How to optimise the cost of transformer use and save money

The targets of the 20/20/20 EU program led to general performances review of the transformers and introduction of the Ecodesign Regulation

ABSTRACT

The targets of the 20/20/20 EU program led to general performances review of the transformers and introduction of the Ecodesign Regulation in order to ensure that new transformers put into service in the EU become progressively more efficient. The resulting energy savings have been estimated at 16 TWh per year from 2020 onwards, which corresponds to 3.7 Mt of avoided CO_2 emission.

KEYWORDS

ecodesign, efficiency, losses, CO_2 emission, total owner cost

The targets of the 20/20/20 EU program led to general performances review of the transformers.

The Ecodesign Regulation, adopted in 2014 and its new amendment adopted in 2019 by the European Commission, ensure that transformers become progressively more efficient as new power transformers are put into service in the internal EU market.

Transformers have to fulfil minimum energy efficiency requirements starting from July 1st 2015. The second step in the energy efficiency improvement process is to be made in 2021. The resulting energy savings have been estimated at 16 TWh per year from 2020 onwards, which corresponds to 3.7 Mt of avoided CO_2 emissions. This is equivalent to saving half of the annual electricity consumption of Denmark (32 TWh per year).

This review of performance, done by the amendment adopted in 2019, has also shown how the transformer specifications should be implemented to achieve economical benefits for the user.

In this article, we will develop an approach regarding how to specify a transformer to optimise the total owner cost for the user by mastering the energy performance phenomena.

The range of transformers in the EU is divided into 2 families, one for repetitive transformers in general with a nominal power less than 3,150 kVA, in which the standardization of components is relevant in terms of cost and another, without repetitive transformers (without series), in which the standardization components are not possible and not relevant. Therefore, fixed losses for transformer which have a rated power less than 3,150 KVA, identical components and optimal prices for the users have been chosen. The standardisation body has decided to introduce peak efficiency index (PEI) for larger transformers above 3,15 MVA to reduce the cost of use if the user is able to define its load factor well during the period when the transformer is in use.

After a long study, the European commission with main stake holders or their representatives (TD Europe for the manufacturers, ENTSO for utilities, CENELEC for standardisation bodies, etc.) have decided to fix two levels of efficiency for the transformers above 3,15 MVA (corresponding to two levels of peak efficiency) applicable for the leaner requirements from 2015 and for the stricter requirements to be applied starting from 2021.

The PEI technique that is used to determine the energy performance of the transformers is a new method created to easily guide the user to reduce the total cost of use. Unfortunately,

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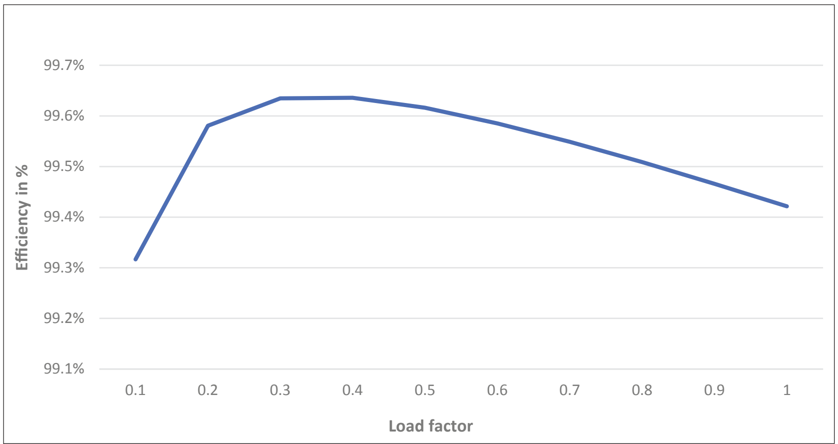

