ANALYSIS OF ENERGY EFFICIENCY OPTIMIZATION IN DISTRIBUTION TRANSFORMERS CONSIDERING REGULATION CONSTRAINTS

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ABSTRACT

The European Union has put effort on providing suitable policies in order to guarantee the requirements for the "20-20-20" action plan and this has been a clear move after the ratification of the Kyoto Protocol. Electrical networks can offer a wide span of action for the improvement of energy efficiency and due to their installed number, distribution transformers are a good field to study. Energy policies should also guarantee the optimization of energy efficiency and this work presents a MATLAB based tool that maximizes the profit for a utility in case of changing a distribution transformer, considering the optimization of energy efficiency and the constraints of the Spanish Royal Decree 222/2008.

INTRODUCTION

Transformers are one of the major components of a distribution system and their losses represent almost the 30% of the overall losses in transmission and distribution systems. In Europe T&D losses consume between 4 and 15% of generated electricity and such a large span suggests a huge improvement potential [1].

A cut in transformers losses would also represent a cut in CO_2 emissions and this point should be seen as strength for Europe's Energy Policy, considering the "20-20-20" objectives set by the European Community [2]. The target in energy efficiency will be hardly met without enhancing energy savings in T&D systems.

It is then clear that regulation policies should be the way to achieve losses reduction in T&D systems and distribution transformers. This work is focused on how distribution losses are treated in the Spanish Regulation policy and how this policy can affect decisions making for a utility when it comes to install distribution transformers.

The aim of this article is to study a specific case, considering the constraints listed in the Spanish Royal Decree 222/2008 [3] for the maximum revenue that the utility can receive, established as a percentage that cannot be topped. Technical constraints are also considered, such as demand fluctuations and transformers breakdowns.

SPANISH REGULATION POLICY AND OPTIMIZATION PROBLEM

In electrical network the aim of regulation is to facilitate competition over the networks with the final aim of improving their efficiency and the Spanish Regulation Policy is focused on supporting three issues for electrical networks. The main issues presented in the RD 222/2008 are the guarantees for system security, the incentive to quality supply and loss reduction in distribution network. In the distribution market, the regulation period is set to be 4 years and the remuneration is different for each utility, considering the parameters presented in the RD 222/2008. Remuneration procedures are valid for any utility and for each one a reference remuneration level is set.

A utility can face two different issues that may bring to new distribution transformers installation: changes in the demand (for instance, growth) and possible breakdowns that might be suffered during the revenue time. In case the utility should undergo a decision making process, considering all the constraints that the regulation policy implies, a Matlab based program was developed, meant to be a decision help tool, Figure 1. The program works using lineal optimization techniques and it considers different transformers efficiency classes.

The final objective of the analysis is to balance two needs: the growth of energy efficiency for the company transformers and the investments required to satisfy the demand growth and the possible breakdowns in transformers. The transformers replacement is studied considering the policies introduced by the regulation and it is discussed whether the regulation considered leads to an optimal decision making, considering energy efficiency as a weight factor.

APPLICATION CASE

The application case is the optimization of transformers owned by a company, considering three different energy efficiency classes: the Spanish standard A-B', another class better than the standard class C-C' and high efficiency transformers, such as AMDT. It is also possible to add a fourth non standard class that the company may wish to install.

The interface is presented in Figure 1 and it shows how the necessary data are inserted in order to solve the problem. This is a linear optimization problem due to the nature of the objective function and the linearity of the given constraints.

$$Pr = 0.0352\ €/kWh$$

The mathematical formulation is represented below and it explains how the benefit is maximized, Equation 1, considering technical constraints for demand growth and fail rate, Equation 3, and it shows also how the remuneration constraints for losses is treated according to the constraints of the RD 222/2008, Equation 2.

