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Reduction of distribution system losses through WAPDA distribution system line-loss reduction program

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ABSTRACT

The losses in the power system vary the gap between energy supply and demand. Among these losses, the distribution system has major contributions compared to the transmission system. This paper thoroughly examines the PESCO distribution losses and implements a practical approach that forties in the loss's minimization. Using the bifurcation and restoration strategies, the PESCO distribution system can be well-organized and an effective system can be designed. The proposed approach also helps in estimating the entailed capital investments and the rate of return over time. Both the HT (High Tension) and LT (Low Tension) distribution systems are considered for observation and the proposed systems are endorsed. Computer-based software, such as ELR (Energy Loss Reduction) and CADPAW (Computer-Aided Distribution Planning Work) is exploited to measure the results of both the proposed and existing system. After the restoration of a particular system, recommendations are concluded. The proposed approach applies to any existing power system.

1. Introduction

Energy crises are alarming concerns for several developing countries. Economic development is not possible in the absence of adequate energy reservoirs including electricity requirements for domestic, agriculture, and industrial sectors. The increasing electricity cost and high growth rates revealed the significance of energy conservation. The 2014-15 statistical report reveals that the total installed capacity of Pakistan was 23928 MW whereas, the peak demand was measured as 23,242 MW [1]. The power sectors in Pakistan have mostly encompassed an overhead infrastructure which causes unmatchable system losses and power load shedding. During the summer season, Pakistan has faced a severe shortfall of 9475 MW and resulted in force load shedding up to 20 hours in both the urban and rural areas [2]. Moreover, a comparison study indicated that the distribution loss has a major contribution to the power system losses. According to the NEPRA (National Electric Power Regulatory Authority), the transmission loss of the NTDC (National Transmission and Despatch Company) and DISCO

(Distribution Company) was 2.31% and 2.43% respectively, whereas, the distribution loss was estimated at 11.19%.

The highest contribution of the distribution loss was from PESCO (Peshawar Electric Supply Company) which was 17.31% [3]. The distribution losses are further categorized as technical and non-technical losses [4]. The technical losses occur as a result of poor power factor, distribution transformer losses, poor maintenance of the distribution system, and substandard materials. On the other hand, the non-technical losses occur as a result of mismanagement and stealing of electricity among the different customer groups.

In the WAPDA (Water and Power Development Authority) distribution system, non-technical losses contributed 33% of the total power losses. Consumers are using different means of stealing electricity through energy meters [5]. Unfortunately, electricity pilferage is a common practice in Pakistan, which is dominated largely by the industrial sector. Similarly, pilferage by agricultural customers has its origins in the hierarchical establishment of a society in rural areas, whereas in the domestic sector it is typically triggered by individuals who are unable to pay or by very high-income classes who believe that their place in society is proportional to the number of air conditioners working around the clock [6]. Mismanagement and inadvertent administrative practice are also the root cause of non-technical losses [7] and in this case, non-technical persons control the working of the technical staff. The WAPDA distribution systems are extended devoid of an accurate arrangement, thus increasing the burden on the existing power system. Due to rising demand, the power supply keeps the WAPDA power system under extreme pressure which created an imbalance in the distribution system parameters [8]. Load mismatch, overloading of the power systems apparatus, and failure of the devices are the major concerns that increased the probability of the transient current [9] [10]. These situations permit timely arrangements for the restorations of the overloaded system to accommodate the rising load demands. Under the WAPDA distribution system line-loss reduction program, WAPDA has set up a task force for the reduction of energy loss called DTSG (Distribution Technical Services Group). The purpose of the DTSG is to evaluate the system loss and develop a precise method and guideline for the WAPDA distribution planning.

Various researches have been conducted that consider the distribution losses of DISCO and approached to minimize with the rehabilitation technique [11]. However, these findings are based on limited experimental data. Moreover, the aforementioned studies only considered the LT distribution system whereas; the HT distribution losses are not fully investigated. Despite having high power losses, there is inadequate information on the minimization of the PESCO distribution losses. This paper investigated both the HT and LT distribution systems of Shahi Bagh grid station which is under the Territory of the PESCO Distribution Company. A new CADPAW software package will be used for the analysis of the LT distribution line while the ELR package will investigate the HT line. The proposed study will yield an extensive acquaintance on the bifurcation and power factor enhancement. By this means, the energy can be saved, and finally, the efficiency of the Shahi Bagh grid station will be improved. The proposed approach is effective in considering the problem of the power loads, reduction of line losses, and interpretation of the penalty imposed by the WAPDA. Using the proposed approach, any existing distribution system can be designed as an effective power distribution system.

The structure of the rest of our paper is presented as: Section 2 discusses the literature review of the distribution system losses. The methodology in Section 3 focuses on the various parameters involved in this study whereas the re-designing of the existing system can be revealed from Section 4 in which both the HT and LT lines are considered for analysis. In Section 5, remedial measures are provided whereas; the conclusions are drawn in Section 6.

2. Literature Review

In this study, reduction of technical losses was achieved employing the HT distribution restoration methods, and based on the results, recommendations were concluded. When the losses in the distribution systems will reduce, the maximum capacity of the system will be preserved [10]. In the Tai power system, two distribution feeders were preferred for computer-based simulation. The determination was to develop a loss-model through an ANN (artificial neural network). The proposed ANN provides an efficient tool for the distribution engineers in feeder's assessment [12]. Percentage reduction in the line losses and voltage regulation were concluded through the feeder's restructuring and DG (Distribution Generator) realization [13].

An algorithm was proposed in [14] that balanced a three-phase load through the interaction of main and slave units. The proposed approach was also constructive in controlling the electricity stealing and hazard associated with the voltage dip. Simulation has been carried out in

[15] to examine the consequences of DGs on power and energy losses. The power loss and bus voltage were improved by selecting an appropriate size and location of the DGs. A new technique in [16] of load measuring was proposed that assessed the distribution losses and loss factor in the distribution network of Iran. Through the adjustment of load and addition of the capacitor bank, a well-organized distribution system was achieved.

