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Energy efficiency of distribution transformers in Europe

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Abstract*—*Losses in distribution transformers account for almost one third of overall transmission and distribution losses. Previous European Copper Institute studies indicated that improving energy efficiency of existing European stock of transformers by 40% would result in about 22 TWh energy savings equivalent to about 9 million tonne of CO2eq. SEEDT is one of the projects developed under Intelligent Energy – Europe programme which converts EU energy policy for today's energy challenges like energy efficiency. One the main goals is to update and scrutinize knowledge about energy efficiency in distribution transformers in Europe. This paper presents findings of analysis of existing situation.

Keywords-distribution transformer, no load and load losses, energy efficiency

I. INTRODUCTION

The overall objective of SEEDT project is to promote the use of energy efficient distribution transformers, which can be profitable for investors, and by contribution to European Community energy saving potential, may help to fulfill EU energy policy targets. Strategies will include proposals for labeling, mandatory standards or voluntary agreements and development of different dissemination mechanisms.

One of the SEEDT deliverables will be analysis of existing situation of distribution transformers in Europe. The analysis covers three out of four biggest EU countries; France, Germany, Italy, but also Greece, Poland, Spain and partly Scandinavia and Central Europe. The rest of EU-25 is result of our estimate and extrapolation from the collected data from above mentioned countries and regions.

Distribution transformers operated and owned by electricity distribution companies are responsible for supplying about 70% of low voltage electricity to final users and represent about 80% of distribution transformers stock, see fig. 1. Practically almost all electricity to household and commercial sectors is distributed by electricity distribution companies. The transport sector is dominated by railways which do not operate traditional distribution transformers (usually 3 kV or higher). In industry, about 50% of devices and systems are supplied from medium voltage level. Almost half of the non-household and non-services sector's electricity low voltage consumption is supplied through transformers owned by electricity distribution companies (utilities) and the remaining part are privately owned (usually referred to as industrial) distribution transformers.

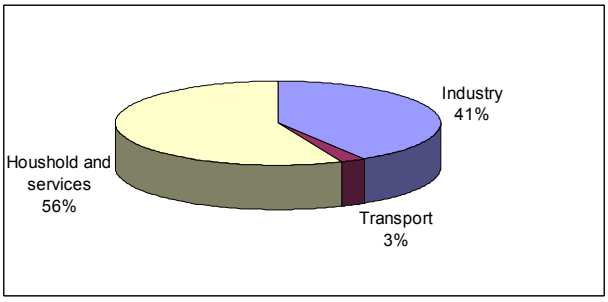


Figure 1. Division of final electricity consumption by sector, Eurostat 2004

II. EUROPEAN DISTRIBUTION TRANSFORMER CHARACTERISTICS

A. Population and rating

The overall population of EU-25 utility distribution transformers is estimated at 3,6 million units. Fig. 2 presents the utility summary on EU-25 countries and Norway. Both the number of installed transformers and their average rating is given. Population of privately owned (usually referred to as industrial) oil filled distribution transformers installed in EU-25 is estimated at 800 thousand units with 400 kVA average transformer rating. The number of privately owned dry type transformers is estimated at less than 200 thousand units but the average rating is more than double of oil private fleet i.e. slightly more than 800 kVA.

