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Analysis of Electrical Power Network for Udi 11kV, Mile 2 Diobu, Port Harcourt for Improved Distribution

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ABSTRACT : *Electric power distribution network systems form the last part of the network that deliver electricity from the generation stations to the consumers via the transmission or the sub transmission systems. This research paper is a study about the analysis of electric power network for Udi 11kV network, mile 2 Diobu Port Harcourt for improved distribution. Collection and analysis of data collected from the injection substation that supply electricity to mile 2 Diobu, Port Harcourt was the first task. This study used Electric Transient Simulation software (ETAP) to conduct load flow analysis using Gauss-Seidel power flow equation and from the simulation, the existing distribution network has transformers overloading problems along Udi 11KV network. To address the problems, feeder bifurcation and up gradation as optimization techniques were employed to improve the Udi 11kV distribution network. The simulation of the improved distribution network shows that the loading of the transformers in Udi 11KV network are all below 60%.*

KEYWORDS: *Electric power distribution network, overloading of distribution transformers, feeder bifurcation, up gradation and Electric Transient Simulation software (ETAP).*

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I. INTRODUCTION

Electric power distribution network systems form the last part of the network that deliver electricity from generation stations to the consumers via the transmission or sub transmission systems. The first component of the electrical distribution system is the injection substation, which is a place where the transmission line voltage (132kV) or sub transmission line voltage (33kV) is lowered by step down transformer to obtain primary distribution line voltage (11kV) and this primary distribution line called feeder takes the energy to the load center and the distribution transformer at the load center further steps down the voltage to secondary distribution line voltages, which are: 415Volts for three phase supply while 240Volts for single phase supply and neutral [1].

A good distribution system must have the following requirements: The rated voltage of the system must not be interrupted, the distribution system should not be overloaded, the dielectric strength of the insulation used in the system should be high, the system should be reliable and losses in the line should be minimum and the efficiency should be high [2].The role of an electric power system is to fulfill the customers demand requirements with good assurance of quality and supply continuity, electric power is the utmost engine for any form of development such as: economic development and technological development. So the availability of electric power is very crucial for any form of development in any nation [3].

In the development of any nation, the supply of an adequate electricity is a key driver to any energy poor society [4]. Electrical energy in Nigeria is generated mainly from coal, natural gas and hydroelectric stations. Because natural gas, coal, oil and hydro power are abundant in Nigeria [5].

II. RELATED WORK

[6]: This research paper focuses on the study of distributed generation in enhancing the power system reliability (Addis center substation a case study). According to the research paper, the substation suffered regular electricity interruptions and energy reliability problems and these problems were caused by earth fault and short circuit conditions. The average electricity interruption duration and frequency was below standard and this called for research work to provide adequate technique for enhancing the reliability of the distribution network. A single distributed generation of 3.5MW is incorporated to the grid which serves as a back up when

electricity interrupt occurs. The kind of technology employed for the distributed generation is the fuel cell, for the reliability analysis Dig Silent soft ware is employed for the simulation and the placement or location of the distribution generation is done at the place of the load point.

[7]: In his research paper analyses the daily outage data collected for a period of about twelve (12) months (April 2003 to April 2004). From these data, the type, number and duration of the outages were recognized, the plots of outage distribution of five 11KV feeders were obtained. Their forced outages were compared as well. Also, the outage plots of three 33KV feeders were obtained and their forced outages compared. Power losses due to the feeder outage were considered and the feeders, at each voltage level were investigated for power loss. the results obtained were discussed, possible reasons for the causes of the outages were presented and befitting recommendations and solutions were proposed.

[8]: This research is a study on improved distribution substation at Beshoftu city. After evaluating and analyzing the data collected from the existing substation, it is observed that the substation is faced with the following problems: the energy management ability is low the maintenance service is poor and very low reliability level. The following design and simulation softwares are used: Dig Silent, Auto CAD and ETAP. A new substation that having automatic switches, communication and earthing systems to reduce electricity interruption durations, to pass information from control room to load dispatcher center and to provide safe working environment is proposed. After simulating the new substation, it shows that it yields the required and desired improvements.

