SOLUTIONS TO IMPROVE THE EFFICIENCY OF INDUSTRIAL CONSUMERS. S.C. CELESTICA ROMANIA S.A. - CASE STUDY

FELEA I., ALBUȚ-DANA D., BARLA E.
UNIVERSITY OF ORADEA, FACULTY OF ENERGY ENGINEERING

Abstract: The paper has a structure in four parts. In the first part is justified the concern of the authors regarding the electric energy audit (EEA). In the second part are presented the synthesis of the work style in elaboration of EEA at S.C. CELESTICA ROMÂNIA S.A. The third part contains the synthesis of the results, as in the last part are given the conclusions obtained from analyzes.

Keywords: energy efficiency, industrial consumers, electric energy audit

1. INTODUCTION

One of the dominant topics of the globalization is the sustainable development. In domain of energy, the operation of this concept means the reducing of the fossil fuels in two ways:

- By improving the efficiency of the energy processes;
- By improving the utilization degree of the sources of renewable energy.

The action scope and ways of EU are very clear defined and regulated [1, 2], targeting to reduce the fossil fuels consumption until 2020 with 20% and increasing the weight of renewable sources.

In Romania, the energy efficiency is with more under the countries with high technology.

There are still many technological processes and services that run in Romania with 2-3 times higher intensity than the similarly processes modernized in "pennant" countries.

In the last period there are made high legislative and financial efforts [3,4], to align the facts in Romania to European standard, both in terms of energy efficiency and in terms of a more intensive utilization of renewable energies.

The electric energy audit (EEA), is one of the regulated modalities [5] to identify the ways of improving the energy conversion efficiency processes.

This paper makes a synthesis of EEA made at S.C. CELESTICA ROMANIA S.R.L. After mentioning the contour elements and of some specific aspects of mathematical modelling, it is presented in integrity the conclusions of the made studies, this having a general interest leading to the improving of the energy efficiency.

2. DEFINITION OF THE CONTOURS

The stabilized contour to make the EEA is at the level of the factory, with distinct assessments for the general contour of the components, equipments and supplying installations with electric energy of S.C. CELESTICA ROMANIA S.R.L., so:

- The power transformers: 3 PT with S_n = 1000 kVA, 3PT with S_n = 2000 kVA.
- Electricity distribution installations: 50 departures.

In table 1 are given the technical data for transformers and installations which supplies BC; technical data of the analyzed contours are given in integrity in [11].

Table1. Main technical data for transformers and installations of the analyzed contour

No. Crt.	Name of equipment	Technical characteristics	
1.	Power transformers (T1, T3,T5)	S_n =1000kVA; U_{1n} / U_{2n} =20/0,4 kV; f_n = 50Hz; ΔP_{wn} =12 kW; ΔP_{Fn} =1,95 kW; u_{kn} =16%, i_{0n} =2%; Connection: Δ/y_0 - 5	
2.	Power transformers (T7, T7,T9)	S_n =2000kVA; U_{1n} / U_{2n} =20/0,4 kV; f_n = 50Hz; ΔP_{wn} =22 kW; ΔP_{Fn} = 3,2kW; u_{kn} =6,3%, i_{0n} =1,5 %; Connection: Δ/y_0 – 5	
3.	Distribution instalations EE	CA de la T1 la BA1	WT2 2x(C2XY4x300)+C2XY1x150; L=14m
		CA de la T3 la BA2	WT4 2x(C2XY4x300)+C2XY1x150; L=14m
		CA de la T5 la BA3	WT4 2x(C2XY4x300)+C2XY1x150; L=13m
		CA de la T7 la BA4	4xCXY 4x1x300+C2XY 1x300; L=15m
		CA de la T8 la BA5	4xCXY 4x1x300+C2XY 1x300; L=15
		CA de la T9 la BA6	4xCXY 4x1x300+C2XY 1x300; L=14m

The **provided service** by CELESTICA ORADEA, is manufacturing of computers, receivers, TV-s, servers, telephones, to customers such as IBM, PHILIPS, SAMSUNG, BskyB, RIM, EMC, SIEMENS, etc.

The technological flux of S.C. CELESTICA ROMANIA S.R.L., is given in fig.1.