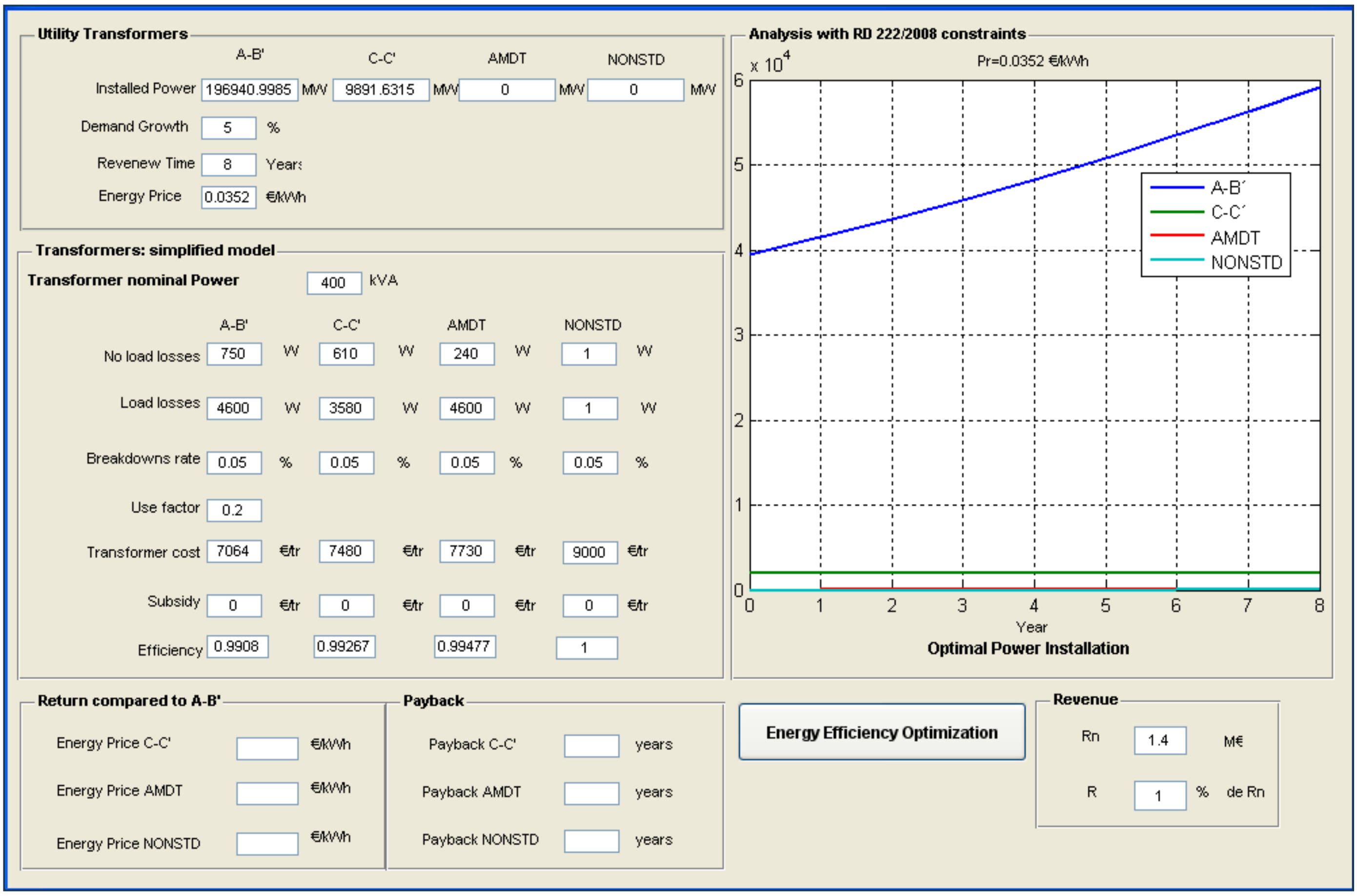

Figure 1: Matlab Interface

The objective function is the benefit maximization for the company and it is represented by Equation 1. The benefit maximization is obtained with the subtraction of the installed power in a year to the previous one, considering both new transformers purchase and losses compounding. Equations from 2 to 4 represent the constraints of the problem.

This benefit can be represented in euros applying the losses price given by Spanish Market Operator OMEL to set the reference price. This reference price has been evaluated using the annual average monthly prices of 2009 and its value is:

$$\max z = -0.8 \cdot Pr \cdot 8760[\textstyle\sum_{i=1}^{N}(x_i - x_i')(1-\eta_i)] + -\sum_{i=1}^{N} C_{Ti} \cdot (x_i - x_i'') \qquad (1)$$

$$-0.01 \cdot R_{n-1}^{d} \leq 0.8 \cdot Pr \cdot 8760[\textstyle\sum_{i=1}^{N}(x_i - x_i')(1 + -\eta i) \leq 0.01 \cdot Rn-1d \qquad (2)$$

$$\textstyle\sum_{I=1}^{N} x_i \geq \sum_{i=1}^{N} x_i' \,(1+\delta) \qquad (3)$$

$$x_N \geq 0 \qquad (4)$$

Where:

- d: Utility
- xi: Transformer power installed at year n
- i: Transformer efficiency class
- x'i: Transformer power installed at year n-1, no failure
- x''i: Transformer power installed at year n-1, with failure
- Pr: Energy loss price
- CTi: Cost of the i-th transformer
- δ: Demand growth
- η: Efficiency

SIMULATION RESULTS

Simulations have been performed using the interface created and presented in Figure 1.

According to the constraints of RD 222/2008, the increase of energy efficiency is not guaranteed, as shown in Figure 2. In fact, in case a transformer suffers a failure or the demand increases and new transformers are needed, the utility finds more profitable to install a transformer that does not increase the overall energy efficiency.

