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Evaluation and Effects of a Technical and Non-Technical Losses on 11kv and 33kv Feeders, a Case Study of Baga Road Substation, Maiduguri

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ABSTRACT: *An attempt is made to reduce the various power losses in practical distribution systems. Power System faces a big problem of distribution losses. In this paper, distribution power losses are calculated by taking daily loading for a month of some feeders of one part of the city. Analyses of various types of distribution losses of radial distribution network are also considered. It is was observed that, in a distribution power system, more than 40% power loss are due to technical, non- technical and administrative losses. A new attempt of calculation of various distribution losses in power system and their economic effect on the utility are introduced. With the help of the case study of Baga Road distribution substation, Maiduguri city, Nigeria some detailed explanation of the losses are also stated in the paper.*

Keywords: *distribution, feeder, losses, power, substation*

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I. Introduction

Electric power losses are wasteful energy caused by external factors or internal factors, and energy dissipated in the system. These include losses due to resistance, atmospheric conditions, theft, miscalculations, etc., and losses incurred between sources of supply to load canter (or consumers). Loss minimization and quantification is very vital in all human endeavours. In power system, it can lead to more economic operation of the system. If we know how the losses occur, we can take steps to limit and minimize the losses. Consequently, this will lead to effective and efficient operation of the system. Therefore, the existing power generation and transmission can be effectively used without having the need to build new installations and at the same time save cost of losses. Basically, losses in electrical power system can be identified as those losses caused by internal factors known as *Technical losses* and those caused by external factors which are called *non-technical* losses. The Nigerian electricity grid has a large proportion of transmission and distribution losses - whopping 40%. This is attributed to technical losses and non-technical losses. Due to the size of the area the power system serves, the majority of the power systems are dedicated to power transmission. Generally, system losses increase the operating cost of electric utilities and consequently result in high cost of electricity. Therefore, reduction of system losses is of paramount importance because of its financial, economic and socio-economic values to the utility company, customers and the host country. However, low losses in transmission system could be achieved by installing generating stations near the load centres.

Distribution power losses can be divided into two categories; also technical and non-technical losses. The technical losses are related to the material properties and its resistance to the flow of the electrical current that is dissipated as heat. The most obvious examples are the power dissipated in distribution lines and transformers due to their internal electrical resistance. In addition, technical losses are easy to be simulated and calculated. On the other hand, non-technical losses are caused by clandestine connections, frauds in energy meters, diversity of readings and deficiencies (or losses) in the processes of energy measurement.

High rate of technical and non-technical losses might occur due to:

· Poor quality of service offered to customers;
· High cost due to useless or premature investments;
· Reduction in revenue resulting in cash difficulties with all ensuing economic consequences.

Technical losses are part of the electric losses in the system, resulting in: losses in drivers, corona effect, iron of the transformers, eddy currents, connectors, and ohmic losses. These losses can still be grouped according to the segment of the electric system where it happens, being subdivided into losses in the transmission system, substation power transformers, primary distribution system, secondary distribution system, connection extensions and measurement systems. Transformer losses can be classified into two components, namely, no-load and load losses. No-load losses occur from the energy required to retain the continuously varying magnetic flux in the core and its invariant with load on the transformer. Load loss mainly arises from resistance losses in the conducting material of the windings and it varies with loading. The cost of losses is the most important factor in selecting a transformer because it is quite possible for the estimated value of future losses to exceed the first cost of a transformer. Therefore, the right balance between the initial expenses and the upcoming loss expenses should be considered when buying a transformer.

One of the main sources of losses in the distribution system is the copper losses in power overhead lines and cables. Furthermore, unbalanced loading is another factor that can contribute to the line losses, where if one of the phases has more load than the other two, the losses will be larger than that if these phases are balanced. Temperature rise introduces significant increase of power consumption, where the power loading can increase by 3.75 % for 1 °C temperature rise. For the rainy day with higher humidity and lower temperature, a negative correlation among the power consumption was also found. On the other hand, the temperature change has less effect to feeder power losses because transformer losses dramatically contribute more in the power losses.

