Technical Losses in Non-Rural Distribution Feeders of Nawabshah Substation - Analysis & Estimation

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Abstract

This paper presents the energy loss of the non-rural distribution feeder. Currently in Pakistan, the distribution companies in Water and Power Development Authorities (WAPDA) have implemented different methods to reduce technical losses of distribution feeders. But these methods are difficult to adopt due to their complexities. Therefore, the main aim of the research is to assess the energy loss of non-rural distribution feeders of Nawabshah region. The methodology is based on an on-site survey while providing the inductive loads on distribution feeders. Three main parameters have been analyzed in this study which include monthly power loss in percentage, power factor (PF), and line capacity. The method adopted for the on-site survey and the results obtained through the analysis of the collected data unraveled the techniques which lead to a substantial reduction in electricity cost and improvement in the overall efficiency of the system.

Keywords—Energy loss, non-rural distribution feeders, on-site survey, technical losses

1 Introduction

The ever-increasing human activities are giving rise to an increasing demand of electrical energy [1]. The power loss in any power transmission and distribution system includes technical and non-technical losses. Generally, the assessment of technical losses is an essential condition for assessing non-technical losses [2].

Power distribution is an important link between the utility and the users, therefore, it plays a very important role in the entire power system network. Therefore, one must be careful when planning the system to reduce the amount of damage and provide better quality to the customers [3]. Electricity loss occurs at different levels of the power system, such as production, transmission, and distribution [4].

These grid losses are collectively known as technical losses. In a developing country like Pakistan, the power distribution systems suffer from low voltage and high energy losses. The problems associated to distribution feeders and their possible degradation depend on the load curve [5].

The paper is distributed into 8 sections. In Section 1, the distribution system and its losses have been discussed. In section 2, the research background has been described. In addition to this, the detailed distribution system has been discussed. The technical distribution losses in the network along with their advantages and disadvantages have been explained in Section 3. In section 4, the techniques to mitigate losses, device specifications, and energy losses based on the usage model have been discussed. Apart from this, the measures for removing technical losses with long-term plans are explained. The brief analysis of all three feeders has been explained with the power factor and month-wise units of Nawabshah substation in Section 5. The detailed analysis of 11 kV feeder has been presented in Section 6. The suggestions for system improvement are given in Section 7. Finally,

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the remedial measures for energy loss, proper selection of transformer, and research methodologies with future prospectives are presented in Section 8.

2 Research Background & Problem Statement

In electrical network, resistance is offered to the power flow. It passes the electrical current through the network but produces energy loss. Energy losses are actually known as technical losses. In Pakistan, power quality disturbance due to energy loss is a problem offered by the distribution system. Voltage drop and energy loss of the distribution system are linked with each other. In Pakistan, overall transmission and distribution energy losses are up to 26-30%. Also 70-80% losses are observed in transmission and distribution. According to Water & Power Development Authority and National Electric Power Regulatory Authority, there is about 1.5 billion rupees per year total losses due to power theft and technical losses. In Pakistan, distribution companies launch some plan of action to overcome the energy loss and theft control, system upgradation and guidelines. About10% voltage variations at the consumer service mains and 3-5% power losses are allowed in Pakistan [6].

3 Technical Losses

Technical networks cause technical losses due to low conductor materials, transmission equipment, transformers, high transmission, and magnetic damage to the distribution lines [7][8]. Technical losses are due to the inherent electrical properties of system components [9]. Fixed or iron losses occur in the transformer core and are independent of load current. Copper or variable losses are dependent on load current and occur in conductors, cables, and transformers [10]. The current loss depends on the resistance and current in the circuit. Outdated power distribution systems, small-size connectors, improper maintenance, loose connections, improper gaskets, and coils are some of the reasons for the high resistance of lines and transformers, leading to technical power losses. Overload, unbalanced load, poor load capacity factor, and improper reactive power compensation will cause the current to increase, which leads to power loss. Therefore, the power loss will be reduced by reducing current or resistance [11].

The technical loss is usually 22.5% and it depends directly on the network function and the operating mode [12]. These technical disadvantages are inherent in the system and can be reduced to a favorable level [13].

Technical loss is categorized as fixed loss and variable loss. Fixed losses have nothing to do with the load and mainly occur in distribution transformers, such as hysteresis and Eddy current losses. Variable or load-related losses mainly occur in transformers, lines, and cable conductors [14]. Technical losses in the distribution network can also be converted into energy losses in terms of revenue. However, diffusing the silver conductor and minimizing the core loss of the silver conductor helps to reduce the loss. Also, by using the correct cable gauge ratio and avoiding knots along the cable, excessive cable length can lead to power loss, unimproved customer load, and eventually cable removal. All these factors can reduce energy loss and affect the total energy revenue of the region [15].

