IMPROVING THE ENERGY EFFICIENCY BY REDUCING THE LOSSES IN THE LOW-VOLTAGE POWER DISTRIBUTION GRIDS

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În actuala criza energetică, economisirea energiei a devenit o problemă internațională majoră.

Eficiența energetică reprezintă cea mai ieftină resursă dintre toate resursele existente.

Se compară un caz real de rețea centralizată cu 2 variante de rețea descentralizată. Calculul tehnico-economic se realizează pe criteriile venit net actualizat, cheltuieli totale actualizate şi durata de recuperare a investiției.

Metoda propusă pentru reducerea pierderilor (tehnice si comerciale) prin distribuția la medie tensiune are un efect benefic asupra mediului ambiant, prin micşorarea emisiilor corespunzătoare energiei economisite.

Given the current energy crisis, saving energy has become a major international issue.

The energy efficiency accounts for the cheapest resource from all of the existing resources.

We are going to compare a real case of a centralized grid to 2 variants of decentralized grids. The technical and economic calculation is based on the updated net income, updated total expenses, and investment return criteria.

The method proposed for reducing the (technical and commercial) losses by medium-voltage distribution grid has a positive effect on the environment through the reduction of the emissions accounting for the saved energy.

Keywords: energy efficiency, loss reduction, decentralized grid

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1. Introduction

The dedicated literature discusses the new conditions in which energy losses must be viewed after the coming of the energy crisis, in relation with both the cost of losses and the need to save in itself. Currently, it is acknowledged the fact that reducing the losses, mainly in the distribution grids, leads to obtaining certain powers and energies with costs much lower than for building new production and transmission assets (amount saved/amount invested = 15/1).

On the other hand, power is being more and more seen as a public service for the population, yet in the meantime as a need for industries. The consumers must see the responsibility to provide this service not only as a right to be served, but also as a duty to use energy rationally, in energy efficiency conditions. This is one of the messages of the Green Chart, which deals with a new energy demand management.

Worldwide, the concerns for the reduction of costs for building new power cable grids and extending the old ones, but also the concerns for the reduction of their operational and maintenance costs, are targeted towards changing the technologies and using reliable materials that provide for the simplification of the connection schemes while keeping the same safety levels.

In this paper, we will discuss the possibility and opportunity to use MV / LV transformers directly at the consumers', and propose a method to reduce the losses in the distribution grids by replacing the centralized grid by a decentralized one.

- The centralized LV grid (created in Europe) is based on a large number of high-power transformers and an extended LV grid that serves 10 – 200 consumers;

- The decentralized LV grid (created in North America) is based on small transformers installed at the consumption centers or in their vicinity, with a limited or even without LV distribution system, while each transformer supplies 1 to 15 consumers according to the load density.

The distribution grids in most of the European countries have been significantly extended in the '60, so that they are now close to the end of their operational lifetime and must be replaced. Therefore, the need for investment is obvious and relatively urgent for the LV distribution grids, as much as the age of these facilities is added to by the constant increase in consumption during the latter years.

Loss calculation

Hereunder, we will analyze a supply scheme for a residential area located in a centralized LV grid, comprising a 10/0.4 kV, 400 kVA transformer that exclusively supplies households: 5 blocks with 488 apartments divided as follows:

block A – 8 entries, 160 apartments

block B – 4 entries, 80 apartments

block C – 8 entries, 160 apartments

block D – 1 entry, 44 apartments

block E – 1 entry, 44 apartments

The transformer has been commissioned in 1977 so its operational lifetime has expired.

On the other hand, the real evolution of the consumption and this estimated evolution under the PE132/2003 recommendations show that the current transformer cannot cover the increase in the household consumption for the given blocks of flats.

The household power consumption is constantly increasing at an annual pace of about 2% in the industrialized world and the consumption efficiency is high.

Therefore, we must think of a power supply solution that could take over the increased consumption while we would like to build some distribution grids with the lowest losses.

We will study the following options:

1. Development of the current transformer from 1 x 400 kVA, 10/0.4 kV to 1 x 800 kVA, 10/(20)/0.4 kV as for the next 10 years, the consumption may go up to 690 kVA. The LV grid will be of the centralized type and its scheme is provided in Fig. 1.

