Improved Performance Of 132kv Transmission Line Of Afam Power Station To Elelenwo Substation, Port Harcourt

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ABSTRACT:This research work considered the analysis of load-flow, voltage-drop, voltage rise, mismatches and active and reactive power flow from Afam generating station to Elelenwo substation (132/33KV). The increasing demand of power at the receiving-end does not match the available generated capacity, making the substation to constantly experienced overload beyond the declared statutory limit. Evidently, the investigation shows that some of the feeders, transformers are overloaded, low voltage profile, poor power factor and the cross sectional area of the conductors are undersized in order to withstand the load currents. However, the existing data collected from Port Harcourt Electricity Distribution Company (PHEDC) were used for the study case, in order to investigate the level of voltage drop via electrical transient analyzer tool (ETap-version 12.6), so as to know which of the feeders/buses that is critical or fairly loaded in order to compensate the affected feeder for the purpose of improving network stability performance and operation. The simulation of the existing network of 132/33KV (from Afam to Elelenwo) shows that one of the transformers indicated overloaded. Therefore, this research work evaluates the capacity of capacitor-bank needed to compensate the network on the view to improve the voltage profile and stability. The capacity size of 7MVAR capacitor were determined and installed in order to improve the voltage stability problems in the network. This means that to solve these problems, the application of capacitor bank, additional transformer(s) to the existing network will seriously enhance effective performance. The simulation of the existing case and the compensated network shows that the improved voltage profile, active and reactive power injected and demand are within the declared statutory limit of ±5% or 0.95pu – 1.05pu of the declared voltage as recommended by IEE regulation.

Keywords: Capacitor Bank, Improved Performance of Transmission line, Voltage Profile, Voltage Regulation Techniques, Voltage Stability

INTRODUCTION

The nature of mankind in retrospect and the present-day civilization proved that man's life depends on energy. Thus, there is no doubt in future, our existence will continue to depend on energy more and more. Electrical energy occupies the top position in the energy hierarchy.

It finds innumerable uses at home, industry, health care services, agriculture and even transport. Besides, due to rising cases of insecurity, it is required for increasing defense and agricultural production. Electrical energy can be generated in bulk centrally, transmitted economically over long distance and is almost pollution free at the consumer end. Thus, it appears to be the most convenient form of energy [3].

Electrical energy forms the basic need for economic development of any country. Thus availability of it has been the most powerful vehicle of introducing economic development and the social change throughout the world. The process of modernization, increase in productivity in industry, agriculture and improvement in standard of living of the people basically depend upon the adequate supply of electrical energy [8].

Transmission network forms the vital links between generating stations and the consumers via distribution systems. In Addition, electricity, unlike water cannot be stored in large quantities, as such should be used as the productions go on. Transmission network therefore is the medium through which the bulk power can be conveyed from one place to another over long distances. Transmission voltage varies from 132KV, 220KV, 330KV, 400KV and above [19]. In Nigeria however, the transmission levels are mainly 132KV and 330KV, while distribution levels fall into 33KV and 11KV respectively [11].

Due to tremendous industrial growth and rapid population, requirement of power has increased manifold. Thus, it is pertinent to transmit power from the source to load centres down to consumers with minimum possible losses and disturbances. This objective can be achieved only if the transmission systems are so designed and constructed in such that they are efficient, technically sound and reliable [20].

The lines should have sufficient current carrying capacity so as to transmit the required power over a given distance without an excessive voltage drop and overheating. Line losses should be small and insulation of the lines should be adequate to cope with the system voltage. There should be sufficient mechanical strength to cope with the worst probable (not worst possible due to economic factor) weather conditions and provide satisfactory service over a long period of time without too much maintenance necessity.

Transmission lines vary according to distances and are classified as such, known as short lines, medium lines and long lines [15].

Transmission network forms the vital links between generating stations and the consumers via distribution systems. As we all know, electricity, unlike water cannot be stored in large quantities, as such should be used as the productions go on. Transmission network therefore is the medium through which the bulk power can be conveyed from one place to another over long distances. Transmission voltage varies from 132KV, 220KV, 330KV, 400KV and above (Gupta, 2015). In Nigeria however, the transmission levels are mainly 132KV and 330KV, while distribution levels fall into 33KV and 11KV respectively [16].

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Related Works

[5] opined that the general lack luster attitude towards maintenance let alone proactive maintenance led to the level of decay in the nation's power sector. The preventive (proactive) and corrective (reactive) maintenance which are imperative to keep sensitive power equipment to constant operational mode was practically unavailable or lacking until recently. A well designed power system integrates a large number of generating stations, transmission stations, switching stations and distribution stations. The maintenance of each of these stations has its peculiarity though none is mutually exclusive in operation hence lack of maintenance in one facility can lead to sabotage of all other stations regarding service delivery.

