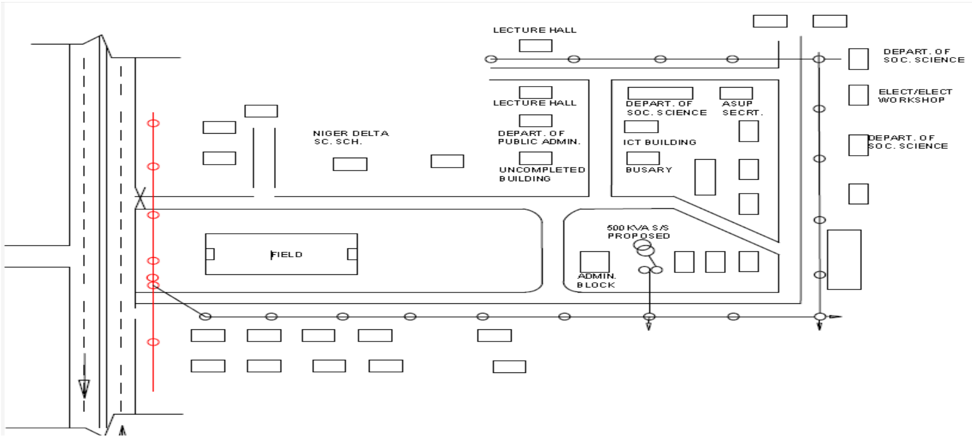

Fig 1: ROUTE SURVEY DRAWING

B. DESIGN CRITERIA

In order to be certain that our design has acquired technical quality, the engineering part of the job must be done according to the standards and technical specifications. Hereunder, some important criteria are presented.

- **VOLTAGE LEVEL**

The following voltage levels have been selected for electrical system at the rated frequency of 50 HZ. Equipment's will be suitable for continuous operation with voltages variation within 5% of nominal values.

Table 4: Voltage Levels

SERVICE	NOMINAL VOLTAGE (V)	PHASE
Generation	11,000	3
Transmission	330,000 or 132,000	3
Primary distribution	33,000	3
Distribution	11,000	3
Motor Load	400 or 230	3 or 1
Lighting Circuit	230	1
Power Socket	400 or 230	1
Control Voltage for Contactors	230	1

- **VOLTAGE DROP LIMITS**

Normal operation voltage drop

In this project, cable voltage drops at load shall be limited to the following values according to IEE Regulation.
At the loads terminals: 5%

- **SHORT CIRCUIT CURRENT LIMITS**

Power systems with a voltage in excess of 1000V shall be designed somehow that the root mean square (RMS) value of the a.c components of the short-circuit breaking current of the circuit breakers shall not exceed 25 KA as per IEC 60056.

For power systems with a voltage less than 1000 volt, the RMS value of the a.c. component of the short circuit breaking current of circuit breaker designed shall be as per IEC 60947-2 and shall not exceed 50 KA.

- **POWER FACTOR**

The overall system power factor, inclusive of reactive power losses in transformers and other distribution system equipment shall not be less than 0.85 lagging at rated design throughout of the station. The power factor shall be determined at the terminals of the transformer(s).

- **TRANSFORMER**

In case of trip on one transformer, another transformer should be able to withstand the entire downstream load. In addition each transformer should at least have 20% spare in normal operation according to IPS-E-EL-100.

The short-circuit voltage in percent VK% according to IEC 60076-5 for 500 KVA 5%

C. CABLE SIZING & EQUIPMENT SELECTION CALCULATION

- **CABLE SIZING**

For determination of electrical power cables it is necessary to do the following studies:

*Cable Ampacity
*Voltage drop
*Short circuit withstanding current

Since there are different methods for physical arrangement of cables as well as a possibility of having different environmental and physical conditions, therefore before cable sizing, it is necessary to accurately consider the physical and environmental condition of cable route.

- **Cable Ampacity**

By considering load wattage, voltage, power factor and electrical efficiency, it is possible to calculate the current that passes through the cable in the ideal situation.

