DISTRIBUTION LOSS MINIMIZATION: A CASE STUDY IN A COMMERCIAL SECTION IN MASHHAD

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ABSTRACT

Power system faces a big problem of distribution losses. In this paper an attempt is made to reduce the distribution losses in a commercial section in Mashhad. The first step in power loss minimization procedure is loss calculation which is a common tool to optimize the design, operation and planning of the electrical network. In this paper calculation and analysis of distribution losses is fulfilled in a commercial section in Mashhad. Two methods are introduced, utilized and compared for power loss calculations: "Field measurement" and "Simulation study". Afterward some techniques are utilized to minimize technical and non-technical power loss of the studied section. Technical loss is minimized by complete removal of low voltage network and non-technical loss is minimized by Implementation of AMI system. Finally the results of power loss reduction indicate proper planning of this project.

INTRODUCTION

The main function of power system is to supply the load and energy requirements of customers. It is well known that large amounts of power loss occur in transmission and distribution network. The main objective of transmission line is to transfer electrical power from generation stations to substations. Distribution substations step the high voltage of transmission line down to lower levels; In other words, the distribution system provides a link between transmission system and customer and provides the power for local use. It is estimated that more than 40% of power loss occurs in distribution system [1]. Total losses have two components: technical and non-technical. Technical losses occur naturally and consist mainly of power dissipation in electricity system components such as transmission and distribution lines, transformers, and measurement systems. Non-technical losses are caused by actions external to the power system and consist primarily of electricity theft, non-payment by customers, and errors in accounting and record-keeping.

Ideally losses in the distribution system should be around 3 to 6%. However in developing countries distribution loss is around 20%: therefore, there is an increasing trend in developing countries to reduce technical and non-technical distribution losses [2].

In order to improve the efficiency, reliability and service quality of distribution system, trends to automate distribution system is increasing wildly. Several methods were utilized to reduce technical and non-technical losses. In [3], they have developed a method for optimal operation of distribution network and loss minimization by installation shunt capacitors and reconfiguration of the network. In [4], they have proposed a two stage and heuristic method for designing a minimum loss configuration of a distribution network. In [5], an evaluation of advantages and impacts of utilizing AMI system on distribution system is presented.

In this paper an attempt is made to reduce the distribution loss in a commercial section in Mashhad. In this case the first step is power loss calculation of the section. Power loss calculation methods are common tools to optimize the design, operation and planning of the electrical network. It is well known that power loss calculation is a challenging step that faces numerous problems and limitations. Two methods are introduced, utilized and compared for power loss calculations: "Field measurement" and "Simulation study".

Afterward, this paper reviews experience with efforts in technical and non-technical loss reduction the studied section, located at north side of "Khosravi Street". In this case, firstly, the distribution loss in the section is measured and analyzed. Finally, some critical techniques are introduced and utilized to reduce the technical and non-technical losses.

POWER LOSS CALCULATION

Power loss calculation methods are common tools to optimize the design, operation and planning of the electrical network [6]. In this project in the first step, power loss of the section is calculated in order to evaluate the power loss reduction planning. It is well known that power loss calculation is a challenging step that faces numerous problems and limitations . In this project, power loss of the section has been calculated in two methods: "field measurement" and "simulation analysis".

This project focuses on distribution loss reduction in a commercial section in Mashhad, located at north side of Khosravi Street. Current condition of the distribution network plays an important role in selection of the section from technical and planning point of view.

Traditional network, low accurate metering system and high level of consumptions are some critical characteristics of Khosravi Street that makes it a reasonable choice for loss reduction planning. Table 1 represents network characteristics of Khosravi Street.

Table 1: network characteristics of Khosravi Street

Feeder number	Network length(meter)	No. of consumers
1	123	45
2	115.5	8
3	143	41
4	92.25	16
5	148.25	32
6	127.75	2
7	139.7	31

Field measurement

In this method, simultaneous readings of metering equipments of feeders and consumers were carried out at the beginning and at the end of measuring period. In this project the measuring period was selected one month from 2009/07/11 to 2009/08/11. This method faces some struggles and limitations as listed below:

- **Simultaneous readings of metering equipments**: The power and energy output of the transformers can be easily measured simultaneously by installing a three-phase energy meter on each feeder. The problem is simultaneous readings of consumer meters. Some methods have been proposed in order to overcome this limitation [7]. In this project after obtaining permissions and public notifications, the power input of section has been turned off temporarily in order to provide simultaneous readings of consumer meters.
- **Metering accuracy calculations**: This could be obtained by statistic evaluation of consumptions in order to obtain the unreliable cases and test them to improve reliability.

The results of distribution loss calculation on each feeder based on field measurement are shown in table 2.

