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PERFORMANCE IMPROVEMENT OF DISTRIBUTION NETWORKS: A CASE OF NEW-ROAD-OKILTON BY ADA-GEORGE RIVERS STATE, NIGERIA.

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Abstract

The study assessed the performance improvement of New-Road-Okilton by Ada-George electric power distribution system consisting of twenty-three (23) distribution transformers. The network was modelled in Electrical Transient Simulation software (ETAP12.6) and load flow performed using Newton-Raphson technique. The result obtained from the pre-upgrade network shows that buses [17(0.949pu), 18(0.948pu), 19(0.947pu), 20 (0.947pu), 21(0.946pu), 22(0.946pu) and 23(0.945pu)]violates thebus voltage statutory limit conditions 0.95-1.01pu. Also, the transformers that are loaded above 80% are as follows:- [4(107.67%), 5(118.33%), 6(113.67%), 11(106.33%) and 21(107.67%)]. Real and reactive power losses on the line are 130.978KW and 161.086kvar. However, tap setting the transformer LTC, upgrading overloaded transformers and placement of capacitor bank improved the voltage profile of the transformers [T4(64.6%), T5(69.0%), T6(68.2%), T11(63.8%) and T21(64.6%)]and the real and reactive power losses in the line have been reduced to 81.94KW and 94.359kvar. It is thereby concluded that the proposed optimization techniques impacted significantly in the improvement of the distribution network.

Key word:Buses, Capacitor bank,Distribution network, Losses, Substation, Voltage profile, Transformer LTC setting.

1.0 Introduction

The pre-requisite condition for socio-economic and technological development of any society is electricity (Gupta, 2006). The distribution system which is the most noticed and exposed part of the power system has received less attention compared to generation and transmission despite the huge amount of returns in investment(Sunday, 2010). According to Patil and Kiran(2013), a good distribution system must not be overloaded and power supply uninterrupted. In the same vein, Uhunmwangho (2013) optimal supply of uninterrupted electric power supply to its teeming consumers is the basic function of electric power system. The existing distribution system infrastructure is overstressed, this has led to epileptic nature of power supply to New Road Okilton by Ada-George. Many homes, small scale businesses and industries operate their private power in order to meet their daily energy demand. Consequently, this have skyrocketed the cost of goods and services and high cost of production. The utility company in a beat to alleviate this challenge has resulted to unplanned load-shedding as an alternative means of providing power to the consumers. Therefore, it is important to critically look at

some of the challenges facing the distribution system and proffer technical solution as a measures to improve electric power supply.

1.1 Objective of Assessment

- 1. To model and simulate the network in Etap 12.6 software environment.
- 2. To determine the weak buses in the network.
- 3. To determine the overloaded transformers in the network.
- 4. To improve the bus voltage in the network using transformer LTC and capacitor bank.
- 5. To improve the load profile by upgrading the overloaded transformers.
- 6. To reduce the real and reactive power loss in the line.

1.2 Significant of the Assessment

Application of the result will reduce losses in the network and improve voltage and load profile of the distribution system. Secondly, it will help in mitigating the unplanned load shedding implemented by the management of the Port Harcourt electricity distribution company (PHED) in a bid to solve the electricity challenges in New Road Okilton by Ada-George.

2.0 Literature Review on Distribution System Network improvement

According to Metia and Ghosh (2015) network reconfiguration is one of the method used in minimizing losses in the distribution system. The techniques involve sectioning of switches.

Hosseinzadeh, and others (2009) in their research reiterated that distribution network reconfiguration is an important aspect of operation geared towards reducing distribution feeder losses.

Metia and Ghosh (2015) pointed out that DG allocation techniques are used in an interconnected system where distributed sources are available. They noted that distribution networks are mostly operated as passive network but with the incorporation of DG makes it an active network.

According to Sai and others (2013) DGs are small generator units placed in the network to provide electricity to the consumers. They noted that DG can be used as an alternative energy source for regular power supply. Some of the merits of DG are simplicity, reliability, efficiency and the use of modern technology.

Zhang and others (2018) proposed an analytical equation to determine the optimal size and the corresponding optimum location for DG placement. The proposed technique was effective for minimizing the total power losses in primary distribution systems

Murthy and others (2010) they noted that capacitors are installed in distribution systems for reactive power compensation and is one of the most effective and useful optimization techniques deployed for reducing power losses in distribution network.