By having ampacity easily cable cross section can be selected but this cross section in real situation must be calculated considering physical and environmental conditions. Respectively, cable capacity for passing current depends on ambient condition and method of laying cable.

If the cable is buried underground, passing above ground or in the water, different de-rating factors should respectively be applied.

In this project, all the cables are buried cables and the following de-rating factors such as ambient temperature, soil temperature, soil thermal resistance, type of cable armour, distance between adjacent cables, burial depth and etc. have been taken into account according to IEC 600502. [2]

After calculating the ampacity of the cable cross section, it can be selected but should still be checked against the short circuit withstanding ability and voltage drop.

- **500KVA, 33/0.4KV Distribution Transformer incoming cable sizing**

For the purpose of sizing of the primary cable, the 500KVA transformer primary current is considered.
The line ampacity is given by:

$$I = \frac{P(KVA)}{\sqrt{3}V} \qquad (13)$$

Where I = line current
P = 500KVA Maximum transformer power
V = 33kV Line rated voltage

$$I_P = \frac{500 \times 1000}{\sqrt{3} \times 33000} = 8.75A \qquad (14)$$

Reference to IEE Table 4B1 gives correction factor of 0.80 for single layer Single core on cable buried direct to ground = 0.80 x 8.75 = 6.99A
From Pirelli general cable manufacturer Table for 19000/33000V Single core XLPE Insulated Cable

Table 5: Single Core PVC Insulated PVC Sheathed Armoured & Unarmoured, 600/1000V Cables, BS6346, Nigerchin Data Sheet

NIGERCHIN wire and cable

Single Core PVC Insulated PVC Sheathed
Armoured and Unarmoured
600/1000 V Cables
BS 6346

COPPER

			DIMENSIONS AND WEIGHTS							
			UNARMOURED			ARMOURED				
Nominal Area of Conductor mm²	Number and Nominal Diameter of Wires mm	Thickness of Insulation mm	Thickness of Sheath mm	Approx. Overall Diameter mm	Approx. Cable Weight kg/km	Thickness of Extruded Bedding mm	Armour Wire Diameter mm	Thickness of Sheath mm	Approx. Overall Diameter mm	Approx. Cable Weight kg/km
50	19/1.78	1.4	1.4	15.1	581	0.8	1.25	1.5	19.1	1024
70	19/2.14	1.4	1.4	16.9	795	0.8	1.25	1.6	21.1	1034
95	19/2.52	1.6	1.5	19.4	1084	0.8	1.25	1.6	23.4	1665
120	37/2.03	1.6	1.5	21.0	1333	1.0	1.6	1.7	26.3	2178
150	37/2.25	1.8	1.6	23.2	1623	1.0	1.6	1.7	28.3	2534
185	37/2.52	2.0	1.7	25.8	2038	1.0	1.6	1.8	30.8	3048
240	61/2.25	2.2	1.8	29.0	2646	1.0	1.6	1.9	34.1	3782
300	61/2.52	2.4	1.9	32.1	3280	1.0	1.6	1.9	37.0	4554
400	61/2.85	2.6	2.0	35.8	4170	1.2	2.0	2.1	42	5928
500	61/3.20	2.8	2.1	39.6	5210	1.2	2.0	2.1	45.6	7140
630	91/2.97	2.8	2.2	43.8	6794	1.2	2.0	2.2	49.7	8764
800	91/3.35	2.8	2.3	48.3	8339	1.4	2.5	2.4	55.8	11000
1000	703/1.35 or 127/3.20	3.0	2.5	53.7	10460	1.4	2.5	2.5	61.0	13370

Table 6: Current Ratings& Associated Voltage Drop, Single Core PVC Insulated PVC Sheathed Armoured 600/1000V Cables, Nigerchin Data Sheet

NIGERCHIN wire and cable

Current Ratings and Associated Voltage Drop
Single Core PVC Insulated PVC Sheathed Armoured
600/1000 V Cables

