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Utilizing Load and Loss Factors in Determination of the Technical Power Losses in Distribution System's Feeders: Case Study

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ABSTRACT

This study uses load factor and loss factor to determine the power losses of the electrical feeders. An approach is presented to calculate the power losses in the distribution system. The feeder's technical data and daily operation recorded data are used to calculate and analyze power losses.
This paper presents more realistic method for calculating the power losses based on load and loss factors instead of the traditional methods of calculating the power losses that uses the RMS value of the load current which not consider the load varying with respect to the time.
Eight 11kV feeders are taken as a case study for our work to calculate load factor, loss factor and power losses. Four of them (F40, F42, F43 and F45) are overhead lines while the others (F185, F186, F187 and F188) are underground cables. The greater differences between their losses were obtained, due to various types of route length, type, and dimension of conductors. The study takes different configuration feeders for computation with determination in power losses.
Keywords: Technical Power Loss, Distribution System, Load Factor, Loss Factor

استخدام عاملي الحمل والفقد لتحديد مفاقيد القدرة في مغذيات توزيع الطاقة الكهربائية: دراسة الحالة.

دارا حمه امين محمد
مدرس
المعهد التقني السليمانية - جامعة السليمانية التقنية

الخلاصة

في هذا البحث، تم استخدام عاملي الحمل والفقد لتحديد مفاقيد القدرة في المغذيات الكهربائية. تم طرح طريقة لحساب مفاقيد القدرة في جزء منظومة التوزيع لمدينة السليمانية. حيث ان البيانات والسجلات اليومية للقراءات الفنية الخاصة بالأستهلاك من تم استخدامها لحساب وتحليل المفاقيد.
حيث انه قدم استخدام طريقة اكثر واقعية لحساب مفاقيد القدرة مقارنة بالطرق التقليدية بأستخدام معاملي الحمل والفقد بدلا من استخدام معدل الجذر التربيعي للتيار والذي يكون غير واقعي نتيجة تغير الحمل مع مرور الزمن في اوقات مختلفة. تم اخذ ثمان مغذيات نوع 11kV كحالة دراسية للبحث لحساب معاملي الحمل والفقد. حيث ان اربعٌ من هذه المغذيات هي خوط تغذية هوائية بينما الاربع مغذيات الاخرى هي مغذيات تحت الأرض. الفرق بينهما في مفاقيد الطاقة تم احتسابه وهو نتيجة لفرق اطوال

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المغذيات ونوع وحجم الموصل المستخدم فيها. الدراسة اخذت بنظر الاعتبار انواع مختلفة للمغذيات لغرض الحسابات وايجاد مفاقيد الطاقة

الكلمات الرئيسية: مفاقيد القدرة- منظومة التوزيع- عامل الحمل- عامل الفقد.

1. INTRODUCTION

The civilization development of any country depends on energy. Within the various types of energy, the electrical energy is considered as the best kind of them **(Shahzad Sarwar Bhatti, et al., 2015)**. Even the power industry changed according to the community requirements **(Hassan k. and Mounir E., 2018)**. The electrical power system contains three main stages which are generation, transmission, and distribution. Overhead lines, underground cables, transformers, and some other equipment are used to delivery electric power from generating station to consumers. Consumers connect their loads to the system via distribution part **(Adejumobi I.A, and Adebisi O. I, 2012)**.

The planning, design, and operation of the electric power system is achieved through the knowledge about distribution sector which is the most significant part of the system **(Adegboyega Gabriel A., and Onime Franklin, 2014).**

Many efforts have been made to fix the challenges of power system and improving its performance like what **(**Ruba **A., eta al. 2018)** have mentioned in their research. But one of the major operational challenge facing the distribution power system is the power losses, which can be classified in to two sorts:

- Technical losses are the physical components of the system especially conductors which depends on route length of feeders and its cross-sectional area. Current flow in the feeders is also another reason that should be considered. Physical components are constant during operation whereas the current varies from time to time depending on power consumption.
- Non-technical losses or commercial losses include power stealing, wrong metering, and etc.

Accurate estimation of power losses determines operating costs for providing supply to consumers. This results in a better estimation of system lifetime costs. Additionally, it is important not only know the expected target of technical losses is actually technical but also reduction is achievable without charging the parts and design of the system.

Provided technical loss is reduced, cheaper electricity with a lower production cost is obtained which positivity affects economic growth over the years; numerous studies have been conducted to estimate energy losses in distribution network. Therefore, the following are the literature reviews of paper and some other publications to get the gaps from them:

(Mohsin Mahmood, et al., 2014) analyzed and simulated the losses technically that caused by the physical properties used material in transmission lines, explaining its effects on the flow of electrical current in distribution system through electrical transient analysis program. Their research showed that the efficiency of the transformers depends on the operating load and the losses are reduced by reducing the distance between the load and the feeding transformer.

Researchers **(Ade-Ikuesan, O. O., et al., 2018)** have presented the investigation of electric power losses on primary distribution feeder, the results demonstrated the losses increases annually and average annual power losses was found.

(Su Hlaing Win, and Pyone Lai Swe, 2015) presented distributed generation method to minimize power losses. Their method calculated the size and optimum location of distributed generation installation as a result minimized the real power losses, reactive power losses and improved the corresponding voltage profile values.

(Mehdi Izadi., et al., 2014) reported a study in which the power loss, energy loss, and loss factor were measured in an actual distribution network; the results indicated that the method proposed for evaluating load was appropriate.

(J.E. Mendoza, et al., 2013) studied four methods for estimating annual technical power losses in distribution networks due to the distributed generation (DG) connection; the proposed method assists the engineer not only for fast, accurate and reliable control but also operating and planning of the distribution sector.

Minimizing energy losses strategy has been used by **(Hamed Emara Kassem, et al., 2013)** for the electrical distribution network based on Genetic Algorithm. Their results showed that the multi criterion algorithm has succeeded to reduce technical losses for all sample networks to reach the acceptable limit.
Finally, **(Sarang Pande, and Prof. Dr. J.G. Ghodekar, 2012)** presented a method for energy loss calculation that demonstrates the capability of Load factor and load loss factor to calculate the power losses of the network, where the results obtained can be used for tariff process.

2. METHODOLOGY

Iraq-slemani Azmer and kampy zanko substations 11kV feeders are taken as a case study for this work to calculate load factor, loss factor and power losses. Azmer substation, shown in figure .1, 11kV feeders (F40, F42, F43 and F45) are overhead lines, while kampy zanko substation shown in **Fig.2** 11kV feeders (F185, F186, F187 and F188) are underground cables.

