POWER GRID PARAMETERS OPTIMIZATION IN INDUSTRY ENVIRONMENT

Lucie FRISCHEROVÁ, Romana GARZINOVA, Pavel ŠVEC

VSB - Technical University of Ostrava, Ostrava, Czech Republic, lucie.frischerova@vsb.cz, romana.garzinova@vsb.cz, pavel.svec@vsb.cz,

Abstract

The paper deals with parameter optimization of power energy distribution networks through a patented reducer device that has a positive effect on the improvement of the customer distribution network, extending the life of the connected appliance, reducing energy consumption and that's why more efficiency production. The principle function of reducer device is to reduce the input voltage to a level that is adequate for the proper operation of all connected appliances and equipment and as the result decrease input power to those appliances. This procedure can be applied to variable of appliances, such as lightning systems, air compressor distribution facility, air conditioning or consumer electronics.

Keywords: reducer, power consumption, alternating voltage, power grid

1. INTRODUCTION

The price of electricity is from the point of view of industrial and household's consumers evaluated as one of the key cost items, and is logically the most commented value of the electricity market. The final price of electricity is determinate by the supply side factors, namely production capacity, input elements (fuel, emission allowances), energy production mix and the weather. In view of the demand side is then mainly a macroeconomic developments and weather.

From evolution of electricity prices in the period (2002-2013) is evident almost continuous increase in prices for selected countries (see **Fig. 1**). The growth trend has been typical for all countries since 2006, the exceptions in this respect are only a partial decrease in electricity prices in Germany, Poland and Slovakia in 2008 and 2009 due to a decline in electricity demand due to the economic recession. These partial drops in electricity prices, however, have very short-term character, always only one year. Despite the significant impact of the economic crisis the prices of electricity did not decrease in other selected countries, although the demand of electricity had the decrease character.

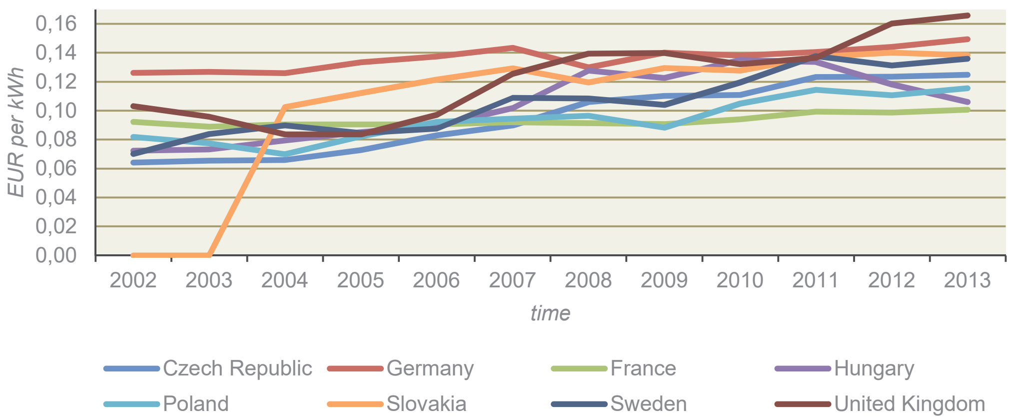

Fig. 1 Electricity prices for household consumers - EUR per 2500-5000 kWh [1]

Categories of industrial consumers recognized in the period that is the same as in the household, from 2002 to 2013, a clear upward trend in electricity prices in selected countries. Industrials consumers are mostly from metallurgical environment. In that branch are input power levels extremely high, because of nature of the processes. [1], [2], [3], [4], [5], [6], [7]

This increase is again determined by the growth in input prices of electricity producers with the related increase in prices of electricity, considering to political influences. Another important component, which raised the price of electricity, was the growth of investment in renewable energy, which is reflected in the growth of regulated prices. The economic crisis has had the impact on the final consumption of electricity, which declined significantly between 2008 and 2010. This decrease did not reflect in final electricity prices, with exceptions (see **Fig. 2**). [8]