COPPER

Nominal Area of Conductor	ARMOURED											
	INSTALLED IN AIR				RUN IN SINGLE WAY DUCTS				LAID DIRECT IN GROUND			
	2 Cables Spaced		3 Cables Trefoil Touching		2 Cables Ducts Touching		3 Cables Ducts Touching in Trefoils		2 Cables Touching		3 Cables Trefoil Touching	
	Current Rating	Voltage Drop /amp/Metre	Current Rating	Voltage Drop /amp/Metre	Current Rating	Voltage Drop /amp/Metre	Current Rating	Voltage Drop /amp/Metre	Current Rating	Voltage Drop /amp/Metre	Current Rating	Voltage Drop /amp/Metre
mm^2	amp	mv	amp	mv	amp	mv	amp	mv	amp	mv	amp	mv
50	193	0.97	169	0.82	183	1.0	170	0.89	200	0.95	170	0.82
70	240	0.69	216	0.57	221	0.76	204	0.66	247	0.65	208	0.57
95	291	0.55	263	0.44	259	0.62	238	0.54	293	0.50	251	0.44
120	338	0.46	306	0.36	289	0.54	264	0.47	332	0.41	285	0.36
150	381	0.42	348	0.31	315	0.49	289	0.42	374	0.36	315	0.31
185	432	0.37	400	0.27	349	0.44	319	0.38	417	0.31	353	0.27
240	498	0.36	470	0.23	391	0.39	353	0.34	485	0.26	408	0.23
300	564	0.33	536	0.21	425	0.37	387	0.32	536	0.24	451	0.21
400	620	0.30	602	0.19	459	0.34	412	0.30	595	0.22	502	0.19
500	686	0.28	677	0.18	493	0.32	442	0.28	655	0.21	544	0.18
630	771	0.26	761	0.17	536	0.30	476	0.25	723	0.19	604	0.17
800	827	0.24	818	0.16	561	0.28	493	0.25	757	0.19	629	0.16
1000	940	0.23	884	0.16	595	0.27	527	0.23	799	0.18	663	0.16

Distance between cable centres: Up to and including $185mm^2$ - Twice overall diameter of Cable. $240mm^2$ and above - 90mm.

Basic Assumptions:

Ground Thermal Resistivity	1.2°C m/w
Ground Temperature	30°C
Ambient Temperature	35°C
Depth of Laying	0.5 metre (to the centre of cable or trefoil group of cables)
Maximum operating conductor temperature at rated current	70°C

Cable shall only be continuously operated at their full rating if the minimum current at which circuit protection is designed to operate does not exceed.
(i) 1.5 times the values tabulated for cables installed in air and cables run in single way ducts and
(ii) 1.3 times the values tabulated for cables laid direct in ground.

To BS 6622 Type: SCTA, AC Resistance of 64μΩ for 1-Core x $50mm^2$/phase XLPE/AWA/PVC Cable.

For the purpose of sizing of the secondary cable, the 500KVA transformer secondary current is considered.

The line ampacity is given by:

$$I = \frac{P(KVA)}{\sqrt{3V}} \qquad (15)$$

Where I = line current

P = 500KVA Maximum transformer apparent power

V = 0.4kV Line rated voltage

$$I_P = \frac{500 \times 1000}{\sqrt{3} \times 400} = 721.71A \qquad (16)$$

Reference to IEE Table 4B1 gives correction factor of 0.80 for single layer Single core on cable buried direct to ground = 0.80 x 721.71 = 577.68A

From Nigerchin cable manufacturer, Table for 600/1000V Single core PVC/SWA/PVC Insulated Cable, 1Core x 500sq.mm Cable with current carrying capacity of 655A and volt drop of 0.21mV Laid direct to ground is recommended

- **Cable Voltage Drop is calculated using the formula.**

Voltage drop analysis is evaluated against permissible allowable voltage requirement for consumer load, Indicated in the design criteria.

