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Loss reduction experiences in electric power distribution companies of Iran

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Abstract

The experiences of the loss reduction projects in electric power distribution companies (EPDCs) of Iran are presented. The loss reduction methods, which are proposed individually by 14 EPDCs, corresponding energy saving (ES), Investment costs (IC), and loss rate reductions are provided. In order to illustrate the effectiveness and performance of the loss reduction methods, three parameters are proposed as energy saving per investment costs (ESIC), energy saving per quantity (ESPQ), and investment costs per quantity (ICPQ). The overall ESIC of 14 EPDC as well as individual average and standard deviation of the EISC for each method is presented and compared. In addition, the average and standard deviation of the ESPQs and ICPQs for the loss reduction methods, individually, are provided and investigated. These parameters are useful for EPDCs that intend to reduce the electric losses in distribution networks as a benchmark and as a background in the planning purposes.

Keywords: Electric distribution networks, Loss reduction, investment cost, economic analysis;

Nomenclature

ES	the anticipated energy saving (kWh) annually gained by implementation of a specific loss reduction method.
IC	the total investment costs ($) of a specific loss reduction method to obtain the anticipated annual kWh saving.
ESIC	the annual energy saving gained by a method divided by the total investment costs of this method (kWh/$).
ESPQ	the annual energy saving gained by a method divided by the total quantity considered for improvements (kWh/unit).
ICPQ	the total investment costs of a method divided by the total quantity considered for improvements in this method ($/unit).

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1. Introduction

Energy resource limitations and cost-effective delivery of electricity to the consumers motivate the engineers, planners, and researches of Electric Power Distribution Companies (EPDCs) to increase the efficiency of electric power distribution networks in last decades. In the other hand, high reduction of the electric loss leads to increasing of the project investments. Therefore, loss reduction is an economic task, which is related to the installed equipments in the networks, the rate of energy and power loss, the inflation and interest rates, Co_2 emission rate, and other economic parameters [1].

The cause of electric loss in distribution networks usually is divided into two major parts: technical and non-technical losses. Technical loss relates to the physical characteristic of the conductor and equipments and refers to the electric loss due to the carrying currents of the conductors. Some main sources of technical losses are as (1) Ohmic losses of primary line conductor, (2) Ohmic losses of secondary and service line conductor, (3) Load and no-load losses of Transformer, (4) Poor management of street lighting [1].

However, non-technical loss causes mostly due to human errors, therefore, can be minimized by having a more effective policy. Most electric losses in developing countries are due to non-technical losses. Some sources of non-technical losses are as (1) Electricity theft, (2) Electric metering deficiencies, (3) Inappropriate meter reading, (4) Mis-billing and unlisted meters, (5) Loose connections, (6) Calculation error of energy delivered and sold, (7) Trees in contact with the overhead lines [2].

Table 1. Loss reduction methods

No.	Methods	Reference
1	Electricity theft preventing	[1], [2], [7]
2	Measurement improvement	[1], [7]
3	Distribution transformers locating and sizing	[1], [5], [8]
4	Conductor sizing	[1], [5], [6], [8]
5	Reactive power compensation	[1], [3], [8]
6	Voltage upgrading	[1], [5]
7	Street lighting standardization	[1]
8	Load balancing and network reconfiguration	[1], [4], [5], [8], [9]
9	Correction of loose connections	[11]
10	Change of service cables	[1]
11	Distributed generation	[10]

In addition, there are many methods to reduce the electric loss in distribution networks [1]-[11]. Some major methods that are employed in EPDCs of IRAN are provided in Table 1. Since the most electric losses occur in distribution networks, the methods of loss reduction focus on such networks.

In this paper, the better experiences of loss reduction methods in EPDCs of Iran are presented. The employed loss reduction methods as well as related economic parameters that indicate the effectiveness, performance and the rate of return of the methods are investigated. In the next section, the distribution electric loss in Iran is demonstrated. In the section III, the experiences of loss reduction methods in EPDCs of Iran are presented in four subsections. Finally, section IV provides the relevant conclusions.