II. Materials and Methods

2.1 Introduction

The power losses on each of the 11kV feeders are obtained on the basis of the daily maximum loading on the feeders, resistance, size of each feeder conductor, route length of each feeder and maximum current drawn from each feeder conductor.

Equations (1) to (3) were used for computation.

Current drawn from feeder (I_L)

$$I_L = \frac{P}{\sqrt{3}\, Vp.f} \qquad (1)$$

$$R = \frac{\rho \ell\, L}{A} \qquad (2)$$

Where P is Power in Mega Watts, V is voltage in Volts, ρ is resistivity in Ωm, R is resistance in Ω, A is cross sectional area in mm^2, and L is route length of the feeder in kilometer.

$$\text{Power loss} = I_L^2 R \qquad (3)$$

Hence, power loss is power received less power consumed.

Data were collected on:

i. Daily return on loading of 33kV and 11kV feeders.

ii. Feeder route length and distance between transformers are as follows:

1. Mafoni 11kV feeder route length is equal to 5.95km;
2. Zabarmari 11kV feeder length is equal to 13.6km;
3. Benishiek 33kV feeder (1) route length is equal to 10.16km;
4. University Campus 33kV feeder (7) route length is equal to 18.05km.

Aluminium conductor (AAC) of size $150mm^2$ with resistivity of 2.82×10^{-8} Ωm was used for both feeders and distributors. The sample data collected are shown in Tables 1 to 5 from which power losses were obtained for 11kV and 33kV for the months of April and September 2016 respectively.

Mafoni Feeder (11kv)

Maximum loading = 8.74MW

Line voltage (V) = 11kV

Power factor (p.f) = 0.8

Cross sectional area of conductor =$150mm^2$

Route length (L) = 5.95km

Resistivity $\ell = 2.82 \times 10^{-8}$ Ωm

Current drawn from feeder (I_L)

$$I_L = \frac{P}{\sqrt{3}\, Vp.f} = \frac{8.74 x 10^6}{\sqrt{3}\, x 11 x 10^3 x 0.9} = 573.41A$$

$$R = \frac{\ell \rho\, L}{A} = \frac{2.82 x 10^{-8} x\ 5.95 x 10^3}{150 x 10^{-6}} = 1.12\Omega$$

Power loss = $I^2_L R = (573.41)^2 \times 1.12 = 0.368$MW

Zabarmari Feeder (11kv)
Maximum loading = 10.12MW
Line voltage (V) = 11kV
Power factor (p.f) = 0.8
Cross sectional area of conductor =150mm^2
Route length (L) = 13.6km
Resistivity ρ = 2.82 x10^{-8} Ωm
Current drawn from feeder (I_L)

$$I_L = \frac{P}{\sqrt{3}\,Vp.f} = \frac{10.12x10^6}{\sqrt{3}\,x11x10^3x0.9} = 663.95A$$

$$R = \frac{\rho\,\ell\,L}{A} = \frac{2.82\text{x}10^{-8}x\ 13.6x10^3}{150x10^{-6}} = 2.55\Omega$$

Power loss = $I^2_L R = (663.95)^2 \times 2.55 = 1.13$MW

Benishiek Feeder (33kv)
Maximum loading = 11.86MW
Line voltage (V) = 33kV
Power factor (p.f) = 0.8
Cross sectional area of conductor =150mm^2
Route length (L) = 10.16km
Resistivity ρ = 2.82 x10^{-8} Ωm
Current drawn from feeder (I_L)

$$I_L = \frac{P}{\sqrt{3}\,Vp.f} = \frac{11.86x10^6}{\sqrt{3}\,x33x10^3x0.8} = 259.37A$$

$$R = \frac{\ell\,\rho L}{A} = \frac{2.82\text{x}10^{-8}x\ 10.16x10^3}{150x10^{-6}} = 1.91\Omega$$