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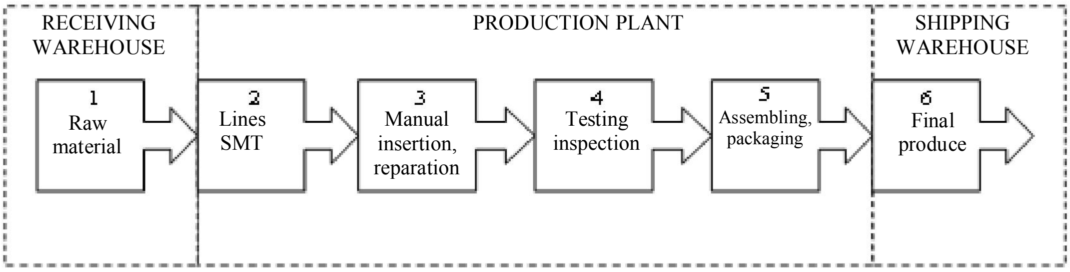

Fig. 1. Diagram of technological flux

The **unit of the reference:** the EE consumed for an hour have been determined basing on the made registrations.

The loading level of the installations and equipments during the measurements is the normal one for the assured service by CELESTICA ORADEA. After making BEE for an average hour, will be make refer on annual BEE, based on the monthly registered EE consume.

The **measuring devices** used:

- Network analyzer (NA) type of C.A. 8334 B (2 pcs.), placed in the secondary of the two transformers in each station;
- Active and passive energy contours of ENEGLUX TCDM – AEM Timisoara, placed in the primary of the transformer.

For example, in fig. 2 ÷ 7 are given the curves of the load currents, powers (P, Q, S) and energies, and the elements of characterization of EE quality for T1.