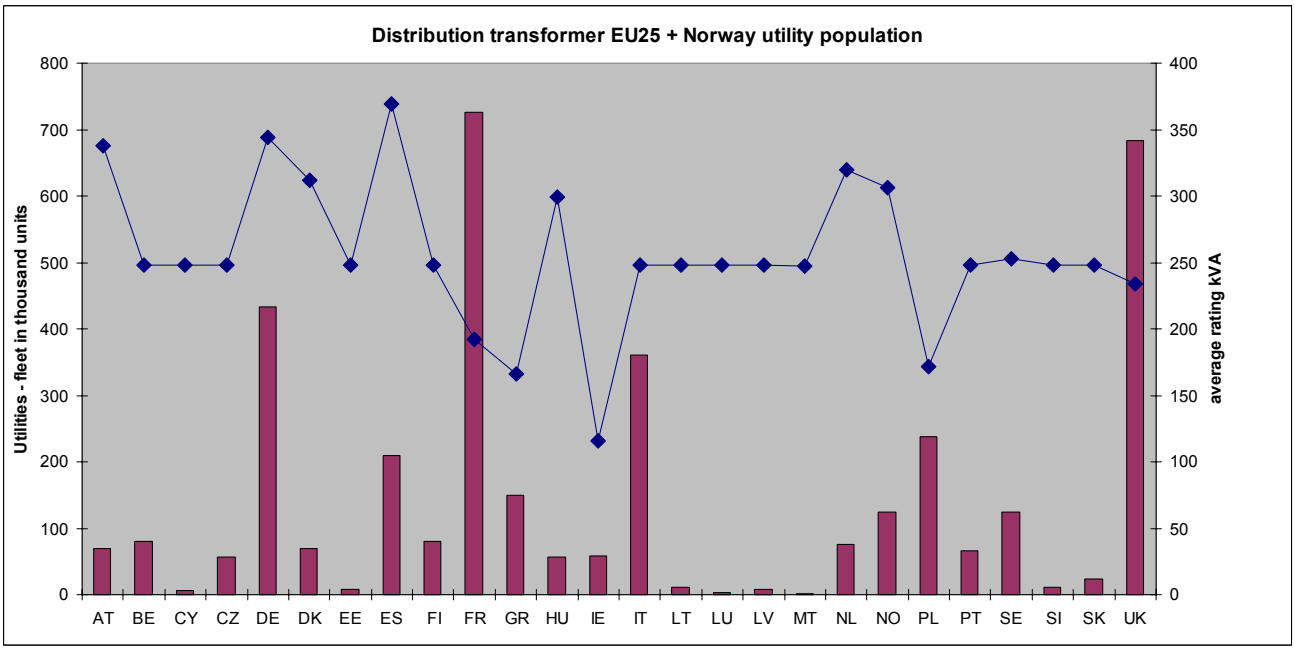


Figure 2. Population and average rating of EU-25 and Norway utility distribution transformers

Figure 3 presents the transformer size (ratings) in kVA relative distribution in population. All three sectors; utility, industry oil filled and industry dry type are covered. It is visible that utilities operate lower ratings especially in rural areas while industry and particularly dry type transformers have much higher ratings in average.

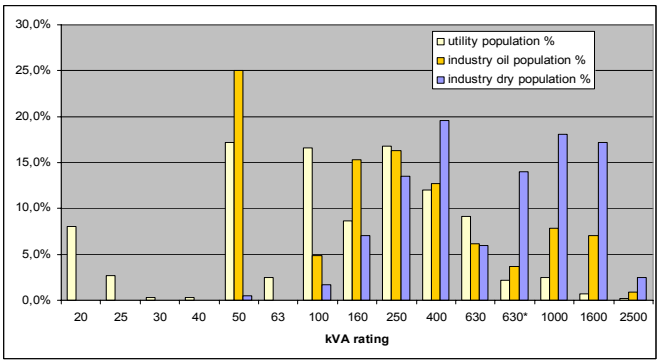


Figure 3. Ratings distribution across populations (* short circuit impedance of 6 %)

B. *Losses and efficiency*

The overall losses in EU-25 distribution transformers are estimated at almost 33 TWh. This corresponds well to previous studies, especially [1] where the whole European losses in distribution transformers are estimated at 55 TWh.

Table 1 presents the EU-25 losses in distribution transformers divided into three sectors. No load losses account for almost 70% of total losses.

TABLE I. LOSSES IN DISTRIBUTION TRANSFORMERS IN EU- 25

ΣPo (no load losses) utility fleet	15682 GWh
ΣPk (load losses) utility fleet	5890 GWh
ΣPkfleet / ΣPtotal utility fleet	27,3%
ΣPo industry oil	5399 GWh
ΣPk industry oil	2110 GWh
ΣPkfleet / ΣPtotal industry oil	28,1%
ΣPo industry dry	2521 GWh
ΣPk industry dry	1100 GWh
ΣPkfleet / ΣPtotal industry dry	30,4%
Ptotal	32702 GWh

The new distribution transformer market can be divided into units which serve new loads or have to replace old units which can no longer serve increasing electricity consumption and new units which for other reasons (low efficiency, damage) are replacing previously installed units. Utility new transformers (market) are only about 3% of existing fleet in terms of installed power (MVA). Industry oil filled transformers market is estimated at almost 5% while industry dry type transformers market at about 10% of existing fleet. Total losses in these new transformers are estimated at 1,24 TWh. Utility market accounts for about 500 GWh of losses.