Power loss = $I^2_L R = (259.37)^2 \times 1.91 = 0.128$MW

University Feeder (33kv)
Maximum loading = 1.61MW
Line voltage (V) = 33kV
Power factor (p.f) = 0.8
Cross sectional area of conductor =150mm^2
Route length (L) = 18.05km
Resistivity ρ = 2.82 x10^{-8} Ωm
Current drawn from feeder (I_L)

$$I_L = \frac{P}{\sqrt{3}\,Vp.f} = \frac{1.61x10^6}{\sqrt{3}\,x33x10^3x0.8} = 35.20A$$

$$R = \frac{\rho\,\ell\,L}{A} = \frac{2.82\text{x}10^{-8}x\ 18.05x10^3}{150x10^{-6}} = 3.39\Omega$$

Power loss = $I^2_L R = (35.20)^2 \times 3.39 = 0.0042$MW

III. Results and Discussion

3.1 Introduction

from the above calculations, It was observed that the power losses of 11KV feeders through mathematical analysis are more as compared to 33kV due to illegal connection resulting to overloading, route length of the feeders, also the transformers location are too far from the load centre, poor maintenance culture, use of inadequate size of conductor and load with poor power factor.

As we know that large amount of power is lost as technical and non-technical losses in power systems. So in this work, thus this result will analyse the power losses and also find some solutions on how to minimize them in power system (distribution part).

As mentioned in previously, total distribution system losses equals technical losses plus non-technical losses, the following are some strategies in which both losses can be minimized, viz:

- Converting LV line to HV line
- Large Commercial/industrial Consumer gets direct line from Feeder
- Adopting high voltage distribution service (HVDS) for agricultural customer
- Adopting Arial bundle conductor (ABC)
- Reduce number of transformer
- Utilizer feeder on its average capacity
- Replacements of old conductor/cables
- Feeder renovation / Improvement program
- Industrial/Urban Focus program.
- Strictly follow Preventive Maintenance Program
- Making mapping /Data of distribution line
- Implementation of energy audits schemes
- Mitigating power theft by power theft checking drives.
- Replacement of Faulty/Sluggish Energy Meter.
- Bill collection facility.
- Reduce Debit areas of Sub Division
- Watchdog effect on users
- Loss Reduction programmed

The loading on the four feeders 11kv (Mafoni, Zabarmari) for the month of April, & 33kv (Beniesheik, University) for the month of September 2016 were presented in TABLES 1,2,3 and 4 respectively with their calculated monthly power losses on the feeders. Their graphical representations of the power loading with losses were also shown in figures 1,2,3 and 4.

Table 1: Mafoni Feeder, 11kv

DAYS	POWER P (MW)	CURRENT I_L (A)	RESISTANT R (□)	POWER LOSS P_{LS} (MW)
1	8.74	573.4138	1.12	0.36826
2	8.28	543.2341	1.12	0.330516
3	8.28	543.2341	1.12	0.330516
4	7.36	482.8748	1.12	0.261148
5	9.2	603.5935	1.12	0.408044
6	7.36	482.8748	1.12	0.261148
7	12.88	845.0309	1.12	0.799766
8	0	0	1.12	0
9	10.12	663.9528	1.12	0.493733
10	0	0	1.12	0
11	9.66	633.7731	1.12	0.449869
12	10.12	663.9528	1.12	0.493733
13	10.12	663.9528	1.12	0.493733
14	9.2	603.5935	1.12	0.408044
15	9.66	633.7731	1.12	0.449869
16	9.2	603.5935	1.12	0.408044
17	9.66	633.7731	1.12	0.449869
18	9.66	633.7731	1.12	0.449869

19	9.9	649.5191	1.12	0.4725
20	9.9	649.5191	1.12	0.4725
21	9.2	603.5935	1.12	0.408044
22	8.28	543.2341	1.12	0.330516
23	6.44	422.5154	1.12	0.199942
24	6.9	452.6951	1.12	0.229525
25	7.36	482.8748	1.12	0.261148
26	0	0	1.12	0
27	8.28	543.2341	1.12	0.330516
28	7.87	516.3348	1.12	0.298594
29	6.44	422.5154	1.12	0.199942
30	0	0	1.12	0

