Power Factor Correction Technique for Power Loss Reduction in Trans-Amadi Distribution Network, Port Harcourt, Nigeria.

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ABSTRACT: This work considered the power factor technique of reducing electricity loss in the Trans-Amadi distribution network for voltage drop analysis, line power loss determination and reactive power for voltage stability purposes. The supply has been taken to the Trans-Amadi distribution network from the Afam power generation plant. This work also considered the penetration of banks of static condensers with a volume capacitors of 285 kVA, in order to increase the current average capacitance factor from 0,83 to 0,90. . However, research shows that some BUS transformers are overloaded, which lead to low power factor, leakage line loading, power failure in the network and malfunctions in network transfer capacity leading to a blackout. The data from Port Harcourt Electricity Distribution Company(PHEDC) were, however, used in the case study to investigate voltage drop levels through an electrical transient analyzer tool (E-Tap-version 12.6), so that we can determine which feeders/BUSses are surcharged in order to make up for their network performance stabilization. Similarly, integration of the condenser size and the power factor correction by using static condenser banks (electronic control) into the affected BUSes were possible for fast reaction to the problems of voltage stability, with the following: BUS 12, BUS 15, BUS 19, BUS 22, BUS 22, BUS 30, BUS 30 BUS 33 and BUS 36. In order to reduce electricity costs due to excessive losses, devices must be integrated, particularly static condenser bank.

Keywords: Power factor correction, Buses, Low Power Factor, distribution Network

1. INTRODUCTION

Power factor correction can be implemented by an electrical power transmission utility to improve the network's stability and efficiency, or by individual electrical customers to lower their electricity bills. The power factor correction refers to the reactive power generation as near as possible to the load it needs, rather than a distance generation and load transfer, resulting in larger conductors and higher losses [7]. When power factor correction is physically close to the load and uses cutting-edge technology, it is most effective. A calculation of how effective electric power is consumed on site is the power factor; while a power factor of 1 (or unit) is optimal, the compensation is seldom economically feasible as there is no linear function. A power factor of 0.95 or higher is widely regarded as efficient use of energy, whereas a power factor of fewer than 0.9 risks breaching agreements and can result in higher-than-necessary kVA demands and, as a result, higher electricity bills [6].

Energy crises in the power sector are hampering the possible growth of the industry in Rivers State, Nigeria. Residential and commercial consumers are also feeling restless due to long-duration load shedding and high electricity prices [8]. No system can have 100% efficiency; therefore every power system will have some energy losses. During the process of transmitting the power from generation sources to end consumers, some portion of the power is lost in system components [3]. In the report presented by [2], approximately 80% of customer interruptions are caused by issues with distribution networks. The low power factor can be dealt with by using power factor correction condensers in the distribution system of the plant. Capacitors serve as reactive power generators, which 'provide' the reactive power supply (KVAR) [7]. Adding condensers and increasing the power factor will contribute to reduced distribution losses in a plant. These losses are determined by incorporating transformer and cable losses figures. Often this loss is known as "I2R" losses since the current flow through the delivery system declines [5]. In general, transmission network loss reduction techniques are not as effective as distribution network loss reduction techniques. As a result, the focus of this study is solely on reducing power losses in distribution networks.

II. Extent of Past Work

Modern power systems are intricate networks that connect multiple generating stations and load centers via long transmission lines and distribution networks [10]. Distribution companies will need new approaches to system management, grid design, interconnection procedures and collaboration with transmission networks and wholesale markets in order to cope with anticipated increases in the penetration of the distribution system [11]. The delivery system binds to the end users the high voltage system. Usually in a distribution circuit are primary or main feeders and lateral dispensers [9].

The phrase "correction of the power factor" refers to a strategy used since the turn of the 20th century to restore the power factor to as close to unity as economically feasible. The add-on of condensers to the electrical system is normally achieved by compensating for the requirement for reactive power of the inductive load and thus reduce the supply burden. Power factor correction, usually as condensers, is used to neutralize the magnetizing current to reduce losses in the delivery system and lower electricity bills to as much as possible. Most power factor correction devices include condensers that draw a current greater than voltage, which leads to a power factor. The circuit is lagered less if the condensers are attached to a circuit with a lagging power factor.