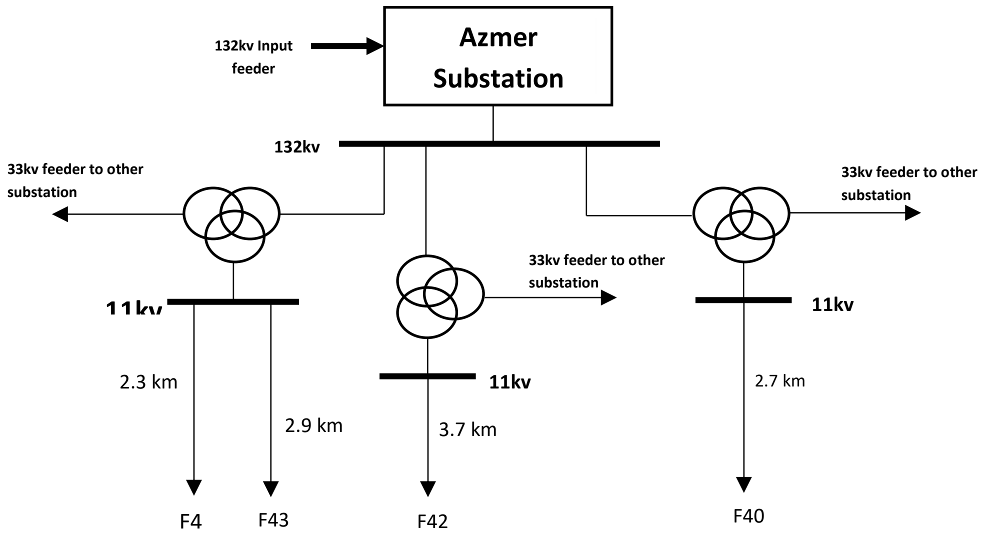

Figure 1. Single line diagram representing Azmer substation and its feeders.

The study takes different configuration feeders for computation with determination in power losses. About more than 30 years passed over Azmer substation 11kV feeder’s installation. While kampy zanko substation 11kV feeders are much newer compare to Azmer substation 11kV feeders that about less than 10 years.
For the mentioned reasons this paper took these feeders as a sample of the study among the existing feeders of Slemani city distribution network. The data of daily loads are taken from data center of Slemani Communication and Control Directorate, and the route length of 11 kV feeders, type and dimension of conductors are taken from Slemani General Directorate of Electricity.

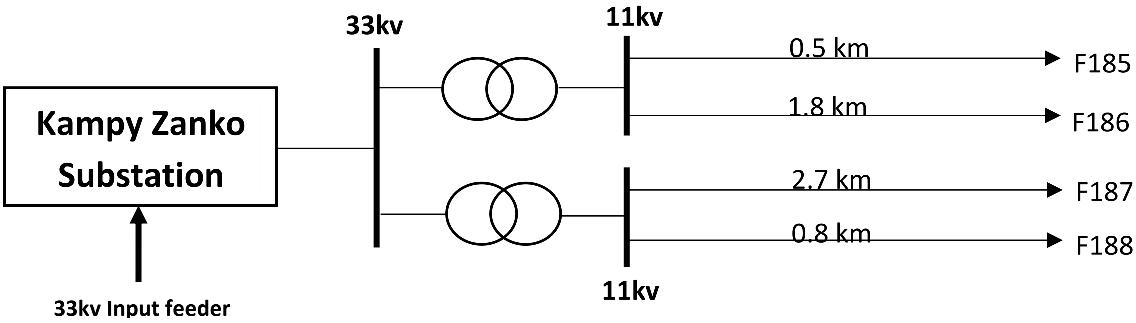

Figure 2. Single line diagram representing Kampy Zanko substation its feeders.

The obtained data (Minimum loading, Maximum loading and Average loading) are calculated from the daily load data. The load Factor, Loss Factor and Power Losses are calculated according the equations of later sections, and MS Excel package is used as tool for calculating of the obtained data and charts.

3. EQUATIONS OF LINE LOSSES

The main reason for losses in transmission and distribution lines is the resistance of conductors against the flow of current. The creation of heat in conductor as a result of the flow of current increases more temperature in it. This increase in the conductor's temperature further increases the resistance of the conductor and this will therefore rise the losses. This indicates that ohmic power loss is the main component of losses in transmission and distribution lines.
The value of the ohmic power loss, is given as

$$P_{Loss} = I_L^2 R \tag{1}$$

The resistance (R, in Ω) of the line is given as:

$$\mathrm{R} = {}^{\rho l}\!/_{A} \tag{2}$$

Where
I_L: Indicates current along the conductor.
R: Indicates resistance of the conductor.
ρ: Is the resistivity of the conductor,
l: Denotes the length of the conductor and
A: Denotes the cross-sectional area of conductor.

Feeder losses were computed using maximum return on loading of feeders considering the place of loss factor **Mufutau, W.O., et al., 2015**. The value of the current at all times is less than the maximum current. Due to this, the computation of feeder losses employs the loss factor approach.

Upon considering loss factor, eqn. (1) becomes:

$$P_{Loss} = I_L^2 R \times (Loss\ Factor) \tag{3}$$

Where Loss Factor as given by **Mufutau, W.O., et al., 2015** is:

$$\text{Loss Factor} = 0.3 \times Load\ Factor + 0.7\ (Load\ Factor)^2 \tag{4}$$

And,

$$\text{Load Factor} = \text{Average Load/Peak Load} \tag{5}$$

4. RESULTS

Equations (2 - 5) are applied on sampled network data of the case study-Iraq Slemani Distribution Network, to compute technical losses in the feeder circuit respectively. Eight loaded feeders were considered for this study. The considered feeders are F40, F42, F43 and F45 11kV overhead line feeders on Azmer substation, and F185, F186, F187 and F188 11kV underground cable feeders on kampy zanko substation. The following data were collected on the feeders considered:

(i) Three (3) years (2015-2017) Monthly average return on loading of feeders.
(ii) Three (3) years (2015-2017) Monthly maximum return on loading of feeders.
(iii) Feeders route length. Using eqn. (2) and the route length of 11 kV feeders, type and dimension of feeder conductors that taken from Slemani General Directorate of Electricity, the result is as shown in **Table (1).**

Table 1. Calculated Resistance of the feeder lines.

	rho(Ω.m)	L(km)	A(mm^2)	R(Ω)
F40	17.5×10^{-9}	2.7	185	0.255405
F42	28×10^{-9}	3.7	95	1.090526
F43	28×10^{-9}	2.9	95	0.854737
F45	28×10^{-9}	2.3	120.	0.536667
F185	17.5×10^{-9}	0.5	240	0.036458
F186	17.5×10^{-9}	1.8	240	0.131250
F187	17.5×10^{-9}	2.7	240	0.196875
F188	17.5×10^{-9}	0.8	240	0.064167

The monthly minimum, maximum, and average loadings (A) on feeders are calculated from the daily loadings that taken from data center of Slemani Communication and Control Directorate. The results are converted to the monthly minimum, maximum, and average loadings in (MW) on feeders as shown in **Table (2) – Table (9).** The Load Factor, Loss Factor and Technical loss in the system were computed using power factor of 0.8 and Eq.(2) – Eq.(5).