TABLE 2: ZABARMARI FEEDER, 11KV

DAYS	**POWER P (MW)**	**CURRENT I_L (A)**	**RESISTANCE R (□)**	**POWER LOSS P_{LS} (MW)**
1	10.12	663.95	2.55	1.12
2	10.12	663.95	2.55	1.12
3	9.20	603.59	2.55	0.93
4	13.34	875.21	2.55	1.95
5	10.12	663.95	2.55	1.12
6	9.20	603.59	2.55	0.93
7	0.00	0.00	2.55	0.00
8	0.00	0.00	2.55	0.00
9	0.00	0.00	2.55	0.00
10	10.12	663.95	2.55	1.12
11	0.00	0.00	2.55	0.00
12	11.04	724.31	2.55	1.34
13	7.36	482.87	2.55	0.59
14	10.58	694.13	2.55	1.23
15	10.12	663.95	2.55	1.12
16	10.12	663.95	2.55	1.12
17	10.12	663.95	2.55	1.12
18	7.36	482.87	2.55	0.59
19	9.20	603.59	2.55	0.93
20	0.00	0.00	2.55	0.00
21	11.04	724.31	2.55	1.34
22	10.58	694.13	2.55	1.23
23	9.20	603.59	2.55	0.93
24	11.04	724.31	2.55	1.34
25	10.12	663.95	2.55	1.12
26	10.12	663.95	2.55	1.12
27	9.66	633.77	2.55	1.02
28	9.66	633.77	2.55	1.02
29	8.74	573.41	2.55	0.84

30	0.00	0.00	2.55	0.00

TABLE 3: BENISHIK FEEDER, 33KV

S/N	POWER P (MW)	CURRENT I(A)	RESISTANCE R (□)	POWER LOSS (MW)
1	11.86	259.37	1.91	0.13
2	11.86	259.37	1.91	0.13
3	10.76	235.31	1.91	0.11
4	12.14	265.49	1.91	0.13
5	10.74	234.88	1.91	0.11
6	11.59	253.47	1.91	0.12
7	10.76	235.31	1.91	0.11
8	12.14	265.49	1.91	0.13
9	12.38	270.74	1.91	0.14
10	10.76	235.31	1.91	0.11
11	12.65	276.65	1.91	0.15
12	11.50	251.50	1.91	0.12
13	11.96	261.56	1.91	0.13
14	10.99	240.34	1.91	0.11
15	11.04	241.44	1.91	0.11
16	11.50	251.50	1.91	0.12
17	12.42	271.62	1.91	0.14
18	11.27	246.47	1.91	0.12
19	13.24	289.55	1.91	0.16
20	14.62	319.73	1.91	0.20
21	12.42	271.62	1.91	0.14
22	12.14	265.49	1.91	0.13
23	12.38	270.74	1.91	0.14
24	12.38	270.74	1.91	0.14
25	12.97	283.65	1.91	0.15
26	13.82	302.23	1.91	0.17
27	10.35	226.35	1.91	0.10
28	13.24	289.55	1.91	0.16
29	13.82	302.23	1.91	0.17
30	12.14	265.49	1.91	0.13

