OPPORTUNITIES TO CONSERVE ENERGY RIGHT FROM DISTRIBUTION INSTALLATIONS

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Lucrarea prezintă o metodologie de evaluare a economiei de energie în rețelele de distribuție prin înlocuirea transformatoarelor vechi cu transformatoare efieciente. Pentrui modelarea sarcinii transformatoarelor s-au utilizat tehnici fuzzy. În finalul lucrării se prezintă rezultatele studiului de caz efectuat pe o rețea de distribuție urbană.

The paper presents a methodology of the evaluation of the energy saving potential in distribution network, by replacement of the old transformers with efficient transformers. The modeling of the transformers load was performed by fuzzy techniques. Finally, a study case for a urban distribution network is presented.

Keywords: smart grids, energy saving, efficient transformers, fuzzy techniques

1. Introduction

Increasing the efficiency of existing distribution and consumption equates to making additional power available at lower cost. Such efficiencies reduce the need for constructing new generation plants and associated transmission facilities. Smart Grid can provide the communications and monitoring necessary to manage and optimize distributed and renewable energy resources and to maximize the environmental and economic benefits.

The term "smart grid" is hyperbole that seems to imply a future when the grid runs itself absent human intervention. The smart grid concept in many ways suggests that utility companies, executives, regulators and elected officials at all levels of government will indeed face a brutal "pass/fail" future with regard to electric service, a driving force of the U.S. world-leading economy, [11].

The essence of the smart grid lies in digital control of the power delivery network and two-way communication with customers and market participants. This intelligent infrastructure will allow for a multitude of energy services, markets, integrated distributed energy resources, and control programs. The smart grid is the essential backbone of the utility of the future, [11].

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In the nearest future we will have to face two mega-trends. One of them is the demographic change. The population development in the world runs asymmetrically: dramatic growth of population in developing and emerging countries, the population in highly develops countries is stagnating, [1]. This increase in population (the number of elderly people in particular) poses great challenges to the worldwide infrastructure: water, power supply, health service, mobility and so on.

The second mega-trend to be mentioned is the urbanization with its dramatic growth worldwide. In less than two years more people will be living in cities than in the country. Depending on the degree of development (developing, emerging, industrialized countries) different regions have very different system requirements, Fig. 1:

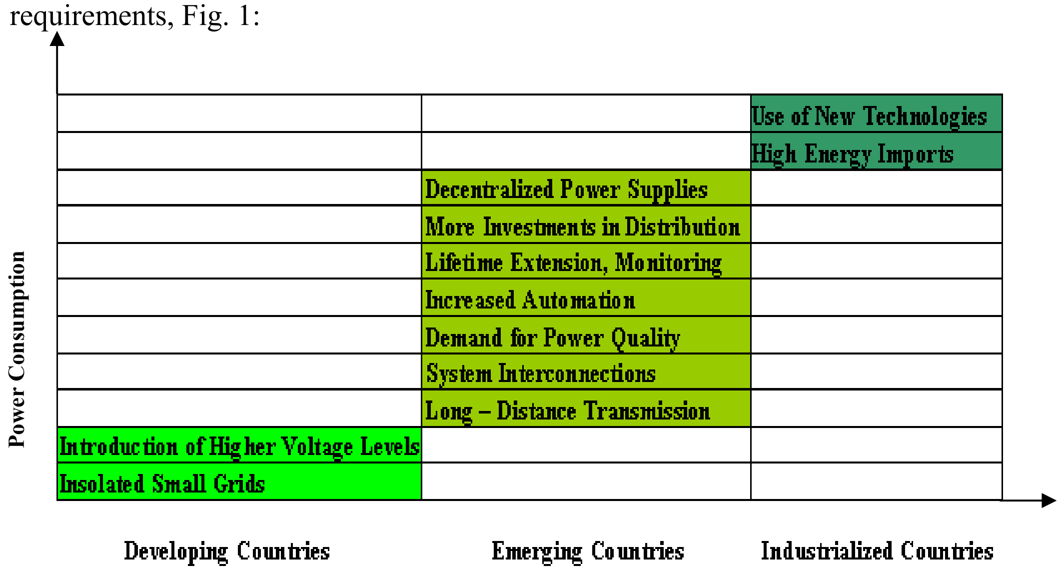


Fig. 1. Development of Power Consumption and System Requirements, [1]

In developing countries, the main task is to provide local power supply. Emerging countries have a dramatic growth of power demand. During the transition, the newly industrialized countries need energy automation, life time extension of the system components, such as transformers and substations. Higher investments in distribution systems are essential as well, [1].

