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Analysis of Rivers State University 7.5MVA, 33/11KV Injection Substation for Improved Performance

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ABSTRACT: *Distribution network is a link between the bulk power system and the consumers. Distribution networks are mostly in a radial configuration with long distance feeder line and several loads connected to it. The voltage at the buses reduces and loss becomes high when moved away from the substation. The decrease in voltage and high losses is as a result of low power factor and insufficient amount of reactive power flow, which can be provided by shunt capacitors. In this research work, analysis is carried out for the Rivers State University 7.5MVA Injection substation with the objective of identifying the optimal locations and sizes (Kvar ratings) of shunt capacitors to be placed in the network to improve the voltages and reduce power losses. The method used is the adaptive Newton-Rapson's load flow techniques embedded in Electrical transient analyzer program (ETAP), for the modeling and simulation of the network. The analysis is in two stages, in the first stage, the load flow of pre-compensated network is carried out. In the second stage, loss sensitivity factors (LSF) indicating the potential locations for compensation are computed to identify the candidate buses and Genetic algorithm is used to identify the sizes of the capacitor that will be placed in the candidate buses to achieve optimal loss minimization and voltage improvement.*

KEYWORDS: *Injection Substation, Capacitor Banks, Voltage Improvement, Power Loss Minimization, ETAP, Distribution System.*

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I. INTRODUCTION

Power is generated in Nigeria at generating stations which are located far away from load centers and transmitted via transmission lines to injection substations for distribution and consumption. An injection substation is a substation where a higher voltage is stepped down to a lower voltage, for transmission in a thickly populated zone. The transformer involved is often in the MVA range, so that the output can serve a wide area, or large consumers. The RSU 7.5MVA 33/11KV injection substation supplies power to the various feeders that serves the distribution system of the University. It receives power from Nzimiro, Port Harcourt town (Zone 4) with total transformers installed capacity of 165MVA, 132/33KV. This Power is transmitted from the Afam transmission station via a 132 double circuit transmission line duly linked to the national grid at Alaoji-Afam transmission station. Power system in Nigeria is made up of networks at various voltages; at the Generation, transmission, switching and Distribution / Load centers. Graphically represented by a line diagram in which three phase circuits are represented by single lines. The system consists of a network of conductors and associated equipment over which energy is transmitted from the generating station to the consumer. This may be divided into two distinct parts: The transmission system and the distribution system. Distribution can further be divided into primary, secondary and tertiary (1), For A.C. systems, there will be a change in voltage at each point where a sub-division takes place. The change is effected by transformation, usually at a substation. This implies that there may be several operating voltage in one system.

In Nigeria the main power stations generate at 10.5-16KV. This is raised by transformers to the main transmission voltages of 132kv and 330kv. The connections between transmission lines and transformers are made at the substations [2]. Power generated in generating stations pass through large and complex networks using transformers, overhead lines, and other equipment before reaching the consumers. It has been established that some percentage of energy is lost in the distribution network. The difference in the generated power and distributed power is accounted for by both technical and non-technical losses in the power network. [3], examined the total power losses in power system and found out that over 50% of losses occur at the distribution network while about 17% was estimated to occur at transmission. Due to this heavy amount of loss in the distribution system, the system must be properly planned so that voltage is within limits. A good and reliable distribution system must have maximum reliability of power supply, minimum operation and maintenance cost, minimum duration of interruption, voltage drop at consumers end should be within 5% of nominal magnitude, but due to load growth and inadequate power injection and frequent network expansion without corresponding increase in power supply, most injection substation transformers and feeders are overloaded and cannot effectively dispatch energy to meet the increasing load demand of the consumers. Consequently, consumers linked to the affected transformers and feeders often times experiences under-voltage and epileptic power supply. However to meet the ever-growing load demand, system upgrade is required and this can be achieved by conducting a power flow study on the existing network to ascertain the various levels of the inadequacy of the power system network.

1.1 Problem Statement

As power distribution system load grows, the system power factor usually declines. Load growth and a decrease in power factor leads to a number of challenging losses, power factor penalties and reduced system capacity. Due to increasing load demand and overload conditions as a result of addition of more faculty buildings and infrastructure in the University, it is imperative to carry out an analysis for the substation that supplies power to the various feeders in the University to ascertain the current load condition and proffer solutions to problems that it may likely face.

1.2 Research Aim

The aim of this research work is to carry out an analysis for the Rivers State University Port Harcourt, 7.5MVA, 33/11KV injection substation for improved operation and Performance.

1.3 Objectives of the Study

The objectives of this research work are:

(i) To carry out a load flow analysis on the Injection Substation by simulating the single diagram of the network in Electrical Transient Analyzer Program (ETAP) software.
(ii) To determine if the system voltage remain within limits under normal operating conditions.
(iii) To improve the voltage profile of the system by capacitor bank placement.
(iv) To minimize power loss in the system
(v) To reduce feeder and transformer overload

II. LITERATURE REVIEW

Electrical energy is generated, transmitted and distributed in the form of alternating current. Therefore, the question of power factor comes to mind. Most loads like induction motors are inductive in nature and hence have low lagging power factor. The low power factor is highly undesirable as it causes an increase in current, resulting in additional losses of active power in all the elements of power system from power station generator down to the utilization devices. In order to ensure most favorable conditions for a supply system, it is important to have power factor as close to unity as possible. In power system the power that is being consumed is a combination of two types of powers, the active power (p) and reactive power (Q). When reactive power demand increases beyond desired value then there is a chance of voltage drop at load end. To prevent this problem several methods have been proposed.