4 Techniques to Mitigate Technical Losses

There are various techniques to mitigate the losses to improve the power and efficiency of a distribution system. These methods are mentioned in Table 1.

4.1 Measures for Removing Technical Losses

There are two types of measures for removing technical losses which are discussed as follows.

4.1.1 Short-Term Measures

Following measures are suggested for short-term losses of electricity.

- Identify the most vulnerable areas in the distribution system and strengthen/improve these areas to get the most benefit from limited resources.
- Reduce the length of LT lines by moving distribution substations/auxiliary distribution transformers (DT).
- The formation and replacement of DT, its no-load loss is small, such as an amorphous iron core transformer.
- Install parallel capacitors to improve the power factor.

4.1.2 Long-Term Measures

Following long term, measures are suggested for electricity T&D technical losses.

- The complete mapping of primary and secondary distribution systems clearly describes vari-ous parameters, such as conductor size, wire length, etc.

Factors Leading to Technical Losses	Extracted Energy Loss
• System drawing • Device specifications used in the network • Parameters of system operation	**i) Short-Term Measures** • System reshaping • System reconductoring • Forbid crack at insulators • Distribution transformers should be Better • Load balancing and load management • Shunt or series capacitor installation • Improving junction connections • Increment in HT:LT Ratio • Acceptance of tall voltage distribution network • Daily continuation of distribution network • Formation of the main substation **ii) Long-Term Measures** • Date collection for current load, operating conditions, expected load expectations, etc. from the network station to the user level. • Mapping of the current system • Study of an existing system • Arrangement for raise the system • Technical options, including the integration of system updates. • An estimate of a variety of alternatives for minimum price best resolution • Seething up of purview of workings • Ground work of rate estimate • Phasing of facility and their price • Fiscal analysis

TABLE 1: Techniques to reduce technical losses

- Carrying out detailed distribution systems studies considering the expected load devel-opment during the next 8-10 years.
- Collect data about the current load, operating conditions, forecasts of expected load, etc.
- Develop long-term plans to strengthen and improve power distribution systems and related transmission networks [16].

5 Analysis of Feeders

We performed feeder analysis for the year 2019 with respect to %age power loss with the three feeders in WAPDA. In a financial year, the ratio of the monthly energy loss to the total input power supplied to the feeder is defined as a cumulative loss. The main reason for using these three feeders is that the peak load is high on these feeders as compared to other feeders such as Gharibabad, Daur, Balooja Quba, Khaddar feeders in Nawabshah subdivision. Nawabshah-I, Nawabshah-II and Nawabshah Society feeders are in the main city, therefore, it is easy to visit them to collect data to analyze losses. Also, there are more losses on these three feeders as compared to other feeders and it is necessary to mitigate these losses.

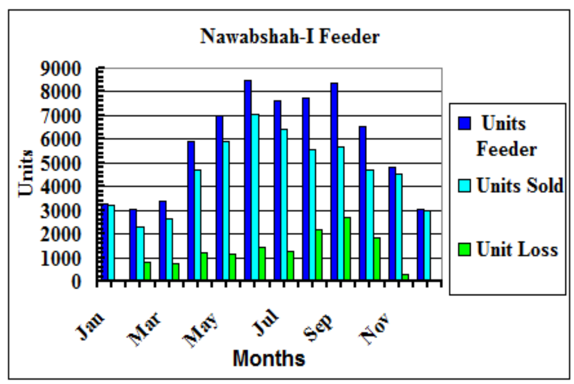

Fig. 1: Nawabshah-I feeder: Month-wise units of Nawabshah substation

5.1 Nawabshah-I Feeder

Figure 1 shows Nawabshah-I feeder's month-wise units of Nawabshah substation for the year 2019. It can be seen that two types of data have been taken for units feeder, i.e, units sold and units loss. The highest units on feeder were nearly 8400.