2. Distribution electric loss in Iran

The annual energy loss rate of electric distribution networks of Iran is presented in Fig. 1 during 2001 to 2009 years (from 1380 to 1388 in Persian calendar). As shown in Fig.1, the loss rate has been increased during several decades until 2006, when its reduction has been begun. The energy loss in EPDCs of Iran in year 2009 was approximately 27.17 TWH [12] whose cost was almost 2.19 Billion Dollars [13]. It is planned to reduce the loss rate from 16.5% in 2009 to 7% in 2025 in total electric power distribution network of Iran [12]. Note that the standard primary voltage levels are 33, 20, and 11 kV and the secondary voltage level is 400 V in Iranian electric distribution networks.

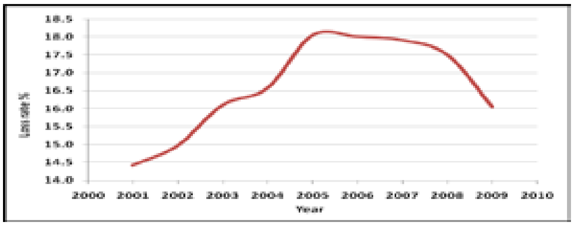


Fig.1. annual rate of electric energy loss (%)

3. The experiences of loss reduction projects

In order to present a general and concise comparison among loss reduction methods and EPDCs' situation, some parameters are used as Energy saving, ES (kWh), Investment costs, IC ($), Energy saving per Investment costs, ESIC (kWh/$), Energy saving per quantity, ESPQ (kWh/unit), Investment costs per quantity, ICPQ ($/unit). ESIC indicates the profitability of a method. In addition, the rate of return can be calculated from this parameter. An example for unit of quantity in ESPQis as: the unit of "Conductor sizing" method is Km and the unit of "Electricity theft preventing" is the number of consumers.

3.1. ES and IC

The 14 EPDCs, sorted in respect to corresponding ES and IC, are presented in Tables 2 and 3, respectively. In Table 2, the proposed methods in Table 1 and distribution annual loss rate reduction of each EPDC regarding to load growth are provided, separately [14].

Table 2. Proposed loss reduction methods and sorted ICs

EPDC no.	Proposed methods	IC (hundred $)	Annual loss rate reduction (%)
EPDC1	1	102,273	6.90
EPDC2	1 to 9	76,766	13.05
EPDC3	1 to 6	64,035	4.48
EPDC4	1	59,668	16.68
EPDC5	1, 5, 7, 10	41,879	9.56
EPDC6	1, 3 to 5, 7	37,076	1.26
EPDC7	1, 3 to 5, 7	33,550	2.57
EPDC8	2 to 5, 7, 10	30,258	5.12
EPDC9	2 to 5, 7, 8, 11	19,263	9.51
EPDC10	1, 3 to 5, 7	10,572	3.87
EPDC11	1, 3, 4, 8	9,100	3.20
EPDC12	2, 3, 7	7,904	0.28
EPDC13	1, 2, 5, 10	7,293	0.94
EPDC14	1 to 5, 7	2,379	1.50
Total	--------	502,017	-------

As shown in Tables 2 and 3, the ESs and ICs are not proportional which is in accordance with the approaches taken in each method of loss reduction, the cost of equipments and human resources in different region of Iran. Therefore, for better comparison, other parameters such as ESIC, ESPQ, and ICPQ are developed to illustrate the performance and effectiveness of the EPDCs' loss reduction projects.

Table 3. Sorted ESs

EPDC no.	EPDC4	EPDC1	EPDC9	EPDC2	EPDC5	EPDC10	EPDC6	EPDC8	EPDC3	EPDC7	EPDC13	EPDC11	EPDC14	EPDC12	Total
ES (kWh)	1,316,110	895,133	709,826	537,147	379,697	235,548	233,640	219,576	209,260	139,236	68,543	41,125	37,185	6,894	5,028,922

3.2. Overall ESIC

The overall ESIC of loss reduction projects of EPDCs is provided in Table 4. As shown, the variation of ESIC is from 0.83 to 36.8 and presents the importance of economical studies and correct prioritization of loss reduction approaches in each proposed methods. In order to study in detail the source of large variation of the overall ESIC, for example, the ESIC, ESPQ, and ICPQ of "Electricity theft preventing" method for EPDCs that proposed this method is presented in Figs. 2 and 3.