Power factor correction was accomplished with the addition of capacitors, which can be implemented on the startern, switchboard, or distribution panel parallel to the linked motor circuits presented in the paper by [7]. [4], through use of fixed and switched shunt capacities on primary feeders, have been developing new generalized procedures to streamline net monetary savings associated with reducing power loss and energy loss. [1] have created a streamlined network approach to the VAR control method for radial distribution systems. Shunt condensers are mounted at suitable locations to minimize power losses and increase the voltage profile of wide distribution systems. By choosing proper condenser sizes and places, the advantages of using shunt condensers can be enhanced.

III. METHOD OF ANALYSIS

The existing case study is modeled on the data collected in the reactive power calculations, distribution losses and the correction of factor of power, as an example of the activities in the device network. Reduced power loss using condenser analysis techniques to study Trans-Amadi Network's operation.

The majority of electrical loads are inductive, which include transformers, welding sets, induction engines and induction furnaces. For operation, inductive loads include operation in the kilo-volt-amper reactive (kVAR) environment and normally calculated in the kilowatt (kilowatt) environment. The working power is used for the actual work, and reactive power is used to maintain the magnetic field necessary for inductive loads. In combination, working strength and reactive power are normally calculated in kilovolt vapours (kVA).

Leistungsfactor is an efficiency measure with which electric loads transform electricity into useful work. It's a power ratio (working capacity) of the total power supplied (evident power). A high power factor is an indication of an effective use of power by the electric loads and a low power factor suggests a failure to use the electrical loads. A low power factor leads to considerable energy waste and reduces the electric system's performance. The disparity between current and voltage at the electric load terminals or the distorted current waveform may be induced.

By having a leading current to compensate for the lagging current the condenser corrects the power factor. Power Factor correction condensers are also built to ensure that the power factor is as near as possible to unity. While power factor correction condensers can significantly reduce the load resulting from inductive supply loading, the operation of the load is not affected. Condensers help to minimize losses in the electrical delivery grid by neutalising the magnetic current and reducing energy bills.

Calculation of Loss Reduction with Power Factor Correction

% Loss Reduction = $\left[1-\left(\frac{PF_{Initial}}{PF_{Final}}\right)^2\right] X\ 100$

Where;

$PF_{Initial}$ = Power factor before correction

PF_{Final} = Power factor after correction

Power factor before correction = 0.82

Power factor after correction = 0.90

Supply voltage = (U_n = 415 V)

Active power = 1275 kW.

% Loss Reduction = $\left[1-\left(\frac{0.82}{0.90}\right)^2\right] X\ 100$

% Loss Reduction = $[1-(0.911)^2]\ X\ 100$

% Loss Reduction = $[1-0.829]\ X\ 100 = \ 0.171\ X\ 100$

= 17.1 %

Reduction of Voltage Drop

The drop of the line-line voltage in $3\emptyset - phase$

Reduction of Voltage Drop = $\sqrt{3}\, I\ (R\cos\varphi + X\sin\varphi)$

$$= \frac{P}{U_n}\,(R + X\ tang\ \varphi)$$

Where;

R = Resistance of the line

X = Reactance of the line

P = Active Power

U_n = Supply voltage

φ = Power factor before correction

Power factor before correction = 0.82

Power factor after correction = 0.90

Supply voltage = (U_n = 415 V)

Active power = 1275 kW.