[12] position that challenges of power availability in Nigeria stems from inadequate generation of power due to lack of critical infrastructure such as gas pipelines, gas plants, etc. The output of available gas plants are not enough to meet the requirements of intended Independent Power Producers (IPPs) in addition to the fact that existing plants are not proactively managed neither are best practices fully implemented at such facilities. The scholars therefore advocated for an effective gas master plan for generating utilities, immediate zero gas flare within a year, regional grid system and private sector participation in the construction and ownership of pipelines to evacuate natural gas to generating stations.

[2] lends support to a robust array of generating system via the integration of a large numbers of generating stations so that the combined output is readily available on the grid and loss of a unit or generating utility is immediately compensated by increase in output of neighboring utilities. In addition, forced outages of generating units usually due to mal-operation, old age and lack of maintenance renders the generating unit idle or inoperable for a long time.

[7] declares the bane of our power system is largely due to aged or poor infrastructural facilities. Despite the abundant energy resources in Nigeria, inadequate infrastructure to generate and transmit energy

effectively is a major issue affecting the entire country. Existing infrastructures are overstretched and existing facilities are poorly utilized or maintained.

Materials

The materials needed in carrying out this work considered the following:

I. The distribution transformer rating: 132/33KV
II. Substation feeder data
III. Conductor size, cross-sectional area with 160mm^2 (aluminum conductor)
IV. Transmission/distribution line data, bus-data including network diagram.
V. Application simulation software, electrical transient analyzer (ETAP)

Transmission network system data are collected from Port Harcourt Electricity Distribution Company (PHEDC) for purpose of analysis and investigation of the study area. The single line diagram of the network is shown inFigure 3.1 for proper simulation and validation.

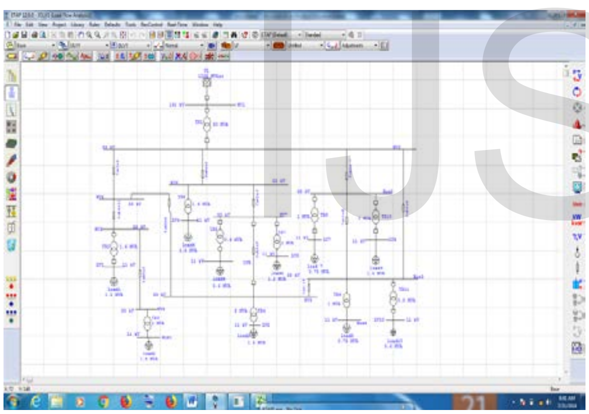

Fig. 1: Existing network from Afam power station to Elelenwo (132/33KV), without simulation

The voltage-drop/voltage-regulation technique will be used in the analysis and investigation of the voltage profile, showing the voltage level, power losses and mismatches between Power Generator, (PG) and Power Distributor (PD) in the 132KV transmission line that can provide a systematic development of the power requirement in order to obtain optimal benefits of system voltage.

The methods needed to improve the transmission to distribution network capability in order to reduce losses in the system thereby enhancing the voltage profile and compensation of reactive power losses, will serially require the application of:

i) Load flow method using Newton Raphson Load flow techniques embedded in Etap environment for simulation of system case network.
ii) Integration of power Electronics Control: automatic capacitor bank.
iii) Resizing/Upgrading of automatic capacitor bank for reactive power compensation.

Most electrical machines draw apparent power in terms of kilovolts-ampere (KVA) which are in expense of the useful power, measured in kilowatts (KW), required by the machines.

However, the ratio of these quantities given as KW/KVA is the power factor and strongly depends on the type of machine in use.

Most machinesin use have extremely low power factor, which means that the supply utilities have to generate much more current than is theoretically analyzed.

Normally, the transformers and cables have to carry this high current. When the overall power factor of a generating station is low, then the system is inefficient and the cost of electricity consumption will be correspondingly high.

To overcome this scenario at the same time ensures that the generators, transformers and cables are not loaded with the watt-less currents; reactive equipment such as capacitor bank, etc will help to modify the system and at the same time improve the power factor.

Therefore the method adopted to improve the power factors, will consider the integration of reactive (KVAR) power into the system in phase opposition to the watt-less or reactive currents. It is a standard practice to integrate current power capacitors or capacitor-bank in the power system at appropriate places to compensate the inductive loads.

Methods of Capacitor Banks Installation

There is need to choose appropriate type, size and number of capacitors for optimization of the transmission/distribution substation. Evidently, the system of connection as well as the preferred location of the capacitor determines the reliability of the entire network. The connection system could either be star or delta. Of which one has advantage over the other. Thus star formation is more ideal technically. This is because, during fault(s), the fault current will disconnect one phase and allowing the remaining two phrases to do the compensation work. The illustration is shown in Figure 3.2.