Given the following parameter;

Length of run in meter = 10m,

secondary cable current, I = 721.71A

Volt drop for 500sq.mm Cable, Vd = 0.21mV

Recall the formula for volt drop,

$$V_{drop} = mV \times A \times m \qquad (17)$$

$$\text{Hence, } V_{drop} = \frac{0.21 \times 721.71 \times 10}{1000} \qquad (18)$$

$$= 1.52 \text{ Volts} \qquad (19)$$

Based on the above voltage drop analysis which is within permissible limit of 5%, the selected 1-core x 500sq.mm PVC/SWA/PVC Cable is adequate

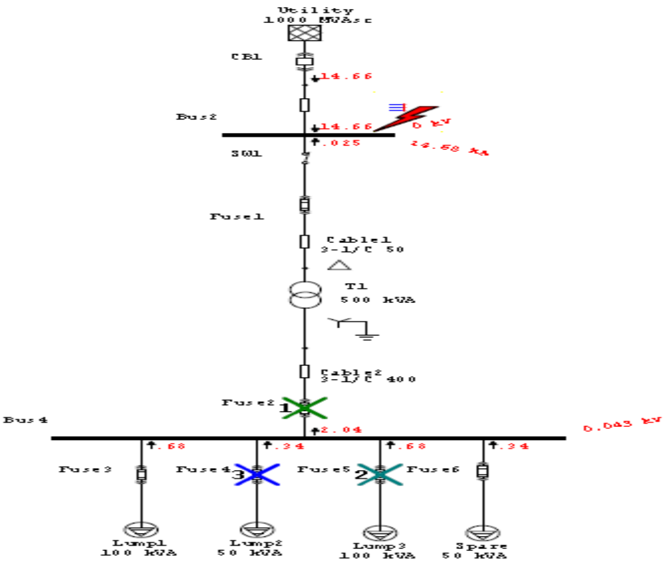

Fig 2: Cable Short circuit withstanding current

The cables must also be evaluated against short circuit rating current. All cables should be able to withstand the highest symmetrical short circuit current of the network at the point of consideration. Short circuit withstanding time is usually considered 1 second and is supposed maximum conductor temperature not to exceed 150ºC for PVC sheathed, 250ºC for XLPE insulated cables.

The general formula for cable short circuit current is:

$$I_{SC} = \frac{K \times A}{\sqrt{t}} \tag{20}$$

Where
t= Short circuit time duration
A= Cable cross section in mm
ISC = Effective short circuit current level as r.m.s value
K= Depends on the cable conductor and insulation material

- **For Transformer Secondary Cable**

Given the following parameter;
Cable cross section Area = 500sq.mm
Constant K for PVC Cable = 115
Time, t = 3Sec.

$$\text{Therefore, } I_{SC} = \frac{115 \times 500}{\sqrt{3}} \tag{21}$$

$$= 33{,}198.6\text{A} \tag{22}$$

$$= 33.2\text{KA} \tag{23}$$

- **FEEDER PILLAR SELECTION & SIZING**

From the above ampacity calculation, it is given that the secondary current for a 500KVA transformer is 721.71amps, hence the recommended feeder pillar size is given as; 800A, 400V, 50KA, 50Hz Feeder pillar with 1no. x 800Amps, 2nos. x 100Amps and 2nos. x 50Amps Outgoing HRC Fuses.

D. OPERATION OF A SUBSTATION

Electricity is generated in a thermal power plant, hydroelectric power plant, and nuclear power plant, etc. This electricity is then supplied to a transmission substation near the generating plant. In the transmission substation the voltage is increased substantially using step up transformers. The voltage is increased to reduce the transmission losses over long distances. This electricity then is supplied to a power substation where it is stepped down using step down transformers and then supplied to a distribution grid. In the distribution grid there are additional transformers and voltage is further reduced for distributing further down the grid. From here the electricity is supplied to step down transformers near residential quarters that step down the voltage to 110/220 Volts as per each country's requirement.