In [17], a new approach and realistic consideration for the distribution system were estimated. The technique of load factor and load loss factor was used for the computation of technical power losses in the distribution systems. These provide better results for the financial loss calculation and can be presented to regulate the tariff determination process [18]. A GSM (Global System for Mobile Communications) based smart distribution system was proposed which resulted in the reduction of the non-technical loss [5].

3. Methodology

The detail and methodology used during this study are as follows:

3.1 Scope of DTSG

The DTSG assist WAPDA in establishing the current status, evaluation of the real magnitude of the technical losses, and pilferage of electricity [11]. The DTSG incorporates the flowchart as shown in Figs. 1 and 2 for the measurement of technical losses and the detection of electricity thefts on the distribution system. Moreover, DTSG also supports WAPDA in organizing and implementing the distribution system, mapping of updating programs and projects by the feeders. While at the division level WAPDA's planning and engineering organization to be monitored and implemented through the assistance of Pakistan construction and consulting firms on a contract basis. The task force also assists WAPDA in the management information system, outage-reporting system, distribution system expansion, and project restoration.

3.2 Software Packages

WAPDA uses different software packages for the recuperation of the distribution systems. The ELR is a software package that is simple in operation and the criteria of this package are given by the loan donors. It is used for the analysis of 11 kV feeders and the LT distribution system. Similarly, CADPAW software is used for the analysis of the LT system which facilitates the distribution engineers to evaluate the steady-state characteristics of an electrical network. CADPAW is capable of performing load flow and short circuit analyses of an electrical network and after analysis; the software displays all the results of the load flow. CADPAD (Computer-Aided Distribution Planning and Design) package is also exploited by the WAPDA that is designed and developed by ABB (ASEA Brown Boveri). It is a multi-purpose 11 kV development software and used for the designing of 11 kV feeders.

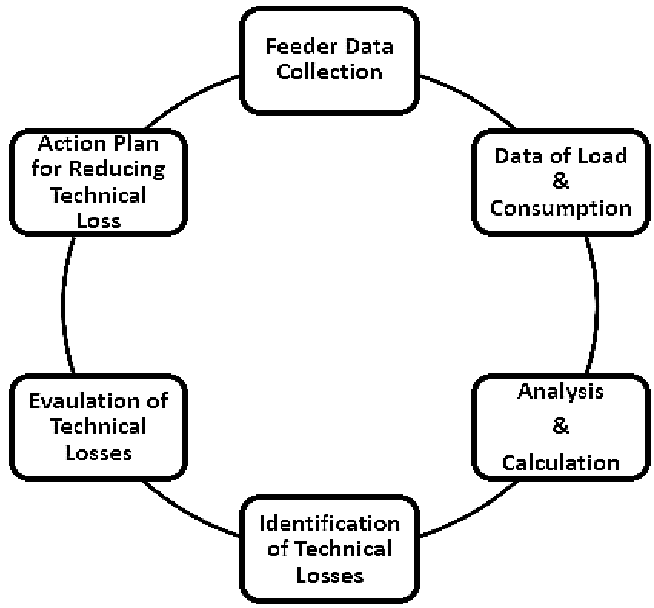

Fig. 1. Technical losses estimation

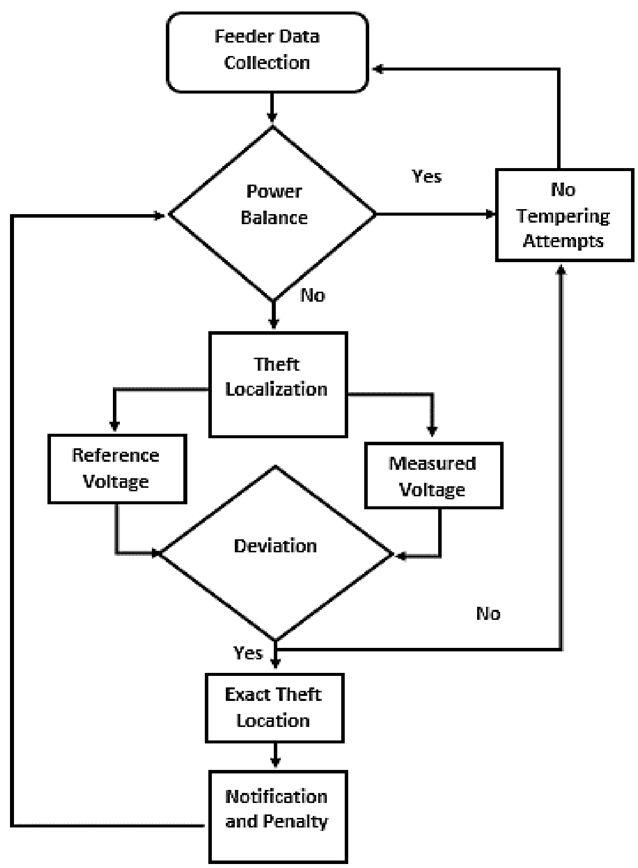

Fig. 2. Electricity theft detection

3.3 Losses Estimation and Calculation

For the estimation of the technical losses by feeders, the power loss will be measured in kW whereas; the energy loss will be calculated in MWh. The monthly energy consumption in MWh (units sent) for each feeder is available in the grid station log sheets and can be computed by subtracting the previous month's consumption value from the present month. The WAPDA is using the coincidence factor [19] for forecasting the distribution planning and in this study; a value of 0.9 will be used as a coincidence factor. The coincidence factor (CF) is the ratio of grid station peak demand to the sum of individual demands within a specific period. Mathematically, the CF can be calculated as follows.

$$\mathrm{CF} = \frac{\mathrm{CE}}{\mathrm{PKhr\ x\ Cload}} \tag{1}$$

where CE is the coincident energy: total kWh of the measure loads, PKhr is the number of hours of peak demand, and Cload represent is the total connected load. Similarly, the load factor (LF) and load loss factor (LLF) can be calculated as follows.

$$\mathrm{LF} = \mathrm{Unit\ sent\ (kWh)}/1.732\ \mathrm{x}\ V_L * I_M * \mathrm{PF} \tag{2}$$

$$\mathrm{LF} = \alpha \times\ (\mathrm{LF}) + (1-\alpha)(\mathrm{LF})^2 \tag{3}$$

where V_L, I_M, PF and α are the line voltage, maximum current, power factor and loading coefficient respectively. The value of α ranges from 0.15 to 0.3.

