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Estimation of Technical and Non-Technical Losses of an 11kV Industrial Feeder: A Case Study in Kawasoti Distribution Centre

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Abstract

Nepal is a developing country currently suffering from power crisis. One of the main causes of power shortage is electricity loss during transmission and distribution. This loss contains technical and non technical losses of the system. Planned and rigid measures shall be taken for the reduction of technical as well as non-technical part of the losses. This paper presents an approach to estimate and clearly interpret the technical and non-technical losses of an industrial feeder of Kawasoti distribution centre, Nepal. From the field study, it was found that in case of industrial feeder, unit of transformer losses is also included in bill of consumers. Therefore in this research, the difference between total energy imported and total energy realized is termed as aggregate line and commercial loss and to find out the actual total losses of the feeder, transformer losses was added to the aggregate line and commercial loss. Technical loss was calculated by simulating the industrial feeder in Electrical Transient and Analysis Program (ETAP) software. From this study the aggregate line and commercial loss was found to be 1.66% and the actual total loss of industrial feeder was 2.388% of the total imported energy. Non technical loss was only 0.385%. Simulation was done by replacing the conductor of the industrial feeder by various types of conductors of upper grade. Results showed that, technical loss can be reduced remarkably by using conductor of upper grade having low resistivity.

Keywords

Technical loss – Non-technical loss – ETAP – Industrial feeder

1. Introduction

Nepal's energy situation is poor with massive power shortages. The system loss of Nepal Electricity Authority (NEA) is 22.90% in fiscal year 2016/17 [1]. Being a growing economy, electricity needs of all the sectors in the country are in increasing trend. However, there has always been a gap between consumers' demand and supply of electricity in Nepal [2]. A lot of industries have reached a closing situation over the years as a result of insufficient power supply. Besides low production of electricity, the other cause for the shortage of electricity is the amount of power lost during the transmission and distribution.

The term distribution losses refers to the difference between the amount of energy delivered to the distribution system and the amount of energy customer is billed [3]. Distribution line losses are comprised of two types: technical losses and non-technical losses.

Technical losses in power system are naturally occurring losses and consist mainly of power dissipation in electrical system component such as transmission lines, power transformers, measurement system etc. According to [3] [4], the causes of technical losses are harmonics distortion, improper earthing at consumer end, long single phase lines, unbalanced loading, losses due to overloading and low voltage, losses due to poor standard of equipment, inadequate conductors size of distribution lines. Non-technical losses are caused by actions external to the power system. The most probable causes of Non-technical losses (NTL) are errors in technical losses computation, hooking on low tension (LT) lines, stealing by bypassing the meter or otherwise making illegal connections, faulty energy meters or un-metered supply, errors and delay in meter reading and billing [3].

The transmission and distribution losses of integrated Nepal power system are high [2]. Accurate analysis of distribution losses is very necessary to optimize the system. Most of the efforts of power planners concentrate on augmenting supply by constructing new power plants. But loss reduction is possible by improving operating conditions for the distribution network. Thus there is some scope for improvement in operating strategies. The main objective of the study is to segregate technical and non-technical losses of industrial feeder and assess different possibilities of reduction of loss by re-conductoring of the feeder.

Most of the researches are focused on the assessment of overall distribution losses of residential sector load. Hence, this research is aimed to assess the technical and non-technical part of the losses in industrial feeder and to calculate technical loss for different options of conductors for the feeder by simulation. After getting the real value of technical and non-technical losses, one can suggest and implement the best option to reduce distribution losses.

2. Methodology

2.1 Description of the Study Area

Dumkauli industrial feeder of Kawasoti distribution centre (KDC) was selected for the study. Dumkauli feeder is one of the eight feeders in Kawasoti DC. It is an industrial feeder supplied through Pragatinagar substation. The cumulative loss of the distribution centre is 21.45% in fiscal year 2071/072. These losses consist of technical and non-technical types of losses. There are only 15 industries connected in this industrial feeder (Figure 2). This feeder contains industrial consumers only and most of the connected consumers have TOD (time of day) meters (except one having whole current energy meter) so the data was reliable and accurate. Figure 1 shows the satellite image of Pragatinagar Substation and its periphery.