Table 2: distribution loss calculation based on field measurement

Feeder No.	Input Active Energy (kWh)	Output Active Energy (kWh)	Power loss (kWh)	Power loss (%)
1	23447	20167.08	3279.9	13.99%
2	7034.68	6299.6	735.08	10.45%
3	22138	17097.8	5040.2	22.77%
4	18983	13646.63	5336.3	28.11%
5	21358	14678.5	6679.5	31.27%
6	8095	429718	3797.8	46.92%
7	24335.72	20152.02	4183.7	17.19%
Total	**96338.8**	**125391.4**	**29052.58**	**23.17%**

Simulation analysis

In the present survey, the studied network is simulated by maximum details in DIgSILENT for balanced and imbalanced analysis. In this case, the consumption and situation of each consumer are considered in simulations to ensure reliability of the analysis. Impact of correction factor and influence of improvements in power factor and phase imbalance on power loss are examined in simulation studies**.**

Balanced and imbalanced analysis: Imbalanced load is a source of distribution loss. In order to realize the impact of this parameter on loss reduction, both balanced and imbalanced analyses are simulated (see table 3).

Power factor improvement: The impact of power factor correction on power loss reduction based on simulations is shown in table 4.

Correction factor: It is necessary to calculate the correction factors in loss calculation procedure based on simulation study. This parameter is used to multiply the load values of the feeders. This multiplication will result in a new load profile. Deducing correction factor for each consumer is not possible, therefore; it is calculated for each feeder separately based on the daily average consumption. This parameter is square of division of feeder current by the current obtained from simulations. Correction factor of feeders are shown in table 5.

Table 3: Impact of phase imbalance on power loss

Feeder No.	Power Loss (Wh)		Loss Reduction
	Imbalanced Load Flow	Balanced Load Flow	
1	635.32	604.54	4.84%
2	40.45	34.72	14.16%
3	46.15	33.32	27.80%
4	112.95	104.58	7.41%
5	285.95	278.74	2.39%
6	15.39	15.37	0.12%
7	50.71	37.30	9.59%

Table 4: Impact of power factor on power loss

Feeder No.	Power Loss (Wh)		Loss Reduction by Improving PF to 0.9
	Existing PF	Improved PF to 0.9	
1	635.32	544.18	14.34%
2	40.45	16.76	58.56%
3	46.15	36.94	19.95 %
4	112.95	108.22	4.18%
5	285.95	242.59	14.93%
6	15.39	8	48%
7	50.71	47.14	7.04%

Table 5: distribution loss calculation based on simulation analysis

Feeder No.	Power loss (Simulation Study)		Correction Factor
	Balanced Analysis	Imbalanced Analysis	
1	4.69 %	4.89 %	2.08
2	1.20 %	1.34 %	1.25
3	7.51 %	10.39 %	17.97
4	1.8 %	1.95 %	3.17
5	4.32 %	4.40 %	3.06
6	6.67 %	6.67 %	13.07
7	0.65 %	0.71 %	4.19

The results of simulation study for balanced and imbalanced analysis after considering correction factor are shown in table 5.
It is found from the survey that there exist some differences between these two loss calculation methods. The main reason for these differences is non-technical losses that are not considered in simulations, such as electrical theft, inaccuracy of traditional meters, etc. Loose connections, distribution network aging and insulation leakage are some other remarkable reasons for this differences that are categorized as technical losses.

POWER LOSS REDUCTION

Power system faces a big problem of distribution losses. It is estimated that more than 40 percents of power losses occurs in distribution system. Total losses have two components: technical and non-technical.
In this paper an attempt is made to reduce the distribution losses in a commercial section in Mashhad. Both technical and non-technical losses are focused to be reduced in this project.

Technical loss reduction

The major part of technical loss is his type of power loss depends directly upon square of current, therefore; it is maximum during peak loads. Other causes of technical loss are low power factor, improper joints, phase imbalance, etc. Technical loss is inherent to the distribution network and cannot be eliminated but can be minimized. In order to reduce technical loss in distribution system of studied section, following operations have been fulfilled:

- **Complete removal of low voltage network**: In this case, 415V, 3-phase, 4-wire network with the length of 900 meters was removed and 22KV line was extended up to very nearer to consumer premises. Higher voltage results in lower current that causes loss reduction.

- **Utilization of pad-mounted transformers:** In order to obtain advantages of pad-mounted transformers such as reduced expenses, economical benefits and improved reliability, simplicity and flexibility, 630KVA transformers were replaced by lower capacity pad-mounted transformers such as 100KVA, 160KVA and 200KVA.

Table 6 shows the characteristics of distribution network of studied section before and after power loss minimization of technical loss reduction.