3.4 Mathematical Model

The general equation for the power system can be described as follows.

$$\sum P_T = \sum P_R + \sum P_{Tech} + \sum P_{non-tech} \tag{4}$$

where P_T is the generated power, P_R is the used power, P_{Tech} is the technical loss, and $P_{non-tech}$ is the non-technical loss.

The non-technical losses are primarily due to human meddling; therefore, it is not possible to describe it in mathematical form. On the other hand, the corona effect, losses in the transformer, and I^2R losses in the transmission/distribution are the root causes of the technical losses.

Various researches have been conducted to consider all the above-articulated factors and provided a mathematical explanation to moderate their effects on the power system. In [20], the corona effect is calculated through Peek's formula (Eq. 5) and conclusions are made through simulation results.

$$P_c = \frac{2.42}{\delta}(f+25)(V-V_c)^2\sqrt{\frac{r}{d}} \times 10^{-3}\ \frac{\mathrm{kW}}{\mathrm{Km\text{-}Phase}} \tag{5}$$

where δ is the air density factor, V is the phase-neutral voltage and V_c is the critical disruptive voltage.

Similarly, the losses in the distribution transformers are mainly due to core (hysteresis and eddy current) and copper (ohmic resistance) losses (Eq. 6). The stray and dielectric losses are relatively small hence they can be neglected [21].

$$P_{DT} = P_{core} + (CF)^2 P_{copper} \tag{6}$$

where P_{core} is the core losses, P_{copper} is the copper losses of the transformers and CF is the capacity factor.

The third and most important factor of the power losses is the I^2R loss in transmission and distribution systems [22]. Due to the resistance of the conductor, a large part of the transmitted power is lost in the form of heat (Eq. 7).

$$P_{TD} = P_{d\_ohmic} + P_{T\_ohmic} \tag{7}$$

where P_{d_ohmic} and P_{T_ohmic} are the ohmic losses in the distribution and transmission systems respectively.

In [23], losses in the energy meters were also considered, however, according to the laboratory report, the average losses per voltage coil are only 1.2W. Thus, the total losses in the power system can be calculated by accumulating all the above-mentioned factors (Eq. 8).

$$P_{Loss} = P_c + P_{DT\_Loss} + P_{TD} \tag{8}$$

The annual input energy and annual energy loss can be calculated as follows.

$$E_{Input} = \mathrm{Total\ Feeder\ demand} \times \mathrm{LF} \times 8760 \tag{9}$$

$$E_{Loss} = P_{Loss} \times \mathrm{LLF} \times 8760 \tag{10}$$

The percentage technical loss of the power system can be determined by the following Eq. 11.

$$\%\mathrm{Technical\ loss} = (E_{Loss}/E_{Input}) \times 100 \tag{11}$$

where E_{input} is the input energy to the system and E_{Loss} is the annual energy loss.

3.5 Cost and Benefit Analysis

The cost and benefit analysis for the improved feeder is the most important consideration which will assist in estimating the expediency of the proposed work. A computer-based approach allows the user to choose the most proficient scheme. These techniques predict the cost/benefit ratio accompanying variation and exploiting a spread-sheet database. Using the cost/benefit ratio related to the project, for instance, the addition of fuses, switch, interrupter, error indicator, and components replacing are fully estimated [24].

The WAPDA distribution system has adopted the cost/benefit ratios associated with both the HT and LT systems for improving the system voltage. The material cost was analysed, which was used for replacing the conductors, transformer shifting, installation of a new transformer, and the LT line. The benefit of improving the system was compared with the cost and justified work was adopted.

4. Proposed Topology

Our research question is how to reduce the distribution system losses? The main contribution of this paper is to presents a proposed solution for the WAPDA distribution system while analysing the following.

1. 11 kV HT Distribution Line (EidGah)
2. 440 V LT Distribution Line (Lakher Abad)

Using the WAPDA distribution system losses in an overloaded distribution system will be reduced. Analysing the above particular distribution system, a proposed solution will be brought out for the reduction of the distribution system losses. The results will be compared before and after the system improvement and recommendations will be concluded.

4.1 HT Distribution Line

To investigate the performance of the HT distribution system, a survey was carried out of the 11 kV EidGah feeder. The nodding information, for instance, pole to pole length, existing kVA, conductor size, and type of poles was collected. During this study, a software package ELR was manipulated to examine both the existing as well as the proposed systems.

4.1.1 Existing System

First, consider the existing system of the EidGah feeder and after analysis, the results are presented in Table 1. The line diagram of the existing 11 kV feeder is provided in Fig. 3 is commenced from the 132 kV GSS (Govt. Secondary School) Shahi Bagh grid station. A Panther conductor is used from the GSS grid station up to Node 18 whereas; a Dog conductor is employed to cover all the branches.

The feeder is fully overloaded with uneven load distribution and the results from the ELR software exhibited that the existing feeder has high energy (819.24 MWh) and power (403 kW) losses. A power factor of 80% was calculated at Node 63 and the feeder has a maximum current of 430 A, consequently, the feeder was in the worst condition. Due to the high load and site situation, bifurcation was recommended for the existing 11 kV EidGah feeder. Bifurcation analysis is a tool that is exploited in the stability study of the system. In this study, the 11 kV EidGah feeder was rehabilitated into two proposed feeders (F1 and F2), and results in each case were studied to estimate the line losses.