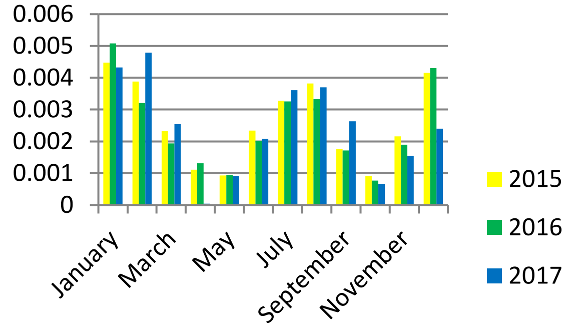

Figure 3. Power Losses (MW) on Feeder 40 of Azmer substation from January 2015 to December 2017.

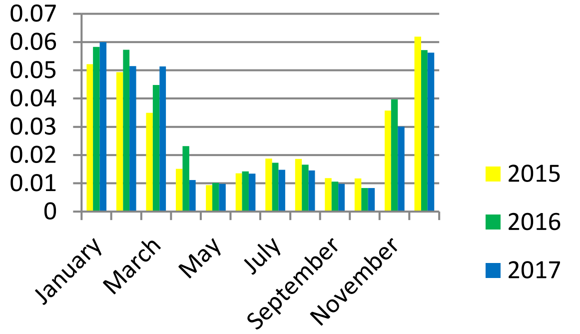

Figure 4. Power Losses (MW) on Feeder 42 of Azmer substation from January 2015 to December 2017.

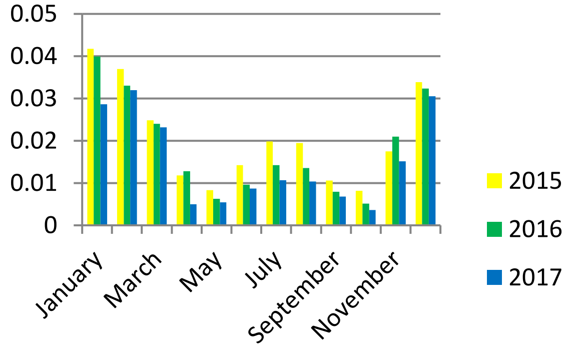

Figure 5. Power Losses (MW) on Feeder 43 of Azmer substation from January 2015 to December 2017.

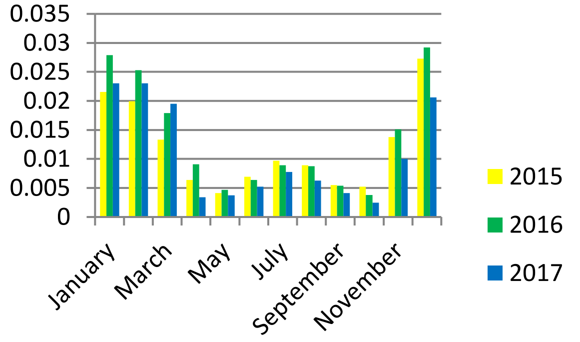

Figure 6 . Power Losses (MW) on Feeder 45 of Azmer substation from January 2015 to December 2017.

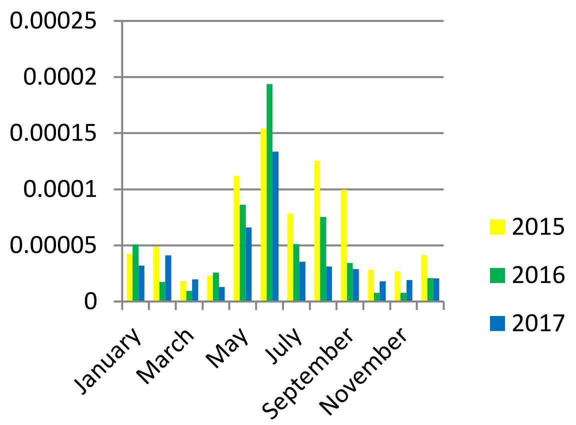

Figure 7. Power Losses (MW) on Feeder 185 of Kampy Zanko substation from January 2015 to December 2017.

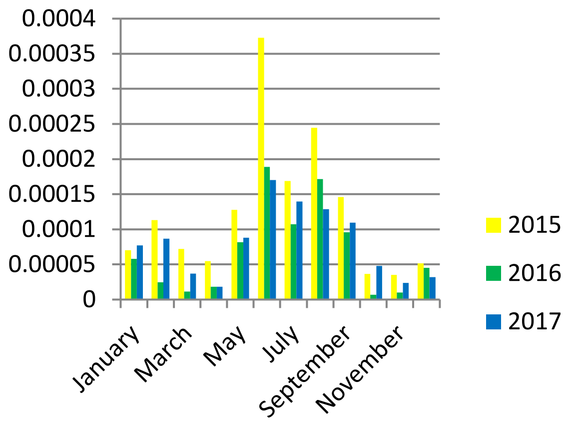

Figure 8. Power Losses (MW) on Feeder 186 of Kampy Zanko substation from January 2015 to December 2017.

The results are as presented in **Table (10) – Table (17).** The yearly average maximum loading and the average power losses on the feeders are presented in **Table (18) and Table (19).** For the sake of clearness, simplicity of observation and comparison of power losses, the obtained results that presented in **Table (10) – Table (19)** were also shown on the **Fig.3 – Fig.12** respectively.