Table 6: Network characteristics of Khosravi street

Before Loss Reduction	After Loss reduction
Number of consumers : 186 Length of low voltage network : 900 meters Installed transformer: 3*30kVA	Length of 20 kV network : 700 meters Installed transformers : 5 * 160kVA 2 * 100kVA , 1 * 200kVA

Non-Technical loss reduction

This type of loss includes loss mainly due to inadequate billing, faulty metering, overuse because of meters not working, and electricity theft. In this project, many of energy meters failed because of poor quality of equipments. The meters were mainly traditional mechanical meters with low level of accuracy.
In this project in order to minimize non-technical distribution loss in the studied section, AMI system is implemented.
Implementation of AMI system: smart meters have become key assets at the edge of the distribution grid, capable of gathering and recording both historical and real-time data also enables utilities to analyze the state of the grid in new ways in order to improve existing distribution operations and aid in long-term planning. While the billing-related cost savings of smart meters and advanced metering infrastructure are already well documented, utilities are just beginning to act upon the wealth of information provided by smart meters in order to operate the distribution grid more reliable, efficient and cost-effective.
This project is the first experience of AMI system in Iran in which traditional meters were replaced by smart meters. Main objectives of this activity are given below:

- **Reduction of non-technical loss**: AMI system is able to minimize non-technical losses due to prevention of electrical theft as well as improvement of accuracy as a consequent of modernization of metering system.
- **Automatic readings of meters**: AMI system in Khosravi Street is able to read consumption details and provide billing system with reduced cost.
- **Load management**: AMI system provides the ability to turn on and off meters from data management center. Furthermore, it has the ability

to limit load of consumers.

- **Technical evaluation of AMI system**: This survey was aimed to be as an experience and a pilot design for FAHAM project in which 1,000,000 smart meters are going to be replaced by traditional meters in Iran.
- **Alarm management**: Any technical or tampering faults could be enabled as an alarmed by AMI system.
- **Distribution loss analysis:** The AMI system is able to calculate the distribution loss and represent power loss in practical graphs. Figure 1 shows an illustration of daily distribution loss of studied section.

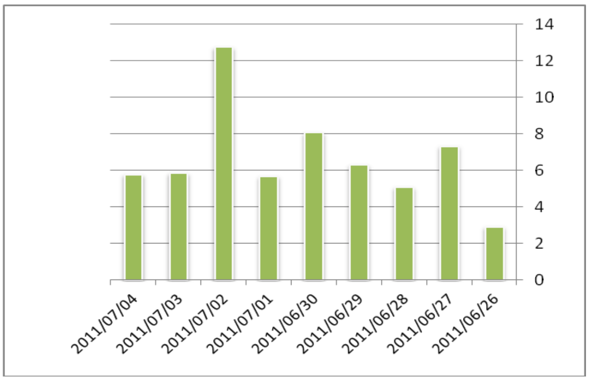

Figure 1: daily distribution loss of studied section.

It is worthy to tell that in this project eight data concentrator units are utilized, also RS485 and GPRS are used respectively as downlink and uplink telecommunication networks (Figure 2). In addition, DLMS/COSEM is the supported protocol for smart metering.

Results of loss minimization

As it was mentioned before, based on field measurement of studied section in the period of 2009/07/11 to 2009/08/11, distribution loss was calculated to be 23.17%. After loss minimization of the section, the percentage of distribution loss deduced as 3.85% in the period of 2011/07/11 to 2011/08/11. Table 1 shows energy calculations after loss minimization

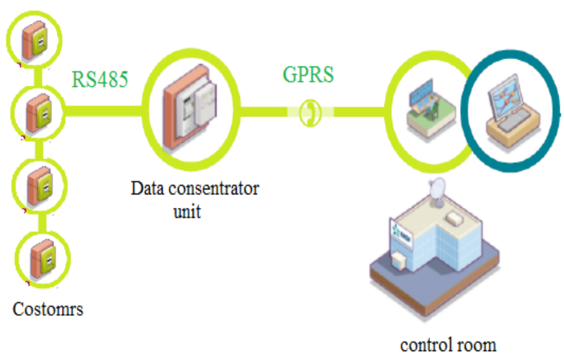

Figure 2: AMI telecommunication scheme.

Table 7: Energy calculations after loss minimization.

Input Active Energy (kWh)	Sold Active Energy (kWh)	Energy Loss (kWh)	Percentage of Energy Loss
78301.950	75283.670	3018.28	3.85%

CONCLUSIONS

A complete loss minimization procedure for a commercial section in Mashhad was fulfilled in this study. Distribution loss has been calculated at first in two methods: field measurement and simulation analysis. The influence of phase imbalance and power factor improvements has been examined on power loss reduction. Some techniques were utilized to minimize technical and non-technical loss in the studied section. In order to reduce technical loss 20 kV line was extended up to very nearer to consumer premises and pad-mounted transformers were utilized. Non-technical loss was minimized by implementation of AMI system also most advantages of AMI system were acquired. Finally it was stated that distribution loss of studied section was successfully reduced from 23.17% to 3.85%.

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