Feeder restructuring under normal operation aims to reduce active losses and balance loads in the distribution system. Distribution feeders may be frequently reconfigured by opening and closing switches while meeting all load requirements and maintaining a radial network [4], used this method to improve the performance of distribution networks of Port Harcourt town (zone 4). The problem associated with this method is that it is very expensive because some of the network equipment has to be replaced. Another method is the use of FACTS, with the invention of thyristor switch, opened the door for development of power electronics devices known as flexible AC transmission controllers. Basically the FACTS system is used to provide the controllability of high voltage side of the network by incorporating power electronic devices to introduce inductive or capacitive power in the network. There are several types of FACTS devices currently in use. In its application the static VAR compensator (SVC) improves the voltage profile and enhances power flow in distribution substations. (5], in their research work, low rated static VAR compensator were installed at load ends on 33/11kv distribution network and load flow analysis was used to simulate the performance at various level of voltage. The optimum location of SVCs shows increased voltage and decreased losses thereby improving the power flow in the substation. The disadvantage of using FACTS is that solid state device which are often incorporated in the circuits which are used for power factor improvement and to raise the limits of the AC transmission system are non linear devices and induce harmonics in the output signal of the system.

Distributed generation implementation has been recently proposed to improve distribution system, when connected to the electric utility's lower voltage distribution lines, it can help support delivery of clean, reliable power to additional customers and reduce losses along transmission and distribution lines. [6], performed an analysis on the 2 x 15MVA, 33/11KV RSU injection substation using distributed generation units, and were able to cushion the drawback related to power losses and low voltage profile on Wokoma feeder by adequately integrating distributed generation optimally in the network. The problem associated with distributed generation is that it may cause negative environmental issues such as noise and air pollution.

According to [7], capacitor bank is a grouping of several identical capacitors interconnected in parallel or series with one another, these groups of capacitors are typically used to correct undesirable characteristics, such as power factor lag or phase shifts inherent in alternating current (AC) electrical power. The capacitive load of the capacitor bank help to adjust the power factor as close to 1 as possible, in which case the voltage and current are in phase and deliver maximum usable power to the load. Capacitors are used to control the level of the voltage by reducing or eliminating the voltage drop in the system caused by inductive reactive loads. The problem associated with this method is the location of the capacitor in the network to achieve optimal result, a variety of techniques have been proposed recently with some heuristics. The features of the heuristics algorithms include robustness and lesser computational effects. [8], used genetic algorithm technique to determine the optimal location and size of the capacitors such that the cost of energy loss and capacitor cost was minimized on IEEE 69 bus distribution system. The test system is a 12.66KV, 10KVA, 69 bus radial distribution feeder consisting one main branch and seven laterals containing different number of load buses. [9], applied the ant colony optimization method to solve the optimal capacitor placement problem in test distribution systems. The obtained capacitor placement result was compared with other optimization methods. [10], used the harmony search algorithm method to find the optimal allocation and sizing of capacitors in distribution network.

III. MATERIALS AND METHODS

3.1 Description of the Substation

The substation considered for case study is a 7.5MVA, 33/11KV located at the estate and works department of Rivers State University. The substation comprise of two phases, phase one (1) and phase two (2), Phase two consist of one (1) 1500KVA transformer that supplies power to the old site of the University. Phase one consist of two major outgoing feeder circuit breakers, namely: Engineering feeder and science feeder. The science feeder has a total of twelve (12) transformers while the Engineering feeder is made up of six (6) transformers table 1.1 is the total transformers connected to the substation.

3.2 Materials Used

Distribution transformers voltage Rating (33/11kv and 11/0.415kv); Network structure; substation feeders data; cross sectional Area of conductor = 182mm2 ACSR/GZ (Aluminum conductor steel reinforced with galvanized); Electrical Transient Analyzer Program (ETAP) simulation software; capacitor banks.

3.3 Method Used for Improving the Distribution Network

The method of simulation and result coordination is a load flow-based method using adaptive Newton-Raphson load flow techniques for the simulation in ETAP environment with the integration of capacitor banks for improvement of the network using genetic algorithm. The following algorithm is applied to improve the network (i) model the network, (the system is modeled using ETAP software package), (ii) Using load flow simulation tool; adaptive Newton – Raphson load flow to study the power flow, voltage profile and power loss in the candidate bases of the distribution network, (iii) apply sensitivity analysis to optimally locate the placement of capacitor banks. To minimize the search position and have a better impact on the voltage enhancement (iv) the optimal sizing and location of capacitor banks is computed using genetic Algorithm.

Table 1.1: Transformers Connected to the substation

S/no	No of transformer	Transformers rating
1	3	1500KVA
2	10	500KVA
3	8	300KVA
Total	21	11900KVA

Sources: (RSU Estate and works, 2018) unpublished

3.4 Input Load Data for the Substation

Transformer capacity	=	7.5MVA
Existing Power Factor	=	0.6
Desired Power Factor	=	0.95
Nominal Rated Voltage	=	33/11kv

Frequency = 50Hz

Table 1.2: Input Load Data for the Substation

Load Parameter	Line Parameter		
Transformer load connected (KVA)	**From**	**To**	**Length (m)**
-	Bus 3	RSU Park	3700
300	Estate Bus	Mgt Bus 1	450
300	Mgt Bus 1	Envi. Bus 1	500
300	Estate Bus 2	Senate Bus 1	4500
500	Chapel Bus 1	Estate Bus 1	500
500	Physics Bus 1	Chapel Bus 1	850
300	Medical Bus 1	Physics Bus 1	800
500	Street light Bus 1	Physics Bus 1	200
500	Law Bus 1	Physics Bus 1	450
300	VC Bus 1	Law Bus 1	250
300	Law Bus 1	Lib Bus 1	250
300	Farm Bus 1	Law Bus 1	300
500	Rd. F Bus 1	Amphi. T Bus	200
500	Amphi T. Bus 1	ECO Bank Bus 1	1000
500	ECO Bank Bus 1	Petro Bus 1	150
300	NDDC Bus 1	Petro Bus 1	150
500	Petro Bus 1	Workshop Bus	150
1500	Phase 2 Bus 1	Estate bus	1500