R = Resistance of the line = 0.327145 Ω

X = Reactance of the line = 0.143000 Ω

Reduction of Voltage Drop = $\sqrt{3}\, I\ (R\cos\varphi + X\sin\varphi)$

$$= \frac{P}{U_n}\,(R + X\ tang\ \varphi)$$

$$= \frac{1275}{415}\left[\left(0.327145\ \ + 0.143000\ \ X\ tang\left(\frac{0.82}{0.90}\right)\right)\right]$$

= 3.072 $[(0.327145 \ + 0.143000\ X\ (0.0159)]$

= 3.072 $[0.327145 \ + 0.0022737\ ]$

= 3.072 X 0.3294187

= 1.012 V

Power Factor Correction Using Capacitor

Power factor before correction = 0.82

Power factor after correction = 0.90

Supply voltage = (U_n = 415 V)

Active power = 1275 kW.

kVAR = kW $(1 \ - power\ factor^2)$

Calculate the value of kVAR using the value of the power factor before correction is expressed as;

$\mathrm{kVAR}_1 = \ 1275\ (\ 1 - 0.82^2\ )$

= 1275 X 0.3276 = 417.69 kVAR

Similarly, calculating the value of kVAR using desired value of power factor.

$\mathrm{kVAR}_2 = \ 1275\ (\ 1 - 0.90^2\ )$

= 1275 X 0.19 = 242.25 kVAR

Therefore, the value of the capacitor required due to power factor correction is calculated by subtracting kVAR_1 $-\mathrm{kVAR}_2$

= $417.69\ -\ 242.25$

= 175.44 kVAR

Calculation to determine the Suitable Capacitor Size for Power Factor Improvement

Power factor before correction = 0.82

Power factor after correction = 0.90

Supply voltage = (U_n = 415 V)

Active power = 1275 kW.

The size of Capacitor is determine using the multiplier table in Table 2.

From the multiplier table, the power factor before correction is 0.82 and the power factor after correction is 0.90 = 0.214.

Required capacitor kVAR = kW X Multiplier Table value of 0.85 to 0.90

= 1275 kW X 0.214

= 272.85kVAR

And rating of capacitor connected in each phase (Since the calculation is based on 3-phase system)

$$\frac{272.85}{3} = 90.95 \text{ kVAR}$$

IV. RESULTS AND DISCUSSION

The findings from a power factor correction technique for power loss reduction were simulated and analyzed for investigation by the Trans-Amadi Distribution Network, Port Harcourt. Figure 1 shows the simulated single line diagram from the Trans-Amadi Nets, via the 132KV Port Harcourt power supply line into the 33KV injection substation at the Trans-Amadi Distribution Network.