III. MATERIALS AND METHOD

The major data source for this research work is Port Harcourt Electricity Distribution Company (PHEDC). In the course of the study, gathering of important data of different types is an essential task, various books, and theories have been referred to. The data gathered are: installed capacity of transmission substation, installed capacity of injection substation, examined feeders, total number and power rating of distribution transformers and singe line diagram of power distribution network for Mile 2 Diobu, Port Harcourt. Source: (PHEDC).

Method: Gauss-Seidel Method was used for computing bus voltages and the simulation Udi 11kV feeders were carried out using ETAP software.

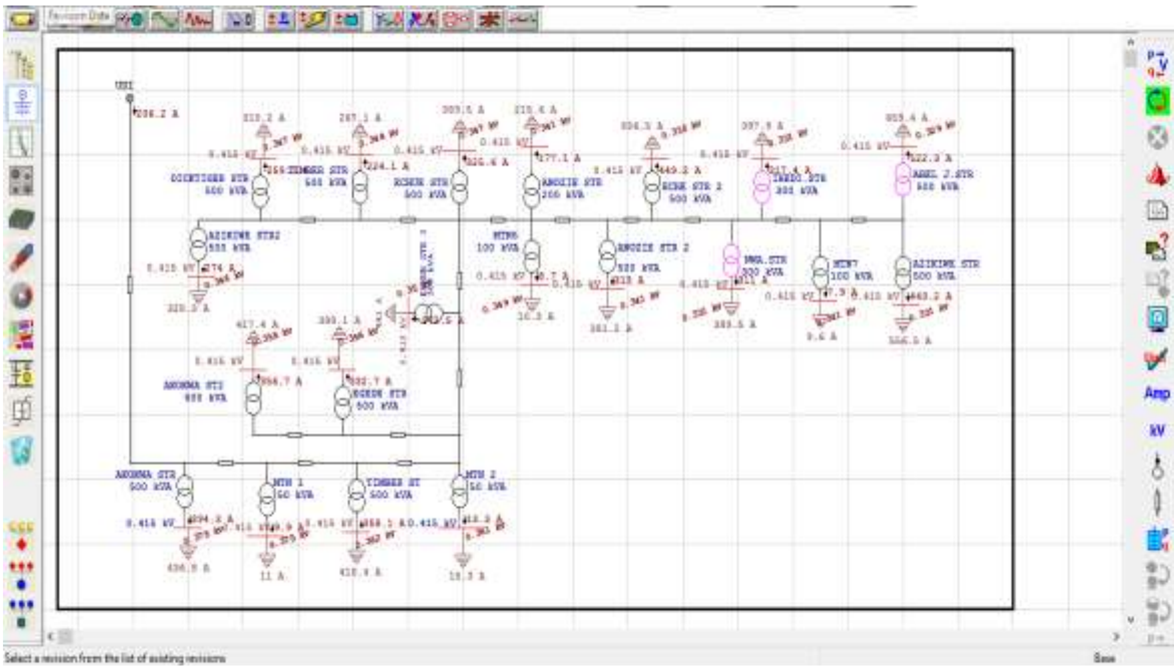

Figure 1: Pre-Upgrade Single Line Diagram of Udi 11kV Network

The figure1 gives pre-upgrade single line diagram for Udi 11kV network. The simulation of the network shows that three transformer are overloaded in the network. A 500kVA distribution transformer is overloaded at Abel Jumbo Street, while the remaining two 300kVA transformers that are overloaded are located at Ihediohama and Nwachukwu Street. The network suffers overloading.

The information in table 1.1 below used to calculate average current, apparent, active, reactive and complex power and percentage loading.