TABLE 4: UNIVERSITY FEEDER, 33KV

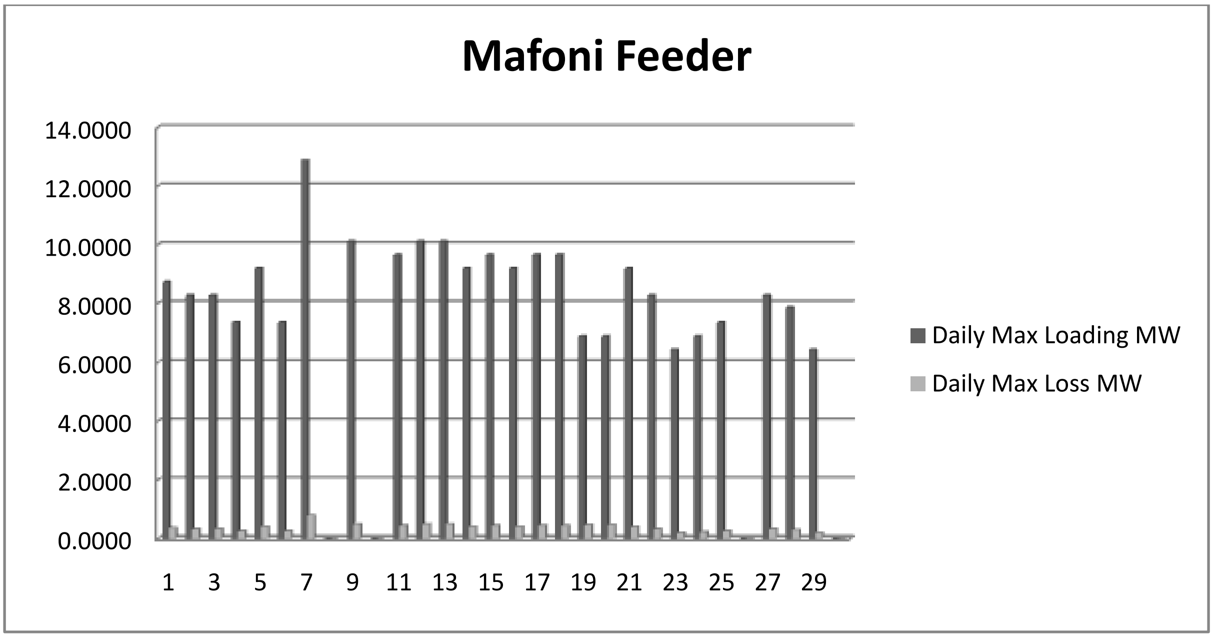
S/N	POWER P (MW)	I(A)	R (□)	POWER LOSS (MW)
1	1.61	35.21	3.39	0.004
2	2.53	55.33	3.39	0.010
3	1.70	37.18	3.39	0.005
4	1.56	34.12	3.39	0.004
5	2.66	58.17	3.39	0.011
6	1.70	37.18	3.39	0.005
7	2.16	47.24	3.39	0.008
8	2.57	56.20	3.39	0.011

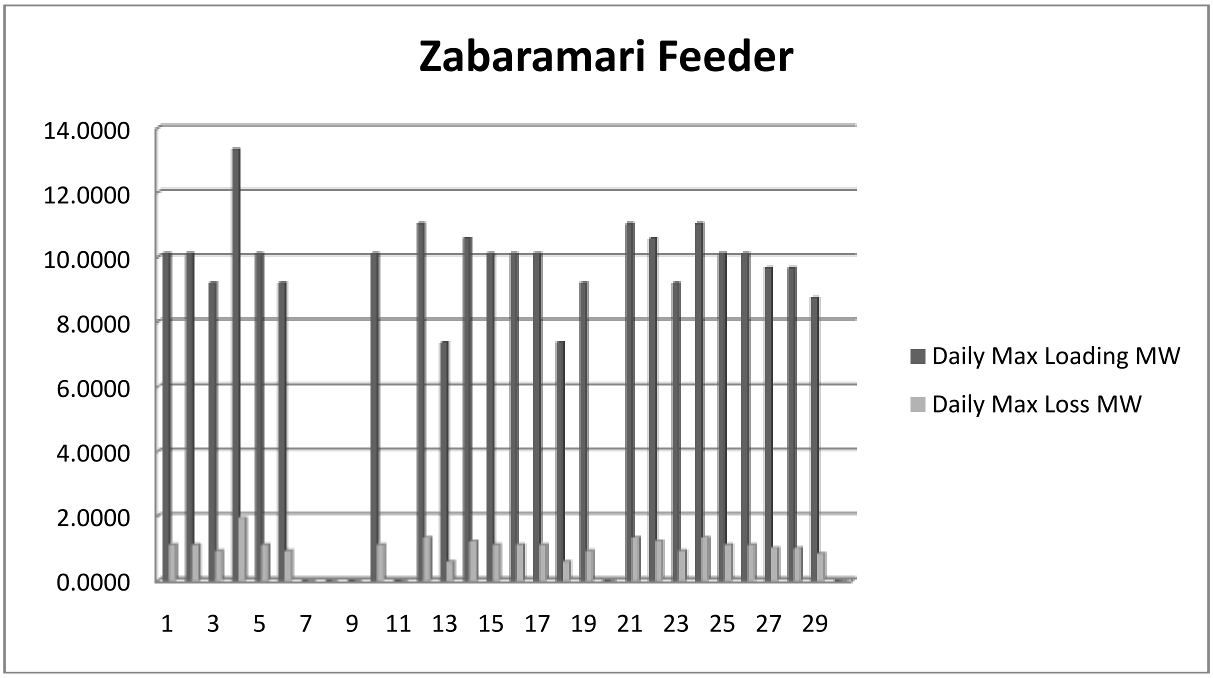
9	2.66	58.17	3.39	0.011
10	1.74	38.05	3.39	0.005
11	1.74	38.05	3.39	0.005
12	1.56	34.12	3.39	0.004
13	1.74	38.05	3.39	0.005
14	2.43	53.14	3.39	0.010
15	2.20	48.11	3.39	0.008
16	2.43	53.14	3.39	0.010
17	1.79	39.15	3.39	0.005
18	1.74	38.05	3.39	0.005
19	2.57	56.20	3.39	0.011
20	2.39	52.27	3.39	0.009
21	2.71	59.27	3.39	0.012
22	2.30	50.30	3.39	0.009
23	2.25	49.21	3.39	0.008
24	1.79	39.15	3.39	0.005
25	1.97	43.08	3.39	0.006
26	2.89	63.20	3.39	0.014
27	2.66	58.17	3.39	0.011
28	2.43	53.14	3.39	0.010
29	2.57	56.20	3.39	0.011
30	2.53	55.33	3.39	0.010

