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ENERGY EFFICIENCY REQUIREMENTS TO OPTIMISE THE INDUCTION MOTORS OPERATING

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Abstract: The paper presents the improvements of electrical drives. In nowadays industry, electrical motors are using almost 80% of used energy, as the aspects of their efficiency has an important weight in the engineering concerns for electrical energy reduction.

Key words: power factor, efficiency, losses

1. INTRODUCTION

Electric motors and electric drive systems use more than half of the electricity production, in the industrial processes, transmission, residential applications. Electrical motors, usually have η about 90% which determine the energy losses, so an increase with 2% of η, which is possible for energetic efficiency motors, has an important effect viewing the electrical energy economy.[1]

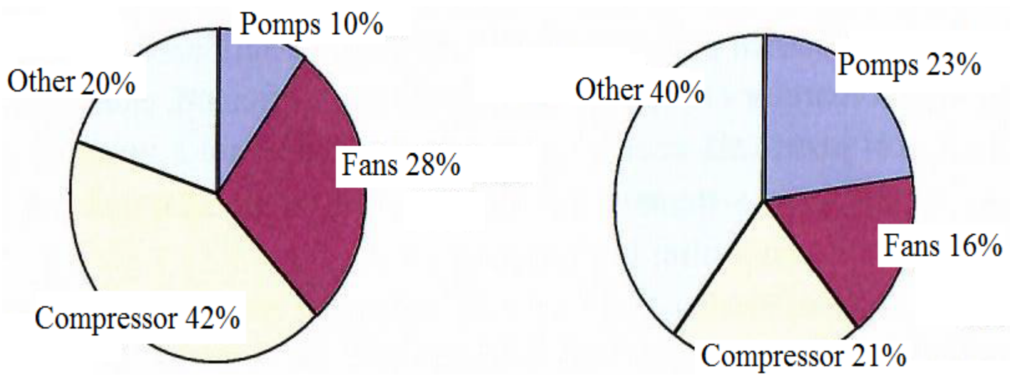

Fig.1. The weight of driven motors in industry and residential applications

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The efficiency of the drive motor is defined through η as the ratio between mechanical active power P_m and the input electrical active power:

$$\eta = \frac{P_m}{P_{el}} \tag{1}$$

The difference between input electrical power and the mechanical power represents the following losses:

- Stator winding losses ΔP_1;
- Rotor winding losses $\Delta P_{2;}$
- Magnetic circuit losses ΔP_{mg};
- Ventilation and friction losses $\Delta P_{m,y}$;
- Release losses ΔP_{σ}.

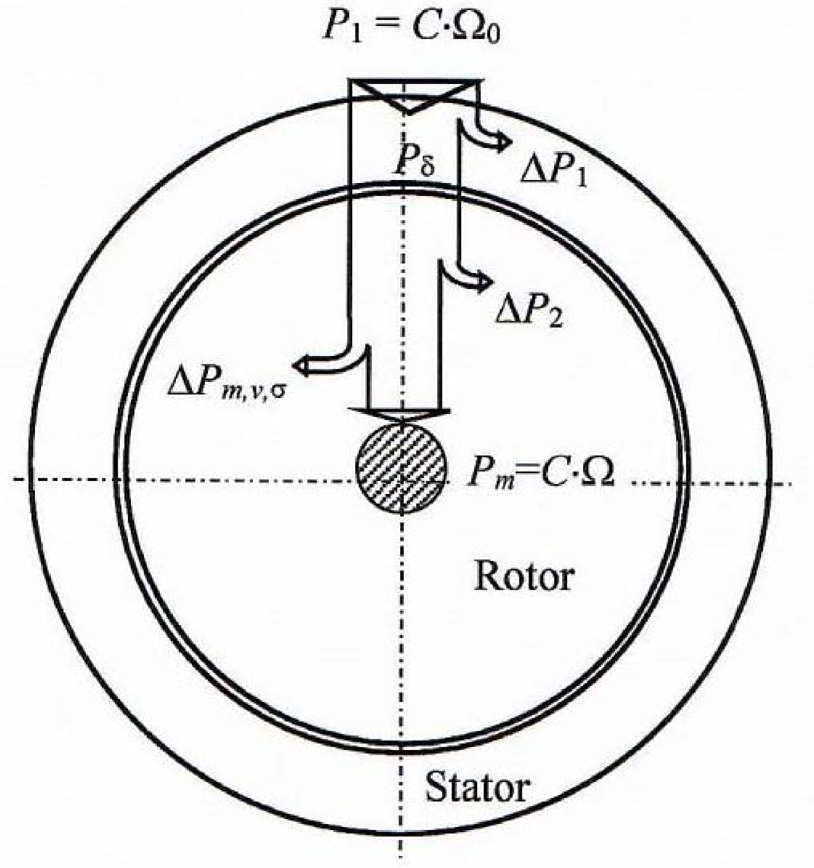

Fig.1 Simplified energetical balance for asynchronous motor

For an asynchronous motor, the loss of active energy ($\Delta\ p_a$) is calculated by the following relation:

