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SOLUTIONS REGARDING THE REDUCING OF INTERNAL ELECTRICAL CONSUMPTIONS IN HYDRO-POWER PLANTS

BY

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Abstract. The level and the repartition of internal consumption in a small hydro-power plant with an installed power of 2 × 7.5 MW is presented, emphasizing the possibilities to reduce them. In the situation when both hydro units are connected to the system, only 53% of electrical consumption is useful energy in services, the rest representing energy losses: cables losses (6%), transformers losses (20%), and motors losses (21%). Because reducing energy losses in cables leads to unreasonably high costs, points in which we can intervene to reduce technical losses remain motors and transformers. But, as the number of motors from a hydro-power is high an option at hand is about to replace the transformers. The analysis from this paper will emphasize the major advantages of replacing old transformers with efficient transformers having small losses.

Key words: hydro-power plant; internal electrical consumption; efficient transformers.

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1. Introduction

The Seventh Framework Program from Research and Technological Development (FP7) define the way in which the objectives of the European SET-Plan regarding energy efficiency and savings can be performed.

Energetic savings are equally applied to all components of the power systems, even if we refer to industrial zones or to domestic ones (EC, 2007). Losses in transformers represents an area in which all factors were mobilized: owners, governmental organizations, technical and research committees. Studies performed lately showed that 2% of total electricity generated is estimated to be lost in distribution transformers. This represents about 5.5 TWh in Australia, 50 TWh in European Union countries, 90 TWh in China, 32 TWh in Japan and 61 TWh in United States (EECA, 2003). Mobilization to reduce transformers losses occurred, first, in technical committees and in non-governmental organizations all around the world. Then the funds for research and development were assigned and legal frame was adopted on governmental level. The broach of this problem was done uncommitted by each country. The result was a development of the research of top technology which enabled to obtain solutions for equipment with better energetic efficiency. An important step was done by means of standards updates in all countries and by including recommendations about design, measurement, testing methods, and aspects about choosing transformers by using Total Ownership Cost. This last aspect set off the importance of taking into consideration not only the initial price of acquisition or repair of a unit but also the total price of holding the transformer for 30…40 years or more.

Reducing losses in transformers is a point from which we can intervene to improve energy efficiency. There are three directions of intervention: reducing load losses, reducing no-load losses and reducing losses produced by operating the cooling systems. In what concerns load losses and losses produced by operating the cooling systems, design and workmanship and remain elements that allowed to obtain most improvements over years. Reduction of no-load losses has been the challenge which focused main strengths as they represent the main losses during the whole transformers life. It is noted that usually no-loaded losses are around 16…17% from total transformer losses, but its reached 55…60% when the load was only 40%, on old transformers. The nominal load taken into consideration in initial design of distribution transformers is around 30…40%. The design takes into account various technical aspects and reasons related to the future consumers development.

Therefore, no-load losses reduction was the main direction of the action. First step was improving the principles of technological design, improving cutting, insulating and assembling technology of each distribution transformer unit. However, the element that can make the major no-load reduction remains the selection of the core steel. Over the years the composition and method of making steel for transformer core has evolved from hot-rolled steel, to cold-rolled steel and than to cold-rolled grain oriented silicon steels (CGO). Today we talk about high permeability grain oriented steel (HiB) and recently about a new solution which was developed: amorphous iron (LET, 2005) This technology for obtaining ferromagnetic materials with amorphous structure represents the turning point in transformers no-loss reduction. Magnetic cores made from amorphous materials have superior magnetic characteristics, such as lower core losses and excellent temperature characteristics. Distribution transformers built with amorphous iron cores can have more than 70% lower no-load losses compared to the best conventional designs, and achieving up to 99.7% efficiency for 1,000 kVA units (Fig. 1).

In Fig. 1 C-AMDT refers to the distribution transformer with core from amorphous materials and load losses imposed by class C in HD 428 standards. The nominal temperature in operation is lower with 10°C and that have two positive aspects: the environmental impact is reduced and power consumption for cooling system is lower. This technology has been used in several hundred thousand distribution transformers in USA, Japan, India and China.