Figures 4 and 5 present EU-25 countries details on utility distribution transformers losses (with load and no load losses division) and operating efficiency of utility distribution transformers (both existing fleet and efficiency) across EU-25. The proportion of no load losses to load losses is close to ratio of 3 while the average EU-25 countries operating efficiency is 93,38%. The general conclusion about focusing on reduction of no load losses especially for small lightly loaded transformers is justified.

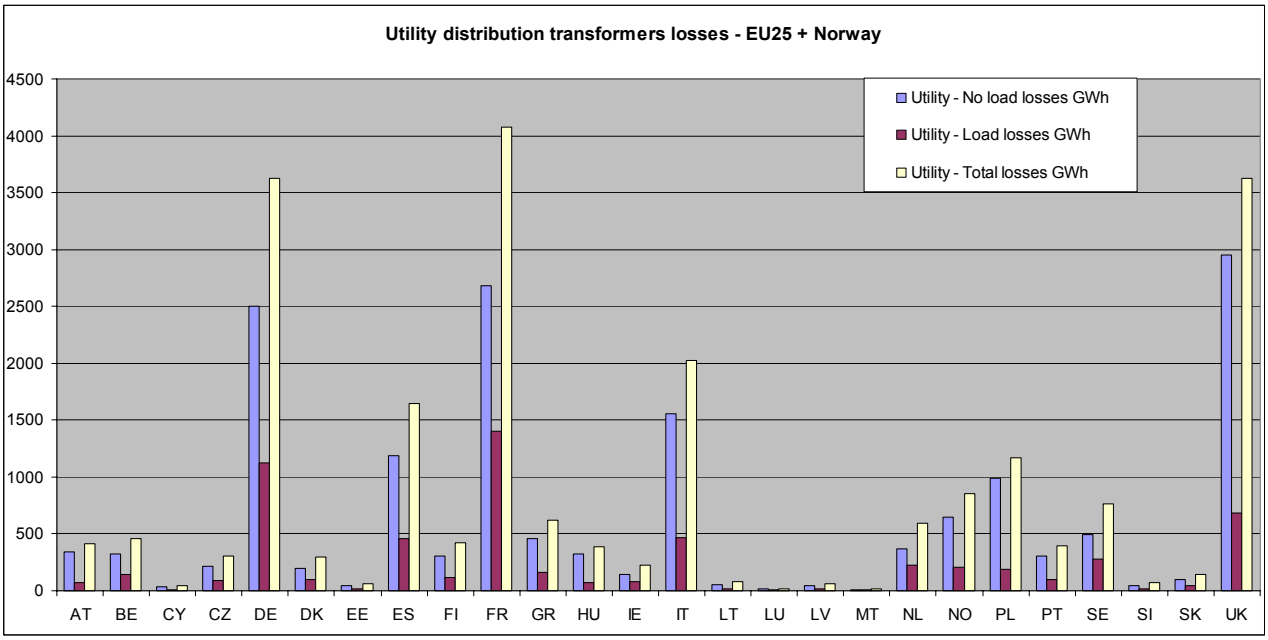


Figure 4. Utility distribution transformer losses in EU-25 and Norway

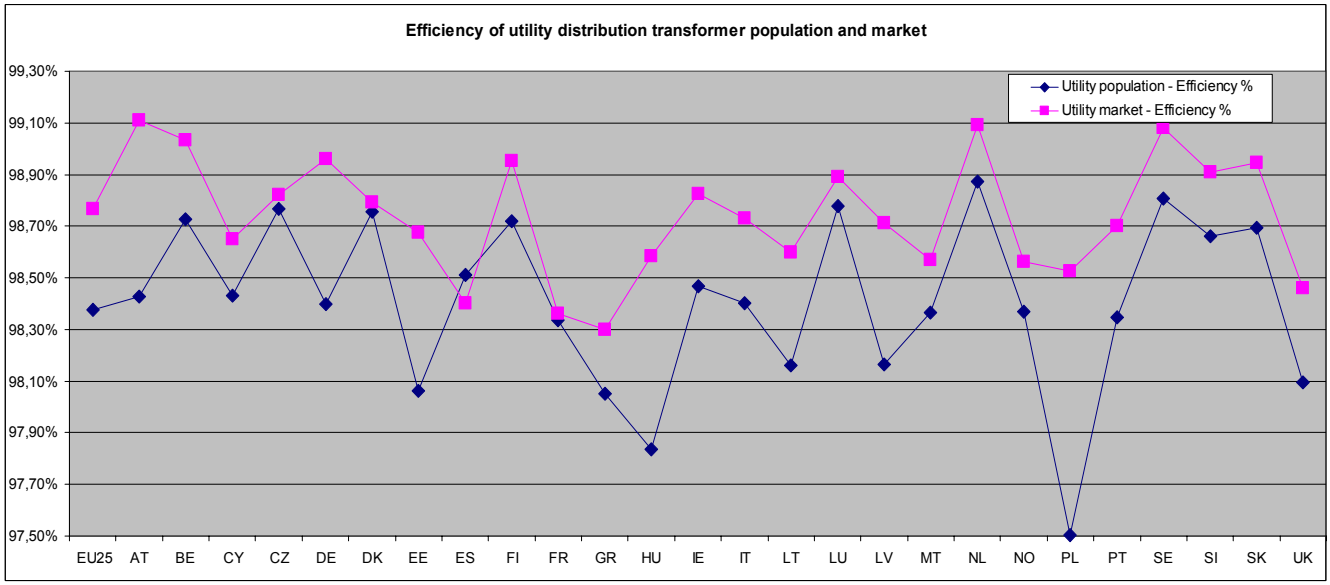


Figure 5. Utility distribution transformer fleet and market efficiencies

General observations are that utilities in different countries have different losses approach. Still a lot can be done to reduce existing level of both no load and load losses. Analysis of situation in utility and industry does not lead to very clear trends. However two observations are:

- Utilities pay more attention to reduction of losses in transformers than industry. However due to higher loading and larger units of industry population, the operating efficiencies remain at similar level.
- In very general, larger units are specified with lower rated losses. This trend is even more distinctly visible in case of load losses.