Table 4. Sorted ESICs

EPDC no.	EPDC9	EPDC10	EPDC4	EPDC14	EPDC13	EPDC5	EPDC1	EPDC8	EPDC2	EPDC6	EPDC11	EPDC7	EPDC3	EPDC12
ESIC (kWh/hundred$)	36.8	22.33	22.02	15.61	9.41	9.1	8.79	7.24	7.03	6.31	4.55	4.13	3.31	0.83

Figure 2 shows that the ESIC of EPDCs 1 and 2 is low while the corresponding ESPQ and ICPQ of these EPDCs are high. EPDCs 1 and 2 supply the high demand consumers in the high temperature and humidity areas. Therefore the ESPQs of "Electricity theft preventing" method for these EPDCs are high. However, the main approach to proposed method for these EPDCs is network expansion. Consequently, the corresponding ICPQs of this loss reduction method are high too. As a result, the ESICs of "Electricity theft preventing" method for EDPCs 1 and 2 are not high. It is important to note that in addition to reduce the electric losses, the quality of supply and load growth need is outcome, too.

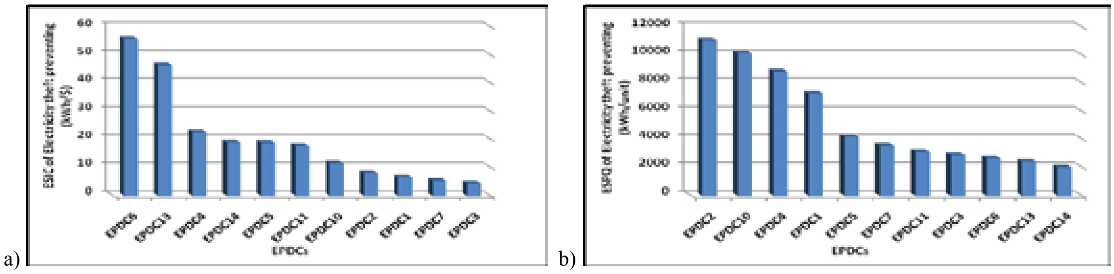


Fig.2. Electricity theft preventing method in EPDCs; a) ESIC b) ESPQ

In another case, EPDC6 takes the periodical inspection of customers' connections to the network and corresponding measurements as only approach for "Electricity theft preventing" method, therefore, the ICPQ of this method is low, while the ESPQ is moderate. Consequently, the ESIC of "Electricity theft preventing" method for EPDC1 is high.

3.3. The ESIC, ESPQ, and ICPQ of Methods

The average and standard deviation (SD) of loss reduction methods in Table 1, which are proposed for EPDCs, are presented. Figures 1 and 2 provide the average and SD of ESIC of loss reduction methods, respectively. As shown in Fig. 5, the economic effectiveness of the "Electricity theft preventing" method is the highest and the ESIC of the "Distribution transformers locating and sizing" is the lowest because of high investment cost of distribution transformer installation. Also, the SD of ESIC for "Electricity theft preventing" method is the highest whose reason was described in the previous section. However, the SD of ESIC for "Distribution transformers locating and sizing" method is lowest because the approaches selected mostly in this method are similar. The mentioned approach is the replacement of transformer with the high efficiency type.