-

3.5 Calculation for the size of capacitor bank Required to improve the network

To improve the network voltage and reduce power loss, the existing power factor needs to be improved. To achieve this, a new power factor will be used. The power factor, the real power, the apparent power are related by the equation

MW = MVA x Pf (3.1)

Where: MW = Active power, MVA = Apparent power

Pf = Power Factor

The reactive power is given as

Mvar = MW x Pf - Correction (3.2)

The apparent power (MVA) is the vector addition of active power (MW) and reactive power (MVAR)

The Mvar capacity of the capacitor bank needed for compensation is gotten from the equation

$$Qc \quad \frac{p}{p_{f1}}(\sin(\cos^{-1}(P_{f1}))) - \frac{p}{p_{f2}}(\sin(\cos^{-1}(P_{f2}))) \qquad (3.3)$$

Where

P = Total Active Power (MW)

Qc = Reactive Power of Capacitor bank

P_{f1} = Existing Power factor

P_{f2} = Desired Powr factor to be used for Improvement

From the load input data

Transformer capacity = 7.5MVA

Existing Power Factor = 0.6

Desired Power Factor = 0.95

From Equation = 3.1

MW = MVA x Pf

MW = 7.5 X 0.6 = 4.5MW

Substituting into equation 3.3

$$Qc = \frac{4.5}{0.6}(\sin(\cos^{-1}(0.6))) - \frac{4.5}{0.95}(\sin(\cos^{-1}(0.95)))$$

7.5 (0.8) - 4.74 (0.312)

Qc = 4.52 M_{VAR}

3.6 Capacitor Placement Using Genetic Algorithm.

The algorithm to identify the size and location of capacitor is an iterative process that starts with a randomly produced set of solutions known as the initial population. The method is implemented in ETAP environment with the following steps

- The initial population of randomly constructed solutions is generated, that is capacitors of given values are placed at random nodes in the network.
- New solutions are obtained with the population during genetic cycle using crossover and mutation operator.
- The new solution is decided and objective function value estimated.
- The better solution joins new population and bad solution discarded.
- Individuals in the initial population ranked higher in terms of fitness value are selected to replenish the shrunken population
- A new genetic cycle is started till the terminating criterion is met
-

IV. RESULTS AND DISCUSSIONS

4.1**Results**

4.1.1 Results of Base-case voltage profile of the 7.5MVA network without Capacitor Placement is shown in table 1.3, Table 1.4, Figure 1.1(a) and (b), Figure 1.2(a) and (b). The results shows that the actual voltage magnitude recorded at each bus is below acceptable limits, when compared with IEEE standard. It is observed from the simulation result that all the buses are operating in critical under voltage state which were clearly shown by their red colours.

4.1.2 Results of optimal placement of capacitor banks

Table 1.5 shows the improved voltage profile of the substation buses with the integration of capacitor banks and Table 1.6 shows the improved power flow on various buses. Figure 1.3, Figure 1.4. shows the improved network.

Table 1.3 Results of Base-case load flow voltage profile at each Bus (without capacitor placement)

Base case load flow (Voltage at each Bus)			
Bus ID	**Normal KV**	**Available Voltage KV**	**Voltage %**
Aphi Bus 1	11	9.13	83
Aphi Bus 2	0.415	0.338	81.45
Bus 1	132	132	-
Bus 2	33	32.386	98.14
Bus 3	33	30.268	91.7
Bus 4	33	28.122	85.22
Bus 5	11	9.171	83.37
Bus 6	11	9.171	83.37
Bus 8	11	9.146	83.15
Chapel Bus 1	11	9.131	83
Chapel Bus 2	0.415	0.338	81.45
Eco Bus 1	11	9.143	83.12
Eco Bus 2	0.415	0.339	81.69
Env Bus 1	11	9.171	83.37
Env Bus 2	0.415	0.345	83.13
Estate Bus	11	9.171	83.37
Estate Bus 1	11	9.171	83.37
Estate Bus 2	11	9.142	83.11
Estate Bus 3	0.415	0.339	81.69
Estate Bus 4	11	9.171	83.37
Farm Bus 1	11	9.113	82.85
Farm Bus 2	0.415	0.343	82.65
Law Bus 1	11	9.114	82.85
Law Bus 2	0.415	0.338	81.45
Lib Bus 1	11	9.113	82.84
Lib Bus 2	0.415	0.343	82.65
Medical Bus 1	11	9.117	82.88

Medical Bus 2	0.415	0.343	82.65
Mgt Bus 1	11	9.171	83.37
Mgt Bus 2	0.415	0.346	83.37
NDDC Bus 1	11	9.146	83.14
NDDC Bus 2	0.415	0.344	82.89
Pet Bus 1	11	9.146	83.14
Pet Bus 2	0.415	0.339	81.69
Phase 2 bus 1	11	9.166	83.33
Phase 2 Bus 2	0.415	0.344	82.89
Phy Bus 1	11	9.117	82.88
Phy Bus 2	0.415	0.338	81.45
Road F Bus 2	11	0.338	81.45
Road F Bus 1	0.415	9.128	82.98
RSU Park	33	28.143	85.28
Street Bus 1	11	9.117	82.88
Street Bus 2	0.415	0.343	82.65
VC Bus 1	11	9.113	82.84
VC Bus 2	0.415	0.343	82.65
Workshop Bus 1	0.415	0.345	83.13