Aman, and others (2014) stated that static capacitor bank in distribution system helps in improving the power factors, reduce power loss and improve the voltage profile. However, they noted that to derive the maximum benefit, the capacitor bank must be placed nearer to the consumer's end.

3.0 Methods used in the Research Work

3.3.1 Load Data:

Table 1:Preliminary Load Data of Distribution Substations

Substation Nominal Data					Ι _Υ	Ι _Β	I _N
Bus No	Bus Name	KVA	kV	(A)	(A)	(A)	(A)
1	Okilton 1	500	11	250	208	200	40
2	Okilton2	500	11	198	118	208	70
3	Aganolu 1	500	11	265	352	414	128
4	Aganolu 2	300	11	415	360	450	102
5	MRS Filling Station	300	11	410	384	512	150
6	Benwosely	300	11	472	420	464	48
7	Chicken Fast Food	500	11	304	310	308	50
8	Lemaco Hall	500	11	290	280	275	35
9	Azeeze Road	500	11	270	285	265	20
10	Okilton Road	500	11	280	274	270	32
11	Road 1	300	11	290	280	275	55
12	Road 2	500	11	270	285	265	50
13	Road 3	500	11	280	274	270	62
14	Road 4	500	11	100	110	125	45
15	Road 5	500	11	315	360	350	75
16	Road 6	500	11	198	118	208	70
17	Road 7	500	11	265	252	214	88
18	Road 8	500	11	250	208	200	40
19	Road 9	500	11	310	384	312	100
20	Road 10	500	11	220	280	200	64
21	Covet	300	11	400	410	425	102
22	Nwobo Street	500	11	315	324	312	80
23	Kali Street	500	11	310	264	296	090

Source: Port Harcourt Electricity Distribution Company (PHEDC)

3.3.2 Load Current Determination (IL)

The average load current (I_L) of the distribution transformer is giving by

 $I_L = \frac{I_R + I_Y + I_B + I_N}{3}$ Where

 I_R = current in the red phase

 I_Y = current in yellow phase

 I_B = current in the blue phase

 I_N = current in neutral

3.3.3 Load Apparent Power Determination (KVA)

The load KVA of a distribution transformer is giving by $KVA_{Load} = \sqrt{3} * I_L * V_s$ 460

(1)

Where

 I_L = average load current

Vs = the secondary voltage of the transformer

3.3.4 Determination of Real and Reactive Power Injected in the Network

Complex power at the *ith* node on the distribution line is given by

$$S_i = V_i I_i^* = P_i + jQ_i \tag{3}$$

$$I_i = \left(\frac{S_i}{V_i}\right)^* = \frac{P_i - j Q_i}{V_i^*} \tag{4}$$

From (4) the current entering the power system is giving by

$$I_{i} = \frac{P_{i} - j Q_{i}}{V_{i}^{*}} = \sum_{k=1}^{n} Y_{ik} V_{k}$$
(5)

$$P_{i} - jQ_{i} = V_{i}^{*}(\sum_{k=1}^{n} Y_{ik} V_{k})$$
(6)

Let
$$V_i^* = V_i \angle -\delta_i$$
, $V_k = V_k \angle \delta_k$ and $Y_{ik} = Y_{ik} \angle \theta_{ik}$ (7)

$$P_i - jQ_i = V_i^* (\sum_{k=1}^n Y_{ik} \, V_k \angle \delta_k + \theta_{ik} - \delta_i) \tag{8}$$

$$P_i - jQ_i = \sum_{k=1}^n |Y_{ik}| |V_i| |V_k| \left[\cos(\delta_k + \theta_{ik} - \delta_i) + j\sin(\delta_k + \theta_{ik} - \delta_i) \right]$$
(9)

Separating (9) into real and imaginary parts we have,

$$P_{i} = \sum_{k=1}^{n} |Y_{ik}| |V_{i}| |V_{k}| \cos(\delta_{k} + \theta_{ik} - \delta_{i})$$

$$Q_{i} = -\sum_{k=1}^{n} |Y_{ik}| |V_{i}| |V_{k}| \sin(\delta_{k} + \theta_{ik} - \delta_{i})$$
(10)
(11)

Where

 Y_{ik} = the admittance matrix P_i = the injected real power Q_i = the injected reactive power

3.3.5Determination of Weak Buses

Voltage Performance Index (VPI) is used to determine the stressed or weak buses in the network.