Table 1: The Location of Transformers, rating and current reading in Udi 11KV feeder

S/NO	NAME OF STREET/LOCATION OF TRANSFORMER	TRANSFORMER RATING	READING			
			R (A)	Y (A)	B (A)	N (A)
1.	Akokwa / Ojoto Street	300KVA	420	426	440	25
2.	Timber / Lumumba	500KVA	378	370	402	80
3.	Akokwa/Lumumba Street	500KVA	350	345	380	25
4.	Egede/Lumumba Street	500KVA	380	371	385	29
5.	Echue Street 3	500KVA	410	389	475	50
6.	Echue Street 2	500KVA	410	342	440	95
7.	Anozie Lumumba Street	500KVA	250	240	245	30
8.	Dick Tiger /III 1	500KVA	305	290	295	40
9.	Timber / III	500KVA	250	270	245	35
10.	Echue/III	500KVA	395	340	390	40
11.	Anozie/III	500KVA	210	205	198	35
12.	Nwachukwu/III	300KVA	348	240	402	80
13.	Ihediohama /III	300KVA	350	359	385	45
14.	Abel Jumbo Street	500KVA	500	456	420	140
15.	Azikiwe /111	500KVA	210	205	200	30
16.	Dick Tiger /1112	500KVA	310	264	350	60
17.	MTN 1	50KVA	12	10	38	3
18.	MTN 2	100KVA	14	17	810	5
19.	MTN 5	100KVA	10	8	49	4
20.	MTN 7	50KVA	8	10	49	2

Source: Port Harcourt Electricity Distribution Company (PhEDC).

a. Calculating the Transformer load and percentage load in Udi 11KV feeder

1. Akokwa/Ojoto transformer (300kVA)

Applying equation 3.2 above

$$\text{Current, I} = \frac{420+426+440+25}{3} = 437\text{A}$$

Loading on the transformer, $S_{VA,}$ applying equation 3.3 above

$$S_{VA} = \sqrt{3}\times V\times I$$

$$S_{VA} = \sqrt{3}\times 0.415kV\times 437A$$

$$S_{VA} = 1.732\times 0.415kV\times 437A$$

$$= 314.10\text{kVA}$$

Applying equation 3.1 above

$$\%\ \text{loading} = \frac{S_{VA}}{S_{MAX}}\times 100\%$$

$$= \frac{314.10kVA}{300kVA}\times 100\%$$

% loading = 104.7%

Applying equation 3.4 above

Active Power = 314.10 × 0.8

P = 251.28kW

Applying equation 3.5 above

Reactive Power = 314.10 × 0.6

Q = 188.19kV_{ar}

Applying equation 3.6

Complex Power, S = 251.28kW +j188.46kV_{ar}

This method was used in determine the current, Percentage loading, Active power, Reactive power and Complex in Udi 11KV network.

3.1 Modeling of Power Flow Equation for Existing Network

The power system is a large interconnected system with several buses connected through transmission lines. The first step in solving power flow problem is the formation of bus admittance matrix which is constructed from transmission line data.

3.2 Gauss-Seidel Method for Computing bus Voltages

Considering a 2-buses system with bus 1 designated as the swing or slack bus. Computation of bus voltage start from bus 1 to bus 2.

IV. RESULT AND DISCUSSIONS

Table 2: below gives the values of current, apparent, active, reactive, complex power and percentage loading of distribution transformers on Udi 11kV feeder. The analysis shows that the 500kVA distribution transformers at Akokwa/Ojoto Street, Nwachukwu/Illaubuchi Street and Ihediohama/Illaubuchi Street are loaded 104.70%, 93.4% and 90.90% respectively.

