INFLUENCE OF NEWLY INSTALLED SUPERTRAFO TRANSFORMERS ON THE LEVEL OF EFFICIENCY OF ENERGY DISTRIBUTION IN A DISTRIBUTION COMPANY

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SUMMARY

The paper presents the analysis of performance of the new generation of SUPERTRAFO transformers. Currently four such units are in operation installed in Łódzki Zakład Energetyczny S.A. (Power Utility in Łódź.) The paper presents both performance results and analysis of their influence on the operation of distribution network as regards the increase of electrical energy distribution effectiveness.

1. INTRODUCTION

Industry and distribution of electrical energy in a distribution company entails inevitable energy losses. The losses amounting to a few percent of energy sold to the users add to the energy bought by the company from its suppliers. The Urząd Regulacji Energetyki (Energy Regulation Office) agrees to include only some of the losses in electrical energy tariffs, the rest of them being the loss decreasing the profit of the enterprise. Consequently, activities which bring about a reduction of the loss rate are necessary. The rate can be reduced with the use of both investment and non-investment activities.

The non-investment activities are actually the splitting of medium and low voltage networks and maintaining the asymmetry in the low voltage network at some acceptable level. The investment activities include extensions of networks with the use of new transmission lines transformer stations.

These activities decisively influence a reduction of the loss rate in distribution network of a distribution company. Additional benefits coming from newly built stations come from the introduction of new generation transformers of significantly lower loss rate per unit. Such energy efficient transformers include SUPERTRAFO transformers series which are gradually being introduced in Polish networks. So far the practice indicates a justifiable extension of their use. This paper is an attempt at comprehensive justification of the benefits coming from a lot of aspects in connection with their use.

2. SUPERTRAFO PROGRAM ASSUMPTION AND PERFORMANCE DATA.

In four substations of Łódzki Zakład Energetyczny S.A., over twenty years old distribution transformers rated 400 and 630kVA 15.75/0.4kV have been replaced with SUPERTRANSFORMERS with considerably lowered losses. The measuring equipment for on-line monitoring of the load and service conditions of transformers have also been installed. Results of measurements are wireless transmitted via GSM modems to a main computer located in Transformer Division of IEN. Data are then processed and the results are shown by means of diagrams presented on supertrafo site: http://www.supertrafo.com.

The diagrams are updated daily and the results of the project have been presented increasingly since December 2001.

The whole methodology and algorithm of the data measurement, transmission and processing are presented on the web site. The figure 1 presents the example from the supertrafo site – energy cost savings in unit no. 4.

After several months of the project duration many conclusions about loading profile have been drawn up

Figure 2 presents comparisons between load factors of substation no. 1 and no. 4.
3. SIMULATION ANALYSIS

The analysis of the influence of the SUPERTRAFO units on the performance of a distribution company network was made with the use of specialist STRATY’2002 PLUS package software designed by the Technical University of Częstochowa [4].

The package is used to calculate the losses of energy in all voltage levels of the electrical network of a distribution company. An average Polish distribution company was used in the calculation and a simulation was done with the replacement of the units being currently in operation in the company with the units from SUPERTRAFO series. The other analytical parameter is the growth of load q.

Fig.3 shows the influence of the new units on the level of losses in transformer iron, Fig.4 – in transformer copper.

Fig.3. Influence of percentage share of new generation transformers on the level of losses in transformer iron

![Fig.3](image)

Source: Own research

The presented figures document a reduction in transformer losses supplying low voltage networks in a distribution company. They are not, however, the final results of such changes. With the use of the program one can also trace the reduction of losses in medium voltage networks – this is a result of smaller flows of electrical energy through that network due to lower losses in transformers. Fig.5 shows load losses change depending on different share of transformers of lower loss rate.

Fig.4. Influence of percentage share of new generation transformers on the level of losses in transformer copper

![Fig.4](image)

Source: Own research.

Fig.5. Influence of percentage share of new generation transformers on the level of losses in medium voltage networks.

![Fig.5](image)

Source: Own research.

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The final results – losses in the distribution company decreased from the level of 100,055 MWh to 93,752 MWh for 100% share of transformers of lower loss rates. The difference for the share of 0 and 100% of new transformers is 6,303 MWh, whereas the reduction of losses in transformers itself gives 5,732 MWh, additional effect of about 10% is the lower losses in medium voltage networks and 110kV.