The analysis of the information is presented in Fig. 2 as:

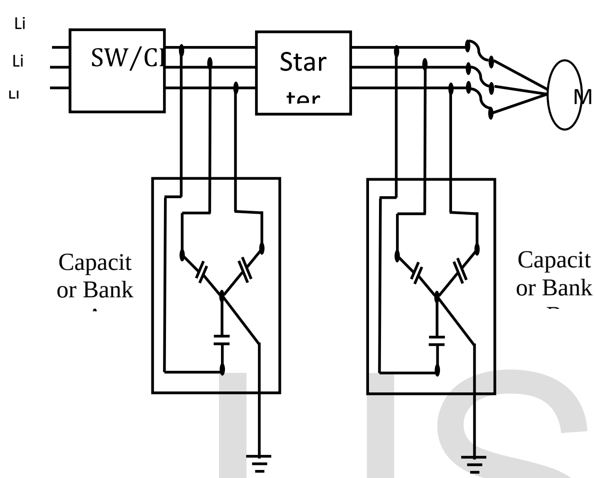

Fig. 2: Capacitor Bank Locations

I. Location A- Sending-end method of installations
II. Location B- Receiving-end method of installations

Capacitor at Supply Condition

In Figure 3.2, the switch/circuit breaker box represents the sending-end of the transmission line, while the starter box represents the transmission lines itself and the motor symbol poses as the load which is the distribution network. The capacitor boxes A and B demonstrate the two important locations of capacitor banks for voltage upgrade or system improvement.

Location A is used in terms of network analysis for a sending-end system of installation. This means that if the capacitor bank is located at point A, it will increase the voltage before sending it to the transmission line. The effect is this, the transmission voltage will be high, consequently will increase the cost of transmission facilities, such as: the conductor sizes the insulators' capacity and probably the towers or any other form of supports used. Most consequentially, the line losses would be high, thus, the aim of the capacitor bank installation will be defeated.

Capacitor at Load Condition

Location B of Figure 3.2 demonstrates the receiving-end method of installations, which in most cases are preferable due to the fact that such locations aid in the system improvement after line losses in form of voltage drops and power losses have been taken care of. Thus, location B is preferable as it helps to safe costs during transmission of bulk power.

Determination of receiving end voltage, the sending side to receiving-end:

VR_1 = sending end voltage (VS) – Voltage drop (Vd_1)

Voltage drop (V_d) = $\frac{V_S - V_R}{V_S}$

Percentage voltage drop (%V_d) = $\frac{V_S - V_R}{V_S} \times 100$

From the collected data on meter readings dated 10/01/2018:

We have: sending end voltage (V_S) = 132KV

Receiving end voltage (V_R) = 129KV

Using the eqn: (% V_d) = $\frac{V_S - V_R}{V_S} \times \frac{100}{1} = \left(\frac{132-129}{132}\right) \times \frac{100}{1}$

$$= 0.02273 \times 100 = 2.273\%$$

$$\simeq 2.3\%$$

∴Percentage Voltage drop = 2.3%

Determination of percentage voltage regulation at one-point to receiving-end:

$$\%\ \text{Voltage regulation} = \frac{\text{sending end voltage} - \text{receiving end voltage}}{\text{receiving end voltage}} \quad (3.26)$$

Thus; % Voltage regulation =

$$\frac{V_S - V_R}{V_R} \times 100 = \left(\frac{132-129}{129}\right)\times 100 \quad (3.27)$$

= 0.02325 x 100 = 2.3%

∴Percentage voltage regulation ($\%V_R$) = 2.3%

This shows that percentage voltage drop ($\%V_d$) equals percentage voltage regulation($\%V_R$) which represents line losses i.e. $\%V_d = \%V_R$

Design Calculation of Capacitor Bank, In Order To Improve System Network Performance

The calculation and analysis of the size of capacitor bank is a major tool for power system improvement, therefore power electronic controller will help control, regulate and compensate powerloss, reactive power losses and voltage- profile inadequacy etc. This means that power system deviation/shortage need to be calculated for purpose of compensation. For example "voltage–rise" needs to be calculated in order to enhance system performance.