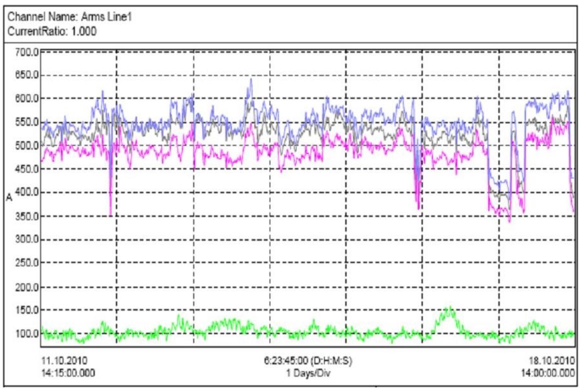

Fig. 2. The curve of the current for T1

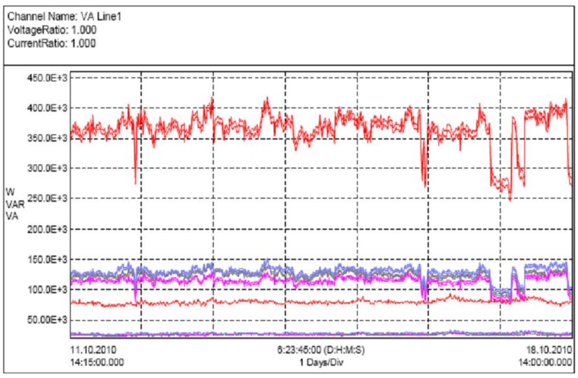

Fig. 3. Load curves of powers for T1

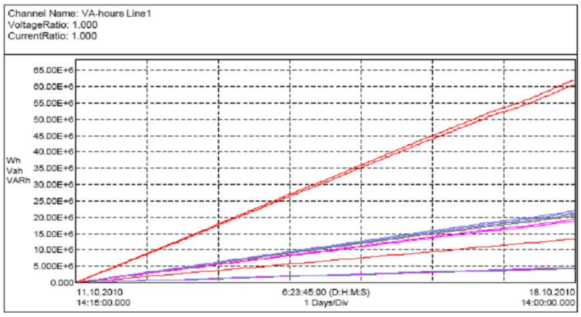

Fig. 4. Load curves of energies for T1

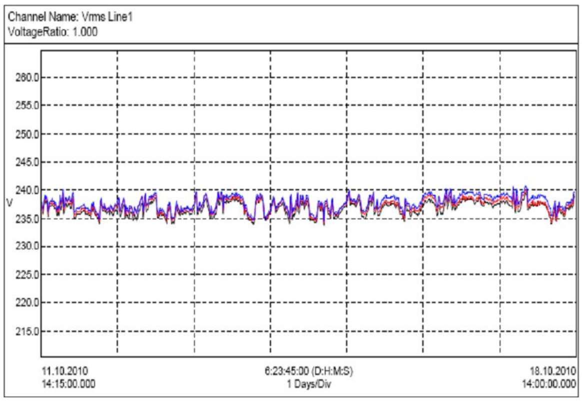

Fig. 5. Phase voltage variation in the secondary of T1

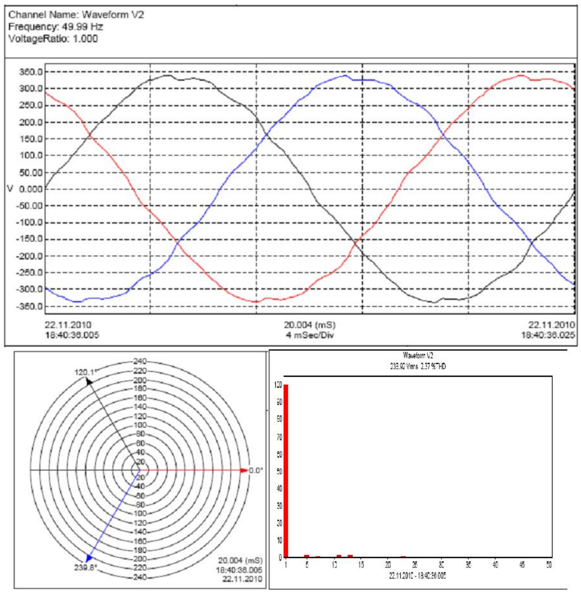

Fig. 6. Elements of characterization of the voltage quality in the secondary of T1

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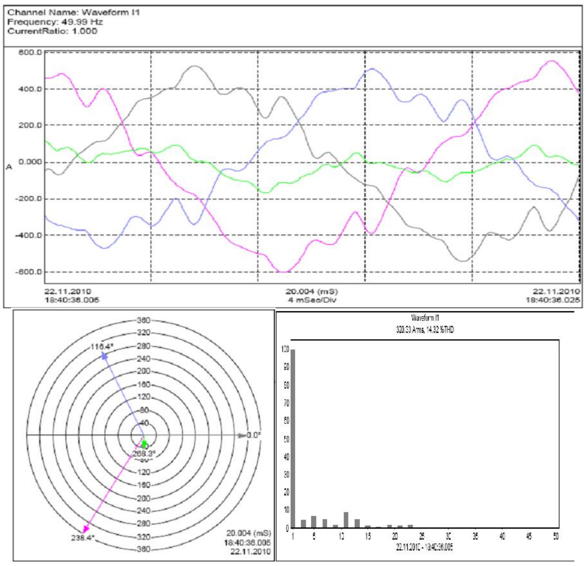

Fig. 7. Elements of characterization of the quality of the current in the secondary of T1

In the secondary of the 5 PT were placed AR, making the same registrations for each PT. The working mode with EEA is well known [5 ÷ 9].

The equation of BEE is specific for the sub contour for which the assessment is made, so:

For the analyzed contour the equation of BEE is:

$$W_a=W_u+\Delta W_T+\Delta W_L \qquad (1)$$

- W_a – absorbed energy, measured in the point of delimitation (in part of MV of the PT);
- ΔW_T – energy losses in the PT, computed basing on the measurements and technical characteristics;
- ΔW_L – energy losses in the short lines of the contour, computed basing on the measurements and characteristics of the lines;

Basing on the equation (1) it is computed the useful energy (Wu), transferred to the output of the contour through the distribution electric grid toward the receivers of EE of S.C. CELESTICA ROMÂNIA S.R.L.

3. THE OBTAINED RESULTS

Basing on the nominal characteristics of the equipments and the obtained results from the measurements, by applying the BEE models it was determined the components of the BEE.

The obtained results refer on the sub contours and general contour it can be seen in [11].