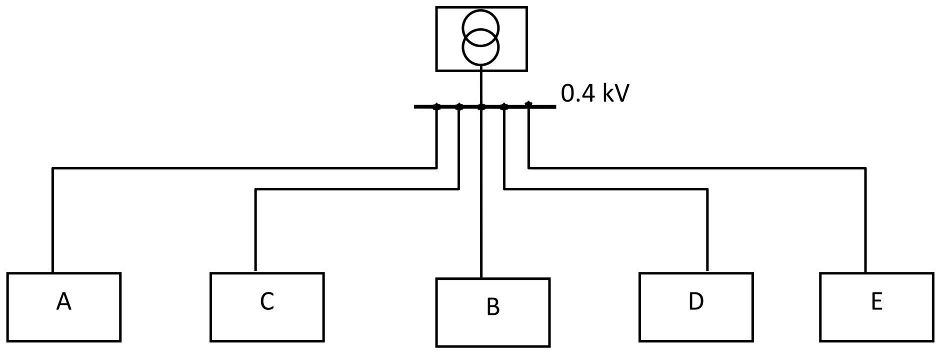

Fig.1. Centralized grid option

2. The LV grid will be decentralized through the installation of low-power transformers at the consumers', as closest as possible to the consumption weight center:

- 1 transformer 250 kVA for block A
- 1 transformer 250 kVA for block C
- 1 transformer 160 kVA for block B
- 1 transformer 63 kVA for block D
- 1 transformer 63 kVA for block E

The scheme is simple and reliable and shown in Fig. 2.

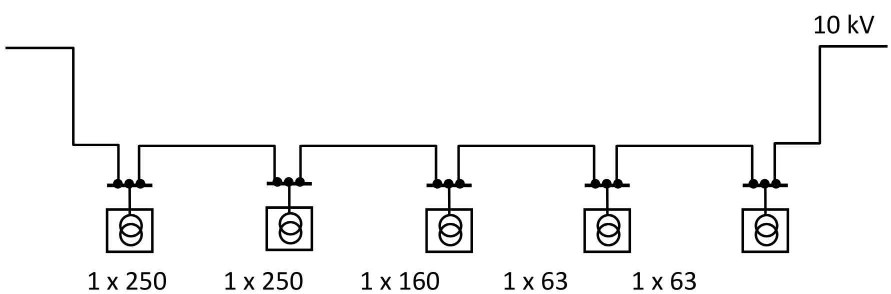

Fig. 2. Decentralized grid option

3. The LV grid which is being decentralized through the installation of very-low-power transformers (63 kVA) at the consumers' comprises:

- One transformer for every 2 entries at the 8-entry blocks
- One transformer for every 2 entries at the 4-entry block
- One transformer per block at the one-entry blocks.

Finaly, the scheme includes 12 pieces of 63 kVA transformers and is similar to the one at the decentralized, 5-transformer scheme.

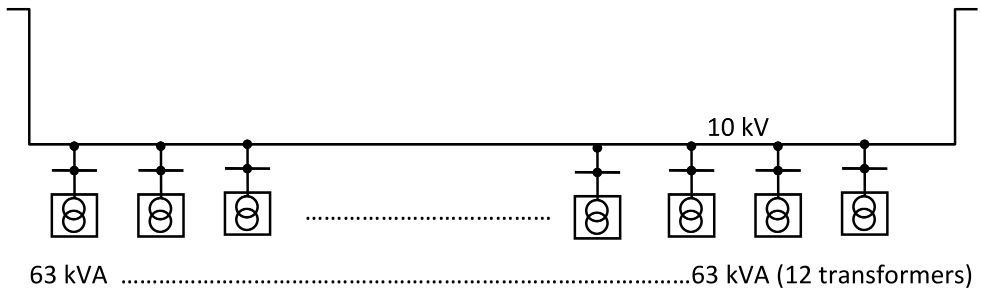

Fig. 3. Decentralized grid

The calculation results are shown below (Table 1):

Table 1

Comparative technical and economic calculation

	Costs (EUR)	Losses (kWh)	UTE (EUR)	UNI (EUR)	ROI (yrs)
Option I	110 000	96 322	160 000	- 60 000	14
	100%	100%	100%		
Option II	90 000	51 012	100 000	5 500	6
	82%	53%	64%		
Option III	190 000	57 945	210 000	- 75 000	11
	175%	60%	130%		

In Table 1:
UTE = updated total expense,
UTE = Costs + (0.4Costs + Losses Costs)x 6.14 (1)
UNI = updated net income,
UNI = $\sum(I-C)/(1+a)^t$, (2)
I = income
C = costs
a = update rate
t = current year
ROI = return of investment,
ROI = Costs / Income (years) (3)

The technical losses for option I are 8.5% for a carried energy of 11,332,000 kWh.

The commercial losses range between 7 and 10% according to the organization of the meter reading, billing/collection, and available IT resources.