IV. RESULT AND DISCUSSION

In design methodology, the design criteria and the load list were defined and it was also noted that they were necessary to know before the design of the electrical system. In this result a proper single line diagram is designed for feeding the loads based on the criteria defined in methodology. To achieve this, manual calculations of the required power should first be performed to assist us in selection of equipment's and bus bars. Then, these calculations are checked by two main studies as Load Flow Study and Short Circuit Current Study which is conducted by ETAP software.

A. Preliminary single line diagram

After preparing load list(s) and understanding the demand, we need to design a stable network to supply our required power. During the design, feeding type mentioned in the load list and voltage level should be taken into account so that we would get general idea how to feed the loads. Normal loads are fed from the normal bus bar and essential loads such as emergency lightings are fed from the emergency bus bar.

The sizing of transformers, bus bars, and circuit breakers should be performed by load balance study as well as software simulations which are mentioned in this result.

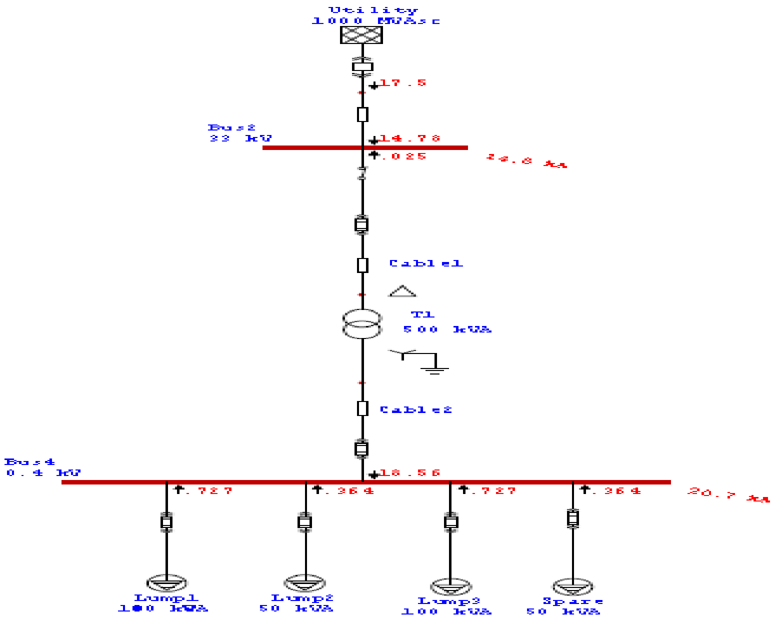

Fig 3: Singe Line Diagram

B. The load flow

The load flow studies should include the preparation of calculations and diagrams showing the distribution of loads under predicted abnormal operating conditions, such as loss of one generator, feeder or transformer due to fault or maintenance conditions. System losses shall also be determined and indicated on the diagrams.

Voltage drop and voltage regulation calculations shall be carried out as part of the load flow studies. These calculations shall determine the voltage profile of the network under full load and light/no load conditions.

The results of the above load flow studies shall be used to check the following:

- System voltage profile and phase angles
- Transformer ratings/loadings
- Power losses
- Transformer taps settings/ratings

C. LOAD FLOW STUDIES

Load flow studies are carried out in order to calculate all bus voltages, branch power factors, currents and power flows throughout the electrical system. The load flow reports shall tabulate the magnitude of active (real) power and reactive power which have been supplied by transformer, feeder and bus bar with the total connected load. Load flow diagrams shall be prepared for both main and essential systems and shall indicate KW, KVAR figures, bus bar volts and voltage phase angles. 25

- **LOAD FLOW REPORT OF SOFTWARE**

Load flow should be done under the normal condition when bus tie is open. According to design criteria 5 percentage tolerance on each bus is allowed.

By studying the reports, it can be concluded that voltage drops are acceptable. The transformer sizing is perfect, and spare capacity of 20 % is met on all transformers.