Analytical Formulation and Data Processing

Processing of data collected so far and analytical formulations are presented as follows:

Using eqn (3.18)

Power factor (pf) = $\frac{Actual\ power\ (MW)}{Apparent\ power\ (MVA)}$

$MVA = \frac{MW}{pf}$

Hence,

Present, MVA (demand) = $\frac{Present\ load\ MW}{present\ power\ factor\ (pf)} = (MVA)_1$ Determination of present MVA demand $(MVA)_1$

Present, MVA (demand) =$\frac{35\ MW}{0.885} = 39.5480$

$$\therefore (MVA)_1 = 39.55$$

i. Determination of desired MVA demand $(MVA)_2$

Desired or proposed power factor (pf), being raised to 95%

Using eqn (3.24) we have

Desired MVA demand =

$$\frac{present\ (MW)}{Desired\ \ power\ \ factor(pf)_2} = (MVA)_2 \quad (3.25)$$

$$(MVA)_2 = \frac{35}{0.95} = 36.8421 \approx 36.84$$

$$\therefore (MVA)_2 = 36.84$$

$(MVAR)_1 = \sqrt{(MVA)_1^2 - (MW)_1^2}$ *for 88.5% power factor* (3.27)

where:

$(MVA)_1$: 39.55 $(MW)_1$: 35

Applying eqn (3.27) gives

$$(MVAR)_1 = \sqrt{(39.55)^2 - (35)^2}$$

$$(MVAR)_1 = \sqrt{1564.2025 - 1225}$$

$$(MVAR)_1 = \sqrt{339.2025} = 18.4175$$

$\therefore (MVAR)_1 = 18.4175$

Similarly,applying eqn (3.27) for the desired power factor of 95%

$$MVAR_2 = \sqrt{(MVA)_2^2 - (MW)_2^2}$$

where:

$(MVA)_2 = 36.84$ fromeqn (3.25)

From collected data

$(MW)_1 = (MW)_2 = 35$

Thus:

$$(MVAR)_2 = \sqrt{(36.89)^2 - (35)^2}$$

$$\Rightarrow (MVAR)_2 = \sqrt{1357.1856 - 1225}$$

$$= \sqrt{132.1225} = 11.4972$$

$$\therefore (MVAR)_2 = 11.4972$$

Hence, Reactive Power rating (sizing) becomes: MVAR = $(MVA)_2 - (MVAR)_1$

$\Rightarrow (MVAR)_2 - (MVAR)_1$

= (11.9972 – 18.4175) = –6.9203

≅–7MVAR

It is imperative to point out that the negative sign represents lagging power factor.

ii. Determination of capacitive reactance per phase of the capacitor bank.

Collected value from the substation meter on 10/01/2018

Line voltage (V_L) = 129KV
Capacitor bank $MVAR$ calculated =$7MVAR$
Line current capacitor bank is I_{LC}

$$I_{LC} = \frac{MVAR}{\sqrt{3}(V_L)} = \frac{7\times10^6}{\sqrt{3}\times129\times10^3} = 31.329A \approx 31.33A$$

Phase current capacitor bank I_{ph}

$$I_{ph} = \frac{I_{LC}}{\sqrt{3}} = \frac{31.33}{\sqrt{3}} = 18.0879A \approx 18.1A$$

Thus capacitive reactance is X_C and $X_C = \frac{V_L}{I_{ph}}$

Where X_C is capacitive reactance
V_L is the line voltage

I_{ph} is phase current to the capacitor bank

Thus: $X_C = \frac{V_L}{I_{ph}} = \frac{129\times10^3}{18.1} = 7127\Omega / ph$

iii. Determination of the capacitance per phase of the capacitor bank:

From $X_C = \frac{1}{2\pi f C}$ we have

Capacitance $C = \frac{1}{2\pi f X_C}$

where: f = system frequency = 50H_z
C = capacitance
$\pi = 3.142$ (a constant for frequency related values)

Thus, capacitance, $C = \frac{1}{2\pi f X_C}$

$$= \frac{1}{2\pi\times50\times7127} = 4.4663\times10^{-7}F$$

$= \boxed{\mathbf{44.66\times10^{-6}F \approx 45\mu F}}$

Thus, the value of capacitor bank per phase is $45\mu F$.

Case 5: Determination of voltage–rise; lower losses; line-current-reduction for $33KV$, $60MVA$ due to voltage-rise.

– The approximate voltage–change due to the integration of capacitor at transformer secondary bus determined by the power system is given as:

Voltage–rise = $\frac{Capacitor\ (MVAR)\times Transformer\ reactance}{Transformer\ MVA}$

– When the capacitor $MVAR$ rating = 7 MVAR
– Transformer reactance; for 60MVA = 15%

Similarly;

% voltage–rise $= \frac{Capacitor\ (MVAR)\times Transformer\ reactance}{Transformer\ MVA} \times \frac{100}{1}$

% Voltage rise= $\frac{7\times15}{60}$ =1.75% ≃ 2%

This means that there is significant voltage increase (V_R) due to addition of $7MVAR$ capacitor-bank in the substation atElelenwo. Evidently, this goes a long way to prove that there is an equivalent compensation of 2% of the voltage made to urgement the previous percentage losses observed in case 4.