5.2 Nawabshah-II Feeder

Figure 2 shows Nawabshah-II feeder's month-wise units of Nawabshah substation for the year 2019. In this graph, relationship between units and monthly

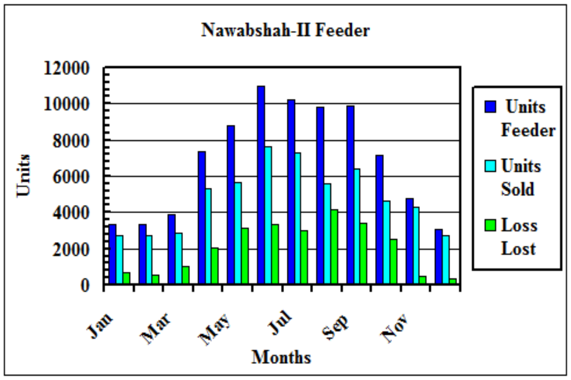

Fig. 2: Nawabshah-II feeder: Month-wise units of Nawabshah substation

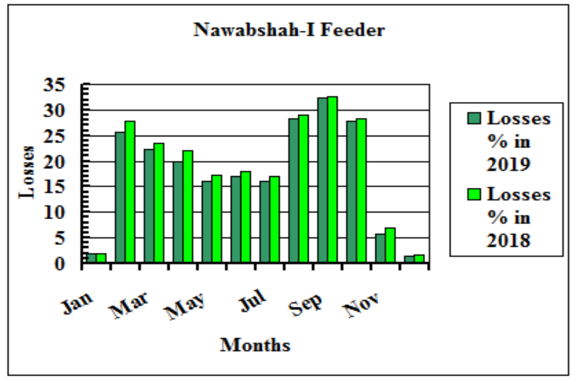

Fig. 4: Nawabshah-I Feeder losses during 2018-19

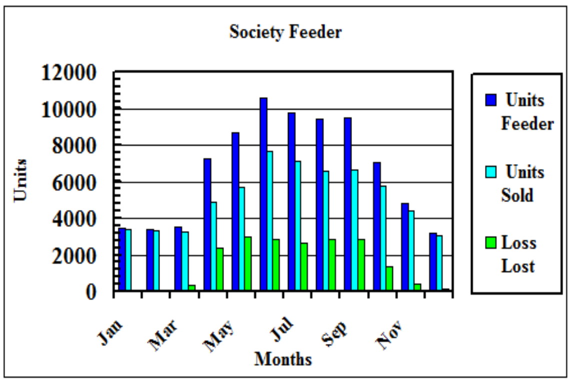

Fig. 3: Society feeder month-wise units of Nawabshah substation

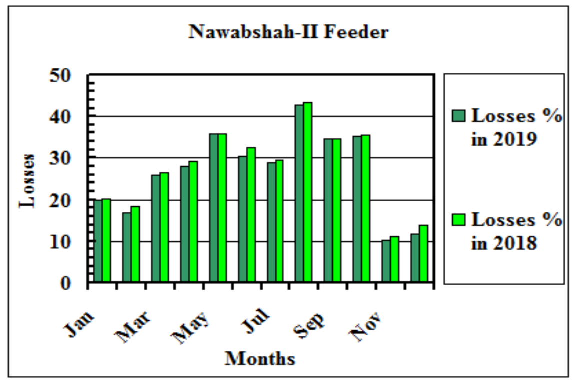

Fig. 5: Nawabshah-II Feeder losses during 2018-19

data is presented. Furthermore, the highest value of units on this feeder was 11010.

5.3 Society Feeder

Figure 3 shows the society feeder's month-wise units of Nawabshah substation for the year 2019. In the month of June, the units of this feeder were 10547. Whereas, sold units to consumers were 7693. It means that the loss of units was 2854. There are mainly two techniques used for loss reduction: i) installation of shunt capacitance, and ii) changing conductor size. Figure 4 shows the comparison of Nawabshah-I feeder losses in percentage from January to December. In this graph, it is shown that the peak of losses in September for the year 2019 was 32.3. Whereas, for the year of 2018, it was 32.5 which shows that losses in 2019 were reduced to 0.2% as compared to 2018. Figure 5 shows the comparison of Nawabshah-II feeder losses in percentage from January to December. In Nawabshah II feeder, it is shown that the peak value of losses in 2019 was 42.7. Whereas, in 2018 it was 43.4 which means that losses decreased by 0.7%. Comparative analysis has been presented in Figure 6 which shows that in May the losses were at peak. As compared to 2018 0.6% of losses were reduced in 2019. Figure 7 shows the comparison of Power factor (Pf) on three 11 kV non-rural feeders for the year 2018 and 2019. It is evident that the value of Pf in Nawabshah I feeder is 0.93 which is better than Nawabshah II and Society feeders.