The relationships presented above take into account only the fact of changing of percentage share of transformers. Fig.6 shows the two-element influence on the level of general losses which depends on \( u \% - \) share of new transformers (SUPERTRAFO) in power network and the dynamics of load changes \( q \).

The figure presented above and the analytical description enables the determination of energy loss changes; their absolute value can be seen in the following relationship:

\[
\Delta E_w = \Delta E \cdot w
\]  

where: \( \Delta E_w \) - absolute losses, taking into account the share of new transformers and growth of load

\( \Delta E \) - initial level of losses

\( w \) - share change rate of transformers and growth of load

The complete replacement of old transformers with new units reduces the losses to the level of 0.937 of previous losses, whereas for the growth of annual load of \( q=1.03 \), the level of losses in the network shall remain the same as long as about 25% of transformers is replaced with new highly efficient units. In such case we can talk about a specific compensation of electrical energy losses with the use of transformers from SUPERTRAFO series, resulting from greater flows of electrical energy.

Assuming that the service life of transformers is at least 30 years, we can make the following estimation of SUPERTRAFO program profitability:

\[
\frac{\Sigma \Delta K_T}{T_D} = \Delta K_{AE}
\]  

where: \( \Sigma \Delta K_T \) - difference of costs of SUPERTRAFO transformers and classic ones

\( T_D \) - service life of transformers, 30 years was assumed

\( \Delta K_{AE} \) - cost of reduction of network losses, described in the following equation:

\[
\Delta K_{AE} = (\Delta E_w - \Delta E_s) \cdot k_{jz}
\]  

where: \( \Delta E_w \) - level of output losses of electrical energy in a distribution company [MWh]

\( \Delta E_s \) - level of losses when SUPERTRAFO transformers are used [MWh]

\( k_{jz} \) - unit cost of purchase of electrical energy [PLN/MWh]

Relation 3 shows the state of balance; the undertaking is profitable if the right side of the equation 3 is bigger that the left one. The following is the result for the company in question with 3,500 replaced transformers and unit cost of purchased energy of 200PLN/MWh.
1.17m PLN < 1.26m PLN

As shown above, in this case the solution proved profitable. It should be mentioned that the calculations were made with the assumption that the difference of prices between SUPERTRAFO transformers and classic ones was at the level of 10,000PLN/piece. At this level the investment efficiency rate factor defined below 1 is as follows:

$$W_{SEI} = \left( \frac{\Delta K_{SEI}}{T_D} \right) \cdot 100\%$$

where: $r_c$ - percentage difference of prices of SUPERTRAFO and classic transformers

$$W_{SEI} = \frac{\sum \Delta K_T}{\Delta K_{SEI}} \cdot 100\% \quad (5)$$

$$W_{SEI} = 7.1\%$$

It seems that with the growth of production of new transformers their price is expected to decrease considerably, in case of difference between the transformers of about 35% (so far the analysis assumed the difference of costs at the level of 50%) the efficiency factor shall increase to $W_{SEI} = 34\%$, the general analytical description of the factor $W_{SEI} = f(r_c)$, where: $r_c$ - percentage difference of prices of SUPERTRAFO and classic transformers

$$W_{SEI} = -183,92 \cdot r_c + 99,228 \quad (6)$$

A similar analysis can be made in regards of each distribution company and where the efficiency rate factor is the highest the new SUPERTRAFO transformers should be introduced in the first place.

The efficiency can also be measured with the algorithm proposed in [5], or with the use of standard econometric means.

Additional aspect further improving the profitability of the solution are the ecological benefits. For example Kyoto ratification can have an impact on investments in energy efficient transformers by attracting additional cash flows from low carbon emission projects. If distribution utilities were allowed to trade emission reduction units, resulting from the investment in efficient transformers, the economics for the investment would shift dramatically towards more efficient units. If a utility would be able to trade emission reduction units at 4 Euro / ton CO2 (available now from the projects), the cumulative savings for one transformer 630 kVA would be like 800 Euro – as results from supertrafo in substation no. 4.

4. CONCLUSION

The presented paper shows the justification of introduction of transformers from SUPERTRAFO series to power networks as the efficiency of this solution fully confirms this direction of development. Additional advantage of the solution is its ecological benefits which make the undertaking even more attractive. It seems the project should be implemented in a lot of utilities in Central and Eastern Europe.

REFERENCES


1 Own research