Case 6: Line-current-losses given as:

% line current-reduction = $100\times\left[1-\frac{present\ \ power\ \ factor}{improve\ \ power\ \ factor}\right]$

where:

$$PF_{present} = 0.885$$
$$PF_{improved} = 0.95$$

Thus, % line-current-reduction: = $100\times\left[1-\frac{0.885}{0.95}\right]$

$= 100\times[1-0.93157] = 100\times[0.0684]$

= 6.84% ≃ 7% line-current-reduction

This indicates that there is existence of percentage current reduction in the line, and can also be attributed to the compensation made due to addition of 7MVAR reactive power rating capacitor bank, as well as power factor improvement.

Case 7:

Determination of lower losses (power losses), the estimate of power losses:

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% loss-reduction =

$$100 \times \left[1 - \left(\frac{present\ \ power\ \ factor}{improve\ \ power\ \ factor} \right)^2 \right]$$

$$= 100 \times \left[1 - \left(\frac{0.885}{0.95} \right)^2 \right]$$

$$\therefore \%\ \text{loss-reduction} = 100 \times \left[1 - (0.931578)^2 \right]$$

$$= 13.22\%$$

This also shows that there is a significant percentage reduction (power-loss) in the network under consideration.

RESULTS AND DISCUSSION

The tables 4.1 down to 4.4 have the columns: The first column represents “Time” in hours of the 24 hours of the day. The second column represents operations’ voltage in (KV) which is referred as “voltage before” i.e. the voltage before the addition of capacitor bank. The third which is also the last column bears the “voltage after”, which are values of the corresponding voltages per hour after the 7MVAR capacitor bank was added and simulated with excel software programme. Thus, that becomes the result of the software programme (excel) simulation. This means, the column three of each table (4.1-4.2) represent the result after simulation of each table.

Evidently, the significance of the result is the fact that, each value of the voltage after addition of the capacitor bank shows the corresponding increase in voltage profile that would take care of the losses along the line, or voltage inadequacies from the supply. This means, there is always a boot in voltage after addition of capacitor bank, this boost in voltage is what would improve the system performance.

Correspondently, below each table represents a graph in a composite bar charts that shows the corresponding voltage profile of “voltage before” and “voltage after” the addition of capacitor bank of 7MVAR simulated in E-tap environment.

The collected data cover some period of time. Each table represents one year record for seven different years. Emphatically consideration was much on the load records, that is the distribution side.

The reasons are simple: The pressure on the load determines the effects on the supply line. The distribution system is more prone to various types of faults during operations than those of transmission lines etc. Also in terms of forecasting, preference is given to the load analysis and forecasting.

So the data presented so far would aid us in forecasting and planning for future networks as well as upgrading and expanding the existing network of the location.

Evidently, by physical appearances of the bars of the graphs, someone can easily compare the two voltages, as well as passed judgment that the differences in the two bars (red and blue) of the individual graphs of Figures 4.1 to 4.4 represent the voltage upgrades of each record after the compensation of 7MVAR capacitor bank to the facility at Elelewon substation would definitely improve the network system performance.

Table 4.1: 2010: Voltage Before and Voltage After,due to Addition of Capacitor Bank

Time(hrs)	Voltage(KV)Before
01:00	33.00
02:00	32.90
03:00	32.90
04:00	32.80
05:00	31.50
06:00	31.90
07:00	31.20
08:00	30.90
09:00	30.70
10:00	30.90
11:00	30.90
12:00	30.90
13:00	31.30
14:00	31.00
15:00	31.20
16:00	30.70
17:00	30.80
18:00	31.40
19:00	31.40

20:00	31.40	33.15
21:00	31.80	33.55
22:00	32.40	34.15
23:00	32.90	34.65
00:00	32.90	34.65

Table 4.1: Representing the record of 2010 voltage profile all in kilovolt (KV) of "voltage before" and "voltage after" the addition of capacitor bank.

Table 4.5: Representing the record of 2014 voltage profile all in kilovolt (KV) of "voltage before" and "voltage after" the addition of capacitor bank.