S/N	Name of street/ location of transformers	Transformer rating (KVA)	Current (A)	Apparent power (KVA)	% loading	Active power (KW)	Reactive power (KV_{ar})	Complex power
1.	Akokwa/Ojoto Street	300	437.00	314.10	104.70	251.28	188.19	251.28kW+j188.19kV_{ar}
2.	Timber/Lumumber	500	410.00	294.69	58.90	235.75	176.81	235.75kW+j176.81kV_{ar}
3.	Akokwa/Lumumba Street	500	366.66	263.54	52.70	210.83	158.21	210.83kW+j158.21kV_{ar}
4.	Egede/Lumumba Street	500	388.33	279.12	55.80	223.29	167.47	223.29kW+j167.47kV_{ar}
5.	Echue Street 3	500	441.33	317.22	63.40	253.77	190.33	253.77kW+j190.33kV_{ar}
6.	Echue Street 2	500	429.00	308.35	61.60	246.68	185.01	246.68kW+j185.01kV_{ar}
7.	Anozie/Lumumba Street	500	255.00	183.28	36.60	146.62	109.96	146.62kW+j109.96kV_{ar}
8.	Dick Tiger/Illoabuchi 1	500	310.00	222.82	44.50	178.25	133.69	178.25kW+j133.69kV_{ar}
9.	Timber/Illoabuchi	500	266.66	191.66	38.30	153.32	114.99	153.32kW+j114.99kV_{ar}
0.	Echue Illoabuchi	500	388.33	279.79	55.90	223.83	167.87	223.83kW+j167.87kV_{ar}
1.	Anozie/Illoabuchi	500	216.00	155.25	31.10	124.20	93.15	124.20kW+j93.15kV_{ar}
2.	Nwachukwu III	500	390.00	280.32	93.40	224.25	168.19	224.25kW+j168.19kV_{ar}
3.	Ihediohanma III	300	379.66	279.89	90.90	218.31	163.73	218.31kW+j163.73kV_{ar}
4.	Abel Jumbo Street	300	475.33	341.66	68.30	273.32	204.99	273.32kW+j204.99kV_{ar}
5.	Azikiwe/Illoabuchi	500	215.00	154.53	30.90	123.62	92.71	123.62kW+j92.71kV_{ar}
6.	Dick Tiger/Illoabuchi	500	328.00	235.75	47.10	188.60	141.45	188.60kW+j141.45kV_{ar}
7.	MTN 1	500	11.00	7.90	16.00	6.32	4.74	6.32kW+j4.74kV_{ar}
8.	MTN 2	100	15.33	11.02	22.00	8.81	6.61	8.81kW+j6.61kV_{ar}
9.	MTN 5	100	10.33	7.42	7.40	5.93	4.45	5.93kW+j4.45kV_{ar}
0.	MTN 7	50	9.66	6.94	14.00	5.55	5.16	5.55kW+j4.16kVar

Table 3: Below gives the values of resistance, reactance, impedance, susceptance, conductance and admittance of Udi 11kV feeders.

S/N	Feeder (11kv)	Resistance of the Feeder (Ω)	Reactance of the feeder (Ω)	Impedance of the feeder (Ω)	Susceptance of the feeder (S)	Conductance of the feeder (S)	Admittance of the feeder (S)
1.	Udi	0.674	1.206	0.694+j1.206	0.00001227	1.483	1.483+j0.00001227

Table 4: Below gives a summary of source voltage, end voltage, voltage drop and percentage voltage regulation of Udi 11kV feeders. Udi feeder is 3.42%. The value is within the statutory limit from -6% to +6%.

S/N	Feeder Name	Source Voltage (kV)	End voltage (kV)	Voltage drop (kV)	Percentage Voltage regulation (%)
1.	Udi	11.00	10.624	0..376	3.42