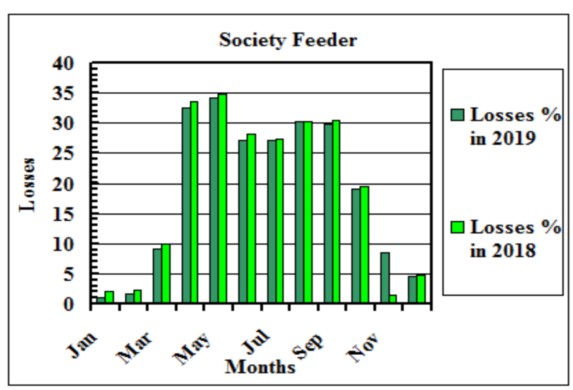

Fig. 6: Society Feeder losses during 2018-19

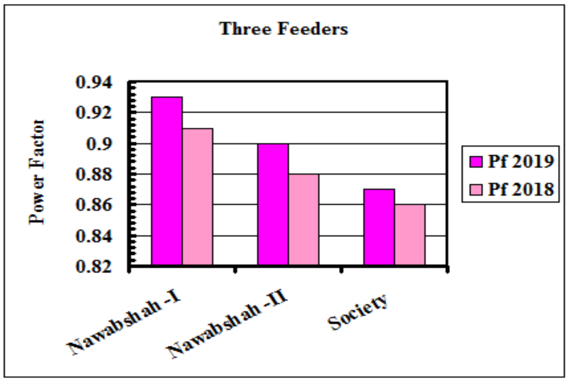

Fig. 7: Power Factors of three Feeders

6 Analysis

During 2018-2019, the average power factor for non-rural feeder was 0.82. The power factor is increased to 0.86 in 2019. There is no regulatory data for 2018-2019, but in 2018-19, the average regulatory data is 5.7%. When studying the 11 kV feeders, our analysis revealed that the nominal value kVA of the distribution transformer (DT) was higher than the maximum demand kVA. This led to a major problem for the distribution transformer. One is higher iron loss being a higher grade, and the other is higher early cost. The energy meters are not linked to a distribution transformer. This results in approximate energy consumption which leads to faults in energy failure analysis. Many power outlets have changeable supply voltages by over 15%. When the voltage level is reduced, as in the case of an induction motor, the current is increased. The induction motor increases the current from 13% to 16%, reduces the voltage drop by 15%, reduces the torque by 20%, and increases the line loss of the distribution line by approximately 23%.

To effectively solve this problem, we should reduce the length of the low voltage line to the transmission line and arrange the high voltage power supply line. In power distribution distributors, the power factor is usually higher than 0.87 to 0.93. When the power factor is comparatively lower, the distribution loss is large [11]. In fact, as the power factor decreases, the current flowing through the conductor increases. The loss is proportional to I2, therefore, with each increment in the current amplitude, the loss will increase several times. This can be fatal to a power distribution network when the capacitors are unstable or do not work properly in the system. For long loads dispersed in non-rural areas, 11 kV transmission lines are usually used. One of the main problems in these areas is high resistance to streaks and energy losses. In January 2019, the rate of percentage loss was low.

7 Suggestions for System Improvements

To reduce the loss of transformer power within an acceptable range, it must be selected sensibly. The nominal value of the transformer should be in acceptable requirements, and very close to the load of the existing system. The power meter must be connected to a distribution transformer, so that precise voltage losses, instead approximate voltage losses, can be noticed . In the process of distributing the low voltage to the feeder, problems were found. The 11/33 kV switch can be used to handle the problem conveniently and automatically, and a hybrid capacitor with a tension regulator can be used in the substation to solve the problem. By using transformer capacitors, we can decrease line loss at the user receiving station. Two-thirds of the user requirements for these shunt-capacitors are located at two-thirds of the distance from the distribution transformer.

These transformer capacitors reduce power-losses by 5% to 6%. As shown in the simulation, this will result in a 15% increase in voltage regulation and a 25% decrease in current. Depending on the degree of improvement of the power factor, the distribution losses will usually be reduced by 11%. Additional optimization of the supply system can be made using a fast feeder (28% loss reduction) and a 25% to 35% loss reduction through HVDS. These recommendations take a crucial role in reducing losses up to 55%.

8 Conclusion

This paper has presented the technical losses and their mitigation for 3 distribution feeders. As the main problem of 11kV distributed feeder is an energy loss which causes a huge impact on revenue. An on-site survey method has been done on the feeders with the analysis of power factor, energy losses, and line capacity. The results conclude that remedial measures for energy loss include: (i) a right selection of transformer based on the peak load in the service area, (ii) the length of feeder units, (iii) and proper reorganization of the distribution network, and (iv) appropriate placement at the receiving end of the transformer scale to check loss using a shunt capacitor. Distribution companies should be interested in initial investment to save future expenses. In an emergency, a high-voltage DC system must be used in place of the power distribution system. To improve the operating system, workers must be properly and regularly trained. Furthermore, the proposed work can be beneficial to other feeders of distribution companies (DISCOs).

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