For example, it is given the obtained results for the real BEE at components level of (T1 + RED1), in table 1, and at level of sub contour in table 3 and fig.8.

Table 2. Results for the real BEE at level (T1+RED1) components

No. crt	Name of components		Specific characteristics				ΔW [kWh]
1.	Transformer (T1)		β=0,37; U=237V; $T_A=\tau$=1 hour $k_{DI}=THD_{I/100}$=0,143; $k_{DF}=8,103\cdot10^{-3}$ $k_{DQ0}=8,38\cdot10^{-3}$; k_{DK}=0,106				ΔW_T= 4,574 From which ΔW_{TD}= 0,103
2.	Electric line		I_m[A]	R_L [mΩ]	k_f	τ [ore]	ΔW_L
	T1 – BA1	3f	518	0,406	1,01	1	0,333
		N	103,2				0,013
	BA1 – LT1	3f	278,218	0,729	1,01	1	0,173
		N	55,385				0,007
	BA1 – TFA PH1	3f	79,164	8,7	1,01	1	0,167
		N	15,739				0,007
	BA1 – TFA PH2	3f	79,164	7,54	1,01	1	0,145
		N	15,739				0,006
	BA1 – ACB1	3f	81,455	0,729	1,01	1	0,015
		N	16,337				0,001

Table 3. Real BEE for sub contour 1 [T1+RED1]

Feature quantity	kWh	[%]
Input energy [W_a]	360	100
Output energy [W_i]	360	100
1-Useful energy [W_U]	354,559	98,489
2-Losses [ΔW]	5,441	1,511
2.1 On transformer [ΔW_T]	4,574	1,271
From which provoked by deforming regime [ΔW_D]	0,103	0,029
2.2 On the lines [ΔW_L]	0,867	0,241
From which in the neutral wire	0,034	0,009

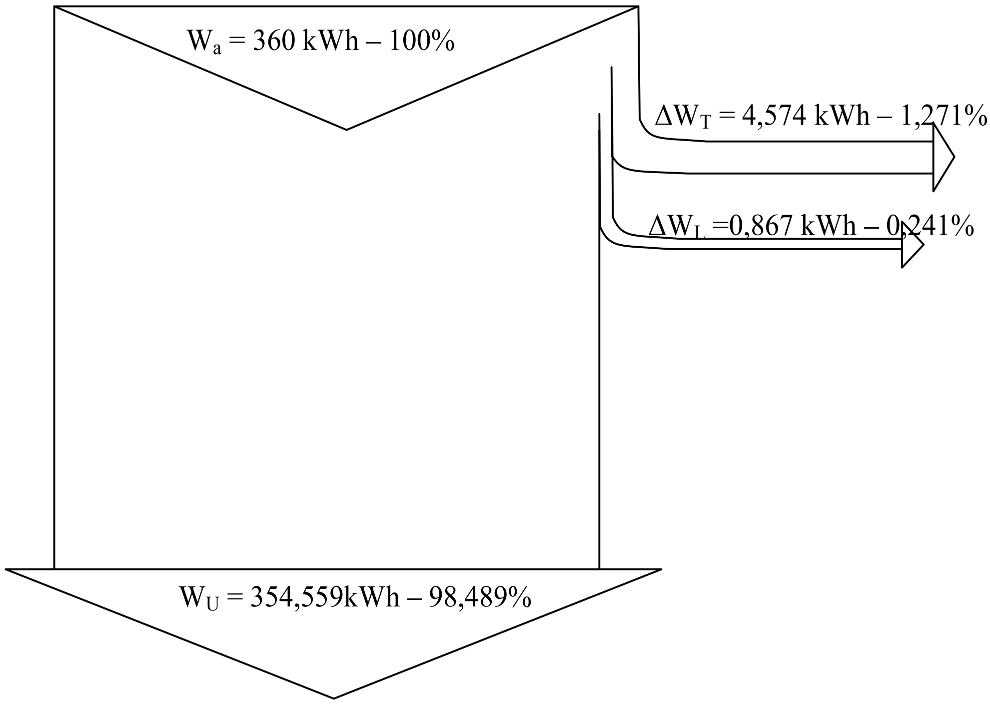

Fig. 8. Sankey Diagram for contour 1

There were computed the indicators of:

- **energy efficiency**: is the consume of EE on momentary unit obtained from the made service:

$$Cw=W_a/V_{sp} = 1.788,360/74096,005= 0,024 \text{ [kWh/leu]}$$

V_{sp} – the values of the made service by CELESTICA ORADEA.