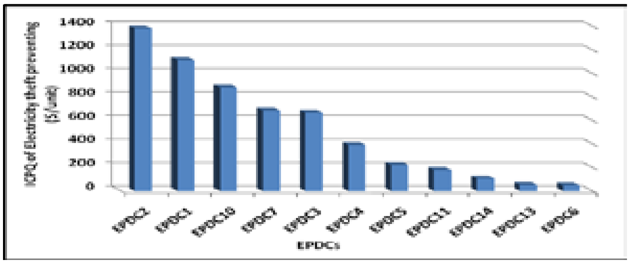


Fig.3. ICPQ of Electricity theft preventing method in EPDCs

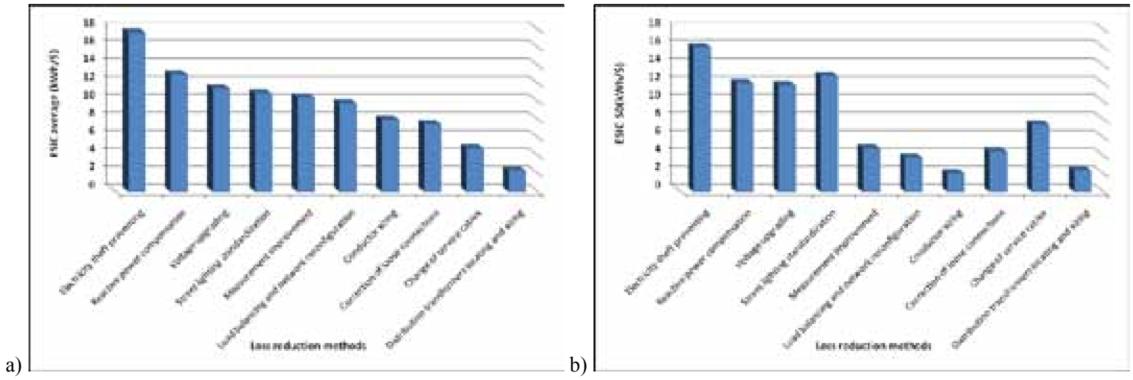


Fig.5. ESIC a)average b) SD

The average and SD of ESPQ of loss reduction methods are provided in Fig. 6, respectively. As shown, the highest ESPQ pertains to the "Voltage upgrading" method, while, the "Correction of loose connections" method has the lowest ESPQ pertains. In addition the SD of ESPQ of the "Voltage upgrading" method is highest. Note that the voltage upgrading cases are divided into two categories: 11 to 33 kV or 11 to 20 kV upgrading whose investment costs are different. In addition, in some networks, the distribution transformers and insulators may be changed and installed conductors are kept left.

In addition, Fig. 7 present the average and SD of ICPQ of loss reduction methods, respectively. As seen, per unit investment cost as well as corresponding SD the "Voltage upgrading" method is highest while, these values are lowest for the "Reactive power compensation" method.

The proposed method can be employed to prioritize the loss reduction approaches in EPDCs. In this point of view, the most important parameter is ESIC, which indicate the economic effectiveness of the proposed loss reduction method. EPDCs can sort descending the loss reduction method in respect to ESIC values. Then regarding to total investment, the high order methods completely or a portion of them can be selected.

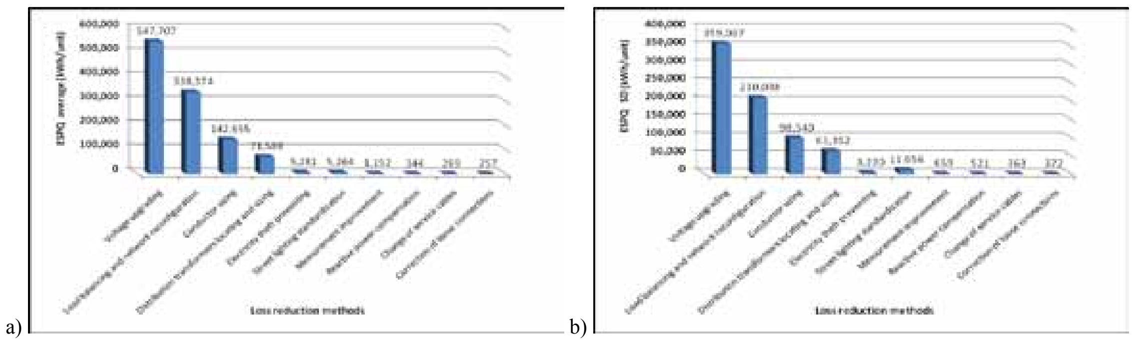
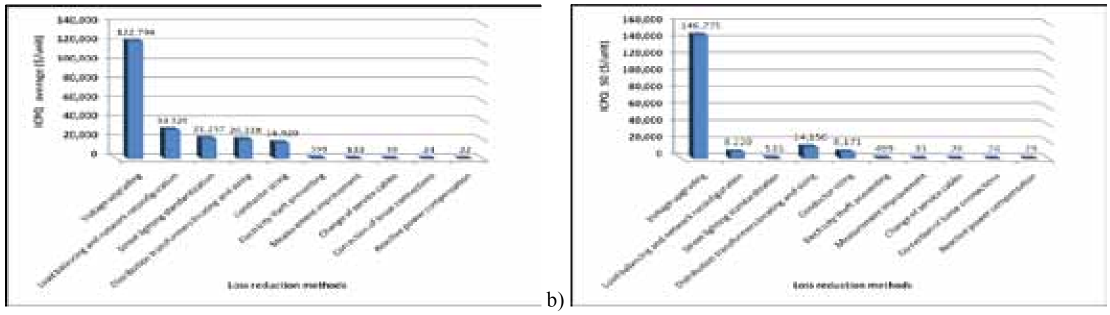


Fig.6. ESPQ a)average b) SD



a) b)

Fig.7. ICPQ a)average b) SD

In addition, these parameters are useful as a background and predefined factors in a loss reduction plan for EPDCs and as a benchmark for EPDCs that purpose to implements some loss reduction methods.