Ratings of connected transformers and maximum demands of the industries recorded during 12 months study periods are shown in Table 1. These data were obtained from name plate of the transformers and the bills recorded in Kawasoti DC. These data were used in calculating technical loss by simulating in ETAP.

Table 1 also shows the average billed unit of consumers per month for the consumers of industrial feeder

Figure 1: Satellite image of Pragatinagar substation

calculating by taking the monthly consumption unit for the 12 months of year 2072 (B.S.). These data were taken from billing software of Kawasoti DC. In case of HT consumer using HT metering unit, transformer loss is recorded in TOD meter installed before transformer. And in case of consumer using LT CT, 3% loss is added in consumption unit as transformer losses. Table 2 shows the energy imported to feeder from substation during 12 months study period. These data were obtained from the log book of substation. Energy supplied to the feeder from substation is recorded by energy meter installed at the feeder.

2.2 Calculation of aggregate line and commercial loss

The difference between energy supplied at the input points and energy billed to consumer in percentage terms for a particular period is termed as aggregate technical and commercial (AT&C) loss [5]

$$AT\&C\ loss = \frac{(energy\ input - energy\ realized) \times 100}{energy\ input} \tag{1}$$

Where, energy realized = sale of energy$\times$collection efficiency. In this study, industrial feeder is chosen for study which has only 15 industries, so collection efficiency is assumed to be 100%. However, for Dumkauli industrial feeder, unit of transformer loss is also included in bill of consumers. In case of HT (high tension) consumer using HT metering unit, transformer loss is recorded in TOD meter installed before transformer. And in case of consumer using low tension current transformer (LT CT), 3% loss is added in consumption unit as transformer loss. Therefore, in this study, the difference between total energy imported and