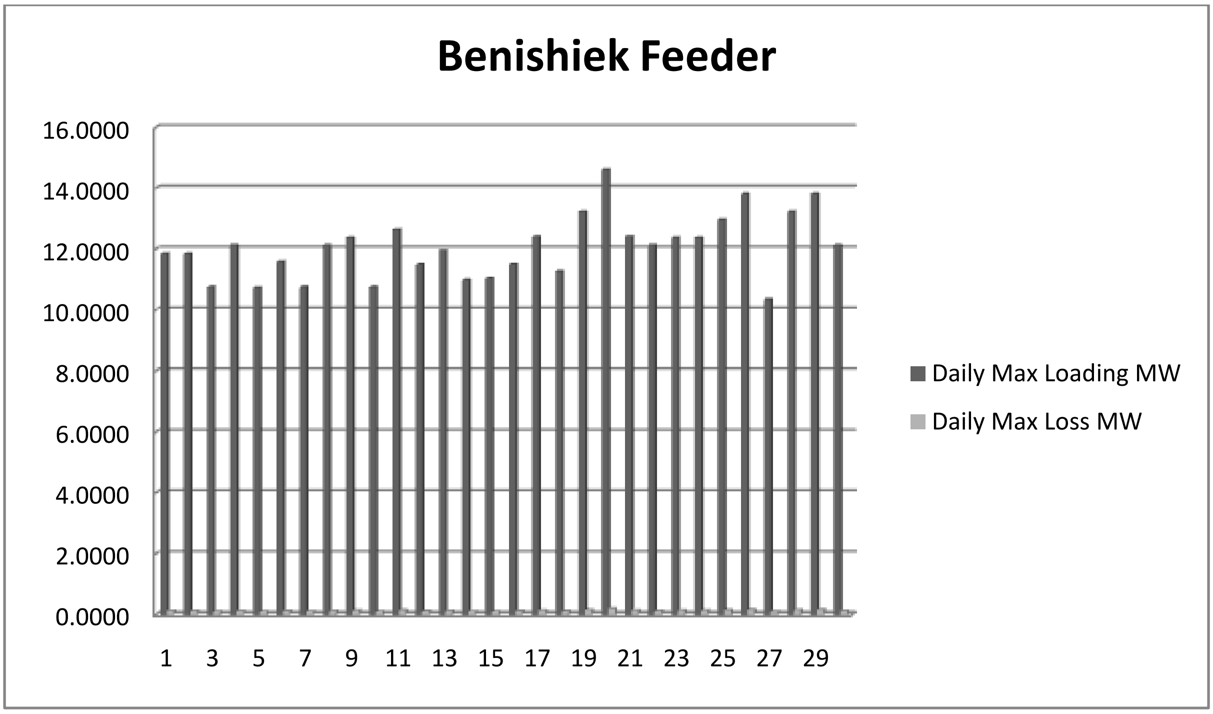
TABLE 5: DAILY MAX LOADING WITH THEIR LOSSES IN MW FOR ALL THE FOUR FEEDERS.