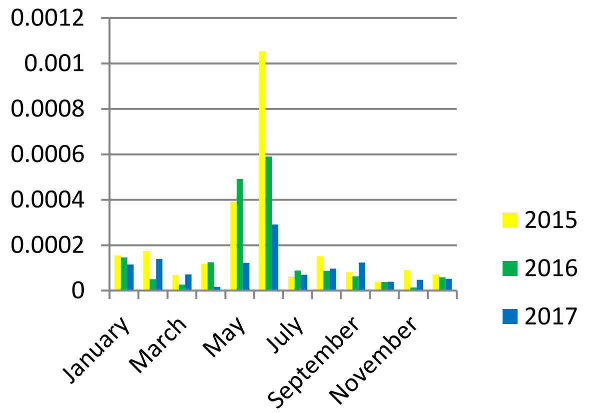

Figure 9. Power Losses (MW) on Feeder 187 of Kampy Zanko substation from January 2015 to December 2017.

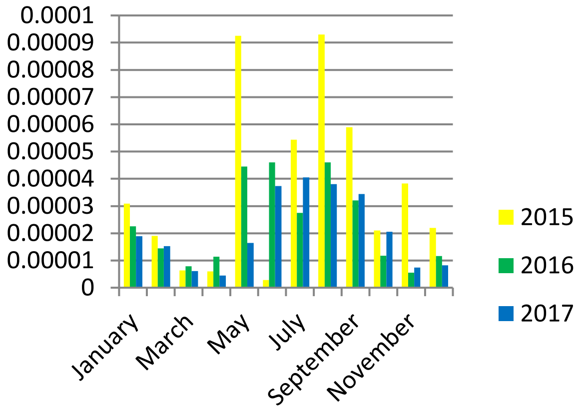

Figure 10. Power Losses (MW) on Feeder 188 of Kampy Zanko substation from January 2015 to December 2017.

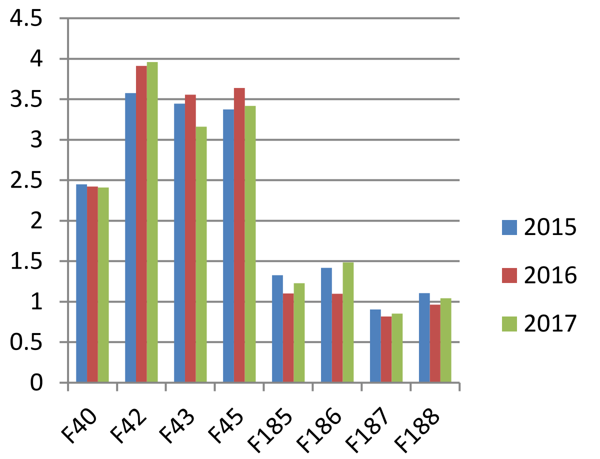

Figure 11. Average Maximum loading on the feeders from 2015-2017.

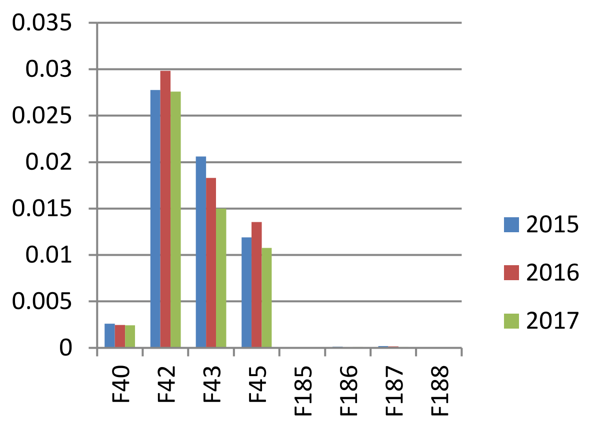

Figure 12 . Average losses (MW) on the feeders from 2015-2017.

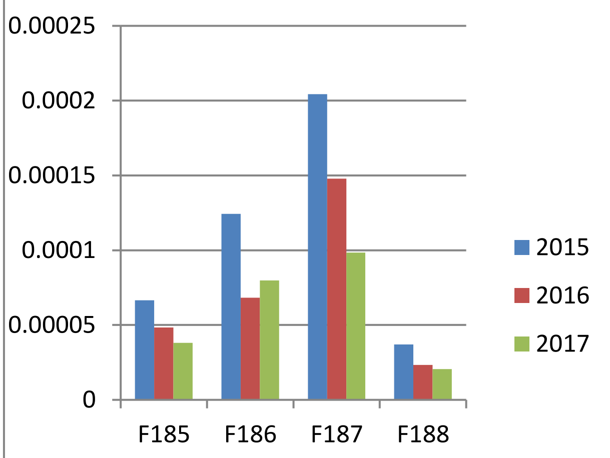

Figure 13. Average losses (MW) on the feeders (F185, F186, F187,F188) from 2015-2017.

5. DISCUSSION

Referring to **Fig.3,** which represents the power losses of three years for Azmar substation that, supply residential and tourism areas which are very active on summer times so it is clearly seen that the power losses for the feeder F40 is much more than the other feeders of the the corresponding summer months. On other hand, the same case can be seen in **Fig.7,** where the feeder 185 is feeding University of Sulaymaniyah and it its maximum power losses on June among

the other months because June the most active month in the university which is the month of the final examinations and all halls are occupied, so the load is at its maximum values.
In **Figs.8, and Fig.10** it is also seen that the power losses is dramatically reduced in 2016 and 2017 compared with 2015 due to the fact that the a new power factor compensators has been installed across the feeders 186, and 188
Referring to **Table (10)** to **Table 19**, the obtained results have been analyzed. We have observed that the losses on Azmer feeders are much greater than Kampy Zanko feeders. Where, Kampy Zanko feeders are newer and they were installed underground thus the corona losses would be omitted. Also, Kampy Zanko feeders' line cables are made of copper, which result in lower resistivity than Azmar aluminum conductor made lines. Moreover, Kampy Zanko feeders feed approximately a constant load (University campus), while Azmar feeder feeds different residential loads.

6. CONCLUSION

The calculation and determination of technical power losses of some different 11 kV feeders of two power substation of Slemani Distribution System has been performed in this paper using load factor and loss factor approach. The results show that some feeders have highest average power losses due to their long route, overhead construction and the nature of the connected load.
According to the fact that amount of power is lost in power system, the losses can be minimize by using the several techniques like Power Capacitor installation, Transformer Relocation, and Load Balancing. For the current case study, minimize the power losses of feeders can be achieved by decreasing the route length of feeders and distinguish the feeders based on the nature of load (commercial, residential, industrial, or other).