4.1.2 Proposed Feeder (F1)

Consider a new line of 2.69 Km by Osprey conductor which was extended from Shahi Bagh grid station to Node 17 of the existing feeder as shown in Fig. 4. With such configuration, the proposed feeder F1 received half load of that of the existing feeder. The proposed feeder F1 was then analysed through the ELR software and the results were compared with the existing system, as depicted in Table1. The results revealed that the percentages of power and energy losses were reduced to 5% and 3% respectively. This moderates the burden on the power system and the reliability of the power system was enhanced.

The ELR software package has an option of installing a fixed capacitor at a proper location, thus, a 450 kVAr capacitor bank was placed at Node 9 and the performance of the proposed feeder FI was further examined. A capacitor bank is in general used for power loss reduction and power factor improvement. After connecting a capacitor bank, consequently, the power losses reduced from 176 kW to 159 kW whereas, the power factor was further improved by 2%.

4.1.3 Proposed Feeder (F2)

The proposed feeder (F2) as illustrated in Fig. 5 was obtained by the rehabilitation of the existing feeder. The feeder (F2) has 39 transformer connection points and a capacitor bank was installed at Node 27. The performance of the proposed feeder F2 was inspected with ELR software and from the data, it was revealed that the percentages of power and energy losses were reduced to 2% and 1% respectively. The feeder of 11 kV EidGah was well-adjusted and the losses were considerably minimized. Consequently, with the installation of the 450k VAr capacitor bank at Node 27, the percentage of power factor was improved by 2%, and the energy losses were reduced to nearly 1% which can be estimated from Table 1.

4.1.4 Benefit

The benefit of the proposed system is estimated considering accumulative results. The results of the modified feeders (F1 and F2) were compared with the existing system. From Table 2, it can be seen that the power loss was 403.1 kW for the existing system which was reduced to 221.3 kW and 196.8 kW when the proposed system is operated without and with capacitor respectively. Similarly, the accumulated results of energy loss for both feeders were reduced by almost 50% when a fixed capacitor of 450 kVAr was installed with the system. The data has been extracted from a credible source to measure the costs of the proposed system. The total project cost was Rs. 1880261 while the price of a fixed capacitor was estimated as Rs. 100000. The study was conducted for 5 years and the annual growth rate was assumed as 5%. The demand and energy charges used by the software were calculated as 9007 / kW and 2.38 / kWh respectively. From the given data, the benefit/cost ratio without the capacitor was calculated as 7.7 and with the capacitor, the ratio further improved to 8.3

Table 1

Results comparison for existing and proposed feeder

Description	Existing Feeder	Feeder (F1)			Feeder (F2)		
		Without Capacitor	With Capacitor (450kVAr)	Benefit	Without Capacitor	With Capacitor	Benefit
Power loss (kW)	403.1	176.7	159.8	16.9	44.6	37	7.5
Energy Loss (MWh)	819.24	359.08	324.77	34.31	90.62	75.32	15.30
Power Loss (%)	6	5	4	-	2	1	-
Energy Loss (%)	4	3	2	-	1	1	
Power Factor (%)	80	84	86	-	86	88	-