Figure 1. Transformer efficiency IEC method

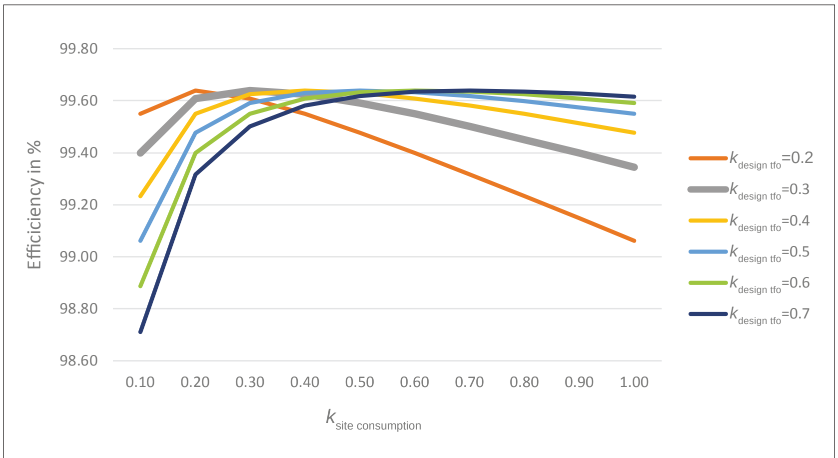

Figure 2. Efficiency *f* (site consumption and $k_{\text{design tfo}}$)

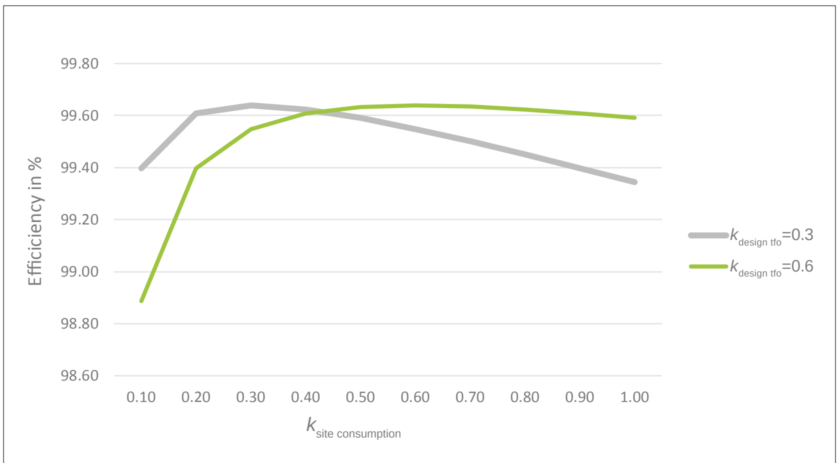

Figure 3. Efficiency *f* ($k_{\text{site consumption}}$ and $k_{\text{design tfo}}$)

currently that method is not well known and is too complex to follow. We will explain this method in detail in continuation.

The reader will probably remember the curve of transformers efficiency.

The efficiency of transformers is given with the reference to the IEC standard by using the formula:

Efficiency = Rated power x K_{factor} - (No load losses + Load losses x K_{factor}^2)/ (Rated power x K_{factor})

Where K_{factor} is the load factor of the transformer (load consumption on the site).

The PEI, that is now common term used by specialists, is at the top of the curve and allows better efficiency for a load given (0.3 of the rated power in this case) as shown on the curve in Figure 1.

This curve has been drawn for a given level of no load and load losses.

The peak efficiency is therefore the derivate of the efficiency formula that shows the maximum of the transformer efficiency. This value is reached when the square of the ratio of *No_load_losses* and *Load_losses* is reached. We can call this value "$k_{\text{design tfo}}$".

$$k_{\text{design tfo}} = \sqrt{\frac{No\_load\_losses}{Load\_losses}}$$

That means that for a rated power given, a transformer can have, for the same value of minimum efficiency, an infinity of solutions to the square of the ratio between the no load losses and the load losses as shown in the Figure 2.

However, the optimum cost of the transformers is given by a certain value of ratio of the losses and large cost differences that exist between a transformer determined with a "$k_{\text{design tfo}}$" of 0.6 and a "$k_{\text{design tfo}}$" of 0.3-0.4 which is around the optimum of cost in most of the cases. Without any specifications, the suppliers of transformers will usually offer transformers that are optimal when it comes to price, but not those that are optimal for the user.