2. Energy Economy–opportunity to recover the costs of old equipment

Energy losses throughout the world's electrical distribution networks vary from country to country between 3.7% and 26.7% of the electricity use, which implies that there is a large potential for improvement. Together with the lines, distribution transformers are a largest loss-making component in electricity networks. Electricity distribution transformers have a relatively long life (estimates range from around 30 years to as much as 50 years for lightly loaded or refurbished transformers), and individual transformers accumulate substantial losses over their working life, [10].

This paper presents forwards the potential of the efficiency distribution transformers, as a technology to saving energy in distribution network. There are several good reasons for such a focus:

- Distribution transformers represent the a largest loss component in the network;
- Replacing transformers is easier than changing cables or lines.

The energy losses in electricity transformers fall into two components, Table 1: no-load losses or iron losses (constant, resulting from energizing the iron core and load losses (variable, arising when providing power to a user, from the resistance of the coils when the transformer is in use, and for eddy currents due to stray flux), [3], [6], [10].

No-load loss (core loss) is the power consumed to sustain the magnetic field in the transformer's steel core. Core loss occurs whenever the transformer is energized; core loss does not vary with load. Core losses are caused by two factors: hysteresis and eddy current losses.

Load loss (copper loss) is the power loss in the primary and secondary windings of a transformer due to the resistance of the windings. Copper loss varies with the square of the load current. The maximum efficiency of the transformer occurs at a condition when constant loss is equal to variable loss. For distribution transformers, the core loss is 15% to 20% of full load copper loss. Hence, the maximum efficiency of the distribution transformers occurs at a loading between 40–60%. For power transformers, the core loss is 25% to 30% of full load copper loss. Hence, the maximum efficiency of the power transformers occurs at a loading between 60–80%. The efficiency of the transformers not only depends on the design, but also, on the effective operating load.

Table 1

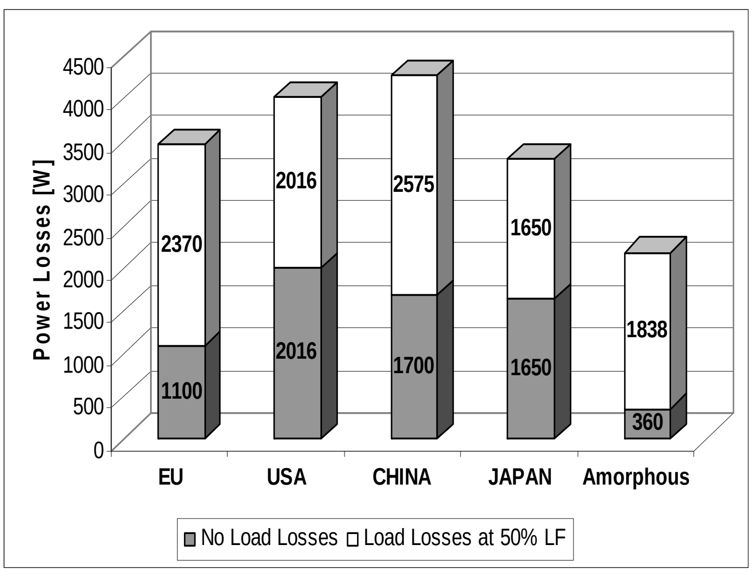
Losses in transformer and it's improvements, [3], [6]

Losses	Location	Main cause	Feature	Improvements
No-load losses	Magnetic core	Magnetic reluctance	Constant, independent of the load	Magnetic material; Core structure; Thin strip.
Load losses	Copper Wire	Electric resistance	Proportional to the square of the load current	Al → Cu Shorten the wire; Thin insulation.

Thus, low loss transformers can be called "efficient transformers". Operating losses are less causing less heat generation and effecting longer life. One of the prime components of losses is the no-load loss which can be drastically reduced by better design and using superior grades of electrical steels. However, the latest technology is to use amorphous material for the core. The expected reduction in energy loss over conventional (Si Fe core) transformers is roughly around 70%, which is quite significant.