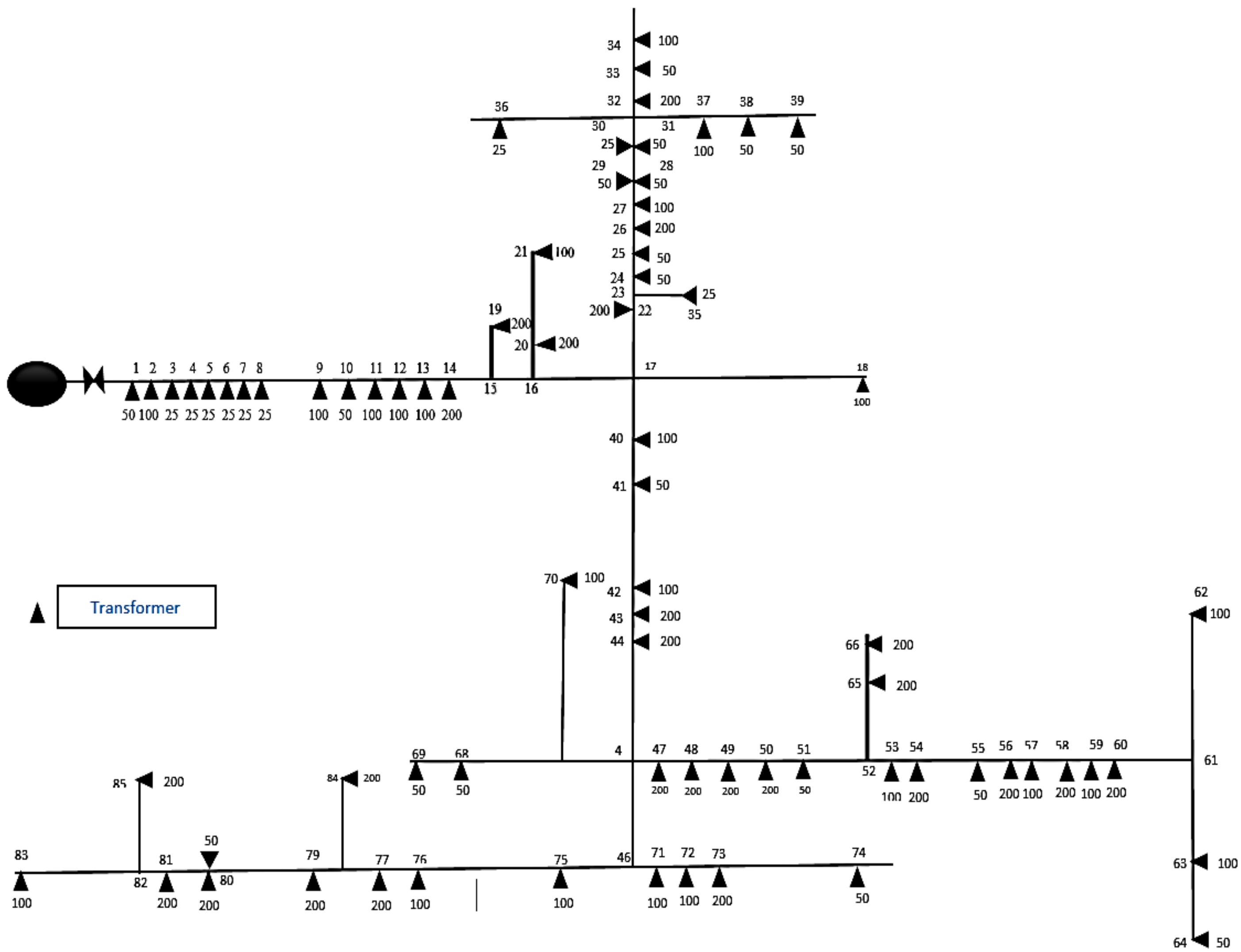

Fig. 3. Line diagram of the existing system (EidGah feeder)