Table 1.4 Base-case load flow Result Branch Losses and voltage drop (without capacitor placement)

Branch ID	KW Flow	Kvar Flow	% voltage Drop	KW Losses	Kvar losses
Aphi TS 2	126	95.96	1.44	1.621	2.432
Chapel TS	126	95.971	1.44	1.621	2.432
Ecobank TS	126	96.049	1.44	1.619	2.429
Enr Workshop 2	8,772	6.425	0	0	-0.046
Env Line	8.957	5.562	0	0	-0.153
Env TS	8.957	5.562	0.15	0.012	0.018
Estate TS	126	96.042	1.44	1.62	2.429
Farm TS 2	8.751	6.418	0.16	0.013	0.019
From PH Town	37407	25724	6.44	2073	2622
Lib TS 2	9.386	6.884	0.18	0.015	0.022
Line 1	1166	931	0.06	0.7	-1.996
Line 4	552	418	0.27	1.419	1.497
Medical TS2	8.753	6.42	0.16	0.013	0.019
Mgt sci Line	18.214	11.156	0	0.001	-0.137
Mgt TS	9.256	5.748	0.16	0.013	0.019
NDDC TS	8.697	6.532	0.16	0.013	0.019
Petro/chem.TS2	126	96.068	1.44	1.619	2.429
Phase 2 TS	70.125	52.994	0.32	0.076	0.457
Phy TS 2	126	95.887	1.44	1.623	2.435
Rd B. TS	126	95.956	1.44	1.622	2.432
Street Light TS	8.68	6.519	0.16	0.013	0.019
T1 Estate 2	1166	931	1.84	1.135	51.069
I1 A	27600	9118	1,86	39.106	1760
T1 B	13800	4559	1.86	19.553	880
T2A	23353	20546	8.28	89.563	4030
T2 B	35030	30819	8.28	134	6046
Amphi 2	253	192	0.12	0.301	0.077
To Ecobank	380	288	0.03	0.10	0.083
To Farm 2	8.751	6.418	0	0	0.091
To Law 2	151	115	0.03	0.05	-0.073
To lib 2	9.386	6.884	0	0	-0.076
To Medical 2	8.753	6.42	0	0	-0.151
To NDDC 2	8.697	6.532	0	0	-.046
To petro/Chem 2	525	398	0.23	1.156	1.193
To phase 2	70.125	52,994	0.05	0.084	-0.416
To Physics 2	297	224	0.12	0.352	0.189
To Rd F 2	126	95.956	0.01	0.015	-0.042
To Street Light 2	8.68	6.519	0	0	-0.061
To Chapel TS	424	320	0.1	0.421	0.382
To VC2	8.751	6.418	0	0	-0.076
TS Law 2	126	95.864	1.44	1.624	2.435