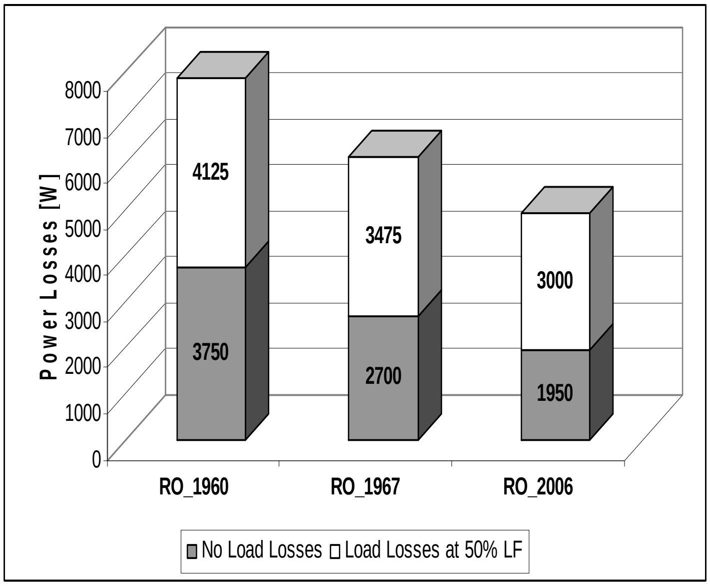
Although the iron power losses is less the copper power losses, Fig. 2, the major part of the energy losses at the transformers is iron energy losses (no load energy losses) because this phenomenon occurs 24 hours per day, 7 day per week, over the lifetime of transformer, 30 years average.

It must be underline if now for us the objective is replacements of old transformers by efficient transformers, (EU, Fig. 2), in Japan the objective the passing to high efficient transformers (Amorphous).



(a)

Fig. 2. (a) Evolution of the transformers losses in Romanian Normative [3] vs. Standard EU [6], and Amorphous Transformer 1000 kVA [6], [9]



(b)

Fig. 2. (b) Evolution of the transformers losses in Romanian Normative [3] vs. Standard EU [6], and Amorphous Transformer 1000 kVA [6], [9]

For example, in the Fig. 3 it is location by components of energy losses in a Romanian Distribution Company. In this figure it shows the major part of the energy losses of a distribution network are the energy losses in iron core because this phenomenon occurs continuously.

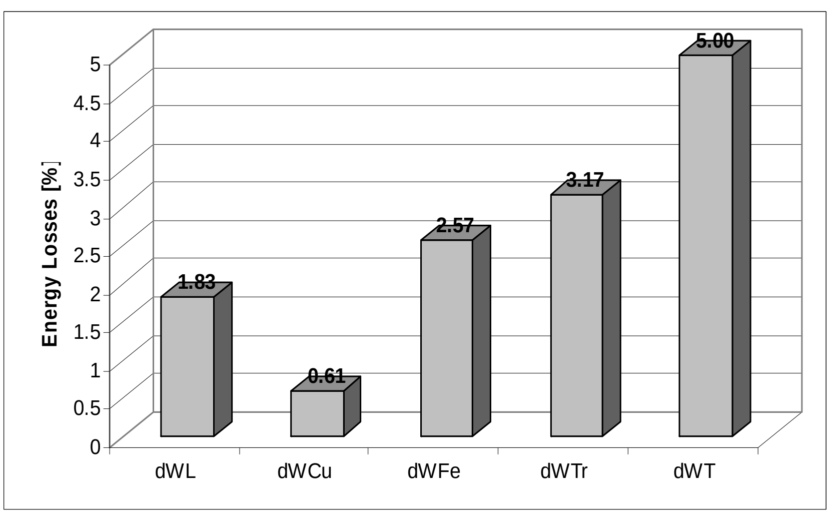


Fig. 3. The energy losses in components of a distribution networks

3. Modeling of the transformers loading for losses evaluation

Modeling of the transformers loading can be performed in numerous ways, inclusively using the Fuzzy Techniques (FT).

The uncertain of the load level, reliability indices, the length of the feeders and so on will be represented as fuzzy numbers, with membership functions over the real domain $\Re$. A fuzzy number $\widetilde{A}$ can have different forms but, generally, this is represented as trapezoidal (or triangular) form, usually represented by its breaking points [2], [3], [4]:

$$\widetilde{A} \Leftrightarrow (x_1, x_2, x_3, x_4) = [m, n, a, b] \tag{1}$$

where:

$$\begin{cases} x_1 = m - a; & x_2 = m \\ x_3 = n; & x_4 = m + b \end{cases} \tag{2}$$

In the case of triangular form, m = n, $x_2 = x_3$.