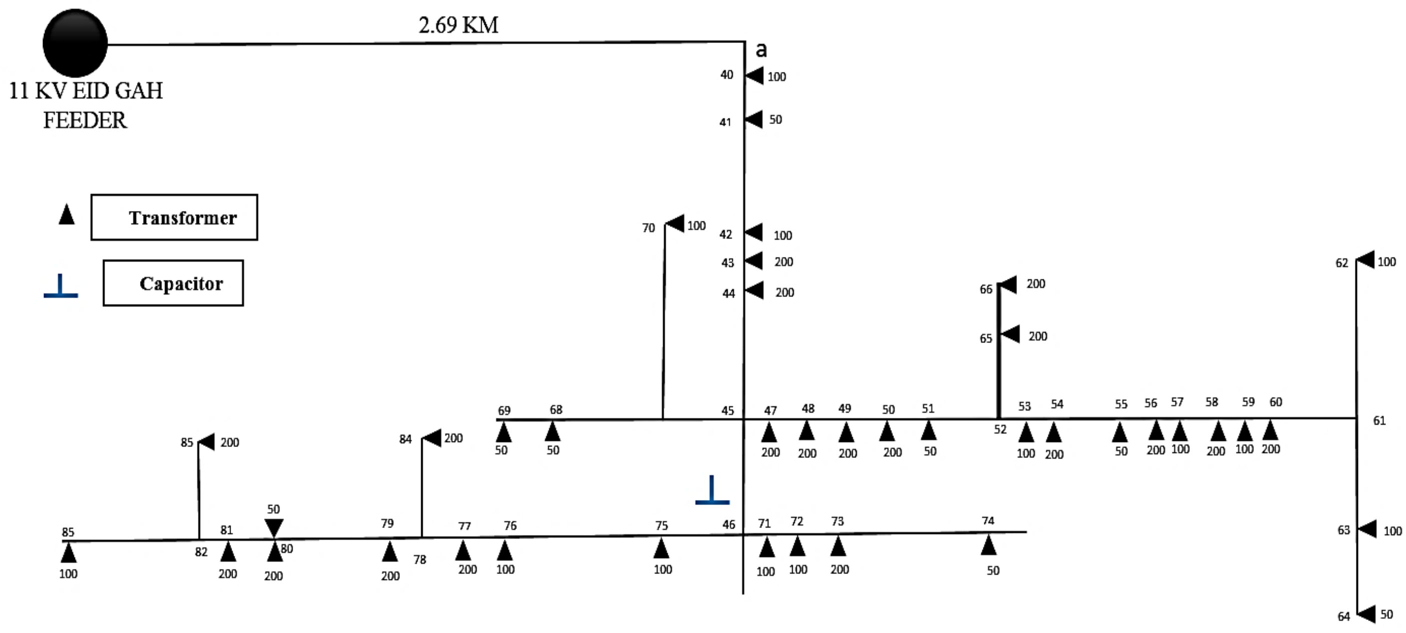

Fig. 4. Proposed (F2) line diagram of EidGah feeder

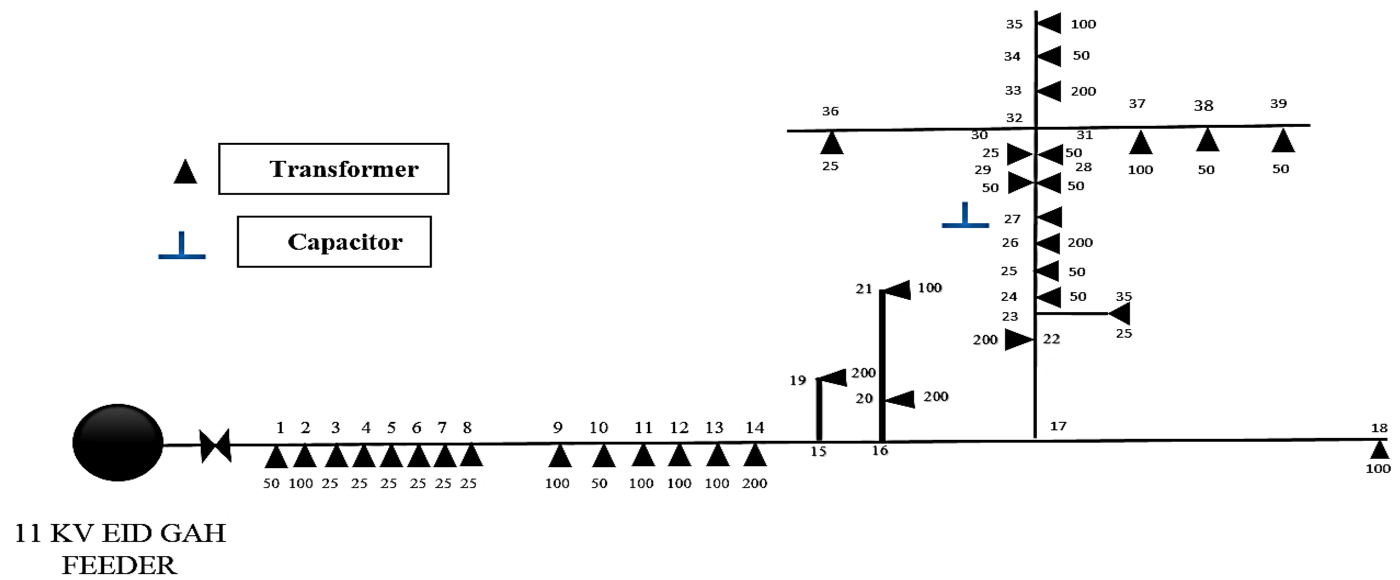

Fig. 5. Proposed (F2) line diagram of EidGah feeder

Table 2

Cumulative results for existing and proposed feeder

Description	Existing Feeder	Proposed Systems			
		Without Capacitor	Benefits	With Capacitor (450 kVAr)	Benefits
Power loss (kW)	403.1	221.3	181.8	196.8	206.3
Energy Loss (MWh)	819.24	449.7	369.54	400.09	419.15

4.2 LT Distribution Line

To analyse the effectiveness of the proposed system, LT at Lakher Abad University Town Peshawar was selected. A complete site survey was carried out and the following data were collected,

1. Single line diagram and connected load on the Node.

2. Node to Node distance and phase position on each span.

3. Size and capacity of the conductor.

4. Current and voltage on each phase during the peak hours are recorded with the help of ampere and voltmeter respectively.

4.2.1 Existing system

To study the existing system, the sketch of the Lakher Abad LT distribution line was studied, as depicted in Fig. 6. The 200 kVA transformer installed at Node 1 received the total load of the system and consequently, the transformer is fully overloaded. The collected data from the survey was analysed through CADPAW software which is generally used for the analysis of the LT system. The existing system was examined before and after five years and the results were compared with the proposed system as shown in Table3 and 4. After considering the acquired data, it was revealed that the existing system has an annual energy loss of 27.05 MWh while the system has a voltage drop of 12%. Similarly, after five years with a 5% load growth rate per year, the existing system showed annual energy losses of 44.96 MWh, and voltage drop surged to 15%. From the results, it was obvious that the existing system will be under extreme pressure to operate in such conditions.

4.2.2 Proposed System

To moderate the effect of high energy losses; a modified system was proposed as shown in Fig. 7 in which an additional 100 kVA transformer was installed at Node 5. With this arrangement, the LT system fed from two transformers, 200 kVA (P1) and 100 kVA (P2). The accumulative annual energy and power losses were reduced to 10.32 MWh and 5.08 kW. The proposed systems (P1 and P2) were also analysed after five years with a 5% load growth rate and the results were presented in Table 4. The data demonstrate the effect of the modified system with a reduction in accumulative annual energy and power losses.

4.2.3 Benefit

The benefit of the proposed system was calculated by comparing the system before and after improvement. In Table4, the existing and proposed system before and after 5 years are drawn along the X-axis whereas, the Y-axis provides the reference value for both the power loss and energy loss. The results showed that more than 50 percent of losses were reduced with the proposed system. The total cost of the proposed work was calculated through the WOS (Work Order System) package and the value comes out as Rs. 193179. The benefit / cost ratio for the proposed work was 1.5.

Table 3

Losses estimation of existing system and proposed system

Description	Existing System	Proposed System		
		P1	P2	Total
Power Loss (kW)	13.31	4.12	0.96	5.08
Energy Loss (MWh)	27.05	8.37	1.95	10.32
Maximum Demand (kW)	180.1	117.8	62.3	180.1
Voltage Drop (kW)	12	8	3	-

5. Corrective Measures

5.1 Technical Losses

The maximum load recorded for the 11 KV EidGah feeder was 430 A and the line losses were 403 kW. These high energy losses and voltage drop overload the existing system. To avoid feeders overloading, bifurcation is an effective technique. After implementing the proposed system, the losses of both feeders were reduced by almost 50%. This bifurcation results in the reduction of technical losses. When bifurcation was completed, capacitors were installed on both the proposed and remaining 11 kV feeder. It compensated for the VARs consumed by the inductive load and evades the losses which occur due to a decrease in the power factor.

By installing a 450kVAr fixed capacitor, the power factor was improved by 4% and 6% respectively. Also, the line losses were reduced by 16.9kW and 7.5kW for both the proposed and remaining 11kV feeder respectively. Similarly, when the transformer is away from the load center, there will be a considerable line loss and voltage drop at the tail end. The 200kVA transformers installed at Node 01 results in high losses because the whole current from the transformer flows through the section between Nodes 1 and 2. Thus, by installing an additional transformer, the power, and energy losses will be reduced by more than 50%.