TS VC 2	8.751	6.418	0.16	0.013	0.019
W. Shop TS2	8.772	6.425	0.1	0.008	0.011

Total Power Losses = 2373.107 KW
Total % voltage Drop = 40.96

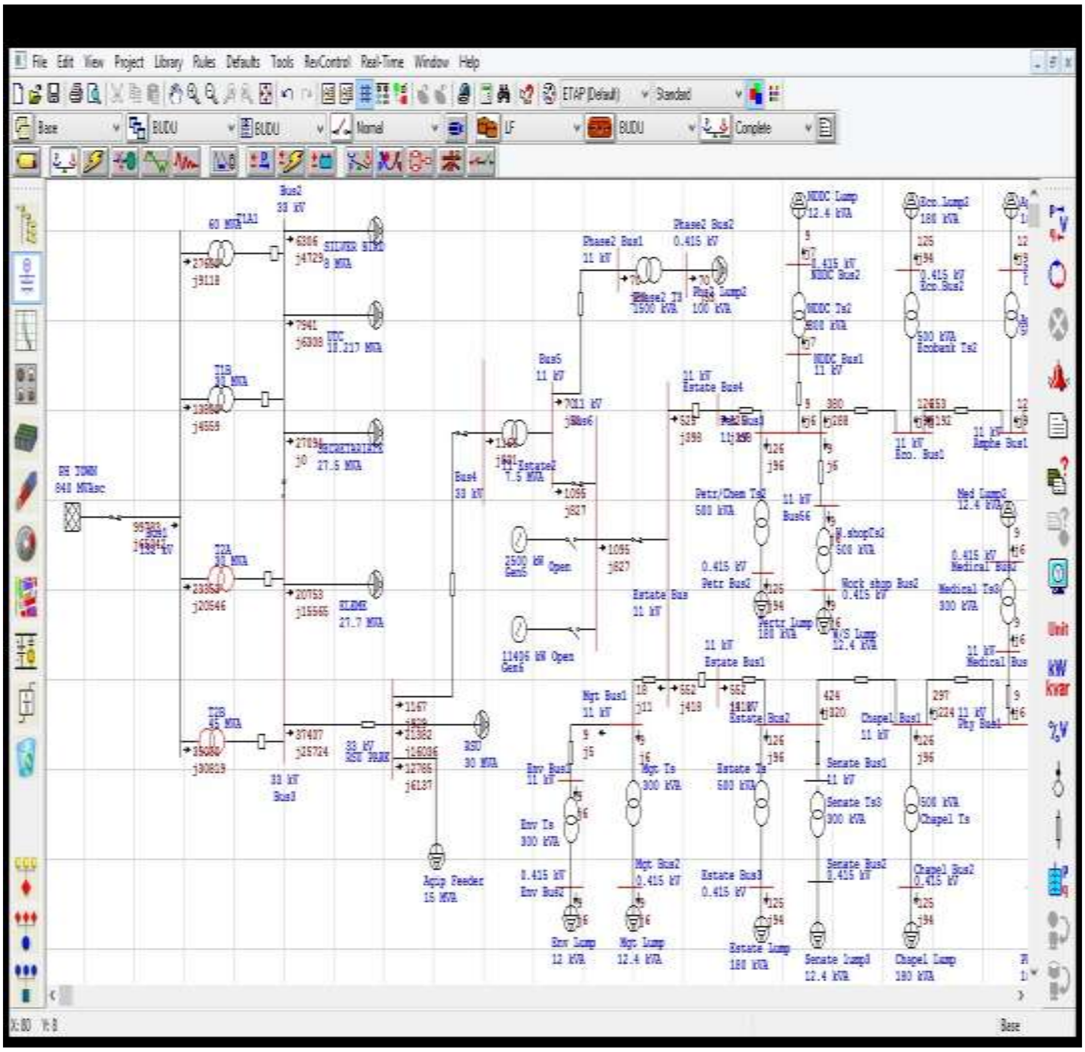

Figure 1.1(a) Electrical distribution diagram for RSU 7.5MVA substation without (capacitor placement)

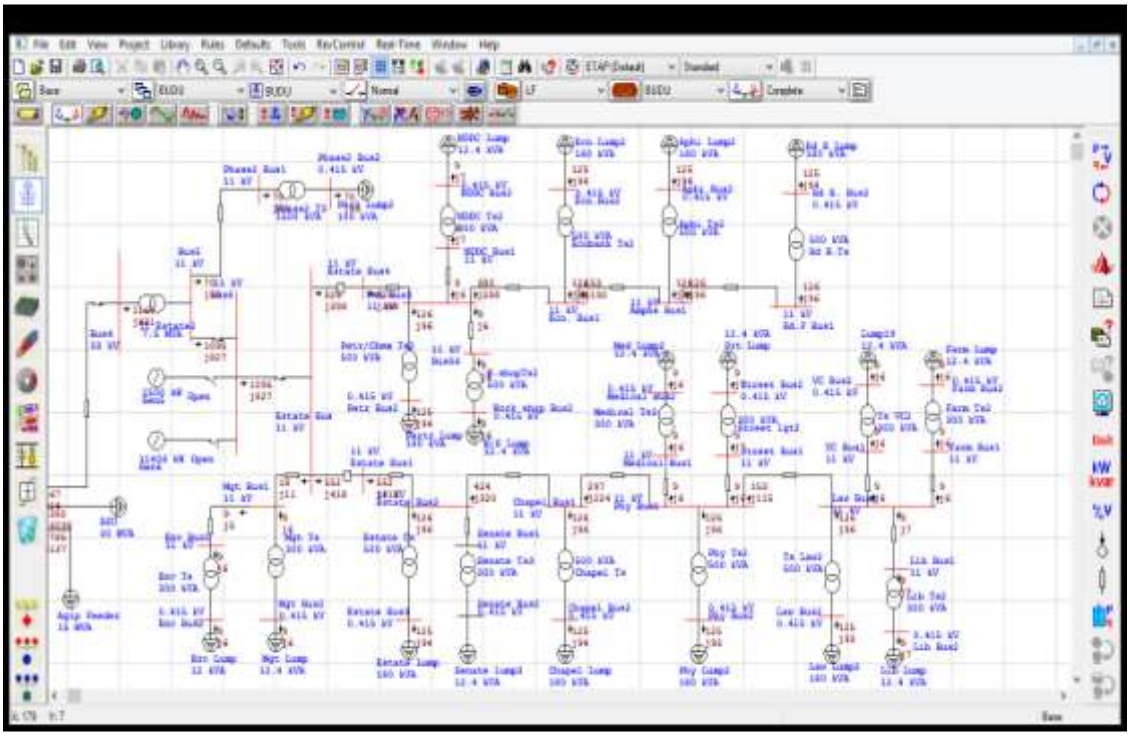

Figure 1.1(b) Electrical distribution diagram for RSU 7.5MVA substation without (capacitor placement)