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Table 2. Monthly Loading (MW) on Feeder 40 of Azmer substation from January 2015 to December 2017.

F40	**2015**			**2016**			**2017**		
Months	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
January	0.333333	3.25	2.032083	0.5	4	2.079866	0.666667	2.916667	2.04185
February	0.916667	3.25	1.857116	1	2.833333	1.705457	0.666667	3.333333	2.105716
March	0.416667	2.5	1.436261	0.75	2.166667	1.332451	0.916667	2.666667	1.495617
April	0.416667	1.833333	0.975803	0.416667	2.333333	1.014462	0.5	1.666667	0.083333
May	0.416667	1.5	0.922809	0.5	1.5	0.926687	0.5	1.416667	0.923674
June	0.083333	2.583333	1.432615	0.5	2.25	1.351217	0.75	2.166667	1.392298
July	1.166667	2.5	1.784835	0.333333	2.5	1.777127	0.083333	2.833333	1.836904
August	1.166667	2.916667	1.890942	0.416667	2.416667	1.81465	1.333333	2.75	1.880804
September	0.583333	2	1.278933	0.583333	2.166667	1.234829	0.166667	3.25	1.440795
October	0.416667	1.583333	0.898376	0.5	1.25	0.854931	0.083333	1.166667	0.796522
November	0.666667	2.333333	1.39792	0.333333	2.583333	1.248317	0.5	2.333333	1.129458
December	0.666667	3.166667	1.949611	1.333333	3.083333	2.008564	0.333333	2.416667	1.479915

Table 3. Monthly Loading (MW) on Feeder 42 of Azmer substation from January 2015 to December 2017.

F42	**2015**			**2016**			**2017**		
Months	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
January	1.75	4.916667	3.428865	0.333333	5	3.658823	0.25	5.5	3.639478
February	1	4.916667	3.310509	1.833333	5	3.618605	1.833333	5	3.387648
March	1.416667	4.666667	2.703206	1.5	4.916667	3.121423	1.5	5.166667	3.358315
April	0.166667	3	1.789372	0.916667	4.833333	2.046735	0.183333	5	1.211806
May	0.833333	2.083333	1.451642	0.833333	2.666667	1.435665	0.666667	2.666667	1.399835
June	1	2.25	1.794104	1	2.833333	1.746643	0.166667	2.916667	1.67183
July	1.5	3.166667	2.019182	1.5	2.666667	2.000839	0.333333	2.5	1.845878
August	1.333333	3	2.042476	1.416667	2.666667	1.951489	0.166667	2.75	1.785419
September	0.75	2.333333	1.638292	0.833333	2.333333	1.527434	0.916667	2.166667	1.48432
October	0.75	3.25	1.482632	0.666667	2.416667	1.298259	0.583333	3.083333	1.201164
November	1.166667	4.333333	2.792997	0.833333	6.5	2.656559	0.666667	4.916667	2.418542
December	2	5	3.794553	1.666667	5.083333	3.599594	1.416667	5.833333	3.444376

Table 4 . Monthly Loading (MW) on Feeder 43 of Azmer substation from January 2015 to December 2017.

F43	2015			2016			2017		
Months	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
January	2.416667	4.916667	3.473893	2.083333	4.666667	3.419842	1.666667	4.166667	2.859906
February	1.75	4.583333	3.273494	1.666667	4.833333	3.013897	1.666667	4.166667	3.06353
March	1.583333	4.25	2.605181	1.25	4.5	2.509718	1.333333	3.916667	2.546081
April	1	3	1.783854	0.25	4.333333	1.679229	0.583333	3.333333	0.969697
May	0.916667	2.25	1.543642	0.75	2.416667	1.266525	0.583333	2.416667	1.153659
June	1.416667	2.666667	2.061374	0.916667	2.583333	1.632026	0.833333	2.583333	1.533342
July	1.5	3.333333	2.405812	1.5	2.833333	2.032374	0.25	2.416667	1.766361
August	1.333333	3.166667	2.40121	0.666667	2.75	1.988991	1	2.416667	1.733499
September	1	2.583333	1.729535	0.833333	2.416667	1.467325	0.166667	2.083333	1.388281
October	0.666667	2.75	1.448486	0.583333	2.083333	1.157295	0.333333	1.666667	0.983046
November	1.333333	3.583333	2.180947	0.833333	4.666667	2.277598	0.416667	4.083333	1.918434
December	1.583333	4.25	3.155353	1.333333	4.583333	3.015172	1.25	4.666667	2.89595

Table 5. Monthly Loading (MW) on Feeder 45 of Azmer substation from January 2015 to December 2017.

F45	2015			2016			2017		
Months	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
January	1.916667	4.833333	3.089125	1.916667	5	3.592503	1	4.666667	3.245004
February	2	4.333333	3.02081	0.333333	4.916667	3.397364	1.416667	4.833333	3.219178
March	1.333333	3.833333	2.421045	1.5	4.5	2.80168	1.5	4.583333	2.939906
April	0.833333	2.833333	1.651621	0.75	4.166667	1.847389	0.666667	3.833333	0.962121
May	0.75	2	1.367504	0.75	2.583333	1.381601	0.666667	2.166667	1.264773
June	0.166667	2.583333	1.780016	0.916667	2.5	1.703179	0.166667	2.5	1.504928
July	1.083333	3.083333	2.098303	1.25	2.833333	2.028462	1	3.666667	1.737971
August	1.333333	2.75	2.043155	1.333333	2.75	2.018917	1	2.5	1.679931
September	1	2.416667	1.562196	0.833333	2.416667	1.549871	0.833333	2	1.372388
October	0.666667	3.166667	1.402052	0.666667	2.166667	1.274487	0.5	1.833333	1.007526
November	1.333333	3.666667	2.501349	0.833333	4.833333	2.463592	0.583333	4.083333	1.983739
December	1.833333	5	3.547644	1.75	5	3.699208	1.333333	4.333333	3.082614

Table 6. Monthly Loading (MW) on Feeder 185 of Kampy Zanko substation from January 2015 to December 2017.