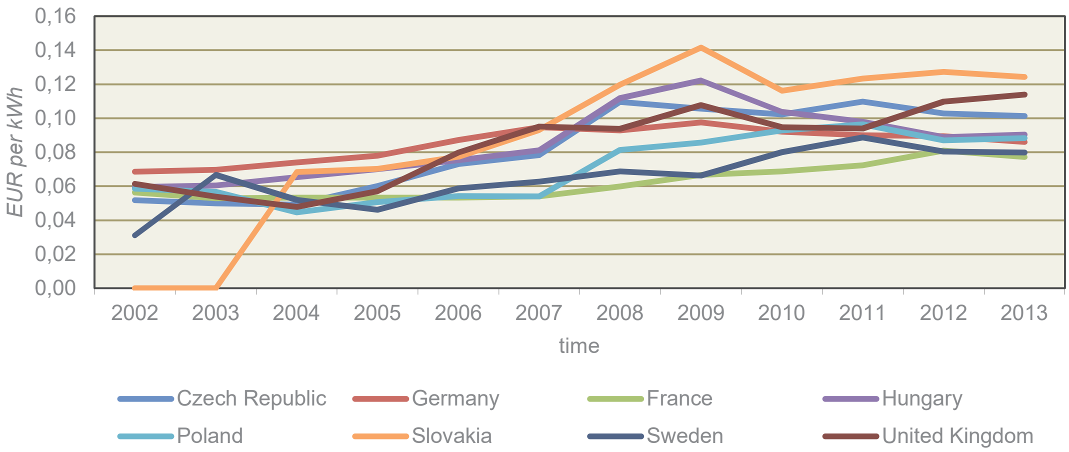

Fig. 2 Electricity prices for industrial consumers 500-2000 MWh [8]

The price of electricity is composed of unregulated part which determines the electricity trader, and contains a fixed price per month and electricity prices. Another part of the price is regulated by the Energy Regulatory Office (ERÚ), and includes a distribution fee, fee for service system, contribution to the promotion of renewable sources and fee billing activities of the electricity market operator. An integral part is the tax, it is the value added tax (VAT) and the tax on electricity. The share of the components of prices is shown in (see **Fig. 3**). [9]

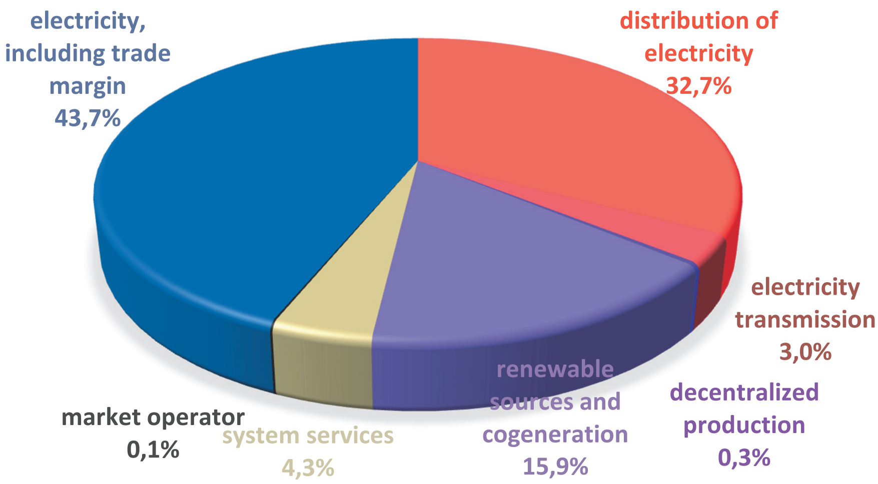

Fig. 3 The share of individual components of the price for the supply of electricity for households in 2011 - no tax items

Many industrial and household consumers in the current economic situation strive to reduce costs in maximum measure. They choose different saving measures, which include the energy saving and energy costs. Opportunities for savings can be found directly in production, renovation or construction of the building. Another important aspect is an effective energy management and maintenance management.