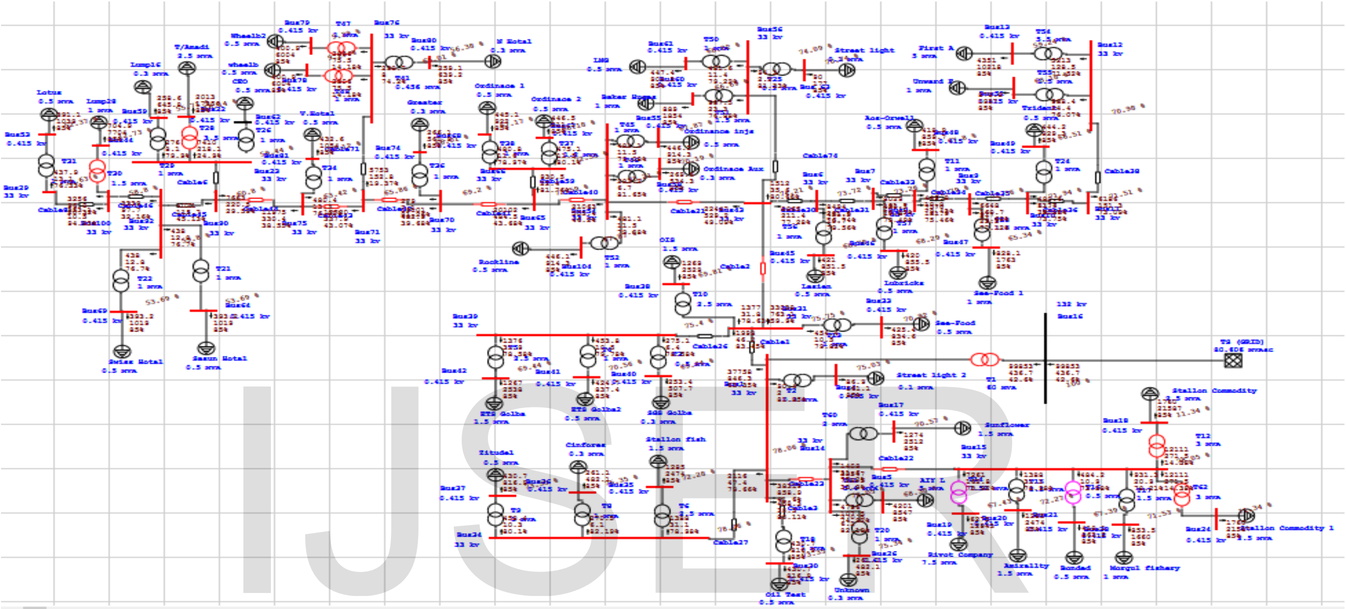

Figure 1: Presentation of Simulated Single Line Diagram of Trans-Amadi Network

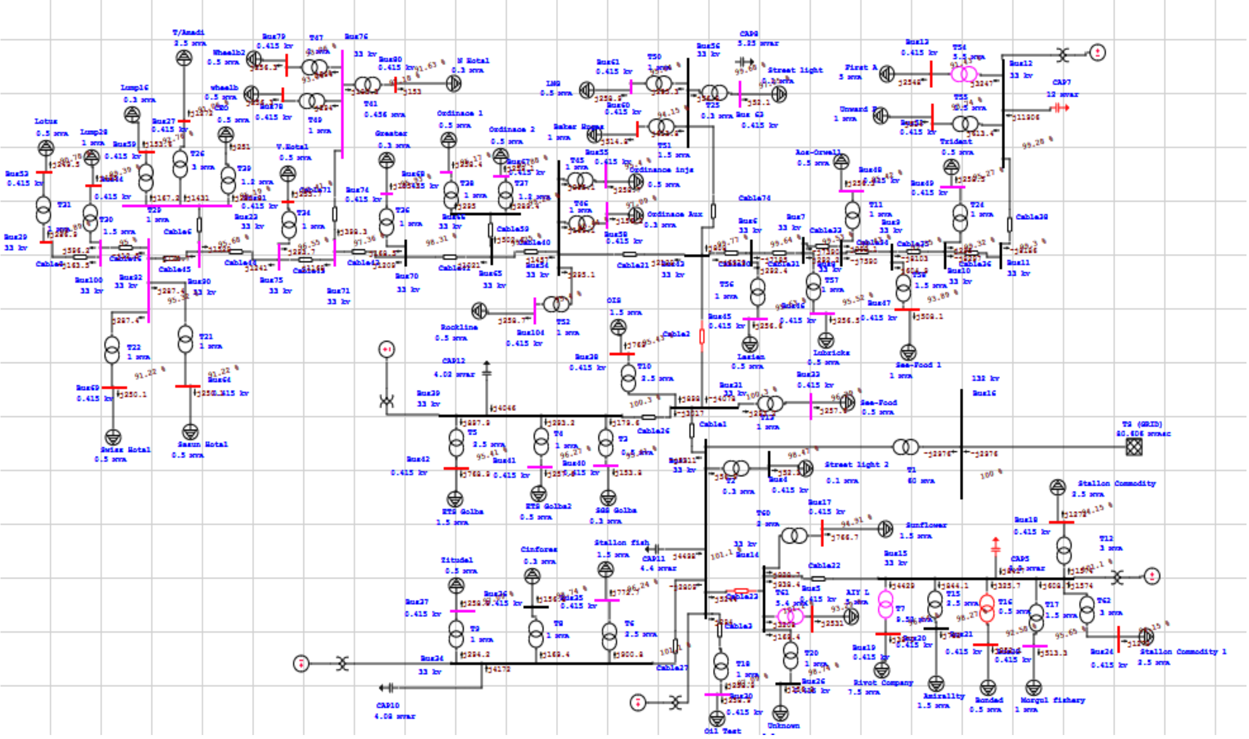

Figure 2: Presentation of Simulated Single Line Diagram of Improved Trans-Amadi Network