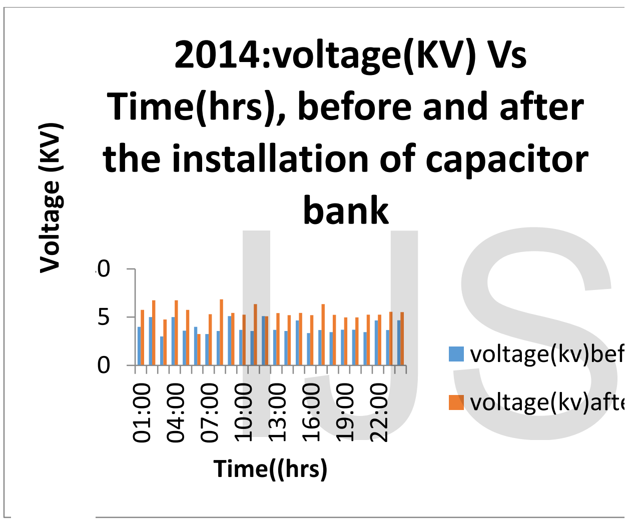

Figure 11: Voltage Profile Before and After the Addition of Capacitor Bank

Table 12:2015: Voltage Profile, Before and After the Addition of Capacitor Bank

Time(hrs)	Voltage(KV)Before	
01:00	33.08	34.83
02:00	33.00	34.75
03:00	32.80	36.5
04:00	30.98	32.73
05:00	30.78	32.53
06:00	30.59	32.34
07:00	31.89	33.64

08:00	32.66
09:00	33.90
10:00	29.89
11:00	33.76
12:00	33.66
13:00	32.34
14:00	29.98
15:00	30.45
16:00	31.67
17:00	32.98
18:00	30.28
19:00	28.98
20:00	28.09
21:00	29.98
22:00	29.09
23:00	33.03
00:00	31.08

Table 16: Representing the record of 2015 voltage profile all in kilovolt (KV) of "voltage before" and "voltage after" the addition of capacitor bank.

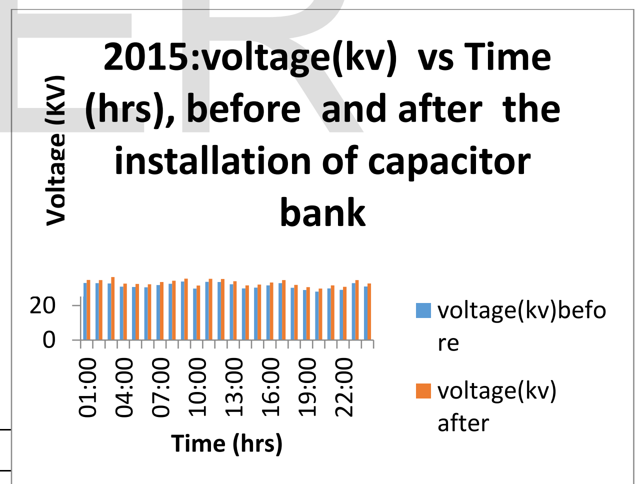

Figure 12: Voltage Profile Before and Afterthe Addition of Capacitor Bank

Table 13: 2016: Voltage Profile of Existing Case and Capacitor Addition

Time (hrs)	Voltage(KV) Before	Voltage (KV) After

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01:00	32.00	33.75
02:00	33.00	34.75
03:00	32.00	33.75
04:00	30.00	31.75
05:00	31.00	32.75
06:00	29.89	31.64
07:00	29.09	30.84
08:00	30.00	31.75
09:00	29.99	31.74
10:00	30.00	31.75
11:00	31.00	32.75
12:00	32.00	33.75
13:00	33.00	34.75
14:00	33.67	35.42
15:00	34.00	35.75
16:00	32.00	33.75
17:00	33.00	34.75
18:00	34.00	35.75
19:00	33.47	35.22
20:00	33.56	35.31
21:00	28.89	30.64
22:00	33.57	35.32
23:00	34.56	36.31
00:00	33.00	34.75

Table 17: Representing the record of 2016 voltage profile all in kilovolt (KV) of “voltage before” and “voltage after” the addition of capacitor bank.

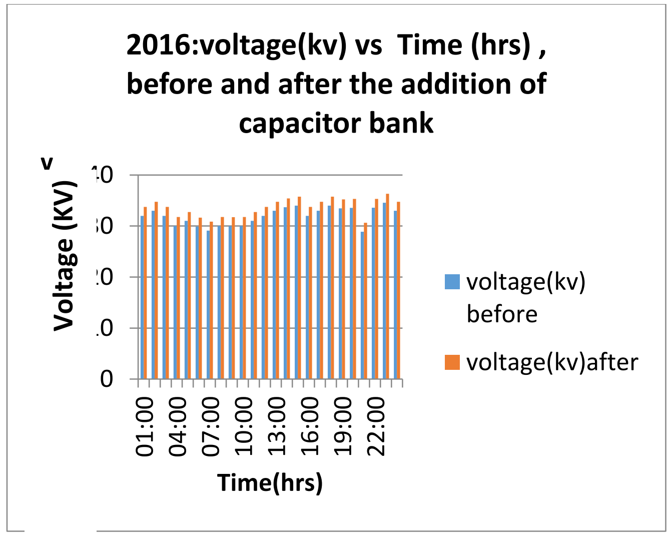

Figure 13: Voltage Distribution Before and After Addition of Capacitor Bank

Table 14: 2017: Voltage Profile of Existing Case and Capacitor Addition for an Improved Network of the Mains