2. ENERGY SAVER DEVICE APPLICATIONS

One of the possible saving solutions, which concern energy saving and expenses for energy consumption, is installation of reducer device into the customers grid. The principle of the device is, that input AC voltage is reduced into the desired level. This level has to be as high as to ensure proper appliances operation and also as low as to ensure maximum power saving [10]. There is several solutions how to lower power supply voltage. The first way is to apply some kind of transformer which basically reduces input voltage to desire level which is defined by transformer's taps. The solution is very simple and easy to implement to customer's grid, but it is bulky and heavy. On the other hand this solution is not prone to unwanted voltage spikes and against short circuit currents.

The second solution can be electronics reducer devices which can cut off small part of voltage sine wave, that's why RMS voltage value became lower (see **Fig. 4**). This device is described in [11], [12]. The advantage is small size, low weight and smooth output voltage level change.

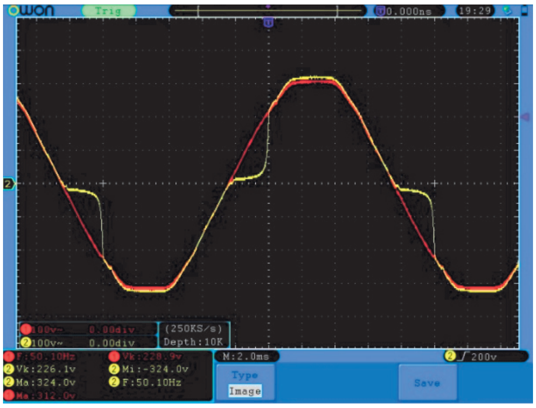

Fig. 4 Voltages running when Triac driving is applied (yellow curve is output voltage)

The main disadvantage is prone to input/output voltage spikes and limited driving current. Output voltage is controlled by semiconductor power switching device called triac. Triac has to be activated by a single pulse (For one half-period) to the gate electrode. Then the passing current through the triac is held in a conduction state. One main disadvantage of the triac in comparison to the standard bipolar or unipolar switching components is that it cannot be switched off. Triac closes itself when passing current disappears. Then it remains in a closed state until next trigger impulse is generated. In principle, we are cutting off a part of the sine wave. Therefore, the output running voltage is not clearly continuous, but partly discrete. The main switching waveform can be seen in (**Fig. 4**). As we can see, maximum and minimum voltage levels are preserved. One value which will change is RMS voltage. RMS value is expressed by formula (1). If we are passing into the digital area RMS expression will change to (2), where n is the number of samples and u(i) is the actual voltage value.

$$Urms = \sqrt{\frac{1}{T}\int_{t0}^{t0+T} u^2\,(t)\,dt} \tag{1}$$

$$U_{RMS\ DISCRETE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} u_i^2} \tag{2}$$

Another problematic issue is the ΔI/Δt transition. The value of about 100A/µs is very high and causes unwanted disturbances in higher frequencies. This is very important and the issue needs to be solved, because any disturbance may results in a failure of the devices in power line path.

Analogue based triac drivers cannot react quickly enough to changes which are common in real world. Changes in load character, load amount, input voltage level and reactive power present real issues. [13], [14] Especially reactive power is relatively dangerous, because it can cause triac to remain in a conduction state due to a phase shift of passing current. If it is using MCU (micro controller unit), it can span every possible occasion and making an algorithm to precede it. It is need to MCU measures, among others, input and output voltage. The main task is to stabilize output voltage in demand level. Therefore, if we have output voltage value, we can adjust trigger pulse to be precise at a specific time which leads to the right RMS value. Having output voltage stabilized has one main advantage. If it is, for example, driving street lights voltage drop under safe level will lead to further lamps shutting down. It is obvious that right timing is critical. MCU should monitor input voltage and current and their crossing through zero level. This is an important moment, because its value is proportional to the passing reactive current. Also the triggering impulse is derived from this precise time. The circuit which is responsible for the recognition this time is very simple. It is a common comparator which is continuously comparing passing current with the ground signal. If the current is negative, comparator's output is logically 0. As soon as the current rises above the zero (ground) level, comparator turns over and its output is logically 1. The same comparator is on the voltage side and the time between both transitions is proportional to the phase shift between voltage and current (reactive current). The matching resistor network aimed at measuring high AC voltage and current is shown in (see **Fig. 5**).