Table 1: Showing the Active, Reactive, and Apparent Power of the existing BUS Location in the network

BUS ID	BUS Location	KW	kVAR	kVA
BUS 1	First Aluminum	4250.00	2633.91	5000.00
BUS 2	Sunflower	1275.00	790.17	1500.00
BUS 3	Stallion Commodity	2125.00	1316.96	2500.00
BUS 4	Rivot Company	6375.00	3950.87	7500.00
BUS 5	Admiralty	1275.00	790.17	1500.00
BUS 6	Bonded	425.00	263.39	500.00
BUS 7	Stallion Commodity 1	2125.00	1316.96	2500.00
BUS 8	Trans-Amadi	2125.00	1316.96	2500.00
BUS 9	Morgul fishery	850.00	526.78	1000.00
BUS 10	Sea-Food	425.00	263.39	500.00

BUS 11	Stallion fish	1275.00	790.17	1500.00
BUS 12	Cinfores	255.00	158.03	300.00
BUS 13	Zitudel	425.00	263.39	500.00
BUS 14	OIS	1275.00	790.17	1500.00
BUS 15	SGS Golba	255.00	158.03	300.00
BUS 16	ETS Golba2	425.00	263.39	500.00
BUS 17	ETS Golba	1275.00	790.17	1500.00
BUS 18	Lump28	850.00	526.78	1000.00
BUS 19	Lasien	425.00	263.39	500.00
BUS 20	Lubricks	425.00	263.39	500.00
BUS 21	Sea-Food 1	850.00	526.78	1000.00
BUS 22	Aos-Orwell	425.00	263.39	500.00
BUS 23	Trident	425.00	263.39	500.00
BUS 24	Lotus	425.00	263.39	500.00
BUS 25	Ordinance injs	425.00	263.39	500.00
BUS 27	Ordinance Aux	255.00	158.03	300.00
BUS 28	Baker Hughes	850.00	526.78	1000.00
BUS 29	LNG	425.00	263.39	500.00
BUS 30	Sasun Hotel	425.00	263.39	500.00
BUS 31	Ordinance 2	425.00	263.39	500.00
BUS 32	Ordinance 1	425.00	263.39	500.00
BUS 33	Swiss Hotel	425.00	263.39	500.00
BUS 34	Greater P.H.	255.00	158.03	300.00
BUS 35	Wheelberg	425.00	263.39	500.00

BUS 36	Wheelberg 2	425.00	263.39	500.00
BUS 37	N Hotel	255.00	158.03	300.00
BUS 38	V. Hotel	425.00	263.39	500.00

The table shows the active, reactive, and apparent power of the existing BUS location in the network.

From the table, Rivot Company has the highest active power, reactive power, and apparent power of 6375 kW, 3950.87 kVAR, and 7500 kVA, follow by First Aluminum with 4250 kW, 2633.91 kVAR, and 5000 kVA, while Cinfores, SGS Golba, Ordinance Auxiliary, Greater Port Harcourt and N. Hotel has the lowest active power, reactive power and apparent power of 255 kW, 158 kVAR and 300 kVA respectively.