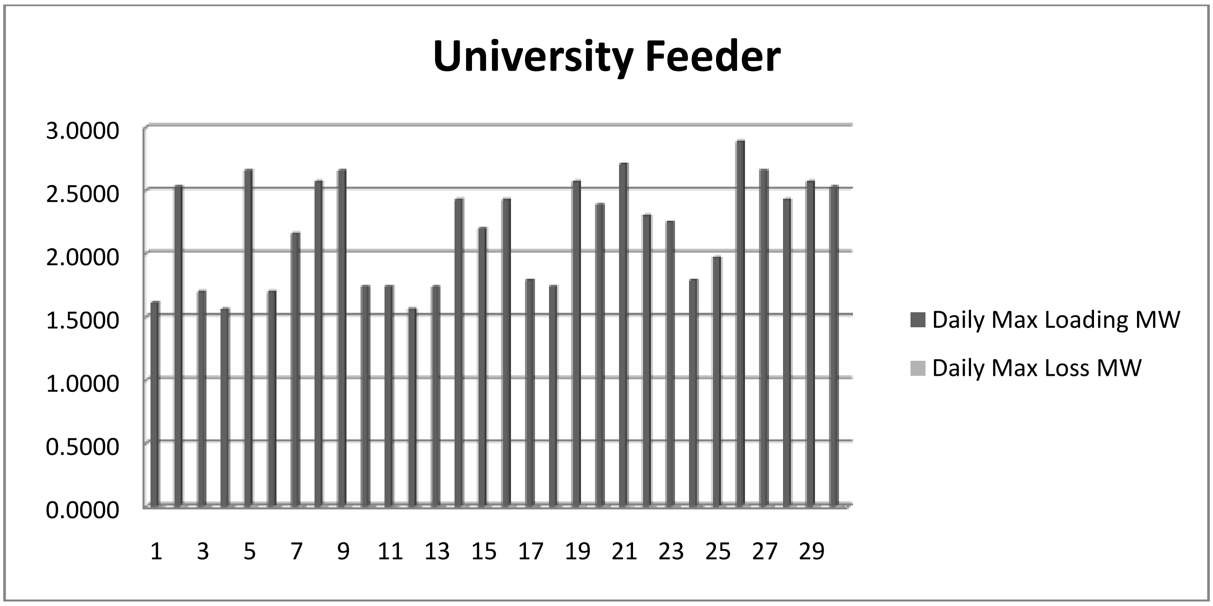
DAYS	**MAFONI**		**ZABARMARI**		**BENISHIEK**		**UNIVERSITY**	
	APRIL 2016, 11KV FEEDER				**SEPTEMBER 2016, 33KV FEEDER**			
Power MW	**Daily Max Loading MW**	**Daily Max Loss MW**	**Daily Max Loading MW**	**Daily Max Loss MW**	**Daily Max Loading MW**	**Daily Max Loss MW**	**Daily Max Loading MW**	**Daily Max Loss MW**
1	8.7400	0.3683	10.1200	1.1200	11.8600	0.1300	1.6100	0.0040
2	8.2800	0.3305	10.1200	1.1200	11.8600	0.1300	2.5300	0.0100
3	8.2800	0.3305	9.2000	0.9300	10.7600	0.1100	1.7000	0.0050
4	7.3600	0.2611	13.3400	1.9500	12.1400	0.1300	1.5600	0.0040
5	9.2000	0.4080	10.1200	1.1200	10.7400	0.1100	2.6600	0.0110
6	7.3600	0.2611	9.2000	0.9300	11.5900	0.1200	1.7000	0.0050
7	12.8800	0.7998	0.0000	0.0000	10.7600	0.1100	2.1600	0.0080
8	0.0000	0.0000	0.0000	0.0000	12.1400	0.1300	2.5700	0.0110
9	10.1200	0.4937	0.0000	0.0000	12.3800	0.1400	2.6600	0.0110
10	0.0000	0.0000	10.1200	1.1200	10.7600	0.1100	1.7400	0.0050
11	9.6600	0.4499	0.0000	0.0000	12.6500	0.1500	1.7400	0.0050
12	10.1200	0.4937	11.0400	1.3400	11.5000	0.1200	1.5600	0.0040
13	10.1200	0.4937	7.3600	0.5900	11.9600	0.1300	1.7400	0.0050
14	9.2000	0.4080	10.5800	1.2300	10.9900	0.1100	2.4300	0.0100
15	9.6600	0.4499	10.1200	1.1200	11.0400	0.1100	2.2000	0.0080
16	9.2000	0.4080	10.1200	1.1200	11.5000	0.1200	2.4300	0.0100
17	9.6600	0.4499	10.1200	1.1200	12.4200	0.1400	1.7900	0.0050
18	9.6600	0.4499	7.3600	0.5900	11.2700	0.1200	1.7400	0.0050
19	6.9000	0.4725	9.2000	0.9300	13.2400	0.1600	2.5700	0.0110