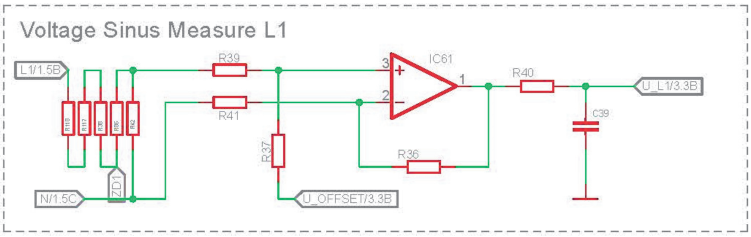

Fig. 5 Matching resistor network necessary when measuring high AC voltage and current

Our solution relies on transformer based reducer. We have used prototyped autotransformer design with 15 taps (see **Fig. 7**). Theoretical principle is presented in **Fig. 6**. Real voltage running of input and output is presented on (see **Fig. 8**). Input voltage level was purposely on 265V level. Output level was lower, 197V and with current flow of 6A. These input and output levels should prove that connected load will work under these extreme conditions. One of the advantages against above mentioned solution is no presence of harmonics frequencies (see **Fig. 9**). This is very important if the appliances are sensitive electronics devices.

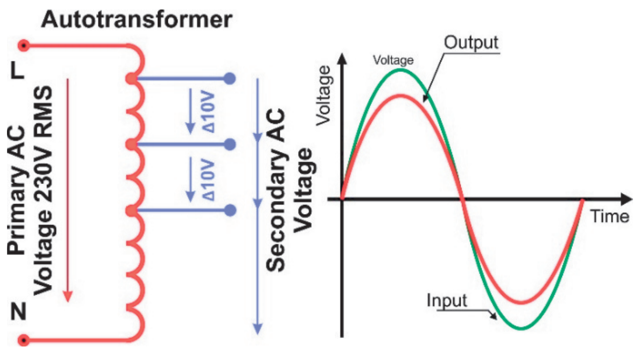

Fig. 6 Basic principle of the reducer device [3]