$$VPI = \sum_{i=1}^{n} \left(\frac{2(V_i - V_{inom})}{V_{imax} - V_{imin}}\right)^2 \tag{12}$$

Where

 V_i = pu value of the operating voltage

 V_{inom} = pu value of the nominal voltage =1

 V_{imin} = pu value of the minimum voltage limit = 0.95

 V_{imax} = pu value of the maximum voltage limit =1.05

3.3.6Determination of Over Loaded Transformer

Power Performance Index (PPI) is used to determine overloaded transformers in the network

$$PPI = \sum_{i=1}^{n} \left(\frac{s_i}{s_{nom}}\right) * 100 \tag{13}$$

Where

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 S_i = the operating apparent power from NR load flow S_{inom} = the nominal rating of the transformer

4.0 Result Presentation

Pre-Up	ograde	Post-Upgrade			
Vi(pu)	Vi(pu) VPI		VPI		
0.983	0.12	1.010	0.04		
0.980	0.16	1.007	0.02		
0.976	0.22	1.004	0.01		
0.973	0.28	1.002	0		
0.970	0.35	0.999	0		
0.968	0.41	0.997	0		
0.965	0.48	0.995	0.01		
0.963	0.54	0.993	0.02		
0.961	0.61	0.991	0.03		
0.959	0.67	0.990	0.04		
0.957	0.73	0.988	0.06		
0.956	0.79	0.987	0.07		
0.954	0.85	0.986	0.08		
0.953	0.9	0.985	0.1		
0.951	0.95	0.984	0.11		
0.950	1.00	0.983	0.12		
0.949	1.04	0.982	0.13		
0.948	1.08	0.981	0.14		
0.947	1.12	0.981	0.15		
0.947	1.14	0.980	0.15		
0.946	1.17	0.980	0.16		
0.946	1.19	0.980	0.16		
0.945	1.19	0.980	0.16		
	Pre-Up Vi(pu) 0.983 0.980 0.976 0.973 0.970 0.968 0.965 0.963 0.965 0.963 0.961 0.959 0.957 0.956 0.954 0.954 0.953 0.951 0.951 0.950 0.949 0.948 0.947 0.946 0.946 0.945	Pre-Upgrade Vi(pu) VPI 0.983 0.12 0.980 0.16 0.976 0.22 0.973 0.28 0.970 0.35 0.968 0.41 0.965 0.48 0.963 0.54 0.963 0.54 0.963 0.54 0.963 0.54 0.963 0.54 0.963 0.54 0.959 0.67 0.957 0.73 0.956 0.79 0.951 0.95 0.953 0.9 0.951 0.95 0.950 1.00 0.949 1.04 0.948 1.08 0.947 1.12 0.946 1.17 0.946 1.19 0.945 1.19	Pre-Upgrade Post-U Vi(pu) VPI Vi(pu) 0.983 0.12 1.010 0.980 0.16 1.007 0.976 0.22 1.004 0.973 0.28 1.002 0.970 0.35 0.999 0.968 0.41 0.997 0.965 0.48 0.995 0.963 0.54 0.993 0.961 0.61 0.991 0.959 0.67 0.990 0.957 0.73 0.988 0.956 0.79 0.987 0.954 0.85 0.986 0.953 0.9 0.985 0.951 0.95 0.984 0.950 1.00 0.983 0.949 1.04 0.982 0.948 1.08 0.981 0.947 1.12 0.981 0.946 1.17 0.980 0.946 1.19 0.980 0.945 1.19		

Table 2: Bus Voltage for Pre-Upgrade Network State

 Table 3: Transformer Power for Pre-Upgrade Network State

TFX	Pre-Upgrade			Post-Upgrade			
ID	Rated KVA	Si (kVA)	PPI (%)	Rated KVA	Si (kVA)	PPI (%)	
T1	500	167	33.40	500	169	33.8	
T2	500	142	28.40	500	143	28.6	
Т3	500	279	55.80	500	282	56.4	
T4	300	323	107.67	500	323	64.6	
T5	300	355	118.33	500	345	69.0	
T6	300	341	113.67	500	341	68.2	
T7	500	233	46.60	500	235	47.0	
T8	500	210	42.00	500	212	42.4	
Т9	500	200	40.00	500	202	40.4	
T10	500	204	40.80	500	206	41.2	
T11	300	319	106.33	500	319	63.8	
T12	500	207	41.40	500	209	41.8	