$$\Delta\ p_a = (1-\eta)\cdot\frac{P_N}{\eta} \quad \text{(kW)} \tag{2}$$

where: η = nominal efficiency; P_N =nominal power

The loss of reactive energy (Q) is calculated by the following relation:

$$Q = P_N \cdot tg\varphi \quad \text{(kVAR)} \tag{3}$$

Out of the losses generated in an asynchronous motor, the mechanical losses Pm are practically independent from the charging power, and only the losses from the wrappings and the ferromagnetic core remain variable according to the electrical and mechanical variations.

The losses from the wrappings are practically dependent only on the charge and the quantity of the materials.

The losses in the stator $\Delta P_1 = 3R_1\ I_1^2$ are the losses with caloric effect, determined by the current I_1, the energetic parameters of the asynchronous motor are defined by efficiency (η) and power factor (cosφ), which help calculating the loss of active power and the loss of reactive power.

$$I_1 = \frac{P_{el}}{\sqrt{3}U\cos\varphi} = \frac{P_m}{\sqrt{3}U\eta\cos\varphi} \tag{4}$$

we can notice that for a given current, the only measure is to increase the section of the conductor, and so to decrease the density of electricity.

The losses wight for three phases asynchronous motor, on nominal load, is shown in the below table. The losses adjustment in dependence of shaft load is shown in the (figure 2).

Table 1 ***The losses in the asynchronous motor***

Type of losses	**Losses weight**
Joule losses in stator	37
Joule losses in rotor	18
Magnetic circuit losses	20
Mechanical and friction losses	9
Release losses	16

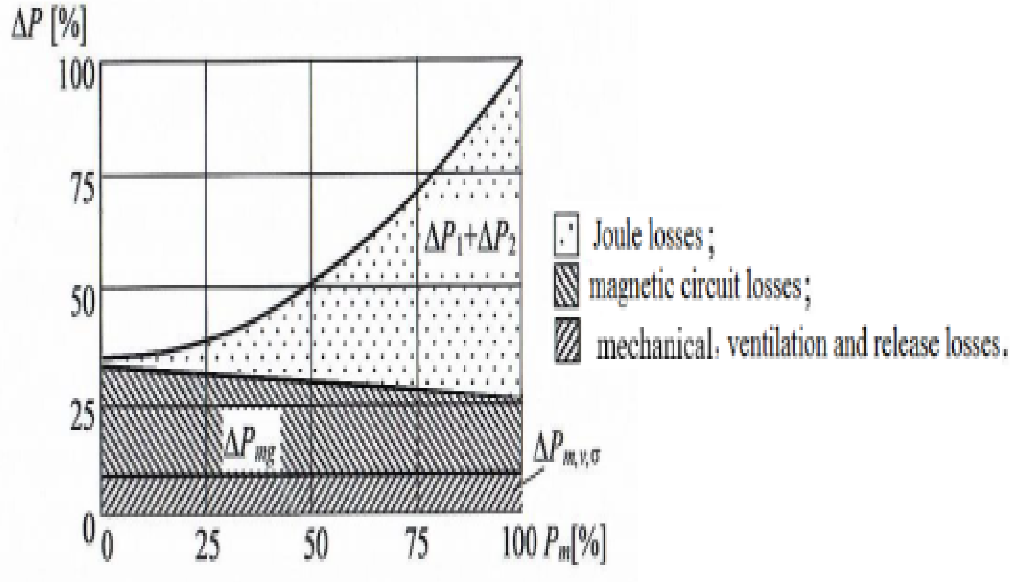

Fig. 2 The losses variation for asynchronous motor

For the asynchronous motors with contact rings, this measure can be applied for both rotor and static armatures. The limit is given only by the possibility to place spires, limited by the exterior diameter of the machine.

In the case of asynchronous motors with a caged rotor, the measure can be applied only at the static wrapping. The rotor wrapping must satisfy other requests corresponding to the rotation moment necessary to accelerate and the starting current, as compared to the one with rings, so the degrees of freedom for this motor are lower.

Usually, the asynchronous motor with a squirrel cage rotor requires relatively big starting moments and low starting currents. This requires a certain shape of the rotor notch, which must have a pronounced refutation of the current from the rotor bar, in order to increase the apparent resistance.