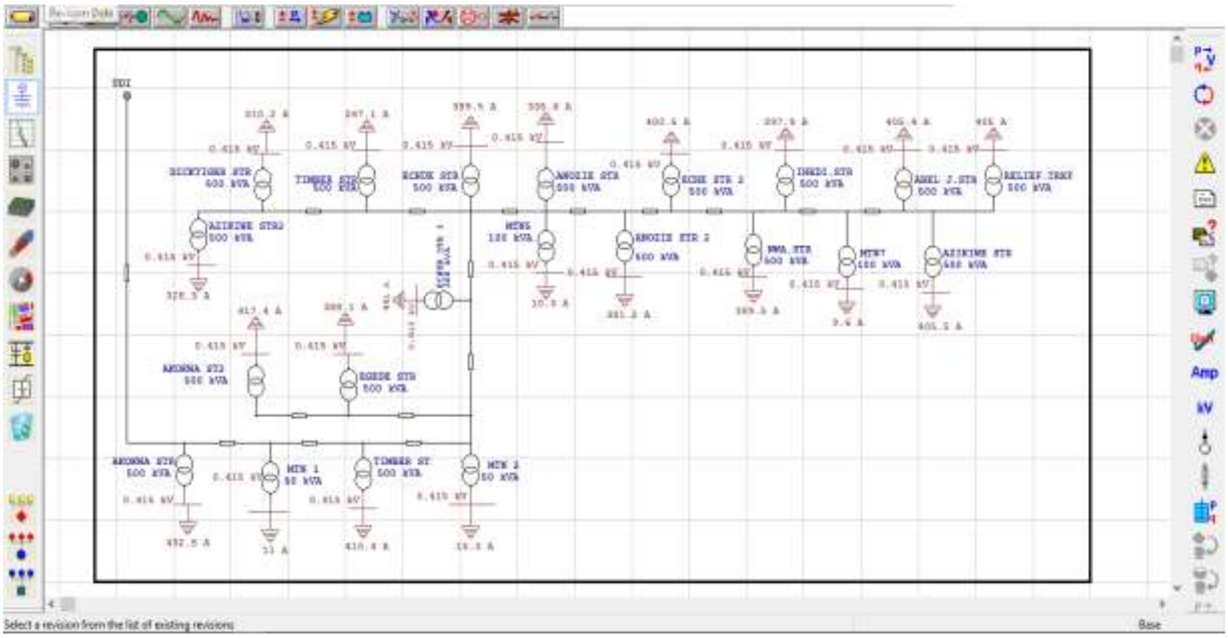

Figure 2: Post-Upgrade Single Line Diagram of Udi Feeder

Figure 2: above gives post-upgrade single line diagram for Udi 11kV network with two 300kVA distribution transformers at Nwachukwu and Ihediohama Streets upgraded to 500kVA transformers, it was done based on calculations to reduce or minimize losses in the network and 500kVA relief transformer was added at Abel Jumbo Street and load bifurcation was carried out to relief the overloaded transformer at Abel Jumbo Street.

Table 5: Bus Voltage Operating Condition for Udi Feeder

S/NO.	NAME OF STREET / LOCATION OF TRANSFORMER	RATED VOLTAGE KV	OPERATING VOLATGE KV	% OPERATING
1	Akokwa Street 1	0.415	0.398	96.000
2	Akukwa Street 2	0.415	0.409	98.600
3	Egede Street	0.415	0.410	98.700
4	DickTiger Street	0.415	0.411	99.000
5	Nwachukwu Street	0.415	0.409	98.700
6	Azikiwe Street 1	0.415	0.409	98.600
7	Azikiwe Street 2	0.415	0.411	99.000
8	Timber Street 1	0.415	0.409	98.600
9	Timber Street 2	0.415	0.412	99.300
10	Anozie Street 1	0.415	0.41	98.700
11	Anozie Street 2	0.415	0.411	99.000
12	Echue Street 1	0.415	0.398	95.900
13	Echue Street 2	0.415	0.409	98.700
14	Echue Street 3	0.415	0.399	96.100
15	Ihediohama Street	0.415	0.409	98.600
16	Abel Jumbo Street	0.415	0.409	98.600
17	Relief Transformer	0.415	0.407	98.100

Table 5 above gives the post-upgrade simulation result for bus operating voltage condition and percentage operating for Udi 11kV network. From the result, the bus operating voltage has improved and percentage operating is within 95.9-99.3%. The network is in an improved condition. Because the percentage operating of the busses are within the statutory limit been 95.9-99.3%.