Table 6: Unbalanced Load Flow Report

Project:	Distribution Substation Design	ETAP		Page:	1
Location:	Rivers State College of Art Sc	6.0.0		Date:	26-10-2015
Contract:				SN:	12345678
Engineer:	Uchenna Osim	Study Case:	ULF	Revision:	Base
Filename:	Distribution System			Config.:	Normal

UNBALANCED LOAD FLOW REPORT

Bus			Voltage		Generation		Load		Load Flow						XFMR
ID	kV	Phase	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	Phase	MW	Mvar	Amp	% PF	% Tap
* Bus1	33.000	A	100.000	0.0	0.085	0.054	0	0	Bus2	A	0.085	0.054	5.3	84.5	
		B	100.000	-120.0	0.085	0.054	0	0		B	0.085	0.054	5.3	84.5	
		C	100.000	120.0	0.085	0.054	0	0		C	0.085	0.054	5.3	84.5	
Bus2	33.000	A	99.992	0.0	0	0	0	0	Bus1	A	-0.085	-0.055	5.3	84.2	
		B	99.992	-120.0	0	0	0	0		B	-0.085	-0.055	5.3	84.2	
		C	99.992	120.0	0	0	0	0		C	-0.085	-0.055	5.3	84.2	
									Bus3	A	0.085	0.055	5.3	84.2	
										B	0.085	0.055	5.3	84.2	
										C	0.085	0.055	5.3	84.2	
Bus3	33.000	A	99.992	0.0	0	0	0	0	Bus2	A	-0.085	-0.055	5.3	84.1	
		B	99.992	-120.0	0	0	0	0		B	-0.085	-0.055	5.3	84.1	
		C	99.992	120.0	0	0	0	0		C	-0.085	-0.055	5.3	84.1	
									Bus6	A	0.085	0.055	5.3	84.1	
										B	0.085	0.055	5.3	84.1	
										C	0.085	0.055	5.3	84.1	
Bus4	0.400	A	97.942	-31.0	0	0	0.084	0.052	Bus6	A	-0.084	-0.052	438.5	85.0	
		B	97.942	-151.0	0	0	0.084	0.052		B	-0.084	-0.052	438.5	85.0	
		C	97.943	89.0	0	0	0.084	0.052		C	-0.084	-0.052	438.5	85.0	
Bus6	0.400	A	98.124	-30.9	0	0	0	0	Bus4	A	0.084	0.052	438.5	85.0	
		B	98.124	-150.9	0	0	0	0		B	0.084	0.052	438.5	85.0	
		C	98.124	89.1	0	0	0	0		C	0.084	0.052	438.5	85.0	
									Bus3	A	-0.084	-0.052	438.5	85.0	
										B	-0.084	-0.052	438.5	85.0	
										C	-0.084	-0.052	438.5	85.0	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# Indicates a bus with a load mismatch of more than 0.1 MVA

Table 7: BILL OF ENGINEERING MEASUREMENT AND EVALUATION (BEME) FOR 500KVA, 33/0.415KV DISTRIBUTION SUBSTATION

ITEM NO	DESCRIPTION	QUANTITY	UNIT PRICE N K	AMOUNT N K
A	**OHL POLES WITH FITTINGS AND ACCESSORIES**			
1	10.36m concrete poles	14	18,500.00	185,000.00
2	8.54m concrete poles	10	15,000.00	2,400.000.00
3	11kV channel iron	12	3500.00	42,000.00
4	11kV tie strap	60	350.00	21,000.00
5	11kV pin insulator	30	950.00	99,750.00
6	11kV spindle		530.00	50,350.00
7	11kV jumper spindle	6	430.00	6,450.00
8	Disc (strain) insulators	48	1750.00	
9	Tension clamp	16	1500.00	
10	Socket tongue	16	500.00	
11	J-hook	16	500.00	
12	Clevis adaptor	16	500	
13	11kV stay insulator	18	250.00	4,500.00
14	0.415kV stay insulator	42	250.00	10,500.00
15	33kV 7/8 stay wire	100m	250.00	25,000.00
16	0.415kV 5/8 stay wire	200m	150.00	30,000.00
17	33kV stay rod	18	3000.00	54,000.00
18	0.415kV stay rod	10	2000.00	20,000.00
19	Stay thimble	40	150.00	6,000.00
20	Stay block	40	280.00	11,200.00
21	Double groove shackle insulator complete	40	200.00	8,000.00
22	16x51 bolts and nuts	Lot	-	50,000.00
23	16x254 bolts and nuts	Lot	-	50,000.00
24	16x280/305 bolts and nuts	Lot	-	50,000.00
25	Bimetal line tap	10	1000.00	10,000.00