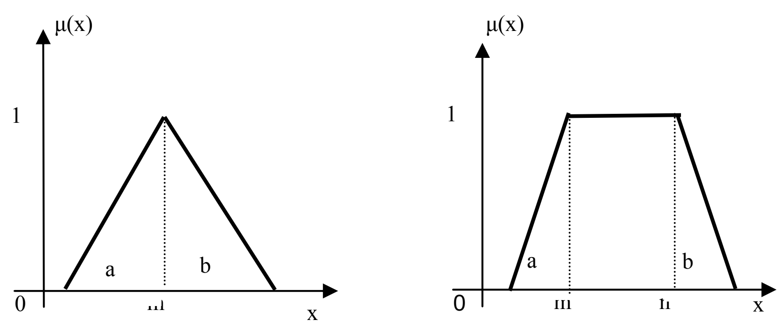


Fig. 4. Triangular and trapezoidal membership functions

In distribution networks, except the usual measurements from substations, there is few information about the network state. The feeders and the loads are not usually monitored.

For modeling of the loads, two primary fuzzy variables are considered: the loading factor K_L (%) and power factor cosφ, so that the fuzzy representation of the active and reactive powers result from relations [2], [3]:

$$P = \frac{K_L}{100} \cdot S_n \cdot \cos\varphi, \quad Q = P \cdot \tan\varphi \tag{3}$$

where S_n [kVA] is the nominal power of the distribution transformer from the distribution substations.

Each loading level represented by a linguistic variable is described by a fuzzy variable and its associated membership function. The loading factor K_L and the power factor cosφ were divided into five linguistic categories with the trapezoidal membership function, Table 2. The energy losses will be calculated for each one of these [4].

Table 2.

Linguistic categories of K_L and cosφ

Linguistic Declaration		x		Linguistic Declaration		x	
		K_L [%]	cosφ			K_L [%]	cosφ
VS (Very Small)	x_1	10	0.72	M (Medium)	x_3	31	0.89
	x_2	10	0.72		x_4	33	0.91
	x_3	13	0.74	H (High)	x_1	31	0.89
	x_4	15	0.75		x_2	33	0.91
S (Small)	x_1	13	0.74		x_3	39	0.92
	x_2	15	0.75		x_4	41	0.93
	x_3	22	0.82	VH (Very High)	x_1	39	0.92
	x_4	24	0.83		x_2	41	0.93
M (Medium)	x_1	22	0.82		x_3	60	0.95
	x_2	24	0.83		x_4	60	0.95

6. Study case: Replacement of old by efficient transformers

Let consider an urban distribution network of with 49 feeders (355 transformers 20/0.4 and 210.279 km of cable length). In the Fig. 5 it is presented simplified representation of a feeder. The nominal power losses for the distribution (old and efficient) transformers are presented in the Table 3, for two variants: variant I – old transformers – RO_1967, [3], and variant II – efficient transformers – EU, [4], [6].

Table 3

Nominal power losses of the distribution transformers (old vs. efficient)

Nominal power [kVA]	Load Losses		No-Load Losses	
	Old [W]	Efficient [W]	Old [W]	Efficient [W]
160	3720	2000	890	425
250	5040	2750	1100	425
400	6850	3850	1470	610
630	9720	5400	1920	860
1000	13900	9500	2700	1100

From the calculation of the energy losses, in the two variants, a typical load profile (G_{P2}) has considered, Fig. 6, [3].