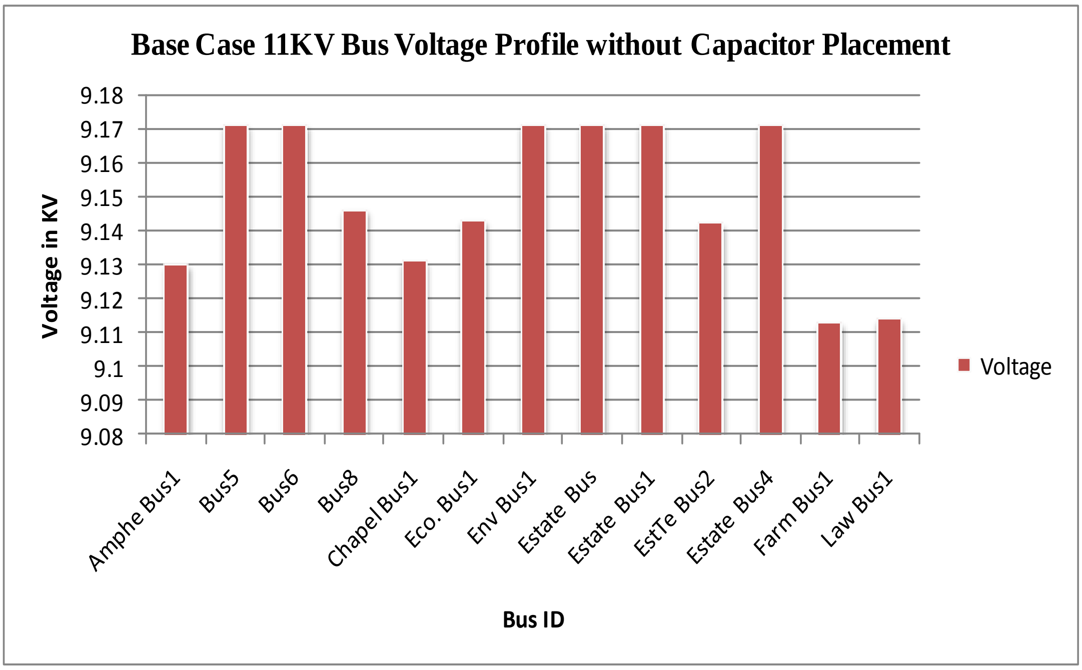

Figure 1.2(a) Base-case 11kv voltage profile without capacitor placement

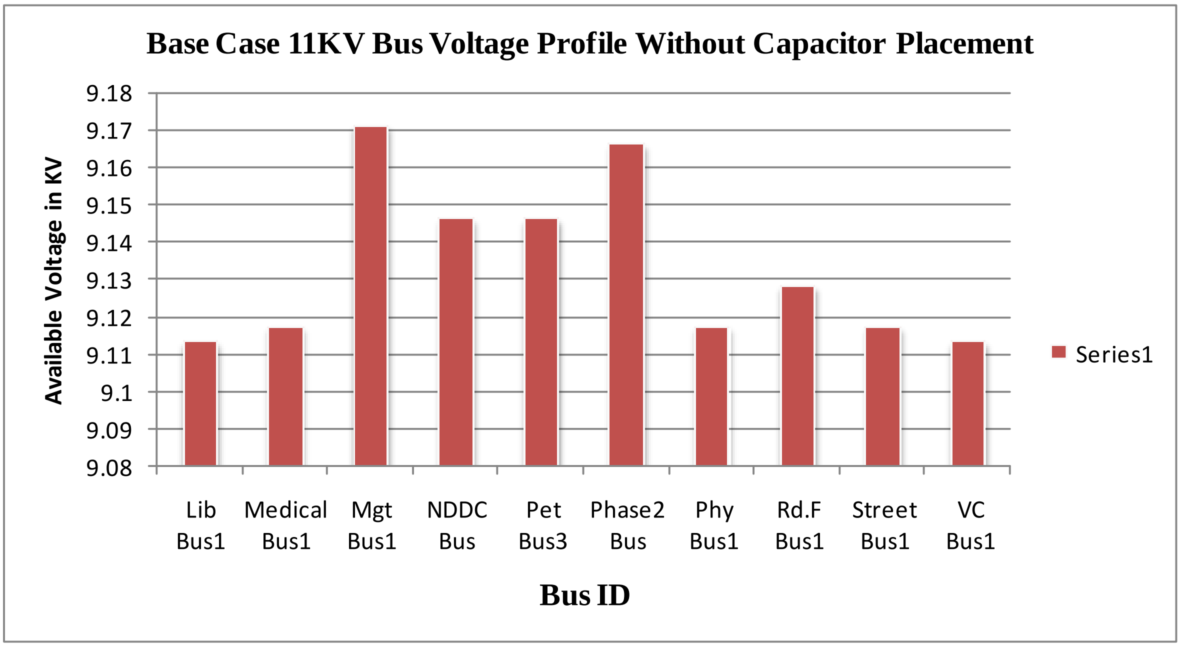

Figure 1.2(b) Base-case 11kv voltage profile without capacitor placement

Table 1.5 Load flow Result (Improved Voltage Profile with Capacitor Bank)

load flow Result (Voltage at each Bus)			
Bus ID	**Nominal KV**	**Improved KV**	**Voltage %**
Aphi Bus 1	11	10.93	99.36
Aphi Bus 2	0.415	0,409	98.55
Bus 5	11	10.876	98.87
Bus 6	11	10.876	98.87
Bus 8	11	10.937	99.43
Chapel Bus 1	11	11.031	100.28
Chapel Bus 2	0.415	0.411	99.04
Eco Bus 1	11	10.942	99.47
Eco Bus 2	0.415	0.407	98.07
Env Bus 1	11	10,875	98.86
Estate Bus	11	10.872	98.84
Estate Bus 1	11	10.876	98.87
Estate Bus 2	11	10.977	98.79
Estate Bus 3	0.415	0.408	98.31
Estate Bus 4	11	10.876	98.87
Farm Bus 1	11	11.071	100.64
Farm Bus 2	0.415	0.417	100.48
Law Bus 1	11	11.071	100.64
Law Bus 2	0.415	0.412	99.28
Lib Bus 1	11	11.971	100.64
Lib Bus 2	0.415	0.417	100.48
Medical Bus 1	11	11.055	100.5
Medical Bus 2	0.415	0.416	100.24
Mgt Bus 1	11	10.875	98.86
Mgt Bus 2	0.415	0.41	98.80
NDDC Bus 1	11	10.937	99.43
NDDC Bus 2	0.415	0.412	99.28
Pet Bus 1	11	10.937	99.43
Pet Bus 2	0.415	0.407	98.07
Phase 2 bus 1	11	10.87	98.82
Phase 2 Bus 2	0.415	0.409	98.55
Phy Bus 1	11	11.055	100.5
Phy Bus 2	0.415	0.411	99.04
Road F Bus 1	11	10.988	99.89
Road F Bus 2	0.415	0.409	98.55
Street Bus 1	11	11.055	100.5
Street Bus 2	0.415	0.416	100.24
VC Bus 1	11	11.071	100.64
VC Bus 2	0.415	0.417	100.48
Workshop Bus 1	0.415	0.412	99.28

Table 1.6 Result of Reduced Branch Power Loss between Buses and Improved with Optimal Placement of Capacitor.