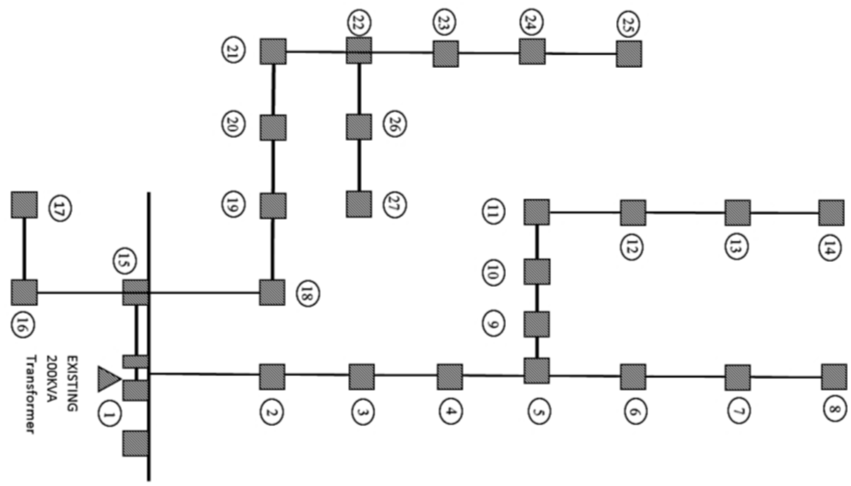

Fig. 6. Sketch showing existing LT line at Lakher Abad, university town Peshawar

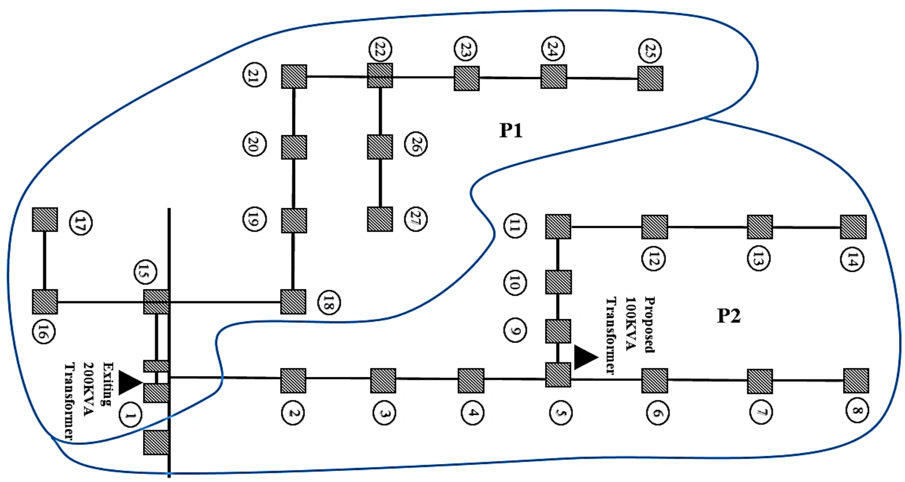

Fig. 7. Sketch showing proposed LT line at Lakher Abad, university town Peshawar

Table 4

Losses comparison after 5 years

Description	Existing System	Proposed System		
		P1	P2	Total
Power Loss (kW)	22.12	6.88	1.55	8.43
Energy Loss (MWh)	44.96	13.98	3.16	17.14
Maximum Demand (kW)	228.7	149.6	79.1	228.7
Voltage Drop (kW)	15	10	4	-

5.2 Administrative Losses

The administrative losses and their minimization are discussed as follows.

1. Old energy meters will be replaced by the prepaid meter system [25] or using GSM based smart distribution system [5]. According to the WAPDA, standard instructions for all the consumer meters should be installed outside their premises.

2. Unit rate revision.

3. Underground cabling/street cabling or PVC (Polyvinyl Chloride) plastic piping on a conductor.

4. The main DB (Distribution Board) point creation/shifting to the pole.

5. It is frequently observed that consumer services wires pass over the roof of the consumer house which provides an opportunity to steal the energy by connecting the load to the WAPDA main directly. These LT lines should be shifted outside the premises.

6. It is also observed that at some point, distribution transformers exist in the consumer premises. These must be shifted to eliminate the chance of stealing.

7. XEN (Executive Engineer) of WAPDA has some judicial powers, at least arresting the culprit's consumer at the site and the power of minimum prison punishment of one month under section 39A Electricity Act should be delegated to these field officers.

8. According to the act rules 1910 and 1937, the punishment for the tempering of meter and equipment of the WAPDA installation is nominal. The punishment should be enhanced so that the consumer feels fear of this act. Necessary amendments in law are to be recommended and speedy trials may be carried out.

9. At the present, the electric inspector (the provincial representative from the department of irrigation and power) being the arbitrator between the consumer and licensee has the final authority to resolve the dispute regarding slowness, tempering of the meters. The consumers as well as the electric inspector misuse the provision in-law. It is recommended that the power must be transferred to the ministry of power.

10. Strict accountability has to be brought out with every employee of the WAPDA regarding their positions.

11. Incentives (cash awards, medals, special increments) should be offered to improve the efficiency of WAPDA's employees.

5.3 Recommendations

From the analysis of the 11 kV feeder and the LT distribution system, the improvement of the existing system is obligatory to reduce I2R losses. This will conversely improve the power factor and moderate the voltage drop. The availability of funds and resources are the basic requirements for the restoration of the existing distribution system. For the computerized analysis of the HT/LT line, the exact field data play an important role inaccurate result. From the above-gotten results, following are the recommendations.

1. Design improvement
2. Prompt implementation of planning proposals
3. Secured metering
4. Delegation of judicial powers
5. Proper accountability
6. Incentives

6. Conclusion

This study provides statistical information concerning the bifurcation and restoration of PESCO distribution systems. The HT (EidGah Feeder) and LT (Lakher Abad) lines are selected based on certain planning parameters including voltage reduction, energy loss, maximum demand, and compensation factor. The existing and proposed LT distribution system has been validated using computer-based CADPAW software, whereas, the HT distribution system was assessed by an ELR package. The findings demonstrate that the power and energy losses of existing PESCO distribution systems can be efficiently mitigated with the implementation of bifurcation and restoration strategies. The study further quantified the financial investments and benefits involved in implementing the proposed system and concluded that the proposed system was more cost-effective than the existing system, considering the power and energy losses. In the end, remedial measures and recommendations were concluded for the existing WAPDA distribution systems. The proposed approach applies to any existing distribution system.