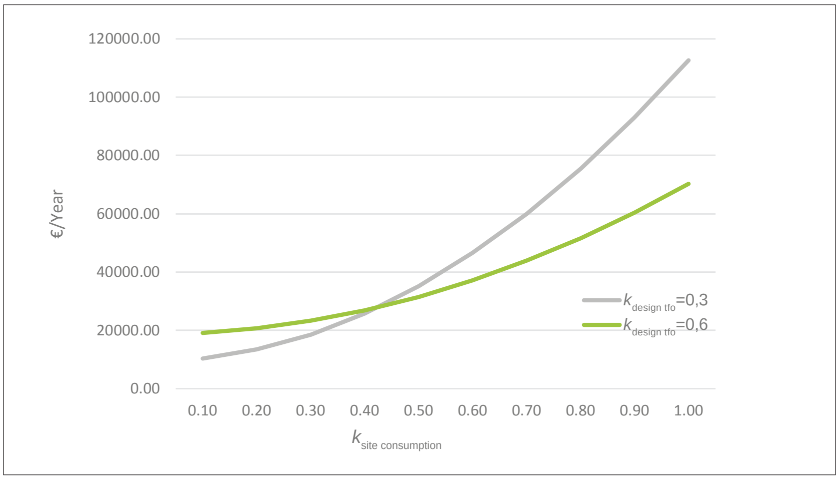

Figure 4. Cost of usage for one year period

The resulting energy savings have been estimated at 16 TWh per year from 2020 onwards, which corresponds to 3.7 Mt of avoided CO_2 emissions, equivalent to saving half of the annual electricity consumption of Denmark

The example in the Figure 3 depicts the efficiency versus load factor for two different values "$k_{\text{design tfo}}$".

For example, a user that needs to have a 12 MVA consumption will choose a 20 MVA transformer. If the user does not indicate "$k_{\text{site consumption}}$" (0.6 in this case), then the interest of the manufacturer should be to sell a transformer with a "$k_{\text{design tfo}}$" of 0.3 to have the lower cost, which will result in the cheaper price, in order to get the order.

We can see in Figure 4 that the curve in grey is representing a 20 MVA transformer designed with "$k_{\text{design tfo}} = 0.3$" and used on site at "$k_{\text{site consumption}} = 0.6$" which has the cost of use of 46,500 euros per year while a transformer designed with a "$k_{\text{design tfo}} = 0.6$" curve in green will have a cost of use of 37,200 euros per year. The cost of energy taken for this calculation was 0.1 € per kWh. This equation leads us to conclude that the energy savings for a period of 40 years will amount to at least 250,000 euros taken into account the currency devaluation of 2 %.

That means that the users have to determine the load factor "$k_{\text{site consumption}}$" of their new transformer for a long time period and choose the "$k_{\text{design tfo}}$" accordingly.

However, it can be difficult and even very expensive to design a transformers with "$k_{\text{design tfo}}$" of 0.8 and then if the "$k_{\text{site consumption}}$" request is above 0.6, the user, in most cases, will have to choose the highest rated power that allows the decrease of this value.

For example, if the user has a need for 16 MVA for a longer period they most probably have to choose a transformer with a rated power around at least 31.5 MVA which has a "$k_{\text{design tfo}}$" around 0.51.

The regulation and the standards for transformers indicate the value of the PEI and the load at which it occurs.

Conclusion

To optimize the cost of the use of transformers, the users must be aware of energy consumption and order transformers with a "$k_{\text{design tfo}}$" which should be equivalent to the "$k_{\text{site consumption}}$". Huge savings in cost and CO_2 emission reduction can be made during the life span of the transformers.

In an upcoming article we will show how to optimize the cost of use of power transformers below 3150 kVA that have fixed losses.

Contact:
Michel SACOTTE
SACOTTE.PARTNERS
For additional information please contact
sacotte.partners@gmail.com

Author

Michel Sacotte is the CEO of SACOTTE.PARTNERS, a new company created just after his retirement from Schneider Electric. Michel Sacotte was the Vice President of Standardization & Prescriptions for Transformers at Schneider Electric. He has founded his own company to share his knowledge and expertise around the world and create new software. He graduated from the Ecole Nationale d'Ingénieurs de Metz. Since 1975, his work included positions such as Chief Engineer of the Technical Department, R&D Manager, Technical & Quality Manager, and Technical/Purchasing/Quality Manager/Industrial in France Transformers for 11 years, and R&D Vice President at Schneider Electric's Transformers Line of Business for 7 years. He acted as a Working Group convener of several IEC and Cenelec standards for distribution transformers (dry type, self-protected filled transformers, wind turbine application, energy efficiency, etc.). He has been a major contributor to the IEC Standardization work surrounding the transformers. He was Chairman of the French National Committee for UTE and Manufacturers (Gimélec) of transformers. Michel was Chairman of the T&D Europe for transformers activity. He has filed numerous patents covering various aspects concerning distribution transformers.