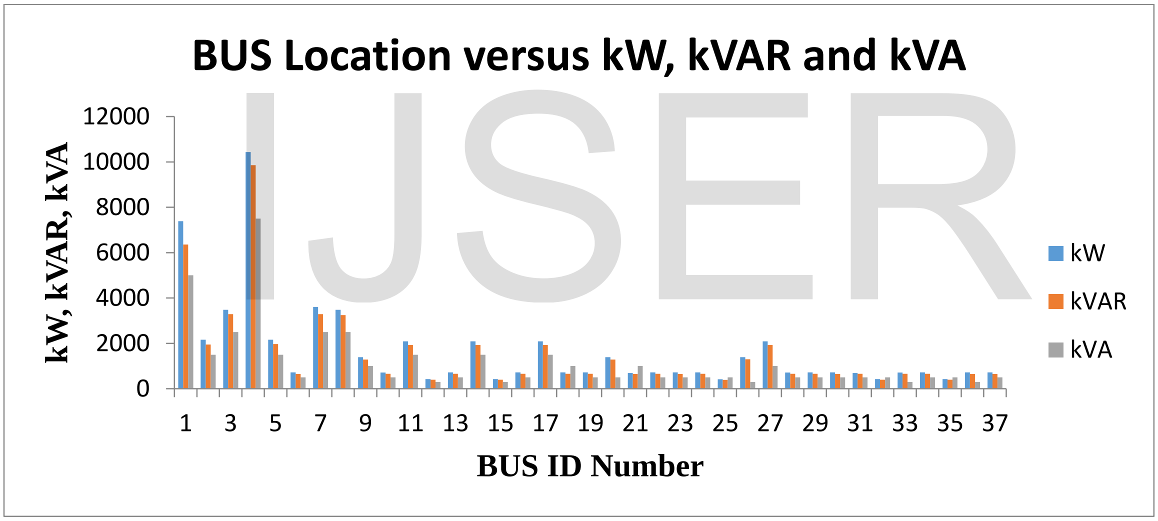

Figure 3: Bar Chart plot showing the active, reactive, and apparent power of existing feeders Versus BUS location/BUS number

The bar chart shows the active, reactive, and apparent power of the existing BUS location concerning BUS location. From the simulated results, the bar chart indicates that BUS 4 has the highest active power, reactive power, and apparent power of 6375 kW, 3950.87 kVAR, and 7500 kVA, follow by BUS 2 with 4250 kW, 2633.91 kVAR, and 5000 kVA, while BUS 12, BUS 15, BUS 27, BUS 34 and BUS 37 has the lowest active power, reactive power and apparent power of 255 kW, 158 kVAR and 300 kVA respectively.

Table 2: The Results of Existing Case Study of Absorbed Current with Existing and Improved Power Factor

BUS ID	Location BUS	Absorbed Current with Existing (% power factor) (A)	Absorbed Current with Improved (% power factor) (A)
BUS 1	First Aluminium	7390	6357
BUS 2	Sunflower	2163	1949
BUS 3	Stallion Commodity	3478	3285
BUS 4	Rivot Company	10434	9854
BUS 5	Admiralty	2163	1970
BUS 6	Bonded	721	649
BUS 7	Stallion Commodity 1	3605	3285
BUS 8	Trans-Amadi	3478	3249
BUS 9	Morgul fishery	1391	1285
BUS 10	Sea-Food	712	657
BUS 11	Stallion fish	2087	1928
BUS 12	Cinfores	427	394
BUS 13	Zitudel	721	657
BUS 14	OIS	2087	1928
BUS 15	SGS Golba	427	394
BUS 16	ETS Golba2	721	657
BUS 17	ETS Golba	2087	1928
BUS 18	Lasien	721	657
BUS 19	Lubricks	721	657
BUS 20	Sea-Food 1	1391	1285
BUS 21	AOS-Orwell	696	648

BUS 22	Trident	721	657
BUS 23	Lotus	721	650
BUS 24	Ordinance injs	721	657
BUS 25	Ordinance Aux	417	389
BUS 27	Baker Hughes	1391	1299
BUS 28	LNG	2087	1928
BUS 29	Sasun Hotel	712	657
BUS 30	Ordinance 2	721	658
BUS 31	Ordinance 1	722	652
BUS 32	Swiss Hotel	696	657
BUS 33	Greater P.H.	427	394
BUS 34	Wheelberg	712	659
BUS 35	Wheelberg 2	721	657
BUS 36	N Hotel	428	396
BUS 37	V. Hotel	721	651
BUS 38	Rockline	721	653

The table shows the Results of the Existing Case Study of the Absorbed Current with the Existing and Improved Power Factor.