Branch ID	KW Flow	Kvar Flow	% voltage Drop	KW Losses	Kvar losses
Aphi TS 2	144	109	1.36	1.447	2.171
Chapel TS	144	109	1.36	1.444	2.166
Ecobank TS	143	109	1.36	1.449	2.174
Enr Workshop 2	9.96	7.294	0	0	-0.065
Env Line	10.107	6.273	0	0	-0.215
Env TS	10.107	6.273	0.15	0.011	0.016
Estate TS	144	109	1.36	1.447	2.171
Farm TS 2	10.055	7.372	0.16	0.011	0.017
From PH Town	37805	18789	5.57	1742	2201
Lib TS 2	10.035	7.358	0.15	0.011	0.017
Line 1	1418	-5918	0.16	11.032	10.971
Line 4	650	-4035	0.92	34.524	43.425
Medical TS2	10.043	7.363	0.16	0.011	0.017
Mgt sci Line	20.551	12.54	0	0.011	-0.193
Mgt TS	10.444	6.483	0.15	0.011	0.017
NDDC TS	9.873	7.414	0.16	0.011	0.017
Petro/chem.TS2	143	109	1.36	1.45	2.174
Phase 2 TS	79.129	59.708	0.3	0.069	0.414
Phy TS 2	144	109	1.36	1.443	2.164
Rd B. TS	144	109	1.36	1.447	2.17
Street Light TS	9.959	7.478	0.16	0.011	0.017
T1 Estate 2	1400	-6722	1.24	17.857	804
I1 A	27600	9118	1.86	39.106	1760
T1 B	13800	4559	1.86	19.553	880
T2A	23589	17383	6.96	79.484	3577
T2 B	35384	26075	6.96	119	5365
Amphi 2	288	-1577	0.35	5.308	6.306
To Ecobank	437	-1462	0.04	0.726	0.857
To Farm 2	10.055	7.372	0	0	-0.134
To Law 2	175	-1388	0.15	1.79	2.093
To lib 2	10.035	7.358	0	0	-0.112
To Medical 2	10.043	7.363	0	0	-0.223
To NDDC 2	9.874	7.413	0	0	-0.065
To petro/Chem 2	601	-2821	0.55	15.587	19.411
To phase 2	74.129	59.708	0.05	0.031	-0.607
To Physics 2	341	-1262	0.22	2.961	3.384
To Rd F2	144	-1388	0.07	0.803	0.932
To senate 2	0	0.176	0	0	-0.176
To Street Light 2	9.959	7.478	0	0	-0.089
To Chapel TS	488	-4166	0.49	18.006	22.654
To VC2	10.055	7.372	0	0	-0.112
TS Law 2	145	110	1.36	1.442	2.163
TS VC 2	10.055	7.372	0.16	0.011	0.017
W. Shop TS	9.96	7.294	-0.09	0.007	0.05