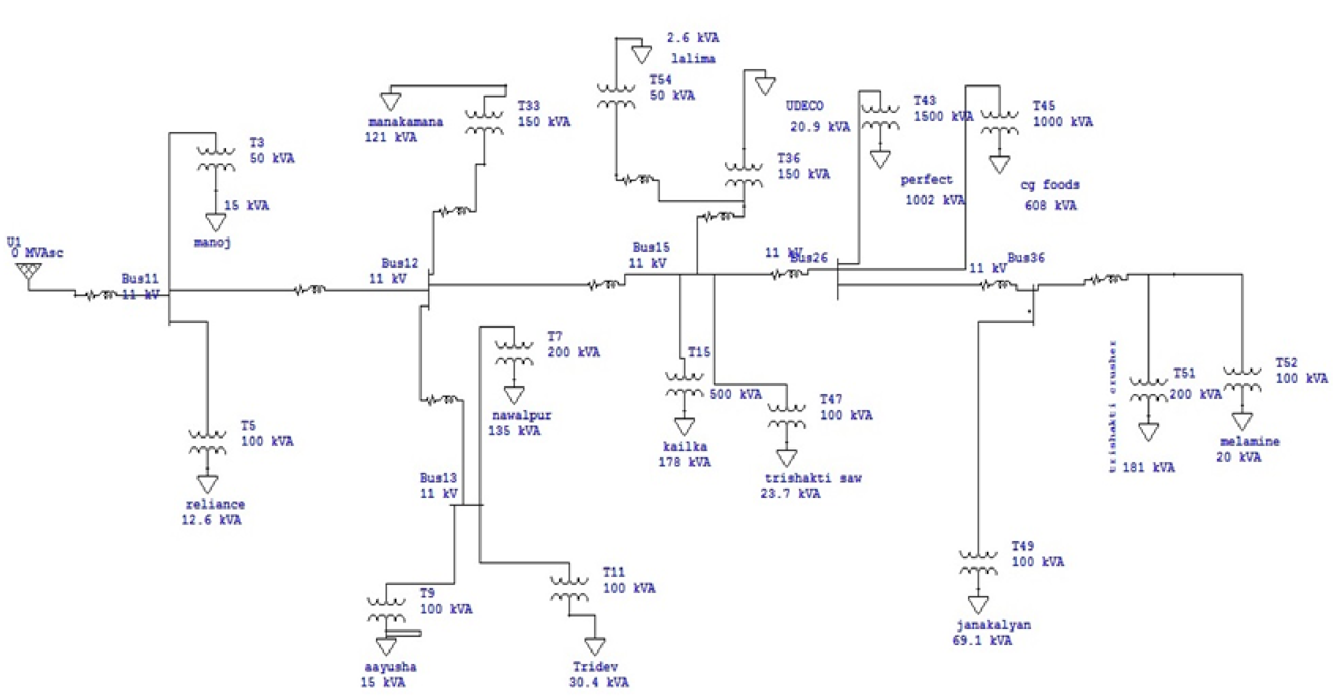

Figure 2: Single Line Diagram of the Industrial Feeder simulated in ETAP

Table 1: Consumers details

S.N.	Consumers	Rating of transformer (kVA)	Maximun demand (kVA)	Consumer type (HT/LT)	Average recorded unit per month (kWh)
1	Kalika crusher	500	160.69	HT	8287.83
2	Manoj furniture	50	12	LT	643.15
3	Tridevrice	150	28.33	LT	35.54
4	Trishakti saw mill	100	23.67	LT	651.13
5	Janakalyan plastic	100	69.1	LT	586.93
6	Udeco Pvt. Ltd.	150	20.85	LT	702.37
7	Subhi melamine	100	20	LT	1130.35
8	Nawalpur crusher	200	138.8	LT	5239.10
9	Manakamana crusher	150	114.9	LT	8187.38
10	Perfect blend	1500	1001.79	HT	163228
11	Aayusha plastic	100	15.01	LT	360.76
12	CG foods	1000	608.3	HT	107182.67
13	Lalima krishi	50	2.56	LT	4.64
14	Reliance Technical	100	8.82	LT	1203.67
15	Trishakti crusher	200	173.05	HT	9664.92
	Total average billed unit per month				307108.37

Table 2: Energy imported to industrial feeder

S.N.	Month	Energy imported (kWh)
1	Baisakh	384061
2	Jesth	425897
3	Asar	425788
4	Shrawan	337410
5	Bhadra	396878
6	Asoj	348263
7	Kartik	224214
8	Mangsir	324444
9	Paush	224613
10	Magh	199385
11	Falgun	207354
12	Chaitra	249201

total energy realized is termed as aggregate line and commercial loss and to find out the actual total loss of the feeder, transformer loss is added to the aggregate line and commercial loss. So, aggregate line and commercial loss of the industrial feeder is calculated as following,

$$Agg.\ L\&C\ loss = energy\ imported - energy\ billed \quad (2)$$

2.3 Estimation of technical loss and non-technical loss

The feeder was simulated in electrical transient and analysis program (ETAP) software by providing the description of the installed transformers and the overhead conductors. The loads of the feeder and consumers are the peak load of the feeder and consumers obtained from the data downloaded/recorded from the energy meter installed at this feeder and consumers premises. The mapping of the 11 kV feeders was conducted with the help of field survey. The distance between the transformers is measured to get the length of the feeder. To run the load flow study, the ETAP software required the single line diagram of the feeder. The single line diagram is drawn showing transformers, load on each transformer and length of overhead lines etc.

In ETAP library, an aluminium conductor steel-reinforced (ACSR) conductor of code ACSR DOG is created which has 6 strands and cross sectional area of 103.6 sq.mm. For the auxiliary branch in case of RABBIT conductor, ARCHERY11 (conductor having 6 strands and cross sectional area of 49.5 square mm) conductor is used as RABBIT conductor for the modeling of the system in ETAP.