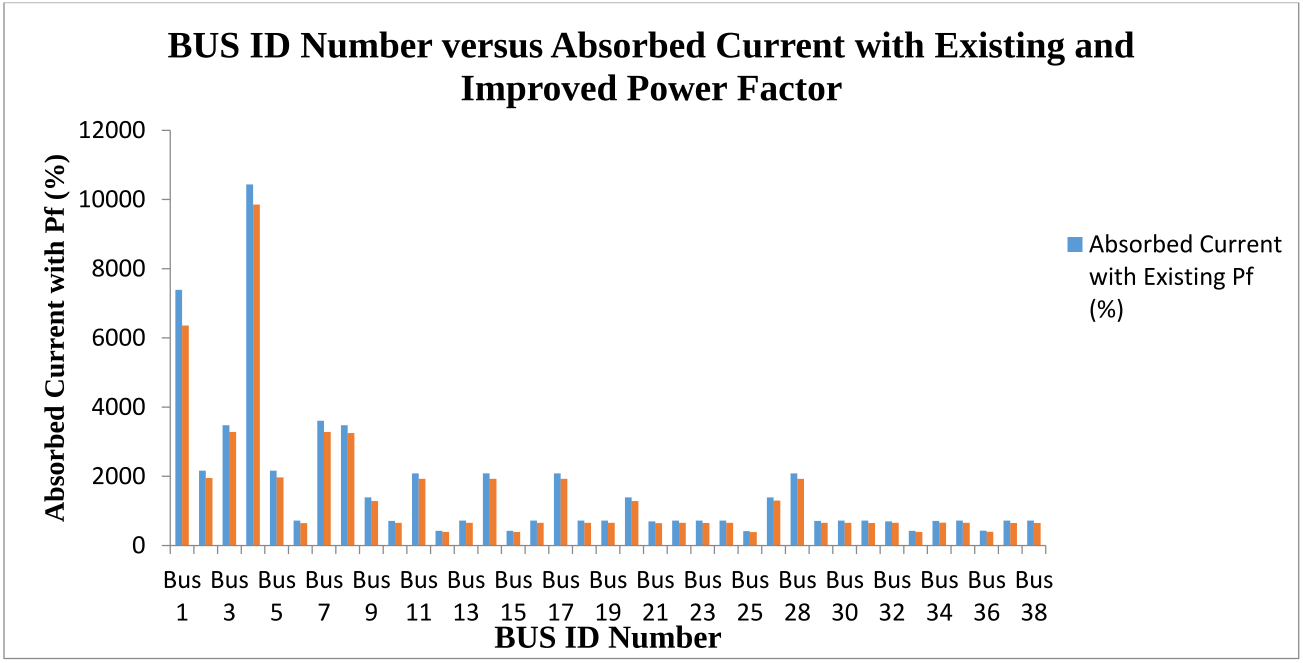

Figure 4: Bar chart plot of Absorbed Current with Existing and After Improved Power factor with BUS location/BUS number

The bar chart shows the Absorbed current with existing and improved power factor concerning BUS location. From the simulated results, the bar chart indicates that BUS 4 has the highest absorbed current of 10434 A and was dropped to 9854 A after power factor correction, follow by BUS 2 absorbed current of 7390 A and was dropped to 6357 after power factor correction while BUS 12 and BUS 15 have the lowest absorbed current of 427 A and was dropped to 394 A after power factor correction respectively.

V. CONCLUSION

Research on the power factor correction techniques to reduce energy loss in Trans-Amadi, Port Harcourt, Nigeria, was discussed at length. The distribution network Trans-Amadi comprises 38 feeder points for review as the case study. The results obtained from the distribution network after simulation demonstrate that BUS 20 has the highest power factor after 92.8 percent correction, while BUS 2, BUS 6 has the highest energy loss reductions of 0.35 MVAR for the purposes of system enhancements, with an overweight factor of 18.8 percent. The capacitor capacity was specified to take care of the affected BUSes accurately, which creates a way of improving network efficiency and performance. Consequently, the power factor needs to be improved by bringing the power factor close to the device, improving power supply and increasing system effectiveness, thereby reducing line losses, as it was found by the mismatch in power stream, Voltage drop, etc

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