26	Pole identification	200	65.00	13,000.00
27	Anti-climbing devices	150m	100.00	9,750.00
28	Danger plates	40	100.00	4,000.00
	SUB TOTAL AMOUNT			**4,171,040.00**
B	**CONDUCTORS**			
1	100mm^2 AAC conductors for 33kV O-H lines	3000m	400.00	1,200,000.00
2	70mm^2 AAC conductors for 0.415kV O-H lines	1200m	350.00	420,000.00
3	33kV gang isolators	1	130,000.00	130,000.00
	SUB TOTAL AMOUNT			**1,750,000.00**

C	**SUBSTATION MATERIAL**			
1.	500KVA, 33/0.4KV, 50Hz, ONAN Cooled power transformer	1	2,400,000.00	2,400,000.00
2.	800Amps, 4-Ways Feeder Pillar with 800Amps incomer HRC Fuse, 2nos. x 100Amps and 2nos. x 50HRC Outgoing Fuses.	1	150,000.00	150,000.00
3.	1-Core x 50sq.mm XLPE/PVC Cable	45m	5,000.00	225,000.00
4	33kv Lighting Arrester	1set	22,000.00	22,000.00
5.	33kv Drop-out Fuse	1set	25,000.00	25,000.00
6.	33kv Raychem termination kit	2set	20,000.00	40,000.00
7.	1-core x 500sq.mm PVC/SWA/PVC Cable	60m	9,000.00	540,000.00
8	70sq.mm Bare copper conductor	100m	1,500.00	150,000.00
9.	500mm Cable lug	10	1,000.00	10,000.00
10.	70mm Cable lug	30	250.00	7,500
11.	50mm Cable lug	10	200	2,000.00
12	Bolt, nut and washers	1lot	20,000.00	20,000.00
10.	3M scotch tape	5	1000	5,000.00
	SUB-TOTAL			**5,950,000.00**
	TOTAL			**11,871,040.00**

V. Conclusion

We have done a design of a 3-phase 500KVA 33KV/0.40KV distribution substation taking into consideration, the incoming voltage of 33KV, a 500KVA transformer rating with output voltage of 0.4KV.

In conclusion, this design is focused on a distribution substation, its classification, type, design diagrams, calculation, rating and cost estimation among others. The implementation of this design, will greatly enhance power distribution in Port Harcourt Polytechnic as well as reduce the frequent power outages experienced here as a result of low voltage, equipment breakdown and system failure.

Reference

[1]. G.B Gupta, "Electrical Power", 15th Edition, S.K Kataria & Sons 4885/109, New Delhi-110002, January 2013

[2]. Mukund R. Patel, "Introduction to Electrical Power and Power Electronics", CRC Press, New York Washington D.C, December 2012

[3]. Stockton Blaine, "Design Guide for Rural Substations", USDA Rural Development, United States Department of Agriculture, USA, Retrieved 4 February 2016

[4]. John Alvin, "EE35T-Substation Design and Layout", The University of the West Indies at St. Augustine, Trinidad and Tobago, Retrieved 4 February 2016

[5]. N.E Oludi, "Basic Electrical Power Systems and Electronics Fundamentals", Trumpet press publishers, Bori-Ogoni, 2008

[6]. www.rivcasonline.com/index.php/about/about-port-harcourt-polytechnic

[7]. W.J.R.H. Pooler, "Electrical Power", Bookboon, 2014, http://bookboon.com/en/search?q=author%3A%22W.%20J.%20R.%20H.%20Pooler%22

[8]. ABB Technical Application Paper Volume 2: MV/LV transformer substations, theory and an example of short circuit calculation, February 2008, 1SDC007101G0202