T13	500	211	42.20	500	213	42.6
T14	500	90	18.00	500	91	18.2
T15	500	232	46.40	500	235	47.0
T16	500	140	28.00	500	142	28.4
T17	500	194	38.80	500	196	39.2
T18	500	165	33.00	500	167	33.4
T19	500	263	52.60	500	266	53.2
T20	500	182	36.40	500	183	36.6
T21	300	323	107.67	500	322	64.4
T22	500	245	49.00	500	248	49.6
T23	500	228	45.60	500	231	46.2



Figure 1: Voltage Profile of New-Road-Okilton by Ada-George



Figure 2: Transformer load profile of New-Road-Okilton by Ada-George



Figure 3: Graph of Line Losses for Pre and Post-Upgrade Network State

5.0 Discussion

The pre and post upgrade single line network simulation diagram is shown in appendix 1 and 2 respectively.

Table 2: shows the bus operating voltage for pre and post- upgrade network state. The voltage performance index VPI is used to identify weak buses in the network and buses with VPI value greater than 1 are considered weak buses and are considered candidate buses that requires compensation. A cursory look at the pre-upgrade network state in table 2 shows the following buses [17(0.949pu), 18(0.948pu), 19(0.947pu), 20 (0.947pu),21 (0.946pu), 22 (0.946pu) and 23(0.945pu)] respectively violated the lower voltage statutory limit of 0.95-1.01pu. However, after, tap setting the transformer LTC as shown in the post-upgrade network state in table 2, the operating voltage of the buses were improved respectively as shown [17(0.982pu), 18(0.981pu), 19(0.981pu), 20 (0.980pu), 21(0.980pu), 22(0.980pu) and 23(0.980pu)]. Figure 1 shows the voltage profile for both pre and post upgrade network state.

Table 3: shows the operating power for both pre and post upgrade network state. The power performance index PPI is used to determine the overloaded transformers in the network. Transformers with PPI value greater than 80% are considered to be overloaded and are selected for compensation. A quick look the pre-upgrade state in table 3 shows that the following transformers T4(107.67%), T5(118.33%), T6(113.67%), T11(106.33%) and T21(107.67%) are overloaded, therefore upgrading is required. Similarly, after upgrading of the overloaded transformers, as shown in the post upgrade network in table 3, the transformer load profile was improved as shown below T4(64.6%), T5(69.0%), T6(68.2%), T11(63.8%) and T21(64.6%). Figure 2 shows the load profile of the transformer for both pre and post upgrade network state. Figure 3 shows the line real and reactive power losses for both pre and post upgrade network state. In the pre-upgrade network state, the total real and reactive power losses in the line is calculated as 130.978KW and 161.086kvar. while in the post-upgrade network state the total real and reactive power losses in the lines after optimization is calculated as 81.94KW and 94.359kvar.

6.0 Conclusion

In this paper, the existing distribution network of New-Road-Okilton by Ada-George was examined. The network consists of 23 distribution substations fed from a 2x15MVA injection substation located at NTA Port Harcourt. The network was modelled in Electrical Transient Analyzer Program (ETAP12.6)software using Newton-Raphson power flow analysis method for both pre and post upgrade. Based on findings, it is here by concluded that the performance of the distribution network was improved after upgradingof the overloaded substations and tap setting of the affected transformer load tap changer.

7.0 Recommendation

The following recommendations are highlighted to ensure optimum performance and reliability of the distribution system.

- 1. The existing 300KVA transformer located at Aganolu2 (Bus4) should be upgraded to 500KVA
- 2. The existing 300KVA transformer located at MRS Filling Station (Bus5) should be upgraded to 500KVA
- 3. The existing 300KVA transformer located at Benwosely (Bus6) should be upgraded to 500KVA
- 4. The existing 300KVA transformer located at Road1 (Bus11) should be upgraded to 500KVA
- 5. The existing 300KVA transformer located at 300 (Bus21) should be upgraded to 500KVA
- 6. A capacitor bank of 500kvar be installed on the weakest busses.
- 7. The load tap changer of the 1x15MVA injection substation at NTA should be set to -3%



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Appendix 1



Figure 4: Pre-Upgrade network simulation of New-Road-Okilton by Ada-George

Appendix 2



Figure 5: Post-Upgrade network simulation of New-Road-Okilton by Ada-George