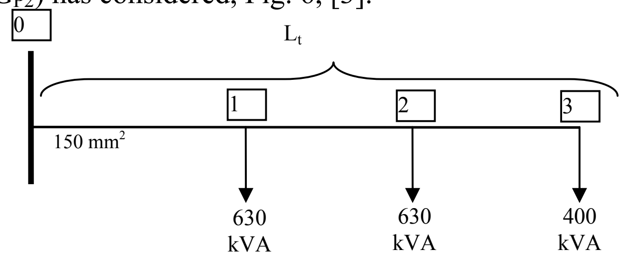


Fig. 5. Simplified representation of a feeder

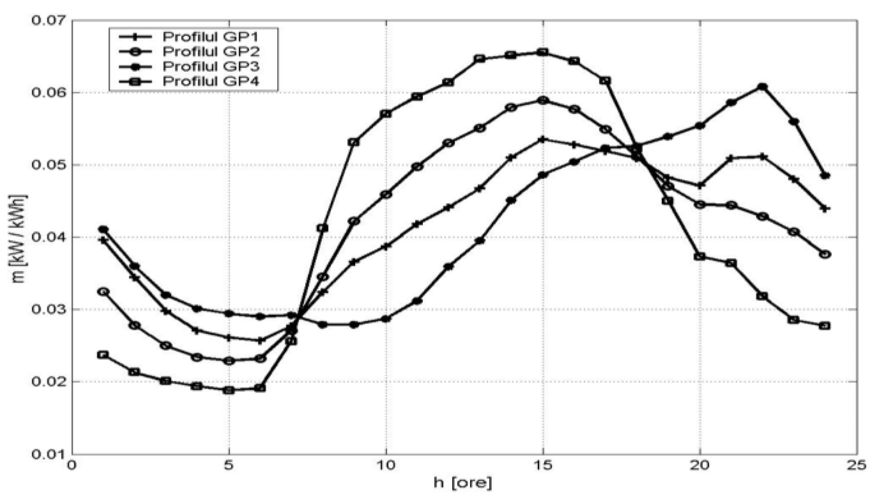


Fig. 6. Typical Load Profiles for the obtained groups

Total energy losses for the two considered situations using of the weights of the linguistic categories, Table 2, from the considered typical load profile, are presented in Table 4.

Table 4.

Total energy losses as function of the weight of the load linguistic categories for the profile

ΔW [kWh]	Variant	Loading Level					Total
		VS	S	M	H	VH	
ΔW_{NoLoad}	I	0	767.82	954.77	1716.30	1134.50	4573.40
	II	0	320.45	398.36	717.80	474.74	1911.40
ΔW_{Load}	I	0	139.14	373.94	1147.50	1540.30	3200.90
	II	0	81.59	219.01	671.15	897.71	1869.50

$\Delta W_{Transf.}$	I	0	906.96	1328.70	2863.80	2674.70	7774.20
	II	0	402.04	617.37	1388.90	1372.40	3780.80
ΔW_{Cable}	I	0	123.78	336.38	1056.60	1521.60	3038.40
	II	0	121.39	331.57	1038.50	1493.60	2985.10
ΔW_{Total}	I	0	1030.70	1665.10	3920.40	4196.40	10813.00
	II	0	523.44	948.94	2427.50	2866.10	6766.00

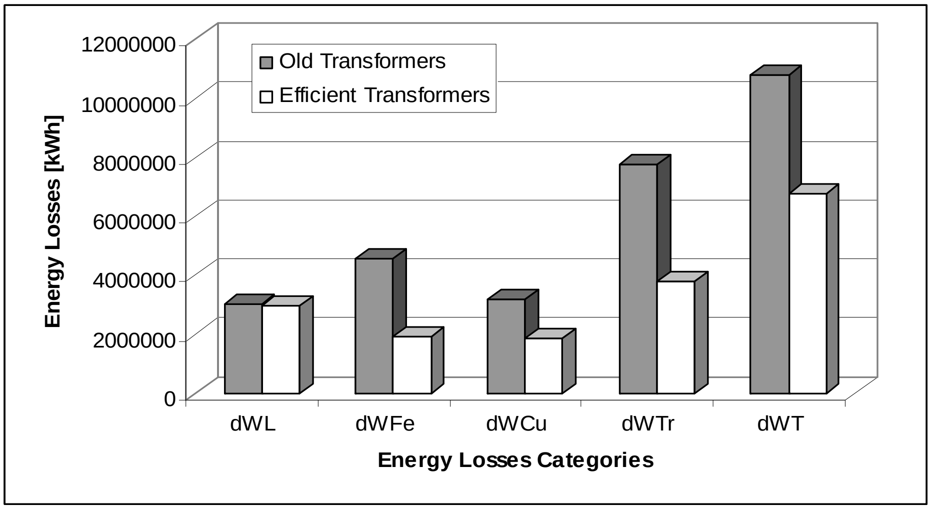


Fig. 7. The total energy losses in components of a distribution networks

For the considered distribution network, the Fig. 7 shows that the replacement of old transformers, installed with 30-40 years ago, by efficient transformers brings important power/energy saving.

The paper presents the opportunity to conserve from distribution networks by replacement of old transformers with efficient transformers. Moreover this provides to recover the costs of equipment rendered obsolete by deployment of the Smart Grids.

5. Conclusions

In distribution networks losses are relatively higher when transformers are lightly or heavily loaded. The paper shows that there is an important energy saving by old transformers replacement with efficient transformers.

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