[9]. Sudipta Sen, Arindam Chatterjee, Debanjan Sarkar, "Design of 132/33KV Substation", International Journal of Computational Engineering Research/Vol, 03/Issue, 7/

[10]. Reza Vafamehr, "Design of Electrical Power Supply System in an Oil and Gas refinery", CHALMERS UNIVERSITY OF TECHNOLOGY,Goteborg, Sweden, 2011

[11]. Chunikhin and M. Zhavoronkov, "High Voltage Switchgear Analysis and Design", Mir Publishers, Moscow, 1981. PP. 207-208

[12]. John Tarilanyo Afa, "Selection of Lightning Arrester in the Niger Delta Environment", International Journal of Innovation and Applied Studies, ISSN 2028-9324 Vol.3 No.1 May 2013, pp. 318-325, http://www.issr-journals.org/ijias/

[13]. Baker, Joseph W, "Eliminating Hurricane Induced Storm Surge Damage to Electric Utilities via In-place Elevation of Substation Structures and Equipment". DIS-TRAN Packaged Substations. Crest Industries, Retrieved 4 February 2016

[14]. Power System Earthing Guide, Version 1, May 2010 Energy Networks Association Limited, ABN 75 106 735 406, Level 3, 40 Blackall Street, BARTON ACT 2600, www.ena.asn.au

[15]. ABB Electrical installation hand book, second edition Published by ABB SACE via Baioni, 35 -24123 Bergamo (Italy)

[16]. Donald G. Fink, H. Wayne Beatty Standard Handbook for Electrical Engineers Eleventh Edition, McGraw Hill 1978 ISBN 0-07-020974-X Chapter 17 Substation Design

[17]. Alexandra Von Meler, "Electric Power Systems: A Conceptual Introduction", publisher: Wiley-IEEE Press, August 2006

[18]. Shehab Abdulwadood Ali, "Design of Lightening Arrester for Electrical Power Systems Protection", Power Engineering and Electrical Engineering, Volume: 11 /Number: 6/ 2013/ December

[19]. IEE, Inc;"Wiring regulations for Electrical Installation", 17th edition, The Institute of Electrical Engineering, London

[20]. IEC 60076-5: Power Transformers Part 5: Ability to Withstand Short Circuit First Edition; (Amendment 2-1994)

[21]. IEC 60947-2: Low-Voltage Switchgear and Control gear Part 2: Circuit-Breakers Second Edition; Corrigendum-1997; Amendment 1-1997

[22]. IEC 60502: Extruded Solid Dielectric Insulated Power Cables for Rated Voltages from 1kv up to 30kv First Edition

[23]. IEC 60909: Short-Circuit Current Calculation in Three-Phase A.C. Systems First Edition

[24]. IEC 60056: High-Voltage Alternating-Current Circuit-Breakers Fourth Edition; Corrigendum- 04/1989; Amendment 1-1992; Amendment 2-1995; Amendment 3-1996

[25]. IEC 60079-10: Electrical Apparatus for Explosive Gas Atmospheres Part 10: Classification of Hazardous Areas Third Edition; Corrigendum-1996

[26]. IEC 60079-12: Electrical Apparatus for Explosive Gas Atmospheres Part 12: Classification of Mixtures of Gases or Vapours with Air According to Their Maximum Experimental Safe Gaps and Minimum Igniting Currents First Edition

[27]. Iranian petroleum standard (IPS-E-EL-100): Engineering standard for electrical system design (industrial and non industrial), original edition, December 1997

[28]. Current Ratings& Associated Voltage Drop, Single Core PVC Insulated PVC Sheathed Armoured 600/1000V Cables, Nigerchin Data Sheet

[29]. Single Core PVC Insulated PVC Sheathed Armoured & Unarmoured, 600/1000V Cables, BS6346, Nigerchin Data Sheet

Ijeoma R.C" Design Of 3phase 50hz 500kva 33/0.4kv Distribution Substation" IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) 14.4 (2019): 38-48.