Total power losses = 2119.502 KW
Total % voltage Drop = 36.97

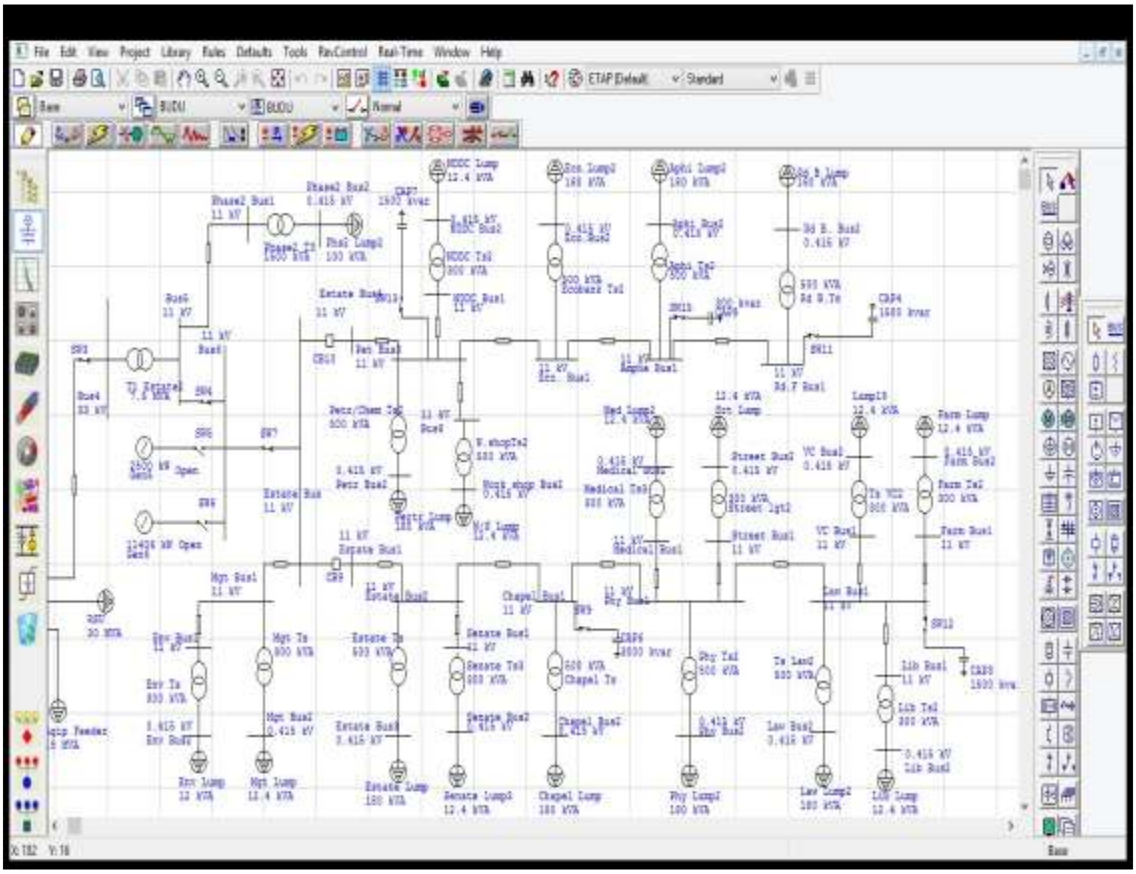

Fig. 1.3: Improved Electrical Distribution Network for RSU 7.5 MVA Substation with capacitor bank placement

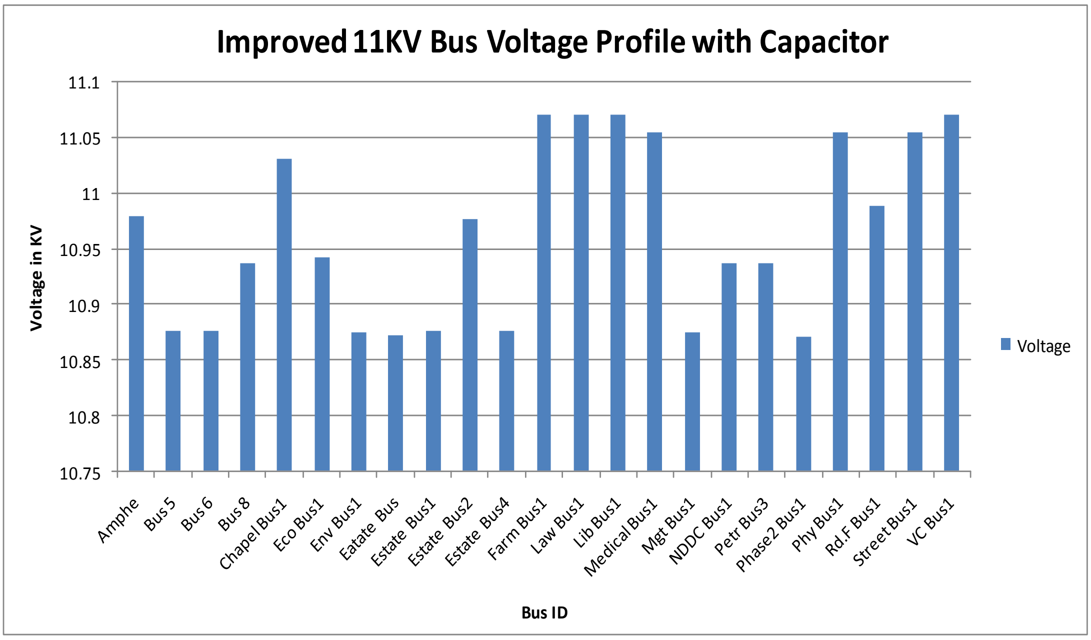

Figure 1.4: Improved 11kv Bus Voltage Profile with capacitor Bank

4.2 Discussions

Results from the base case clearly show that all the load buses have under voltage violations with least voltages of 81.45% of the nominal voltage. Table 1.3 shows the percentage voltage profile of the base case. The branch power losses recorded is shown in table 1.4 with a total power loss of 2373.107KW without capacitor placement. The bus voltage profile when capacitor banks was optimally integrated into the selected buses shows an improved percentage voltage profile with minimum voltage profile recorded at 98.07% of nominal voltage as shown in table 1.5, table 1.6 shows the results of branch reduced power loss in the buses when capacitor banks was integrated in the network from 2373.107KW to 2119.502KW.

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The analysis of the power flow has clearly shown areas of attention. The power dispatched from the primary distribution network (33kv) to the injection substation is inadequate. The total power losses amounting to 2373.107KW on the substation distribution network necessitated upgrade of the network by the introduction of compensator (capacitor bank) at the affected buses to improve the voltage profile and reduce losses to 2119.502KW. A 20.6% of the real power loss reduction achieved when capacitor banks were placed on the sensitive buses. The method employed improves the voltage profile and reduced losses in the substation network. The method can also accommodate large number capacitor sizes and constraints without affecting the accuracy of the results.

5.2 Recommendations

Due to continual increase in electric power demands without corresponding increase in generation and transmission of power, there will always be a drawback in the distribution system, based on this analysis, I recommend

i. Upgrade of the primary distribution system should be made.
ii. 11KV distribution network of the substation be improved by incorporating capacitor banks as realised from the affected buses so as to keep the desirable voltage level.
iii. Periodic load flow analysis should be carried out to ascertain the status of the network.
iv. Protective systems of the substation should be improved by installations of relays, surge arresters etc.

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