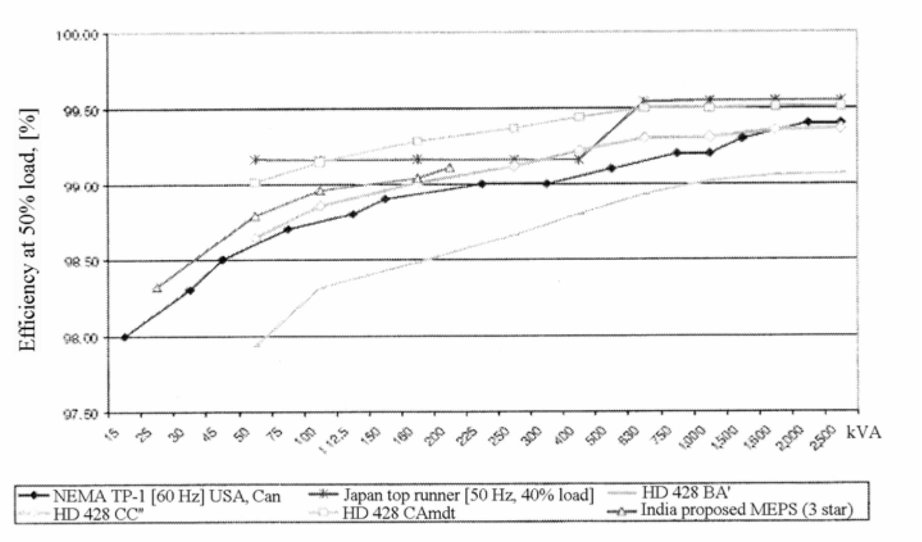

Fig. 1 – Comparison of requirements of several international standards in terms of efficiency (oil immersed distribution transformers with 50% load).

International actions continue on two converging directions. First direction represents a research direction for improving and reduce the price of technology for obtaining amorphous material. The second direction refers to organizational and administrative support for overhaul technical and legal support. In terms of research and development, the technology for obtaining cold-rolled grain oriented silicon steels reached this technological limits, while the price for amorphous ribbon on the market continue to decrease. Looking from this direction it is possible that AMT units to be more accessible soon.

2. Transformers from the Hydro-Power Plants

Supply internal services in a hydro-power plant with an installed capacity between 10 MW and 50 MW (plant has been designed in the period 1960…1990), were achieved through three distributed transformers, so called transformer for internal services (TSI). Rated power of these distribution transformers in a hydro-power plant of the Bistriţa waterfall is of 400 kVA. Normal operational scheme is with one unit in operation of feeding all consumers, groups and general services, one unit in "hot reserve" and one unit set apart in "cold reserve". Unit in "hot reserve", called TSI3, is powered from 20 kV local feeder. The other two units, TSI1 and TSI2, are powered from medium voltage bus bar of the plant. Periodically, for equalizing the number of operational hours, it is necessary to manually change units no.1 and no. 2. Unit "in service" became "in cold reserve" and unit in reserve become operational. In the situation where both hydro units are connected to the network, only 53% of energetic consumption is useful energy in services, the rest representing energy loss: cables losses (6%), transformers losses (20%), and motors losses (21%) (Fig. 2).