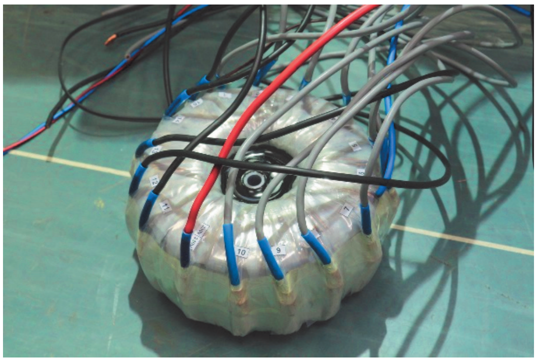

Fig. 7 Prototype of Autotransformer

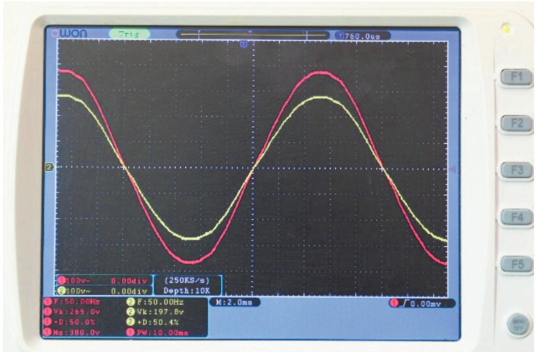

Fig. 8 Input and output voltage running in test conditions

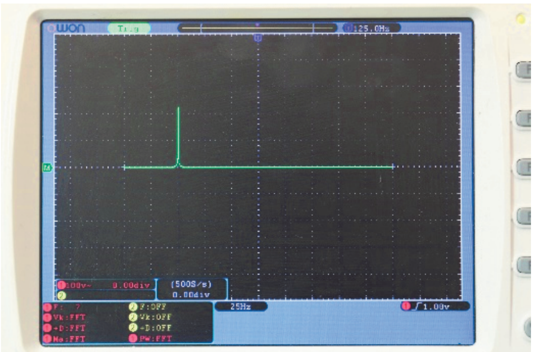

Fig. 9 Output voltage spectrum analysis; only 50Hz main frequency is noticeable

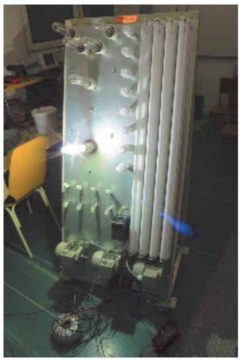

Fig. 10 Special testing board with various types of loads including HID lamps, fluorescent tubes, halogen lamps and electric motors

As a load served specially designed panel with various types of appliances. For testing purposes we choose Metal-halogen HID lamp (see **Fig. 10**). During the test operation we monitored output voltage's harmonics frequencies. Because the transformer based reducer device, we did not find any unwanted frequencies, which can be seen on (see **Fig. 9**).

The reducer is able to lower input power on electric load in AC circuits and restrict current flowing throw the load according preset reduction level. The reducer device did not make any other changes in power grid. It means that it is transparent for passing current. The reducer device is connected into the AC circuit in series, between the energy supplier and customer appliances. This is only way how to affect circuit parameters in that way, to come desired power drain reduction. Function of reducer is controlled by the control system unit based on microprocessor unit. [15]

Operational testing measurements results bring many important data and information. Prototyped reducer device has been tested in various operation areas, where each has different appliances composition. In **Table 1**, there are some of the testing results. There has been proved, that reducer device can make energy saving, but not always it is efficient. In case of lightning or wastewater treatment circuits is economic return fast. But in case of air condition circuits the economic return can be long distance race.

Table 1 Results of test measurements

	Wastewater treatment plant	**Lighting**	**Call centrum**	**Air conditioning**
Input data	pumps, aerating compressors	high-pressure sodium lamps	PC, monitors, lighting	compressors, the compressor control unit
Technical solution	prototype device for current 80A	prototype device for current 40A	prototype device for current 80A	prototype device for current 120A
Total consumption	4 920 kWh/month	2 608 kWh/month	15.600 kWh/month	14 100 kWh/month
Calculation of savings	14%	20%	7%	5%
Price kWh	5 CZK	5 CZK	5 CZK	5 CZK
Investment cost (incl. VAT)	145 000 CZK	77 000 CZK	145 000 CZK	240 000 CZK
Cost savings /month	3 340 CZK	2 553 CZK	5 281 CZK	3 261 CZK
Return ability	43 months	30 months	27 months	73 months

CONCLUSION

The reducer device was developed in term of Pre-seed project activity in VSB-TUO and it is an alternative to other economy steps, which lower energetic demands in customer power grid. In term of laboratory tests and tests in real environment were verified various types of loads (appliances). The goal was to determine behavior of the appliances in lower voltage conditions. Regarding to the test results were target appliance reduced to 4 groups, which can easily be exactly identified and regarding that it is behaving like static system it is possible to drive it with higher efficiency.

In to the second group belong motor based devices, which have similar character like lightning systems and can be also easily controlled. The last two groups, combined circuits and air condition systems, are essentially dynamic systems. The state of these systems cannot be easily determined; therefore the control efficiency is lower.

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