1. 1. Reliability calculation

Currently, there is a worldwide increasing preoccupation for the energy quality and the social developments imply a higher dependence on the quality of the supplied energy.

The development of the electricity market leads to the increase in competition, reduction of costs, penalties for undelivered energy, reduction of maintenance costs, and an increased orientation to the client and his satisfaction.

Therefore, it is important to increase quality, yet with minimum additional costs.

The performance of an electric installation is evidenced by the MTBF (mean time between failures) component, which is the failure occurrence frequency. Throughout the operational lifetime of a system, it is customary to calculate various frequencies related to the occurrence of the failures:

- MTBF – mean time between failure – time between 2 consecutive failures in a repairable system,
  MTBF = $1/\lambda$, (years) (4)
  λ= failure rate
- MDT – mean down time – time between the failure occurrence and the complete restoration of the system (includes the time needed for finding the failure, repair and commissioning),
- MTTR – mean time to repair
  MTTR = $1/\mu$, (hours / interruption) (5)
  μ = repair rate

In this paper, we will calculate the reliability indicators corresponding to the 3 supply options for those 5 blocks of flats.

Studies options:

Option I

This is the current, centralized variant, where the 5 blocks are being supplied through a LV distribution grid from the 800 kVA, 10/(20)/0.4 kV transformer.

The related scheme is shown in Fig. 4.

The reliability calculation elements are:

- MV node consisting in a simple bar, 3 separators and a voltage transformer;

- MV/LV transformer;
- LV panels and LV cables.

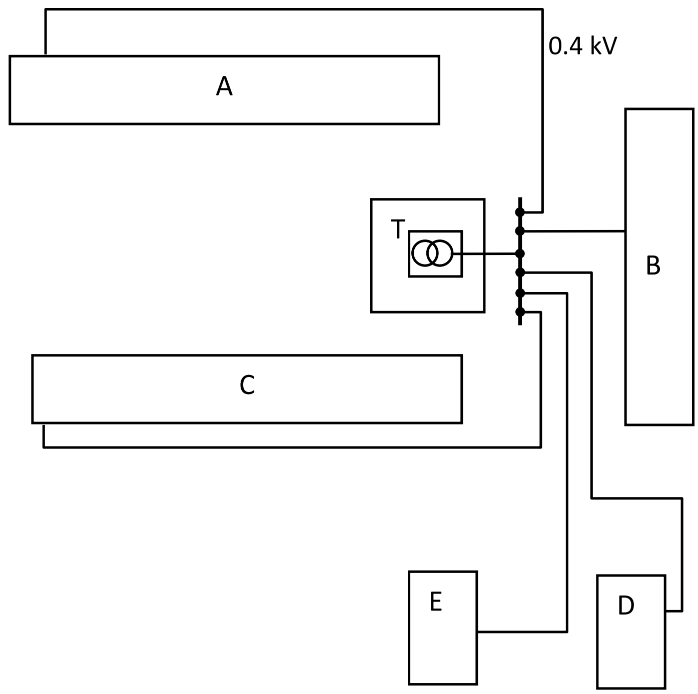

Fig. 4. Option I supply scheme

Option II

This is a decentralized LV distribution grid where the 5 blocks are being supplied through 5 MV/LV transformers as follows:

- 2x 250 kVA transformers (block A and block C);
- 1x 160 kVA transformer (block B);
- 2x 63 kVA transformer (block D and block E).

These 5 transformers are being connected into the existing MV grid by input–output connection. The related scheme is shown in Fig. 5.

The reliability calculation elements are:

- MV cables for the input-output connection of each transformer;
- MV separators on the connections;