Figure 6 presents level of rated no load and load losses of distribution transformers in oil type transformers (utility and private). These losses are referred (as percentage) to AC' losses mix (according to HD428 [2] standard) or CkCo (new prEN50464 [3] Cenelec pre-standard, a draft, which approval is expected between 2008-2010) for most typical ratings. It is visible that private transformers have higher rated losses. The effort to reduce rated losses is more visible in case of larger transformers while for smaller ratings the additional effort to minimize no load losses is noticeable.

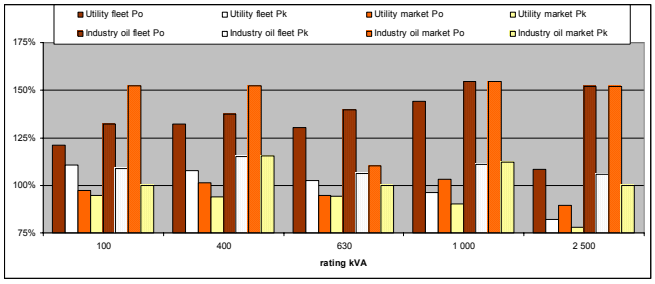


Figure 6. Comparison of rated load and load losses compared to AC' / CkCo level for oil type transformers

III. TIME PERSPECTIVE

For the last decades significant technological challenge in reduction of no load losses have been observed. They still account for about two thirds of total losses in distribution transformers. In the past this proportion was even higher reaching 80% share of no load losses in total losses. This proportion was however not even across Europe. In some countries or regions, because of changing load characteristics, situation might have been reversed.

Observing the case of Poland, applying gradually improved better grades of magnetic steel, technology of cut, decreasing laminations thickness led to reduction of these losses by factor of more than two during last 40 years. When comparing these losses with levels at the middle of the last century, the factor would be close to three. The figure 7 presents this development.

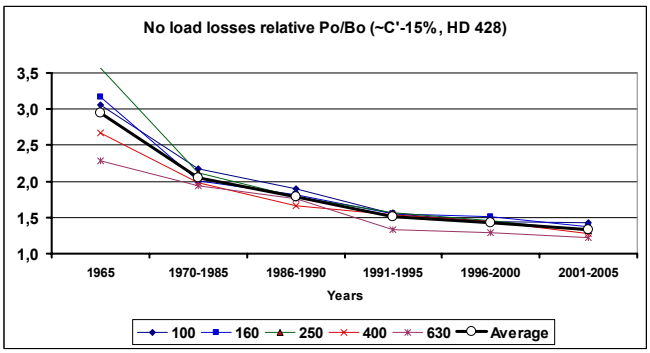


Figure 7. Decrease in no load losses in distribution transformers based on case of Poland – ratio of actual loss related to Bo class of prEN50464 (~C' - 15% of HD 428) loss.