- **Impact on the environment –** it is assessed by determining the quantity of pollutant evacuated in the atmosphere when the consumed EE is produced, so from [12] results:

$$E = B\cdot Q_i\cdot \varepsilon$$

where;
B – the quantity of the consumed fuel in the period of analyze [kg];
Q_i – low calorific power of the fuel [kJ/kg];
ε - factor of emission.

It will be evaluated the impact on the environment, allowing the fact that the consumed electric energy at CELESTICA ROMANIA, is produced from lignite, having the calorific power of:

$$Q_i = 1700 \text{ kJ/kg} = 0,47 \text{ kWh/kg}$$

The considered quantity of consumed fuel (lignite) in one normal working hour (average) to produce the consumed EE by CELESTICA ROMANIA is:

- with reference to absorbed EE:

$$B_a = W_a/Q_i = 3805,021 \text{ kg}$$

- with reference to the losses of EE:

$$B_p = \Delta W/Q_i = 91,896 \text{ kg}$$

Using the computational model indicated in [12] there are obtained the following expression and quantities given in table 4 for the main pollutants (SO_2,NO_x si CO_2);

$$E_{SO2} = 18,4 \times 10^{-3} B$$
$$E_{NOx} = 0,34 \times 10^{-3} B$$
$$E_{CO2} = 166,6 \times 10^{-3} B$$

Table 4 – Quantities of pollutants estimated to be emanated by producing of consumed EE from lignite at CELESTICA ORADEA (average hour)

Pollutant substance [kg]	Components of energy	
	Absorbed EE	EE losses
SO2	70,012	1,691
NOx	1,294	0,031
CO2	633,916	15,31

4. CONCLUSIONS. OPTIMAL BALANCE

The assessed measurements and evaluations within EEA of S.C. CELESTICA ROMÂNIA S.A. ORADEA, allow making the following conclusions:

1. The absorbed reactive energy from SEN is under the properly value of the neutral power factor, which means that the consumer doesn't pay the inductive reactive energy. It can be seen from the made registrations a reactive overcompensation on the transformers T5 (54,85kVAr) and T8 (309,22kVAr). This excess of reactive power generated by the afferent compensators of the two transformers can be consumed internally (which doesn't affect the energy bill), or it can be injected in the SEN (which may imply the payment of the capacitive reactive energy, situation that must be corrected)

2. The electric transformers operate independently, on surrounding receivers and different load level. All transformers are under-loaded, and operate under the optimal load. Transformers (T3, T5 and T9) operate more

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under the optimal load. To reduce the power losses in the transformers in conditions of actual consume are many solutions:

- Solution without supplementary investment should be the parallel operation of the (T7, T8, T9) transformers, closing the longitudinal couples and maintaining two from these in passive reserve and only one in operation ("1 + 2" configuration). At an eventually failure of the basic transformer will enter in the operation the transformers in the reserve. This diagram of operation leads to an economy of 11.022 kWh / hour, to 96.55 MWh/yr.
- Solutions that imply investments in replacing of transformers (T3, T4) with power transformers adequate to the load level, so T3 – 400kVA, T5 – 250kVA. This measure economic is feasible only when the existent transformers of 1000 kVA can be utilized.

3. About the quality of EE in the analyzed contour can be said the followings:

a). The effective value of the voltage at the secondary of the transformer is variable in bands located above the nominal value;

The voltage in the T8 secondary is in sensitive growth at, where the over compensation is appreciable (309,22kVAr) and the maximal value of the secondary voltage crosses the nominal voltage with 6.96%.

The nominal over voltage defines supplementary losses in magnetic circuit of the transformers. By reducing the voltage to the nominal value (average), the power losses in the transformers should be reduce with 1.83 kWh/day, i.e. with 1,604 MWh/yr.