Time(hrs)	Existing Voltage(KV)	Improved Voltage(KV)
01.00	132.00	133.00
02.00	133.00	133.99
03.00	134.20	134.80
04.00	128.50	129.00
05.00	130.90	131.00
06.00	129.20	130.00
07.00	130.99	131.00
08.00	132.00	132.60
09.00	133.00	133.60
10.00	132.67	132.00
11.00	133.00	133.89
12.00	129.00	130.00
13.00	131.78	132.00
14.00	132.56	132.88
15.00	133.00	133.78
16.00	132.00	133.00
17.00	132.50	132.56
18.00	133.00	133.89
19.00	131.89	132.00
20.00	132.67	132.89

21.00	128.99	130.89
22.00	132.00	132.45
23.00	133.67	133.89
00.00	133.00	133.67

Table 18: Representing the record of 2017 voltage profile all in kilovolt (KV) of “voltage before” and “voltage after” the addition of capacitor bank.

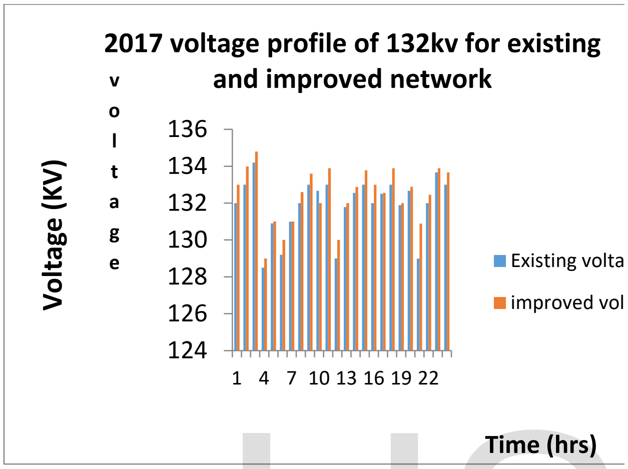

Figure 14:Voltage Distribution Before and After Addition of Capacitor bank

Analysis of the Existing Network without Capacitor Addition

The result of the existing voltage profile of the 33KV distribution feeder is conducted via simulation of excel (software programme) which are presented in figures 4.1 to 4.8.The supply power system is taken from Afam power generating station to Elelewon. The analyses were also simulated using electrical transient analyzer tool (E-tap) on the view of examining the existing state of the system: voltage magnitude, voltage drop and power-flows etc.

The voltage supply in the substation is grossly inadequate due to overloading problems which can be compensated using appropriate size of capacitor bank in order to suppress the voltage problem. The results also revealed that the actual voltage magnitude received at each bus is below the acceptable levels.

Analysis of Simulated Network

With reference to Figure 3.1, the network diagram of the study case, being one of the useful materials under consideration. When simulated gives Figure 4.9, figure 4.9 shows that the network configuration is experiencing a marginal voltage problem as compared to other related networks. This is as a result of overloadingin the distribution network, because of the voltage drop in the feeders.

Figure 4.9 shows the relationship between voltage drops in the respective feeders. One of the feeders is seen to have a high voltage drop. The voltage drop is marginal due to overloading problem in those feeders. Generally, the voltage problems affect all the buses or feeders in the network directly or indirectly when simulated.

Simulation actually helps to validate the system network, thus, determines the level of violation, which might either be marginal or critical. However, it is imperative to highlight this: absence of both showcases normal functional network system. But the presence of any of them signals anomalous.

Evidently, marginally violated feeder is shown on the single line diagram of Figure 4.9 in which the colour of the transformer on that bus changed to pink to show the level of violation. Two different colours: “Pink” and “Red” are actually used to represent the levels of violations.

Violation could either be marginal or critical. Pink colour is marginal while Red is critical. Marginal violation is a mild case of overloaded system problem. Though it gives room for tolerance, but it actually calls for attentions in order to arrest the ugly situation before it gets offhand. Another level of violation is that of critical.

The critical violation is dangerous situation that requires exigencies. Thus, if not properly and urgently handled will lead to system collapses. One major disadvantage of system collapses is the fact that the cost of remedying the situation will be tremendously high compare to preventive measures.

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Now, having discovered e[illegible]y, that the network is marginally violated, the purpose of this research holds. Hence, the cost of arresting the situation preventively will be extremely low while improving the performance on one hand, also avoid system collapse which will be cost effective on the other hand.