The technical energy losses of the distribution network were estimated by simulating the peak load conditions on ETAP. The peak power losses for the network were assessed based on load flow studies. The loss load factor was worked out from the daily load curve. The peak load loss obtained by this simulation and Loss Load Factor (LLF) are used to calculate the average technical loss of the industrial feeder [6].

Load factor: The ratio of the average load during a designated period to the maximum load occurring at that time.

$$LF = \frac{Average\ load}{Maximum\ load} \quad (3)$$

Load loss factor: The actual losses of the circuit is calculated by applying a factor to the total losses assuming maximum current to flow through that circuit during the whole period. This factor is called as load loss factor (LLF) [7] which is defined as:

$$LLF = \frac{Actual\ loss\ during\ designated\ period}{Loss\ at\ maximum\ current} \quad (4)$$

$$LLF = K(LF) + (1-K)*LF*LF \quad (5)$$

Where, LF = Load factor, K is a constant. The value of k is taken as 0.3 for this study [8]. And then, non-technical loss is calculated by subtracting technical losses from actual total distribution losses [9].

Similarly, the line loss and transformer loss for the designated period were calculated separately. The technical loss can be formulated as in equation (6).

$$Total\ tech.\ loss = line\ loss + transformer\ loss \quad (6)$$

Then by using the equation (7), the actual total loss of the feeder was estimated.

$$Actual\ loss = Tran.\ loss + agg.\ line\ \&\ comm.\ \ loss \quad (7)$$

Where, aggregate line and commercial loss is equal to the sum of line loss and non-technical loss. Therefore, equation (7) can also be written as equation (8).

$$Actual\ loss = Tran.\ loss + line\ loss + non\ tech.\ loss \tag{8}$$

Formula for actual loss can also be written as,

$$Actual\ loss = Tech.\ loss + Nontech.\ loss \tag{9}$$

And then, non-technical loss is calculated by subtracting technical losses from actual total distribution losses [9] by using the equation (9).
After getting numerical values of technical and non-technical losses it can be analyzed and one can recommend best conductor to reduce these losses. Effect of conductor upgradation on line losses were investigated for the selected 11 kV feeder and compared with the existing conductor.

3. Results and Discussion

3.1 Calculation of aggregate line and commercial loss of the industrial feeder

Total average energy imported from Industrial (Dumkauli) Feeder in one month=312292.33 kWh
Total billed Energy of consumers of industrial feeder in one month= 307108.37 kWh

Aggregate line and commercial losses of industrial feeder in one month= Total energy imported from feeder - total energy billed =312292.33-307108.37
= 5183.96 kWh
% loss=5183.96/312292.33*100
=1.660 %

3.2 Estimation of technical loss and non-technical loss

ETAP power system software is used for the load flow study of this feeder and to calculate the technical energy losses. The results of the 11 kV industrial feeder simulated in ETAP for existing scenario is illustrated in Table 3. It shows kW flow and kVAR flow at different buses.