In case of load losses reduction, the evolution of improvements is less spectacular. The figure below presents again case of Poland.

Last five years show up that rated load losses have gone up quite significantly. This might indicate that users pay more attention to reduction of no load losses (and accept higher load losses in order to keep the transformer investment costs stable) which still account for usually more than two thirds of overall losses in transformers.

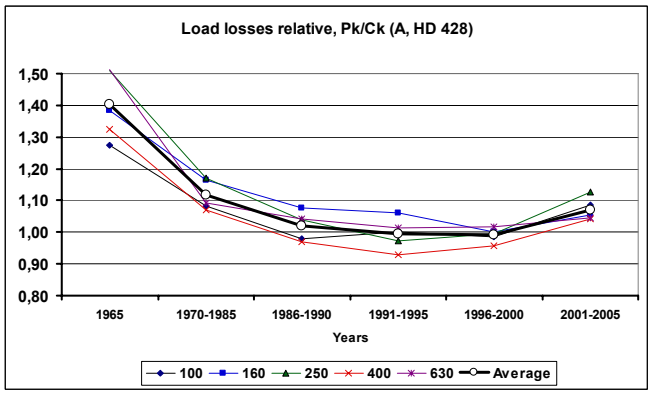


Figure 8. Decrease in load losses in distribution transformers based on case of Poland - ratio of actual loss related to Ck class of prEN50464 (A of HD 428) loss.

IV. CONCLUSIONS

Distribution transformers in Europe may have significant contribution to improvement of energy efficiency. SEEDT will investigate the savings potential of different scenarios which may have impacts on more efficient energy use but also climate change mitigation.

Proven solutions and technologies already exist which may reduce losses as much as to reach operating efficiency of units specified below AkAo equivalent losses levels. Transformer manufacturers may now very dynamically shape transformer designs to accommodate life cycle optimum cost [4].

Only few not very attractive incentives exist in Europe to help in buying efficient transformers. The policy (package) instruments have to be developed which will provide regulatory framework and / or valuable incentives for buyers to benefit from improved efficiency of distribution transformers.

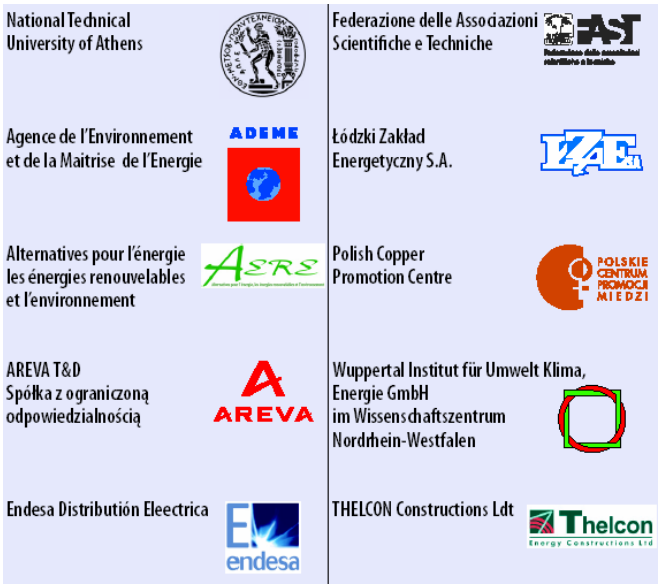
Elements of such a policy package [5] might include:

- regulatory mechanisms setting incentives and avoiding disincentives of electricity distribution companies
- voluntary or mandatory energy efficiency standards (maximum of allowed load and/or non-load losses of a transformer)
- labeling or declaration on the name plate of a transformer
- incentives from energy saving obligations or certificate schemes
- other (direct) financial or fiscal incentive
- more "soft" mechanisms like information and training, audits and procurement.

The SEEDT project will analyse these possible policy instruments, will try to estimate the potential impact they might have on energy savings by more efficient distribution transformers, and develop recommendations.

ACKNOWLEDGMENT

SEEDT Partners have all contributed to SEEDT knowledge inventory presented in this paper. These partners are:



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