- MV/LV transformers

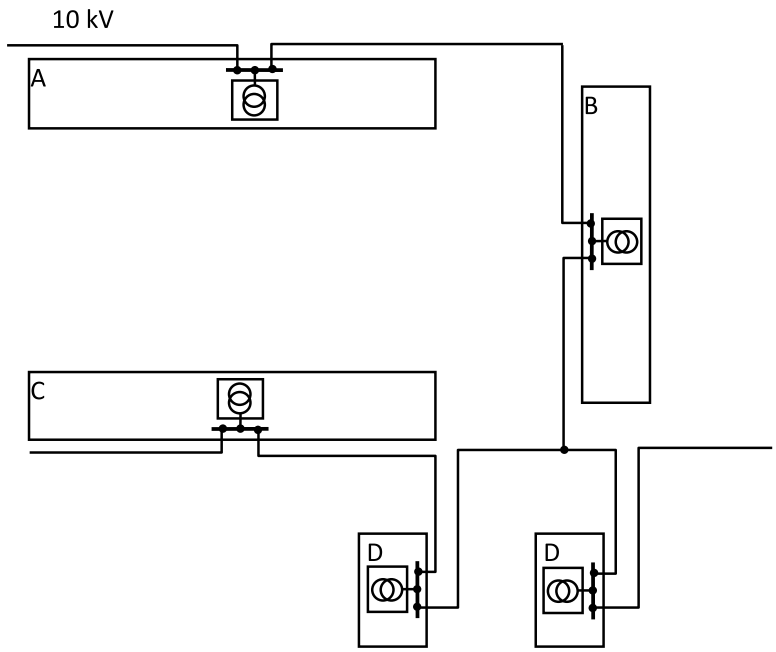

Fig. 5. Option II supply scheme

Option III

This is identical to the second supply option, but the 5 transformers are being connected into the existing MV distribution grid through a derivation plug. The reliability calculation elements are:

- MV cables for the connection itself of each transformers;
- Derivation plugs;
- MV/LV transformers.

The safety parameters in the calculation are:

- λ – success probability;
- μ – failure probability.

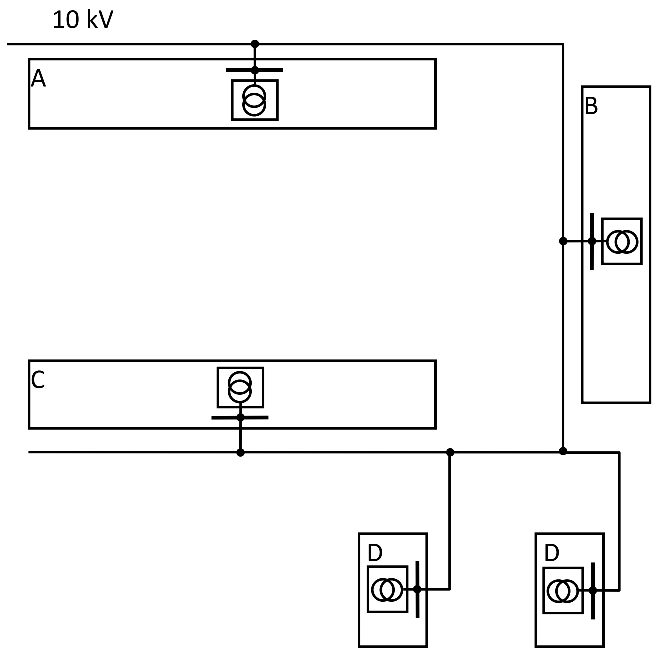

Fig. 6. Option III supply scheme

3. Interpretation of results

In order to discuss the results, we have built the following graphs that show, for each block in the 3 options:

- $U = \lambda/\mu$ = unreliability, (6)
- MTTR values (repair duration);
- Dmed values (average failure duration in one year);
- MTBF values (time between 2 consecutive failures).

The derivation plug option provides the lowest failure intensity for the consumers in that scheme in comparison to the other 2 options.

As regards the failure duration, these values are higher in option III compared to option II and in option II compared to option I. Their interpretation can only be made taking into consideration the aspects pertaining to the operational organization and technical facilities of the distribution operator for whom the study is being performed.

The results are concentrated in table 2 and Fig. 7:

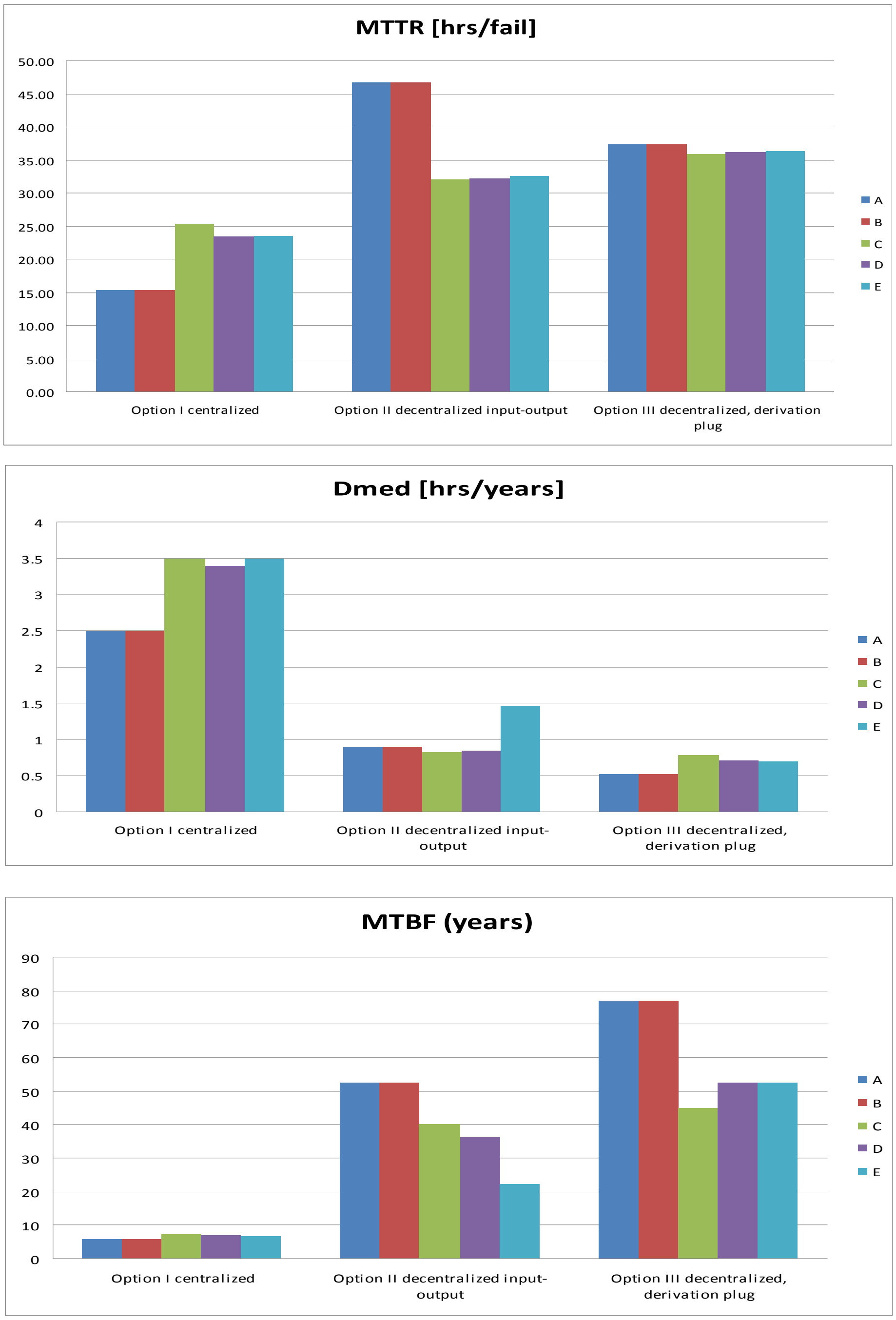

Fig. 7 – Reliability calculation results.

Table 2

Reliability calculation results

		n [fail/year]	U [E -4]	MTTR [hrs/fail]	Dmed [hrs/year]	MTBF [years]
Option I, centralized	A	0.167	2.9	15.4	2.5	5.9
	C	0.167	2.9	15.4	2.5	5.9
	B	0.14	4	25.4	3.5	7.1
	D	0.147	3.9	23.4	3.4	6.8
	E	0.149	4	23.5	3.5	6.7
Option II, decentralized input-output	A	0.019	1	46.7	0.9	52.6
	C	0.019	1	46.7	0.9	52.6
	B	0.025	1.6	32.1	0.82	40
	D	0.026	0.9	32.2	0.84	38.4
	E	0.045	0.9	32.6	1.47	22.2
Option III, decentralized, derivation plug	A	0.013	0.5	37.4	0.52	76.9
	C	0.013	0.5	37.4	0.52	76.9
	B	0.022	0.9	35.9	0.78	45
	D	0.019	0.8	36.2	0.71	52.6
	E	0.018	0.7	36.3	0.69	52.6

4. Conclusions

In the loss calculation chapter, we performed a comparative analysis of the power supply in the centralized and decentralized options, respectively.
In the reliability calculation chapter, we compared the centralized power supply scheme to the decentralized schemes (input-output and derivation, respectively).
The decentralized solution offers much better results than the centralized solution in terms of grid losses (47% lower) and reliability (failure density is 8-9 times lower and the failure hours/year is 4-5 lower).
The power distribution grid operators on the market now have:

- A grid with a certain history and technical characteristics
- Their own development strategy
- A certain customer profile
- Regulatory constraints.

Energy efficiency becomes one of the issue inputs.

This study is proposing a method that can be considered in detail within a pilot project specific for a given area.
The paper itself is a calculation tool for the analysis of the options.
The considered subject – energy efficiency – is no more a challenge as it is a component of the energy policies of the operators on the international energy market.

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