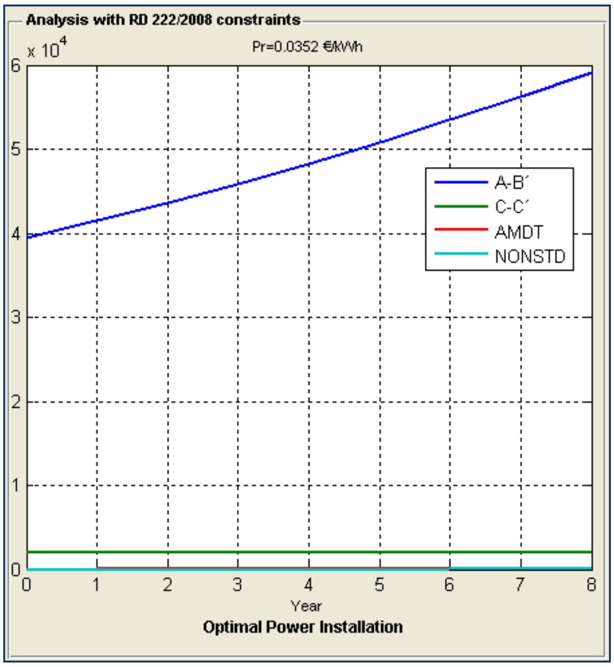

Figure 2: Simulation results, no changes in prices

This result is due to the fact that the price of a transformer is still the most weightful value in the optimization and the current policy does not support the installation of high efficiency transformers.

Two options can be considered in order to ensure the increase of overall energy efficiency:

- A change in the energy price that would guarantee the installation of higher efficiency transformers when needed
- Direct subsidies to buy high efficiency transformers

Any of the two cases presented above leads to an increase of the overall energy efficiency, as presented in Figure 3.

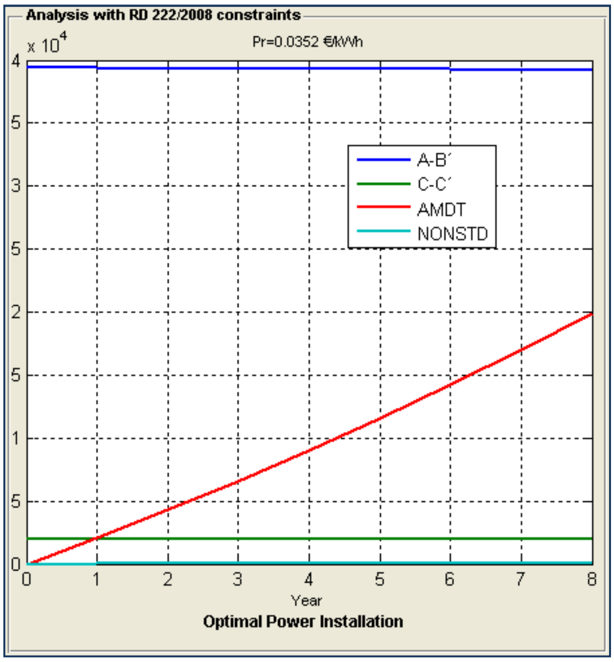

Figure 3: Energy efficiency increased by applying subsidies

CONCLUSIONS

A utility can face two different issues that may bring to new distribution transformers installation: changes in the demand (for instance, growth) and possible breakdowns that the installed transformers may suffer during the revenue time.

This work has studied how the Spanish Royal Decree 222/2008 affects the loss treatment for a utility and how this policy influences the overall energy efficiency in distribution transformers in case the utility has to change a transformer.

The results show that the current policy does not support a utility when it comes to changing a distribution transformer as explained above. In order to be an effective policy, that would guarantee the increase of the overall energy efficiency, two options have been proposed to increase overall energy efficiency:

- A change in the energy price that would guarantee the installation of higher efficiency transformers when needed
- Direct subsidies to buy high efficiency transformers

Both of the proposed options meet the objective: maximize the benefit for the utility and guarantee the increase of energy efficiency.

REFERENCES

[1] SEEDT, 2008, "Selecting energy efficient distribution transformers: a guide for achieve least-cost solutions", *Technical Report*

[2] Directive 20009/28/EC on the promotion of the use of energy renewable sources and amending and subsequently repealing directives 2001/77/EC

[3] Ministerio de Industria Turismo y Comercio, 2008, “Real Decreto 222/2008, por el que se establece el régimen retributivo de la actividad de distribución de energía eléctrica”. BOE 67.

BIOGRAPHY

Paola Pezzini received her M. Sc degree in electrical engineering in 2006 from Politecnico di Milano, Italia. She is now a Ph.D. student at CITCEA, UPC, Barcelona, Spain. Her research interest is in optimization of FACTS devices using heuristic methods, energy efficiency and power systems security.