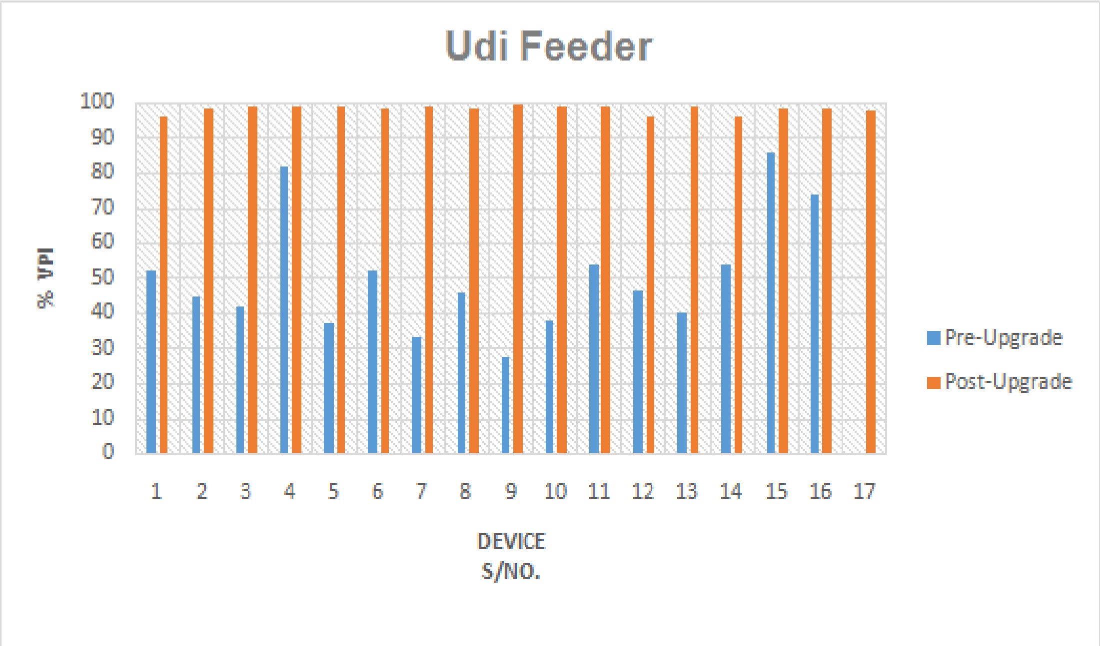

Chart 1: Voltage Performance Index plot for pre and post upgrade network condition

The chart of voltage performance index for pre-upgrade network condition for Udi feeder shows that all busses in Udi 11kV network are operating below 95% of the nominal voltage and for the post-upgrade network condition, an additional transformers was added to relief the overloaded transformers and bifurcation was carried out which reduced the losses in the network and improved the voltage profile of the buses within 95.9-99.0% of the nominal voltage.

Table 7: Transformer Operating Condition for Udi Feeder

S/NO.	NAME OF STREET/LOCATION OF TRANSFORMER	TRANSFOMER RATING KVA	OPERATING LOAD KVA	% OPERATING
1	Akokwa Street 1	500.0	293.0	58.6
2	Akukwa Street 2	500.0	278.0	55.6
3	Egede Street	500.0	277.0	55.4
4	DickTiger Street	500.0	223.0	44.6
5	Nwachukwu Street	500.0	278.0	55.6
6	Azikiwe Street 1	500.0	289.0	57.8
7	Azikiwe Street 2	500.0	235.0	47.0
8	Timber Street 1	500.0	293.0	58.6
9	Timber Street 2	500.0	192.0	38.4
10	Anozie Street 1	500.0	274.0	54.8
11	Anozie Street 2	500.0	240.0	48.0
12	Echue Street 1	500.0	199.0	39.8
13	Echue Street 2	500.0	278.0	55.6
14	Echue Street 3	500.0	272.0	54.4
15	Ihediohama Street	500.0	284.0	57.8
16	Abel jumbo Street	500.0	289.0	57.8
17	Relief transformer	500.0	286.0	57.2

Table 7 above gives the post-upgrade simulation result for transformer operating load condition and percentage operating condition for Udi 11kV network. From the result, all the transformers are loaded below 60.00%. This is a good loading condition.