F185	2015			2016			2017		
Months	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
January	0.166667	1	0.498305	0.166667	1	0.559045	0.166667	0.833333	0.438599
February	0.333333	1	0.545139	0.166667	0.75	0.304957	0.333333	1	0.487476
March	0.166667	0.833333	0.303058	0.083333	0.583333	0.217854	0.166667	0.75	0.331399
April	0.25	0.666667	0.377547	0.25	0.75	0.391204	0.166667	0.583333	0.270833
May	0.166667	1.916667	0.767194	0.333333	1.583333	0.687052	0.166667	1.666667	0.562164
June	0.166667	2.5	0.865162	0.333333	2	1.085591	0.166667	2.583333	0.772685
July	0.166667	1.5	0.656922	0.166667	1.666667	0.468945	0.083333	1.583333	0.36828
August	0.5	1.5	0.890565	0.166667	1.75	0.605063	0.083333	1.583333	0.335125
September	0.083333	1.833333	0.720115	0.166667	1.333333	0.388889	0.083333	1.5	0.323843
October	0.083333	1.333333	0.339261	0.083333	0.666667	0.180617	0.083333	1.166667	0.257728
November	0.083333	0.833333	0.392302	0.083333	0.416667	0.216898	0.25	0.666667	0.335375
December	0.25	1	0.488575	0.083333	0.75	0.342927	0.083333	0.833333	0.327606

Table 7. Monthly Loading (MW) on Feeder 186 of Kampy Zanko substation from January 2015 to December 2017.

F186	**2015**			**2016**			**2017**		
Months	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
January	0.083333	1.083333	0.284402	0.083333	0.916667	0.266149	0.083333	1.083333	0.303215
February	0.166667	1.166667	0.386409	0.083333	0.666667	0.165948	0.083333	1.083333	0.330605
March	0.166667	1	0.299033	0.083333	0.5	0.108657	0.083333	0.916667	0.191929
April	0.166667	0.75	0.276159	0.083333	0.5	0.149884	0.083333	1.333333	0.083333
May	0.083333	1.833333	0.3422	0.083333	1.583333	0.262993	0.083333	1.75	0.262769
June	0.083333	2.5	0.65323	0.083333	2	0.440094	0.083333	2	0.40706
July	0.083333	1.916667	0.413642	0.083333	1.75	0.306783	0.083333	2.25	0.327061
August	0.083333	2.166667	0.512655	0.083333	1.833333	0.427419	0.083333	2.166667	0.313172
September	0.083333	1.75	0.387741	0.083333	1.833333	0.273958	0.083333	1.916667	0.296528
October	0.083333	1.333333	0.151882	0.083333	0.25	0.099686	0.083333	1.5	0.177307
November	0.083333	0.666667	0.212163	0.083333	0.333333	0.116088	0.083333	0.833333	0.142961
December	0.083333	0.833333	0.254256	0.083333	1	0.212804	0.083333	1	0.163067

Table 8 .Monthly Loading (MW) on Feeder 187 of Kampy Zanko substation from January 2015 to December 2017.

F187	**2015**			**2016**			**2017**		
Months	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
January	0.166667	0.75	0.419777	0.083333	0.833333	0.392834	0.083333	0.583333	0.373114
February	0.25	0.75	0.453723	0.083333	0.583333	0.216355	0.25	0.75	0.392981
March	0.083333	0.666667	0.254232	0.083333	0.5	0.147849	0.083333	0.5	0.285252
April	0.25	0.583333	0.37847	0.166667	0.833333	0.353226	0.083333	0.5	0.100694
May	0.25	1.416667	0.632741	0.166667	1.5	0.723902	0.083333	1.25	0.295699
June	0.166667	1.666667	1.142907	0.083333	1.333333	0.841895	0.083333	1.333333	0.531713
July	0.083333	0.833333	0.216062	0.083333	1.166667	0.241117	0.083333	0.666667	0.257728
August	0.083333	1.333333	0.335393	0.083333	0.916667	0.265681	0.083333	0.833333	0.298387
September	0.083333	0.833333	0.261778	0.083333	0.833333	0.218495	0.083333	2.333333	0.205208
October	0.083333	0.75	0.163371	0.083333	0.583333	0.174517	0.083333	0.5	0.194108
November	0.166667	0.666667	0.308437	0.083333	0.25	0.117245	0.083333	0.416667	0.231587
December	0.083333	0.583333	0.274306	0.083333	0.5	0.251563	0.083333	0.583333	0.221621

Table 9. Monthly Loading (MW) on Feeder 188 of Kampy Zanko substation from January 2015 to December 2017.

F188	**2015**			**2016**			**2017**		
Months	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
January	0.166667	0.833333	0.293517	0.166667	0.833333	0.235032	0.083333	0.75	0.216667
February	0.083333	0.75	0.218059	0.083333	0.75	0.178999	0.083333	0.75	0.186483
March	0.083333	0.5	0.118024	0.083333	0.416667	0.14821	0.083333	0.5	0.114882
April	0.083333	0.416667	0.123413	0.083333	0.5	0.178588	0.083333	0.583333	0.083333
May	0.083333	2.25	0.414917	0.083333	1.666667	0.277554	0.083333	0.916667	0.178427
June	1.583333	0.293045	0.083333	1.583333	1.583333	0.293045	0.083333	1.583333	0.248958
July	0.166667	1.583333	0.332549	0.083333	1.333333	0.215541	0.083333	1.5	0.273297
August	0.166667	2.25	0.416491	0.083333	1.666667	0.284946	0.083333	1.666667	0.245072
September	0.166667	1.75	0.335932	0.166667	1.333333	0.243519	0.083333	1.833333	0.21331
October	0.083333	1.166667	0.188757	0.083333	0.666667	0.162186	0.083333	1.416667	0.164763
November	0.083333	0.666667	0.364407	0.083333	0.25	0.138698	0.083333	0.416667	0.142014
December	0.083333	0.833333	0.230959	0.083333	0.583333	0.171015	0.083333	0.583333	0.133373

Table 10. Calculated Load Factor, Loss Factor, and Power Losses (MW) on Feeder 40 of Azmer substation from January 2015 to December 2017.