It is recommended the voltage reducing from the tap changer of the transformer and through the elimination of the over compensation.

b). The quality of the current is affected by the utilization of converter to adjust the operating parameters of electric machines acting some technological equipment and the existence of some mono phase receivers which aren't supplied balanced in the three phases. The non symmetry degree of the current is differentiated on the 6 transformers.

The currents flow through the zero lines determines the supplementary power and energy losses. To identify the technical solutions of symmetrization is necessary the detailed analyze by EEA of EE consume at level of receivers. It is estimated that by symmetrization of the EE consume in the analyzed contour the EE losses can be reduced with 0.124 kWh / hour, respectively with 1079.2 kWh/yr.

The harmonics of the current is relatively high, at some PT being over as the allowed limits by normative (20%).

c). The THD indicator differentiated with reference on the 6 PT with which the measurements were made, are: 14,32% (T1); 7,22% (T3); 33,73% (T5); 14,2% (T7); 14,2% (T8); 11,67% (T9);

d). Must be noted that the deviations from the ideal level of the EE quality, registered in the analyzed contour aren't transferred in the electric grid of the supplier (SEN), the deforming residuum being downloaded in the PT as supplementary power losses. The THD_I diminution should lead to a decreasing of the power losses with 0.55 kWh/hour respectively, with 4821.7 kWh/yr.

Basing on the made measurements to reduce the power losses it is obtained the optimized BEE having the components given in table 5 and fig.9.

Table 5. Results of optimized BEE for the analyzed contour [TR+RED] within S.C. CELESTICA ROMÂNIA S.A.

Feature quantity	kWh	[%]
Input energy [W_a]	1774,835	100
Output energy [W_i]	1774,835	100
1 - Useful energy [W_U]	1747,007	98,432
2 - losses [ΔW]	27,828	1,568
2.1 on the transformer [ΔW_T]	23,286	1,312
From which provoked by deforming regime [ΔW_D]	1,3	0,073
2.2 On the lines [ΔW_L]	4,542	0,259
From which in the neutral wire	0,053	0,003

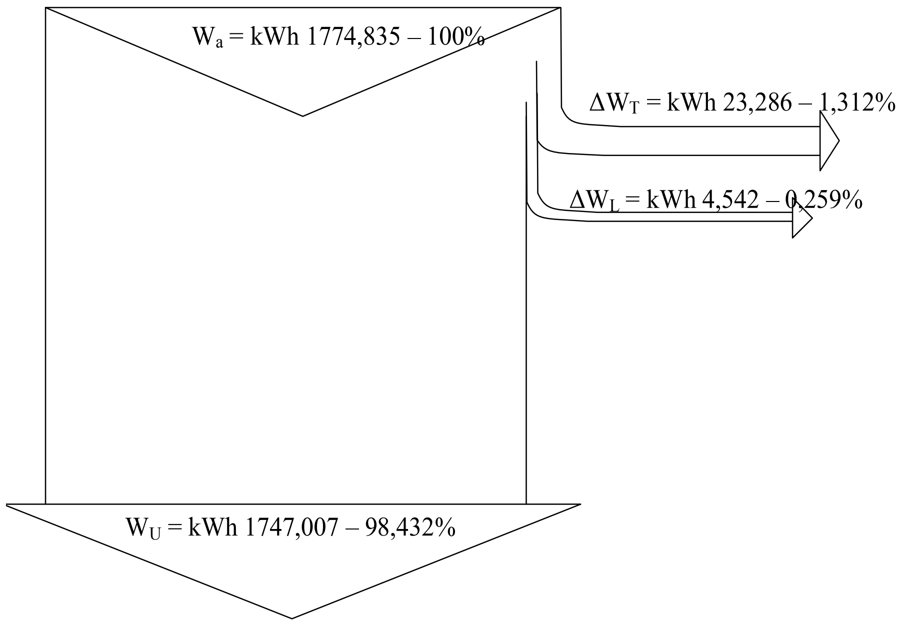

Fig. 9. Sankey diagram of the optimized BEE for the analyzed contour

The value of the indicator "consume of EE on the momentarily unit obtained from the service" in optimized BEE conditions is:

$$C_W = \frac{W_{aopt}}{V_{SP}} = \frac{1774{,}835}{74096{,}005} = 0{,}0239 \qquad \left[\frac{kWh}{lei}\right]$$

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