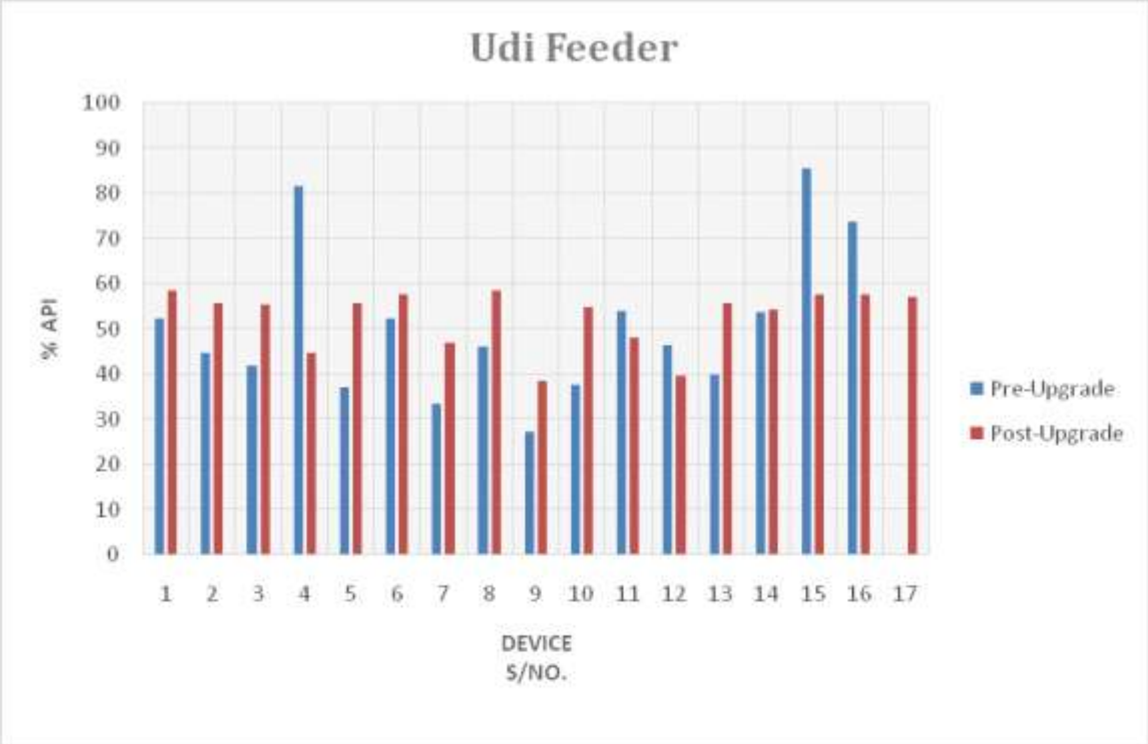

Chart 2:Apparent Power Performance Index plot for pre and post upgrade network condition

The chart of apparent power performance index for pre-upgrade network condition shows that three transformers are loaded above 60%. They are overloaded but in the post-upgrade network condition, an addition transformer was added to relief the overloaded transformers and this reduced the percentage loading of the transformers to be within 38.4.8-58.6%.

V. CONCLUSION

The study examined the existing electric power distribution network of Udi 11kV in Mile 2 Diobu, Port Harcourt. The 33/11kV Water Works injection substation supply power to Udi 11kV and the injection sub station is fed from 165 MVA transmission station (PH Town) at Amadi junction by Nzimiro. The distribution network was modeled in Electrical Transient analyzer program (ETAP) using Gauss-Seidel power flow equation. Power flow analysis was conducted for both existing pre-upgrade network and the modified (post-upgrade) network.

The results were analyzed overloaded distribution transformers were identified. Transformers loading 70% were taken as overloading. The reason for over loading were identified and a cost effective optimization techniques were proposed in the post- upgrade. Based on the finding, it is here by concluded that power flow studies is important for planning of future expansion of power system as well as determining the best operating condition of the existing system. Up-gradation of distribution transformers and feeder bifurcation were found to be effective in eliminating over loading from the system and reduce losses in the system.

RECOMMENDATION

Based on the findings and to ensure optimum performance and reliability of Udi 11kV distribution network, it is recommended that, the two existing 300kVA distribution transformers at Ihediohama and Nwachukwu Streets respectively be upgraded to 500kVA.

Finally, 500KVA distribution transformer should be added to Udi feeder and feeder bifurcation should be carried out to relief the overloaded transformer at Abel jumbo and Azikiwe Street.

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