ENERGY EFFICIENCY – THE MAIN FEATURE OF THE SOLUTIONS DEVELOPED BY ICPE ACTEL

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REZUMAT. Lucrarea tratează aspecte cu privire la obţinerea eficienţei energetice maxime în relaţia sursă-consumator, în mod special în cazul surselor de putere finită, insulare şi a consumatorilor neliniari cu evoluţie dinamică, de tipul convertoarelor statice de putere. Deoarece convertoarele statice de putere sunt utilizate în tandem cu motoare de curent continuu sau alternativ, conversia energiei electrice în lucru mecanic se petrece cu pierderi importante de energie activă pe care soluţiile propuse le diminuează şi conduc la creşterea dorită a eficienţei energetice

Cuvinte cheie: convertoare de putere, control energie, transportul energiei, eficienţă energetică

ABSTRACT. This paper presents aspects about maximum energy efficiency in the relationship electric power supply source - user, especially in the case of limited electric power supply from isolated places and dynamical nonlinear users, of type of static power converters. Because these power converters are used in tandem with DC or AC motors, the conversion of the electric energy in mechanical work is made with an important active power loss. The proposed solution decreases this active power loss and increases the energy efficiency.

Keywords: power converters, power control, power transmition, energy efficiency

1. Introduction

Energy efficiency is a concept available to everyone that is operating in:

- electricity production;
- electricity transport;
- electricity utilisation.

Most of the time the specialists studies are individual and divergent, each of them aiming to obtain maximum efficiency in one of the three domains mentioned before, meaning in the one that they are operating.

ICPE ACTEL implements its efforts regarding experimental research and technological development on solutions that integrates all the three constitutive types of the electricity management: supply – transport – user, this being the reason that we are able to address in this paper the convergence on a solution for obtaining maximum energy efficiency in power supply-user relationship.

From the beginning we will consider the power sources as isolated sources, where the energy efficiency is more visible than in the case of infinite power sources.

We will also consider the non-linear users with a dynamic evolution, aleatory to the static power converters types which implement the hardest problems to the limited power sources.

2. Electrical sources in non-sinusoidal periodic regime

Electric limited power sources are accomplished either by means of industrial standard power tranformers, or by means of diesel-generator sets. We will consider the second sources category with diesel-generator sets, much used in isolated places.

For any source of this type, the output voltage should fluctuate sinusoidal in time, with the same frequency. In reality, the voltage and current waves are not strict sinusoidal, and the deviation from the sinusoid is named distortion or, simply, deformation

From where this distortion?

In the first place from generators, where in reality the voltage is not sinusoidal because in this case the windings are not in a sinusoidal distribution of the magnetic induction in the gear gap air.

In the second place the nonlinear elements of load under sinusoidal voltage distort the current, which produces power failures not sinusoidal in other circuit

elements, either linear or nonlinear. In this category are included the iron core coils and specially the power static converters.

Thirdly, the linear reactive elements produce strong distortions of some elements in relation to others. For example, a linear sinusoidal coil establishes a sinusoidal voltage at terminals, but at non sinusoidal current the voltage is strongly non sinusoidal.

In conclusion the permanent non sinusoidal regime is important both under the appearance of the negative effects in the chain of power supply transportation network.

3. Important measurements for characterising the non sinusoidal periodic regime

Starting from the series expansion of a periodic non sinusoidal measurement in order to characterise the contribution of ICPE ACTEL's specialists in defining efficiency in converting some forms of energy in another forms, we define the following measurements:

3.1 The effective value of a periodic non sinusoidal measurement

For a y (t) type voltage, periodic and non sinusoidal, the effective value is defined as follows:

$$Y = \sqrt{\frac{1}{T}\int_0^T y^2(t)dt} \qquad (1)$$

Replacing y(t) with his Fourier expansion is obtained:

$$Y^2 = \frac{1}{T}\int_0^T \left[Y_0 + \sum_{k=1}^{\infty} y_k(t)\right]\left[Y_0 + \sum_{p=1}^{\infty} y_p(t)\right]dt =$$

$$\frac{1}{T}\int_0^T Y_0^2 dt + \frac{Y_0}{T}\int_0^T \left(\sum_{k=1}^{\infty} y_k(t) + \sum_{p=1}^{\infty} y_p(t)\right)dt$$

$$+\frac{1}{T}\int_0^T \sum_{k=1}^{\infty}\sum_{p=1}^{\infty} y_k(t)y_p(t) =$$

$$Y_0^2 + \sum_1^{\infty} Y_n^2$$

So:

$$Y = \sqrt{Y_0^2 + Y_1^2 + ... + Y_n^2 + ...} \qquad (2)$$

or:

$$Y = \sqrt{Y_0^2 + Y_1^2 + Y_d^2} \qquad (3)$$

where with : $Y_d = \sqrt{Y_2^2 + Y_3^2 + ...Y_n^2 + ...}$ was noted the residual deformation (according to C. Budeanu)