5. References

[1] S. R. Shakeel, J. Takala, and W. S. Malik, "Renewable energy sources in power generation in pakistan", Renewable and Sustainable Energy Reviews, vol. 64, pp. 421-434, 2016.

[2] A. Rehman, Z. Deyuan, A. A. Chandio, and I. Hussain, "An empirical analysis of rural and urban populations'access to electricity: evidence from Pakistan", Energy, Sustainability and Society, Springer, vol. 8, pp. 1-9, 2018.

[3] NEPRA (National Electric Power Regulatory Authority), "State of the industry report", vol. 11, pp. 70-78, 2017.

[4] Y. Al-Mahroqi, I.A. Metwally, A. Al-Hinai, and A. Al-Badi, "Reduction of power losses in distribution systems", World Academy of Science, Engineering and Technology, vol. 6, no. 3, pp. 315-322, 2012.

[5] M. I. Afridi, S. Faisal, H. D. Bangash, Q.W. Ali, and A. Arif, "GSM based smart distribution system", International Journal of Electrical and Computer Engineering, vol. 2, no. 5, pp. 589-596, October, 2012.

[6] Z. Hussain, S. Memon, R. Shah, Z.A. Bhutto, and M. Aljawarneh, “Methods and techniques of electricity thieving in Pakistan”, Journal of Power and Energy Engineering, vol. 4, no. 9, pp. 1-10, 2016.

[7] S. Katyara, M.A. Shah, and B.S. Chowdhary, “Identification of power losses in high- and low-tension distribution systems in Pakistan”, Bahria University Journal of Information and Communication Technologies, vol. 9, special issue, pp. 7-13, 2016.

[8] A.J. Khan, “Structure and regulation of the electricity networks in Pakistan”, The Pakistan Development Review, vol. 53, no. 4, pp. 505–528, 2014.

[9] R. Asghar, “Fault current limiters types, operations and its limitations”, International Journal of Scientific & Engineering Research, vol. 9, no. 2, pp. 1020-1027, 2018.

[10] R. Asghar, F. Rehman, Z. Ullah, Ali. Aman, K. Iqbal, A.A. Nawaz, “Modified switch type fault current limiter for low-voltage ride-through enhancement and reactive power support of DFIG-WT under grid faults”, IET Renewable Power Generation, vol. 14, no. 9, pp. 1481-1490, 2020.

[11] S.A. Qureshi, and F. Mahmood, “Evaluations by implementation of distribution system planning for energy loss reduction” Pakistan Journal of Engineering and Applied Science, vol. 4, no. 1, pp. 43-55, 2009.

[12] C.S. Chen, C.H. Lin, M.Y. Haung, H.D. Chen, M.S. Kang, and C.H. Haung, “Development of distribution feeder loss models by artificial neural networks”, IEEE Power Engineering Society General Meeting, United State of America, June 2005, pp. 1-7.

[13] L. Ramesh, S.P. Chowdhury, A.A. Natarajan, and C.T. Gaunt, “Minimization of power loss in distribution networks by different techniques”, World Academy of Science, Engineering and Technology, vol. 3, no. 4, pp. 661-667, 2009.

[14] B. Ali, and I. Siddique, “Distribution system loss reduction by automatic transformer load balancing”, IEEE 20th International Multitopic Conference, Pakistan, February 2018, pp-1.5.

[15] Z. W. Khan, and S. Khan, “Analyzing the impacts of distributed generation on power losses and voltage profile”, IEEE International Conference on Emerging Technologies, Pakistan, January 2016, pp.1-4.

[16] M. Izadi, F. Razavi, and S. H. Hosseinian, “A cost-effective analysis of the power-loss reduction methods in an actual distribution network”, Electrotechnical Review, vol. 81, no. 4, pp. 167-178, 2014.

[17] G. Singh, “Power loss reduction in practical distribution system”, International Journal of Electrical Engineering, vol. 5, no. 2, pp. 185-195, 2012.

[18] S. Pande, and J.G. Ghodekar, “Computation of Technical power loss of feeders and transformers in distribution system using load factor and load loss factor”, International Journal of Multi-Disciplinary Sciences and Engineering, vol. 3, no. 6, pp. 22-25, 2012.

[19] X. Liu, H. Zheng, S. Song, and G. Fu, “Selection method of community load coincidence factor based on bp neural network”, IEEE 3rd International Conference on Computer Science and Network Technology, China, December 2014. pp. 476-479.

[20] E. A. Yahaya, T. Jacob, N. Mark, and A. Abubakar, “Power loss due to corona on high voltage transmission lines”, Journal of Electrical and Electronics Engineering, vol. 8, no. 3, pp. 14-19, 2013.

[21] D. M. Said, K. M. Nor, and M. S. Majid, “Analysis of distribution transformer losses and life expectancy using measured harmonic data”, IEEE14th International Conference on Harmonics and Quality of Power, Italy, October 2010, pp. 1-6.

[22] T. Paulraj, I.S. Sherin, and M.A. Prakash, “Mitigation of power loss in transmission and distribution line using STATCOM”, International Conference on Advanced Communication Control and Computing Technologies, India, January 2017, pp. 432-435.

[23] C.C.B. Oliveira, N. Kagan, A. Meffe, S. Jonathan, S. Caparroz, and J. L. Cavaretti, “A new method for the computation of technical losses in electrical power distribution systems”, IEEE 16th International Conference and Exhibition on Electricity Distribution, Netherlands, June 2001, pp. 1-5.

[24] W. F. Horton, S. Goldberg, and R. A. Hartwell, “A cost-benefit analysis in feeder reliability studies”, IEEE Transactions on Power Delivery, vol. 4, no.1, pp. 446-452, 1989.

[25] A. Jain, and M. Bagree, “A prepaid meter using mobile communication”, International Journal of Engineering, Science and Technology, vol. 3, no. 3, pp. 160-166, 2011.