20	6.9000	0.4725	0.0000	0.0000	14.6200	0.2000	2.3900	0.0090
21	9.2000	0.4080	11.0400	1.3400	12.4200	0.1400	2.7100	0.0120
22	8.2800	0.3305	10.5800	1.2300	12.1400	0.1300	2.3000	0.0090
23	6.4400	0.1999	9.2000	0.9300	12.3800	0.1400	2.2500	0.0080
24	6.9000	0.2295	11.0400	1.3400	12.3800	0.1400	1.7900	0.0050
25	7.3600	0.2611	10.1200	1.1200	12.9700	0.1500	1.9700	0.0060
26	0.0000	0.0000	10.1200	1.1200	13.8200	0.1700	2.8900	0.0140
27	8.2800	0.3305	9.6600	1.0200	10.3500	0.1000	2.6600	0.0110
28	7.8700	0.2986	9.6600	1.0200	13.2400	0.1600	2.4300	0.0100
29	6.4400	0.1999	8.7400	0.8400	13.8200	0.1700	2.5700	0.0110
30	0.0000	0.0000	0.0000	0.0000	12.1400	0.1300	2.5300	0.0100









IV. CONCLUSION

4.1 Introduction

The research investigates the losses in a distribution power system, i.e technical and nontechnical losses .The mechanisms that is used to determine the technical losses was discussed in details.

Technical losses and non-technical losses causes were discussed and the ways to minimized or completely eliminate them were also stated.

The results of the different cases were represented in tabular and graphical form.

4.2 Recommendations

The following recommendations are made on this type of research work:

The technical losses can be minimized in the following ways:

1. By decreasing the length of the distribution line which leads to reduce the technical losses.

2. By carrying out maintenance the substations periodically and this leads to decrease the transformer core losses and reduce the losses of components and equipments in the substation.
3. By replacing the aluminium conductor with bigger size (120mm to 150mm) in some feeders (3,5,7).
4. By replacing the Aluminium conductor with underground armoured cable or copper conductors where possible.

   For the non-technical losses, the following ways are recommended

5. By classifying the population into sectors and units.
6. By making a periodic inspections which leads to reduction in losses.
7. By motivating the workers in the company which can reduce bribery cases and thus the nontechnical losses.
8. By Installation of pre-paid meters.
9. By establishing of authorized community commercial agents.
10. By carrying out a periodic inspection.

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