4. Conclusion

The experiences of loss reduction projects in electric power distribution companies (EPDCs) of IRAN were presented. The causes of electric losses as well as major loss reduction methods, which are employed in EPDCs, were investigated. The loss reduction methods, which are proposed individually by EPDCs, corresponding energy saving (ES), Investment costs (IC), and loss rate reductions were provided.

Three parameters including energy saving per Investment costs (ESIC), energy saving per quantity (ESPQ), and investment costs per quantity (ICPQ) were proposed to illustrate the effectiveness and performance of loss reduction methods. The overall ESIC of 14 EPDC as well as individual average and standard deviation of EISC for each method was presented and compared. In addition, the average and standard deviation of ESPQ and ICPQ for the loss reduction methods, separately, were provided and investigated. These parameters are useful for EPDCs that intend to reduce the electric losses in distribution networks as a benchmark and as a background in the planning purposes.

References

[1] Tennessee Valley Public Power Association, *Distribution System Loss Reduction Manual*, Alexander publication, 1994.

[2] K. A. Seger, *Revenue protection: combating utility theft & fraud*, PennWell Books, 2005.

[3] M. -R. Haghifam, O. P. Malik, "Genetic algorithm-based approach for fixed and switchable capacitors placement in distribution systems with uncertainty and time varying loads", in: *IET Gener Trans. Distrib.* 2007; 1(2): 244-252.

[4] G. K. Viswanadha Raju, and P.R. Bijwe, "Efficient reconfiguration of balanced and unbalanced distribution systems for loss minimization", in: *IET Gener. Transm. Distrib.* 2008; 2(1): 7–12.

[5] R. J. Sarfi, M. M. A. Salama, Y. Chikhani, "Practical aspects of performing a distribution system loss reduction study", *in: Canadian Conf. on Elec. and Comp. Eng*. 1995; 1:164-167.

[6] S. Sivanagaraju, N. Sreenivasulu, M. Vijayakumar, T. Ramana, "Optimal conductor selection for radial distribution systems", *in: Electric Power Systems Research Journal* 2002; 63: 95-103.

[7] Raymond F. Ghajar, Joseph Khalife, "Cost/benefit analysis of an AMR system to reduce electricity theft and maximize revenues for E´ lectricite´ du Liban", *in: Applied Energy Journal* 2003; 76: 25–37.

[8] M. Gilvanejad, H. Ghadiri, M. R. Shariati, S. Farzalizadeh, and A. Arefi, "A novel algorithm for distribution network planning using loss reduction approach", *in: Power Engineering Conference, Australasian Universities* 2007; 1-7.

[9] A. Arefi, M. R. Haghifam, A. Yavartalab, G. R. Saffarpoor, M. Mostaghi, and et. al., "Load balancing in electric low voltage distribution network considering limited data", in: *24th International Power System Conference (PSC2009), Tehran, Iran* (Persian).

[10] A. D. T. Le, M. A. Kashem, M. Negnevitsky, and G. Ledwich, "Optimal distributed generation parameters for reducing losses with economic consideration", *in: Power Engineering Society General Meeting* 2007; 1-8.

[11] R.S. Timsit, and J.D. Sprecher, "Energy losses in power tap-connectors", IEEE, 1998.

[12] Statistics of Electric Power Industry of Iran, *in: website of TAVANIR Holding Company,* www.tavanir.org.ir.

[13] M. H. Amrollahi, A. Arefi, A. Yavartalab, and J. Olamaei, "Comprehensive model of the loss cost in distribution systems", *in: 22th International Power System Conference (PSC2007), Tehran, Iran* (Persian).

[14] Department of Electric Distribution Engineering, *National Project of Loss Reduction in Electric Distribution Networks*, Power Generation, Transmission, and Distribution Management Company (TAVANIR), 2009-2010.