Table 3: Load flow results of simulation

CKT/ branch	From-To Bus Flow		To-From Bus Flow		Losses	
ID	MW	Mvar	MW	Mvar	kW	kvar
Line1	1.84	1.45	-1.84	-1.45	3.76	3.39
Line5	1.81	1.43	-1.81	-1.43	4.90	4.41
T3	0.01	0.01	-0.01	-0.01	0.04	0.25
T5	0.01	0.01	-0.01	-0.01	0.01	0.09
Line7	0.14	0.11	-0.14	-0.11	0.11	-0.25
Line9	1.58	1.25	-1.58	-1.24	5.62	4.96
Line11	0.09	0.07	-0.09	-0.07	0.07	-0.57
T7	0.10	0.08	-0.10	-0.08	0.68	4.86
T9	0.01	0.01	-0.01	-0.01	0.02	0.13
T11	0.02	0.02	-0.02	-0.02	0.07	0.51
T33	0.09	0.07	-0.09	-0.07	0.72	5.15
Line15	1.40	1.11	-1.40	-1.11	4.47	3.87
Line23	0.02	0.01	-0.02	-0.01	0.00	-0.60
T15	0.14	0.11	-0.14	-0.10	0.49	3.44
T47	0.02	0.01	-0.02	-0.01	0.04	0.31
T36	-0.02	-0.01	0.02	0.01	0.02	0.16
Line19	0.20	0.16	-0.20	-0.16	0.36	-1.23
T43	0.75	0.59	-0.74	-0.56	4.96	35.21
T45	0.45	0.36	-0.45	-0.34	2.75	19.54
T49	-0.05	-0.04	0.05	0.04	0.35	2.50
Line21	0.15	0.12	-0.15	-0.12	0.14	-0.98
T51	-0.13	-0.10	0.13	0.11	1.18	8.40
T52	-0.02	-0.01	0.02	0.01	0.03	0.22
Line25	0.00	0.00	0.00	0.00	0.00	-0.30
T54	0.00	0.00	0.00	0.00	0.00	0.01
Total					30.80	93.40

Table 4: Calculations

Maximum current	89 Amp.
Average current	47.96 Amp.
Load factor(LF)	0.539
K	0.3
LLF	0.365
Length of the Feeder	9km
Resistance per unit length	0.2733 ohm per km.
Loadshedding at that day	7 hrs.
Technical loss of feeder on Asoj 12	191.08 kWh

Total peak power losses of the feeder from the table are =30.8 kW
Total peak transformer loss = 11.2 kW
Total peak line loss = 19.6 kW

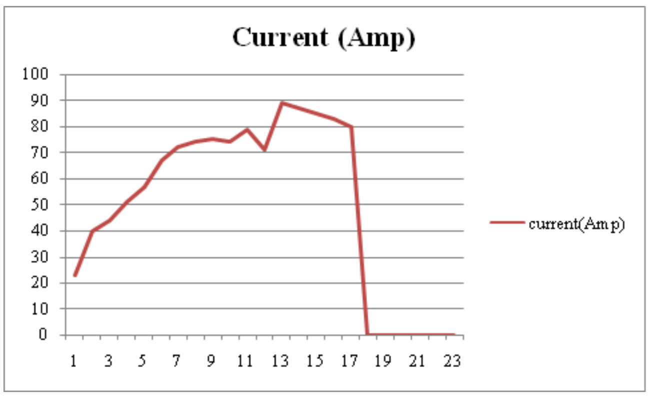

Figure 3: Load curve of 2072/06/12

Figure 3 shows the load curve of recorded current flowing in the industrial feeder during 24 hours on 2072/Asoj/12. There was load shedding for 7 hours during that day. Using the formula I*I*R*LLF*t, technical loss on 13th of Asoj is calculated as 191.08 kWh.
Similarly,
Technical loss of feeder on Asoj 13 = 223.678 kWh
Technical loss of feeder on Asoj14 = 210.710 kWh
Taking data of 3 days, we can calculate average technical loss of industrial feeder.
Average loss =(191.08+223.678+210.71)/3
= 208.489 kWh
There are 30 days on the month of Asoj 2072 (B.S.).
Total technical loss of the month (2072 Asoj) = 6254.68 kWh.