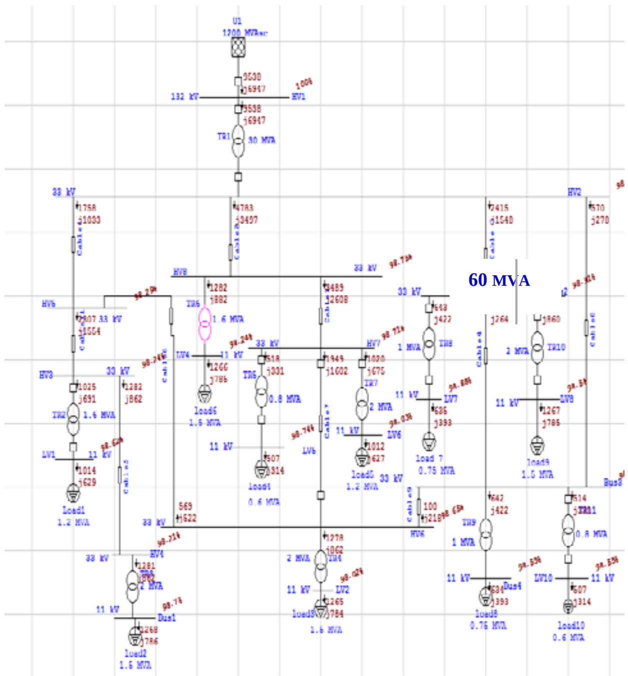

Fig. 15: Existing network from Afam power station to Elelenwo (132/33KV) after simulation with one of the transformer overloaded

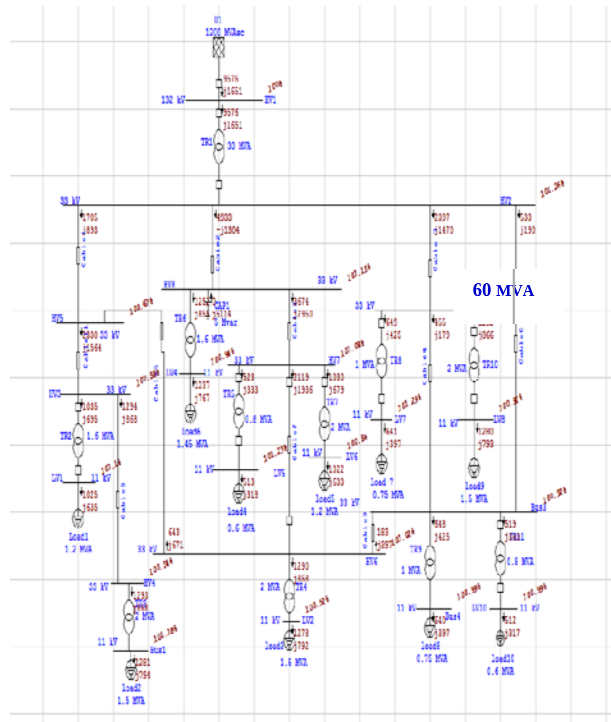

Fig. 16: Existing network from Afam power station to Elelenwo (132/33KV) with the addition of capacitor bank (after compensation with capacitor bank: *7MVAR*)

Validation of Improved Power System Network

Now Figure 4.10 shows an improved power system network diagram after compensation was made with 7MVAR capacitor bank, and simulation was carried out to get the result as seen in the diagram of Figure 4.10.

This has however helped immensely objectives of this research as the troubled area (overloaded bus) has been identified. Of which the solution is clear and is proffered in the conclusion and recommendations chapter.

Conclusion

Considering the analysis of the study, the research work applied some voltage equations for the purpose of improving on the existing power system network. Most AC electric loads draw apparent power in terms of (kVA or MVA) which is in expenses of the useful power, measured in KW or MW, required by the load consumption. The ratio of these quantities (KW/KVA) or (MW/MVA) is the power factor and is dependent on the types of load or machine in use. If the power factor is low or very low, it then means the supply authorities have to generate much more current than is theoretical required. Evidently, the transformers and cables have to carry this high current when, the overall power factor of the generating station is low, then the system is inefficient and the cost of electricity will be correspondently high.

However, in order to overcome this problem at the same time, it is necessary to ensure that the generators, transformers and cables are not loaded with wattles current; the supply authorities often impose penalties for low power factor.

The addition of *7MVAR* capacitor bank to strongly improve the voltage profile.

The distribution of bulk electricity from generation station to the consumer at the receiving end, is a rigorous process. Thus, the ever needed electrical energy consumption is on the increase on regular basis.

Hence, system upgrade and expansion is required to meet the demand increase.

Consequently, the generation of power does not match the power demand and therefore the primary and secondary distribution sections are not delivering enough power as expected, leading to low voltage profile, load shedding, poor energy management system etc.

The addition of reactive compensation device (capacitor) will modifies the electrical impedence of the line and therefore increase the power flow across the line. This is an effective and economic means of increasing power flow in lines not loaded to their thermal limits.

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