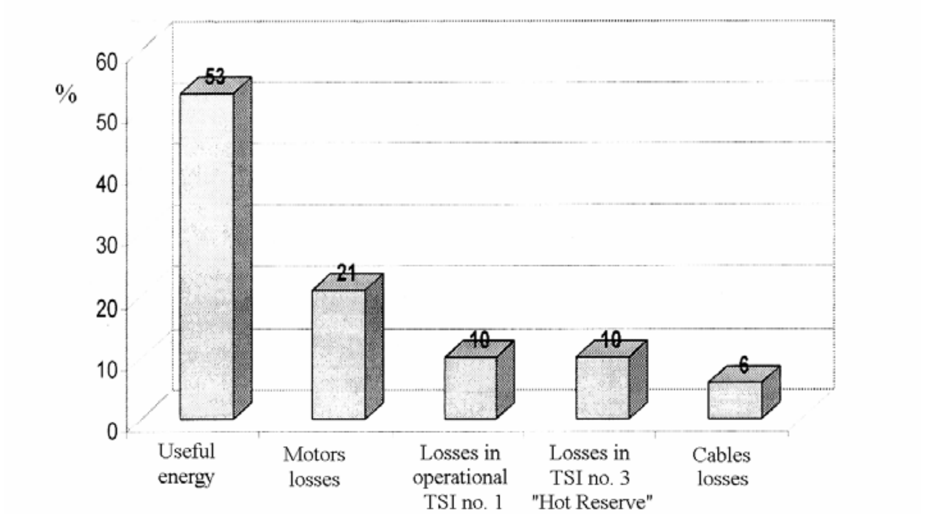

Fig. 2 – Share of total consumption during the summer period in the hydro-plant without considering the losses in evacuation power transformer.

Share of total internal consumption have insignificant changes in summer towards winter season or in operation towards stationary periods of the plant. Analysis showed that because of consumers' type with small installed capacity, frequent starts and stops and short operation time and because of their location in the power field, reducing energy losses in cables, would get unreasonably high costs. Points were we can intercede to reduce technical losses remain motors and transformers. Replacing existing transformers with high efficiency transformers represents the solution which will be proposed here. Thus, it will detail the situation of losses in transformers units.

Load profile on transformer units in the plant were recorded during a whole year. Data were recorded on 15 min period of time. The analysis highlights the following issues:

a) Average consumption varies between 32 kVA and 45 kVA, with 80 kVA as average maximum in summer month, and hang less than 90 KVA in winter month. This consumption is registered on the operational unit. The numbers of hours in which the unit so called “in hot reserve” must take over the load in the plant are under 1% of time.

b) This rated consumption of below 20% of nominal power transformer leads to the very low efficiency of the transformer.

c) No-load losses on transformer unit “in hot reserve” (TSI no.3 – 20/0.4 kV) is equal with no-load losses on transformer in operating (TSI no.1 – 6.3/0.4 kV). Total losses on TSI no.3 unit during an year are about 12.88 MWh/year compared with 15.28 MWh/year on unit in operation, TSI no.1. When this consumptions during all year is analysed we must take into considerations that TSI no.3 is operational on load only 1% per year. So we can say that 12.88 MW/year are only no-load losses.

In this point was not considered the power transformer which is the link between hydro-power plant and the grid.

Small hydro-power plants are quasi-basic producers in the grid. The operational regime is dictated mainly by demand power in the system and secondly by waterfall head available. The development of distributed renewable energy power plants will strengthen the operation regime for hydro-power plants. More of the small hydro units will by operated as top producers instead of quasi-basic one. Under these conditions the load on power transformer link on the grid will be proportional to the number of units operating in the plant, and with the load on each of these units. The rated power of transformer units is of 16 MVA. After we include the power transformer in analysis it will be obvious the importance we must give to the no-load losses in unit transformers.

Table 1

Share of Total Internal Consumption During the Summer Period in the Hydro-Plant with Considering the Losses in Evacuation Power Transformer, [%]

Case	Losses in evacuation power transformer	Useful energy	Motors losses	Losses in operational TSI no. 1	Losses in TSI no. 3 "hot reserve"	Cables losses
Normal operation regime	80	12	3	2	2	1
Peak load regime	83	13	1.6	1	1	0.4

Thus, in the Table 1 it is presented the share of internal consumptions in the hydro-electric plant, during summer conditions, taking into consideration the total losses. In the internal consumption, the power transformer of 16 MVA (110/6.3 kV) is included. Two cases are presented:

a) C a s e 1. Hydropower plant is in normal operation regime, with internal services feed from high voltage level (110 kV).

b) C a s e 2. Hydropower plant is in peak load regime, with internal services feed from high voltage level (110 kV).

If the internal services in the hydro-power plant (in normal operation regime) are fed by medium voltage bar (6.3 kV or 10.5 kV) through TSI no.1, only 20% of load represents consumption in power services. The usefully load consumption is 12%, 8% is represented by losses in power plant, losses which was detailed above. Remain constant losses in power transformer which are 80% of total losses. The nominal load of this power transformer can't be changed because its power is determined by installed power of hydro units. The only thing that can be changed is the nominal no-load losses on it. That why is very important, when the discussions are about rehabilitation the power plant, to take into consideration the Total Ownership Cost.