3.2 Peak factor

$$K_v = \frac{Y_{\max}}{\sqrt{Y_1^2 + Y_d^2}} \qquad (4)$$

3.3 Distortion factor

$$K_d = \frac{Y_d}{\sqrt{Y^2 - Y_0^2}} \qquad (5)$$

3.4 Distorted power

$$D = \sqrt{S^2 - P^2 - Q^2} \qquad (6)$$

3.5 Power factor

$$k = \frac{P}{S} = \frac{P}{\sqrt{P^2 + Q^2 + D^2}} \qquad (7)$$

All the mentioned measurements will characterise the energy efficiency suggested in the power supply source - user applications.

4. Static power converters – sources of deformed regime

Static power converters tend to represent the most important component of the electric loads which produce important faults to the power sources, they absorb and transfer the majority of the electricity for its conversion in mechanical power.

In industrialised countries, over 65% from the produced power is consumed by electric motors through the static power converters, in a huge percentage.

Depending on the technological process in which are involved, the electric drives systems with static power converters are followed especially:

- maximum conversion efficiency;
- maximum utilisation of motors power to low supply voltage, which means a small power factor.

Regarding the power supply source this demands imply:

- strong distortion of the wave current and its voltage;
- significant absorption of reactive power and distorted from the source;
- alarming decrease of the source possibilities to transform the active energy in final mechanical work.

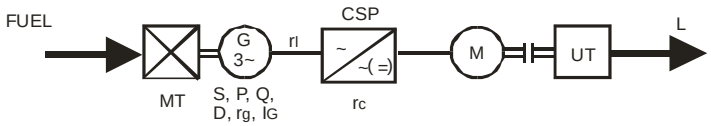
Moreover, the dynamic processes that take place at the level of the load, make very difficult the creation of the mathematical models that can be materialised in the well designed equipment in order to remove or amend this fault.

Today the static power converters are used in tandem operation either with DC motors, or with AC motors (asynchronous or synchronous). In both cases the conversion of electricity in mechanical work is made with important loss of active energy.

Therefore the preoccupations of all specialists are focused in the reduction of that loss and to increase the energy efficiency of these applications.

5. The increase of energy efficiency – objective necessity

Starting from a simplified block diagram of a thermal energy conversion (heat) model into final mechanical work, we will emphasise the quantity and quality aspects of this process and the improvement measurements of the energetic transfer efficiency.



Legend:

MT – thermal motor of the diesel-generator set;

r_g – equivalent resistance of the G windings;

r_l – equivalent resistance of the energy transport paths between generator and the static power converter (CSP);

r_c – equivalent resistance of the current paths from CSP;

UT – technological equipment.

On the consumed thermal energy conversion chain through fuel combustion (diesel, petrol, gas) and the mechanical work at the technological equipment axis, there are produced series of supplementary loss due to the presence of the static power converter (CSP) and implicitly of the non sinusoidal regime at the terminals of the generator G.

This loss is due to two aspects:

- circulation of the reactive power required by the tandem CSP-M;
- the presence of the harmonics due to the distorted regime and the circulation of the distorted power.

Quantifying this loss results:

$$\Delta P_Q = I_Q^2 \left(r_g + r_l + r_c \right) \tag{8}$$

the loss due to the circulation of the reactive current demanded by the tandem

CSP-M.

Neglecting the distorted component of the generator output current:

$$I_Q = I_G \sqrt{1 - k^2} \tag{9}$$

where I_G is the apparent component of the generator output current

$$\Delta P_Q = \left(1 - k^2\right) I_G^2 \left(r_g + r_l + r_c \right) \tag{10}$$

From the relation (10) it can observed that the solution for reduction of these loss is closely related only with the increase of the k power factor, this can be

made with active or passive filters, or external compensation of ΔP_Q with an external reactive power source in controlled regime.

In both situations the amortisation of the investments is made in a period of time depending on the power and structure of the load, but does not exceed 24 months.

6. Conclusions

The reduction of the loss produced by the circulation of the reactive power in the AC source – non-linear strong inductive users' chain, represents a preoccupation with a considerable scope, with special results in obtaining important energy savings.

Regardless of the applied solution, the final scope remains the same: increased efficiency in power electronics complex solutions.

In this respect, ICPE ACTEL has validated the presented solution on 7,5 MVA, 3 x 690 V on isolated power plants and the results where outstanding.

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