F40	2015			2016			2017		
Months	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses
January	0.625256	0.461239	0.004479	0.519967	0.345246	0.005079	0.700063	0.553080	0.004326
February	0.571420	0.399991	0.003885	0.601926	0.434198	0.003205	0.631715	0.468859	0.004790
March	0.574504	0.403390	0.002318	0.614977	0.449231	0.001939	0.560856	0.388449	0.002540
April	0.532256	0.357985	0.001106	0.434769	0.262748	0.001315	0.050000	0.016750	0.000043
May	0.615206	0.449497	0.000930	0.617791	0.452504	0.000936	0.652005	0.493179	0.000910
June	0.554561	0.381645	0.002342	0.600541	0.432617	0.002014	0.642599	0.481833	0.002080
July	0.713934	0.570971	0.003281	0.710851	0.566971	0.003258	0.648319	0.488718	0.003607
August	0.648323	0.488723	0.003823	0.750890	0.619951	0.003329	0.683929	0.532610	0.003703
September	0.639467	0.478082	0.001758	0.569921	0.398343	0.001719	0.443322	0.270570	0.002628
October	0.567395	0.395575	0.000912	0.683945	0.532630	0.000765	0.682733	0.531107	0.000665
November	0.599109	0.430984	0.002157	0.483220	0.308417	0.001892	0.484053	0.309232	0.001548
December	0.615667	0.450032	0.004149	0.651426	0.492477	0.004305	0.612379	0.446219	0.002396

Table 11. Calculated Load Factor, Loss Factor, and Power (MW) on Feeder 42 of Azmer substation from January 2015 to December 2017.

F42	2015			2016			2017		
Months	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses
January	0.697396	0.549672	0.052166	0.731765	0.594365	0.058335	0.661723	0.505031	0.059977
February	0.673324	0.519353	0.049288	0.723721	0.583757	0.057294	0.677530	0.524591	0.051487
March	0.579258	0.408656	0.034939	0.634866	0.472598	0.044851	0.649996	0.490746	0.051430
April	0.596457	0.427970	0.015121	0.423462	0.252563	0.023163	0.242361	0.113826	0.011172
May	0.696788	0.548896	0.009353	0.538374	0.364405	0.010173	0.524938	0.350373	0.009782
June	0.797380	0.684284	0.013600	0.616462	0.450957	0.014212	0.573199	0.401949	0.013424
July	0.637636	0.475897	0.018735	0.750315	0.619175	0.017286	0.738351	0.603119	0.014799
August	0.680825	0.528714	0.018681	0.731808	0.594423	0.016595	0.649243	0.489835	0.014543
September	0.702125	0.555723	0.011878	0.654615	0.496349	0.010609	0.685071	0.534046	0.009842
October	0.456194	0.282538	0.011716	0.537211	0.363180	0.008327	0.389567	0.223104	0.008327
November	0.644538	0.484162	0.035692	0.408701	0.239536	0.039732	0.491907	0.316953	0.030080
December	0.758911	0.630835	0.061915	0.708117	0.563436	0.057158	0.590464	0.421193	0.056267

Table 12 .Calculated Load Factor, Loss Factor, and Power Losses (MW) on Feeder 43 of Azmer substation from January 2015 to December 2017.

F43	2015			2016			2017		
Months	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses
January	0.706554	0.561420	0.041760	0.732823	0.595768	0.039923	0.686377	0.535693	0.028617
February	0.714217	0.571339	0.036931	0.623565	0.459253	0.033013	0.735247	0.598986	0.031998
March	0.612984	0.446919	0.024839	0.557715	0.385047	0.023992	0.650063	0.490826	0.023168
April	0.594618	0.425885	0.011794	0.387514	0.221372	0.012791	0.290909	0.146512	0.005009
May	0.686063	0.535297	0.008339	0.524079	0.349485	0.006281	0.477376	0.302734	0.005440
June	0.773015	0.650191	0.014227	0.631752	0.468903	0.009629	0.593552	0.424678	0.008721
July	0.721744	0.581163	0.019870	0.717309	0.575365	0.014213	0.730908	0.593231	0.010661
August	0.758277	0.629972	0.019438	0.723269	0.583164	0.013570	0.717310	0.575366	0.010340
September	0.669498	0.514608	0.010568	0.607169	0.440209	0.007911	0.666375	0.510751	0.006821
October	0.526722	0.352222	0.008196	0.555502	0.382658	0.005110	0.589827	0.420476	0.003594
November	0.608636	0.441898	0.017459	0.488057	0.313157	0.020985	0.469821	0.295458	0.015159
December	0.742436	0.608579	0.033824	0.657856	0.500299	0.032339	0.620561	0.455735	0.030539

Table 13. Calculated Load Factor, Loss Factor, and Power Losses (MW) on Feeder 45 of Azmer substation from January 2015 to December 2017.

F45	2015			2016			2017		
Months	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses
January	0.639129	0.477679	0.021559	0.718501	0.576920	0.027865	0.695358	0.547073	0.023018
February	0.697110	0.549307	0.019928	0.690989	0.541523	0.025291	0.666037	0.510335	0.023033
March	0.631577	0.468696	0.013306	0.622596	0.458116	0.017923	0.641434	0.480437	0.019499
April	0.582925	0.412739	0.006401	0.443373	0.270618	0.009077	0.250988	0.119393	0.003390
May	0.683752	0.532387	0.004114	0.534813	0.360662	0.004650	0.583741	0.413650	0.003752
June	0.689039	0.539053	0.006950	0.681272	0.529273	0.006391	0.601971	0.434250	0.005244
July	0.680531	0.528345	0.009704	0.715928	0.573565	0.008896	0.473992	0.299466	0.007779
August	0.742965	0.609288	0.008902	0.734152	0.597531	0.008730	0.671972	0.517675	0.006251
September	0.646426	0.486434	0.005489	0.641326	0.480307	0.005420	0.686194	0.535462	0.004138
October	0.442753	0.270047	0.005232	0.588225	0.418673	0.003797	0.549560	0.376279	0.002443
November	0.682186	0.530420	0.013777	0.509709	0.334775	0.015110	0.485814	0.310955	0.010017
December	0.709529	0.565260	0.027302	0.739842	0.605108	0.029227	0.711373	0.567647	0.020593

Table 14. Calculated Load Factor, Loss Factor, and Power Losses (MW) on Feeder 185 of Kampy Zanko substation from January 2015 to December 2017.

F185	2015			2016			2017		
Months	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses
January	0.498305	0.323307	0.000042	0.559045	0.386485	0.000051	0.526319	0.351804	0.000032
February	0.545139	0.371565	0.000049	0.406609	0.237715	0.000018	0.487476	0.312586	0.000041
March	0.363670	0.201680	0.000018	0.373464	0.209672	0.000009	0.441865	0.269231	0.000020
April	0.566320	0.394399	0.000023	0.521605	0.346932	0.000026	0.464285	0.290178	0.000013
May	0.400275	0.232237	0.000112	0.433928	0.261984	0.000086	0.337298	0.180829	0.000066
June	0.346065	0.187652	0.000154	0.542796	0.369078	0.000194	0.299104	0.152355	0.000133
July	0.437948	0.265643	0.000078	0.281367	0.139827	0.000051	0.232598	0.107651	0.000035
August	0.593710	0.424857	0.000125	0.345750	0.187405	0.000075	0.211658	0.094857	0.000031
September	0.392790	0.225836	0.000100	0.291667	0.147049	0.000034	0.215895	0.097396	0.000029
October	0.254446	0.121654	0.000028	0.270925	0.132658	0.000008	0.220910	0.100434	0.000018
November	0.470763	0.296361	0.000027	0.520555	0.345851	0.000008	0.503062	0.328069	0.000019
December	0.488575	0.313666	0.000041	0.457236	0.283516	0.000021	0.393127	0.226123	0.000021

Table 15 .Calculated Load Factor, Loss Factor, and Power Losses (MW) on Feeder 186 of Kampy Zanko substation from January 2015 to December 2017.