3. Solutions Regarding the Reducing Internal Electrical Consumptions

Analysing each transformer in operation for over 40 years, with similar units on the market, we can establish a series of observations and conclusions. Purchasing price of new transformer units, compared with the cost paid to achieved capital repairs of an old one is significantly higher, especially in case

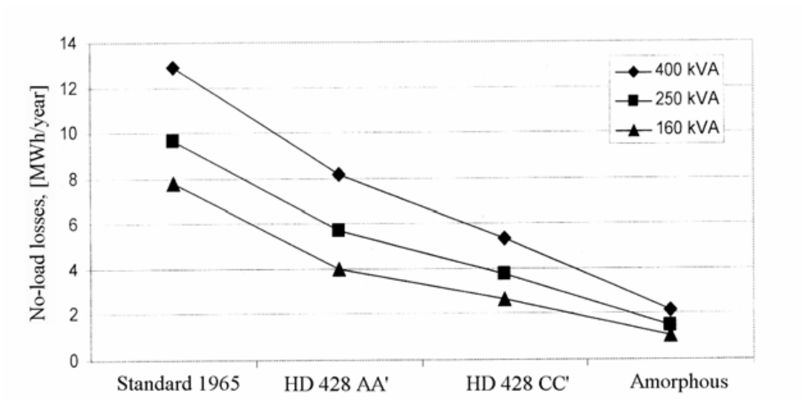

Fig. 3 – Evolution of the no-load losses in distribution transformers.

of power transformer. In this case the repair price can be below 30% of the price for the new units. Replacing existing units with new ones is to be considered in rehabilitations process. Keeping in operation an old unit for the next 30…40 years, means that we accept to maintain the same losses, especial the same no-load losses as being constant in maintenance costs.

When we analyse the distribution transformers used in internal services, the problems must be look ahead in other manner. The purchase price for this type of AMT units has become accessible. So, primary we make a load profile analysis in the most unfavourable situation encountered in operation, analysis of nominal operational scheme in the plant and the solutions offered by the new modern diesel-groups. A reduction of rated power capacity installed in distribution transformer is to be considered. In Fig. 3 it is presented a comparison of no-load losses due to new technology in achievement of magnetic cores. Thus, it can be observed the advantage of reducing the rated power of 400 kVA to 250 kVA, a possible solution that ensures technological consumption.

Very important is to establish basic economic and technical criteria of the acquisition. Today, the acquisition of the power transformers on the market is realized on technical criteria, but for a minimum purchase price. A correct acquisition, in terms of technical and economic criteria, must be based on

a) total operating cost of the transformer including the cost of acquisition, operating, maintenance and decommissioning costs;

b) obtaining a maximum efficiency in operation;

c) validation of the technical parameters at the putting into operation of the transformer.

4. Conclusions

Existing transformers on the market, both distributions and power ones, have higher efficiency than the transformers operating in for 30 or 40 years in the power plants.

Related to purchasing price, replacement of existing transformers does not represent a purpose itself but it must be correct analysed in terms of Total Ownership Cost if we take into consideration another 30…40 years of life.

Establishing technical and economic criteria that will lead to a decision in the selection process of a new transformer unit is essential in optimizing energy consumption and also in saving costs during entire life.

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SOLUȚII PRIVIND REDUCEREA CONSUMURILOR ELECTRICE INTERNE ÎN HIDROCENTRALE

(Rezumat)

Se prezintă nivelul şi repartizarea consumului electric intern în instalațiile aferente unei hidrocentrale cu o putere totală instalată de 2 × 7.5 MW, subliniindu-se totodată şi posibilitățile de reducere a acestuia. Analiza efectuată evidențiază avantajele majore ale înlocuirii transformatoarelor vechi cu transformatoare eficiente care pot contribui la scăderea considerabilă a consumului electric din serviciile proprii ale hidrocentralei.