Similarly, we can calculate line loss and transformer loss separately.
Average transformer loss per month of the feeder = 2274.43 kWh
Average line loss per month of the feeder = 3980.05 kWh
Aggregate line and commercial loss of the feeder in one month =5183.96 kWh
% Aggregate line and commercial loss of the feeder=1.66%
Total technical loss (line loss+ transformer loss) of the feeder in one month=6254.68 kWh

Actual loss = transformer loss+line loss+non technical loss
=Transformer loss+ Aggregate line and commercial loss
=2274.43+5183.96 =7458.39 kWh Total non-technical loss of the feeder in one month=1203.71 kWh
% Technical loss=2.003%

% Non-Technical loss=0.385%
% Actual loss=%Technical loss+%Non-technical loss =2.388%

3.3 Results after upgradation of conductor and financial analysis

Similarly, simulations were carried out by replacing the existing conductor with conductors of upper grade available in ETAP library. To find out the feasibility of the reconductoring process, financial analysis should be carried out. For financial analysis, the cost of only restringing and dismantling of the conductor is considered. Since same pole structure and materials can be used; the cost related to pole has not to be considered. The existing conductor has to be removed before restringing with new conductor. So, the cost of the project is the cost of conductor and stringing and dismantling work.

The results obtained in four different cases were shown in table 5. Results show that reconductoring of feeder with upper grade of conductors reduce the losses of the distribution feeder but financially it is not feasible for the industrial feeder in which transformers are not adequately loading and technical losses are very low.

Table 5: Loss reduction and results of financial analysis after upgrading conductor

Conductor code	Conductor type	Cross sectional area (mm^2)	Rdc(DC resistance in ohm per unit length	Technical loss percentage	Reduction in technical loss(%)	IRR(%)
KRYPTON	AAAC	158	0.189	1.788	0.215	4.7
GRAPE1120	ACSR	182	0.203	1.872	0.131	3.4
CRICKET	ACSR	182	0.182	1.756	0.247	6.7
LUTETIUM	AAAC	183	0.163	1.645	0.358	6.6

4. Conclusions

From the study, it is seen that the actual total loss of industrial feeder is 2.388% of the total imported energy. The aggregate line and commercial loss is found to be 1.66%. The Technical loss of the feeder is 2.003%. Non-technical loss was calculated by subtracting technical loss from actual total loss, which is 0.385%. Non-technical losses are also lie in acceptable level. Non-technical loss is caused by external action to the power system, like error in measuring and billing, theft and fraud. But in case of industrial feeder there are only 15 consumers and they have equipped with TOD meter. So there are less chance of theft and fraud. There may be the possibility of deterioration of metering unit, CT and PT and error in measuring and billing due to which 0.385% of non-technical loss occurred in 11 kV industrial feeder.

Simulations were carried out by replacing the existing conductor with conductors of upper grade available in ETAP library. The results obtained are shown in table 5. Results above show that technical loss of the feeder can be reduced by using conductor of upper grade having lower value of resistivity.

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References

[1] NEA. A year in review fiscal year 2016/17. Technical report, Nepal Electricity Authority, 2017.

[2] NEA. A year in review fiscal year 2013/14. Technical report, Nepal Electricity Authority, 2014.

[3] Navani J., Sharma N., and Sapra S. Case study of analysis of technical & non technical losses in power system and its impact on power sector. *International Journal of Advances in Engineering Science and Technology*, 1:757–761, 2012.

[4] Ramalla I. and Namburi N. Analytical review of loss reduction techniques in indian power distribution sector – techno managerial approach. *International Journal of Research in Engineering and Technology*, 3, 2014.

[5] Kumar M.K., Sairam K. V., and Santosh R. Methods to reduce aggregate technical and commercial (at & c) losses. *International Journal of Engineering Trends and Technology*, 4, 2013.

[6] Pabla A.S. *Electric power distribution*. McGraw-Hill Education, 2003.

[7] S. Pande and P.D. Ghodekar. Computation of technical power loss of feeders and transformers in distribution system using load factor and load loss factor. *International Journal of Multidisciplinary Sciences and Engineering*, 3:22–25, 1994.

[8] Baitch A. Distribution loss factor calculation methodology. *Tasmania: Aurora Energy BES Pty. Ltd.*, 2004.

[9] Singh D., Sharma S., and G Sharma. An approach for measurement of non-technical losses of 11kv feeder and its minimization. *International Journal of Engineering Research and Applications*, 5:34–42, 2015.