F186	2015			2016			2017		
Months	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses
January	0.262525	0.127001	0.000070	0.290344	0.146113	0.000058	0.279891	0.138804	0.000077
February	0.331208	0.176151	0.000113	0.248922	0.118050	0.000025	0.305174	0.156744	0.000087
March	0.299033	0.152304	0.000072	0.217314	0.098252	0.000012	0.209377	0.093500	0.000037
April	0.368212	0.205370	0.000055	0.299768	0.152833	0.000018	0.062500	0.021484	0.000018
May	0.186655	0.080384	0.000128	0.166101	0.069143	0.000082	0.150154	0.060828	0.000088
June	0.261292	0.126179	0.000373	0.220047	0.099909	0.000189	0.203530	0.090056	0.000170
July	0.215813	0.097347	0.000169	0.175305	0.074104	0.000107	0.145360	0.058399	0.000140
August	0.236610	0.110172	0.000244	0.233138	0.107989	0.000171	0.144541	0.057987	0.000129
September	0.221566	0.100834	0.000146	0.149432	0.060460	0.000096	0.154710	0.063168	0.000110
October	0.113912	0.043257	0.000036	0.398744	0.230921	0.000007	0.118205	0.045242	0.000048
November	0.318244	0.166369	0.000035	0.348264	0.189381	0.000010	0.171553	0.072067	0.000024
December	0.305107	0.156696	0.000051	0.212804	0.095541	0.000045	0.163067	0.067534	0.000032

Table 16. Calculated Load Factor, Loss Factor, and Power Losses (MW) on Feeder 187 of Kampy Zanko substation from January 2015 to December 2017.

F187	2015			2016			2017		
Months	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses
January	0.559703	0.387198	0.000154	0.471401	0.296974	0.000146	0.639624	0.478271	0.000115
February	0.604964	0.437676	0.000174	0.370894	0.207562	0.000050	0.523975	0.349377	0.000139
March	0.381348	0.216203	0.000068	0.295698	0.149916	0.000027	0.570504	0.398984	0.000071
April	0.648806	0.489306	0.000118	0.423871	0.252928	0.000124	0.201388	0.088806	0.000016
May	0.446641	0.273634	0.000389	0.482601	0.307813	0.000491	0.236559	0.110140	0.000122
June	0.685744	0.534895	0.001053	0.631421	0.468512	0.000590	0.398785	0.230956	0.000291
July	0.259275	0.124839	0.000061	0.206672	0.091901	0.000089	0.386592	0.220595	0.000069
August	0.251545	0.119756	0.000151	0.289834	0.145753	0.000087	0.358065	0.197167	0.000097
September	0.314134	0.163316	0.000080	0.262194	0.126780	0.000062	0.087946	0.031798	0.000123
October	0.217828	0.098563	0.000039	0.299172	0.152404	0.000037	0.388216	0.221963	0.000039
November	0.462655	0.288632	0.000091	0.468980	0.294654	0.000013	0.555808	0.382989	0.000047
December	0.470239	0.295859	0.000071	0.503126	0.328133	0.000058	0.379922	0.215015	0.000052

Table 17 .Calculated Load Factor, Loss Factor, and Power Losses (MW) on Feeder 188 of Kampy Zanko substation from January 2015 to December 2017.

F188	2015			2016			2017		
Months	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses	Ld Factor	Ls Factor	P. Losses
January	0.352221	0.192508	0.000031	0.282039	0.140294	0.000023	0.288889	0.145087	0.000019
February	0.290745	0.146397	0.000019	0.238665	0.111472	0.000014	0.248644	0.117870	0.000015
March	0.236048	0.109817	0.000006	0.355704	0.195279	0.000008	0.229764	0.105883	0.000006
April	0.296191	0.150268	0.000006	0.357176	0.196455	0.000011	0.142857	0.057143	0.000004
May	0.184408	0.079127	0.000093	0.166532	0.069373	0.000045	0.194648	0.084916	0.000016
June	0.284369	0.141917	0.000003	0.185081	0.079503	0.000046	0.157237	0.064477	0.000037
July	0.210031	0.093888	0.000054	0.161656	0.066790	0.000027	0.182198	0.077897	0.000040
August	0.185107	0.079517	0.000093	0.170968	0.071751	0.000046	0.147043	0.059248	0.000038
September	0.191961	0.083383	0.000059	0.182639	0.078142	0.000032	0.116351	0.044382	0.000034
October	0.161792	0.066861	0.000021	0.243279	0.114413	0.000012	0.116303	0.044359	0.000021
November	0.546610	0.373131	0.000038	0.554792	0.381894	0.000006	0.340833	0.183567	0.000007
December	0.277151	0.136914	0.000022	0.293169	0.148114	0.000012	0.228640	0.105185	0.000008

Table 18. Average Maximum loading on the feeders from 2015-2017.

Feeder	2015	2016	2017
F40	2.451389	2.423611	2.409722
F42	3.576389	3.909722	3.958333
F43	3.444444	3.555556	3.159722
F45	3.375	3.638889	3.416667
F185	1.326389	1.104167	1.229167
F186	1.416667	1.097222	1.486111
F187	0.902778	0.819444	0.854167
F188	1.107754	0.965278	1.041667

Table 19. Average losses (MW) on the feeders 2015-2017

Feeder	2015	2016	2017
F40	0.002595	0.002480	0.002436
F42	0.027757	0.029811	0.027594
F43	0.020604	0.018313	0.015006
F45	0.011889	0.013531	0.010763
F185	0.000067	0.000048	0.000038
F186	0.000124	0.000068	0.000080
F187	0.000204	0.000148	0.000098
F188	0.000037	0.000023	0.000021