2. ABOUT HIGH EFFICIENCY MOTORS

New EU eco-design measures for electric motors and variable speed drives enter into force on 1 July 2021, aimed at improving the energy efficiency of these products across the EU. Applicable to AC induction motors (such as those that can be found in washing machines, air conditioners, or heat pumps and are also commonly used in many types of industrial applications), the new rules update the previous regulation from 2009. The new regulation has a significantly broader scope, covering motors with a power range from 0.12 kW until 1000 kW. The energy efficiency requirements have also been reinforced, reflecting technological progress and market evolution in the past decade. For example, the new rules will now regulate the efficiency of variable speed drives. This will help engineers to optimize the efficiency of entire systems.[3],[4]

The induction motors with power between 0,12kW – 1000kW and voltage till 1kV, are classified in three efficiency classes:

a. Standard Efficiency IE1;
b. High Efficiency IE2;
c. Premium Efficiency IE3;
d. Hight premium efficiency IE4

Table 2 ***The efficiency of regular motor and efficiency of efficient motor***

Power domain [kW]	**Efficiency**	
	Regular motor [%]	**Hight efficient motor [%]**
0,75÷7,5	80	86
7,5÷37	86	90
37÷75	90	93
>75	95	96

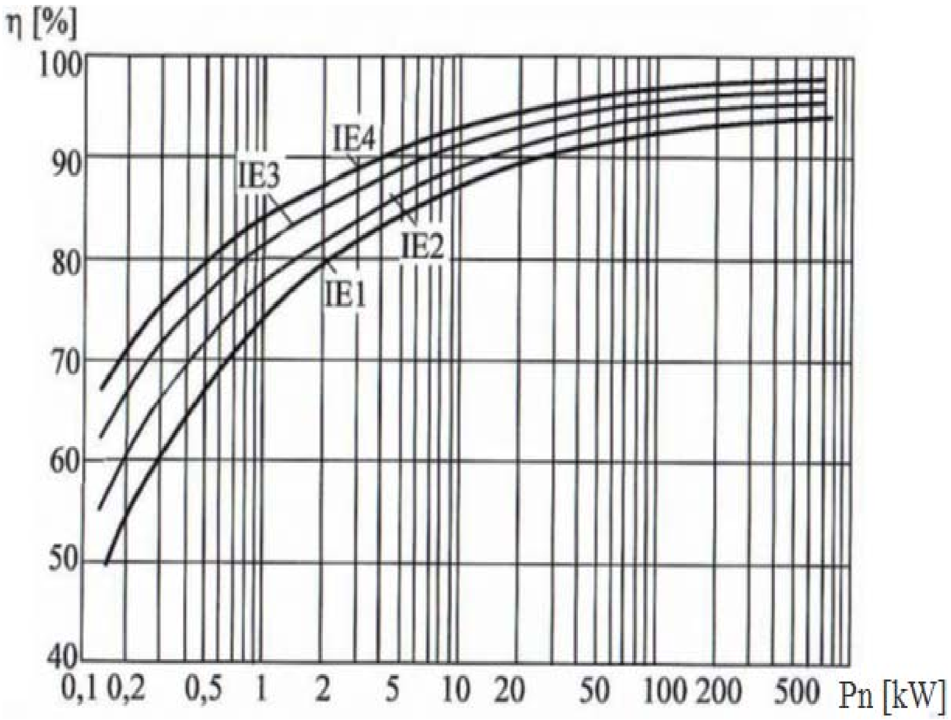

Fig.3 The η adjustment of electrical motors with two poles in dependence of efficiency classes and nominal power

From above diagram, it can notice that an electrical motor with 7,5kW from IE3 has an efficiency about 90,1% in compatation with the corresponding motor from IE1 which has an efficiency is 86%, so the losses reduction is about 20%.

These motors must be executed respecting the standard power-frame size assignment. To increase the efficiency of induction motors there were looked methods to reduce the losses. In the conductors of the stator winding appear principal and supplementary losses.

The IE class and nominal efficiency has to clear subscript on the identify motor plate.[3],[5]

The annual energy economy ΔE from replacing the regular motor (η_r) with an efficient motor (η_e) is calculated with the below relation:

$$\Delta E = P_n \cdot \lambda \cdot t_a \cdot (1/\eta_r - 1/\eta_e) \qquad (5)$$

P_n – nominal power, λ – load factor equal with the ratio between real power and nominal power, t_a – the annual duration of operating at nominal power time.
The annual reduction of CO_2, is C_t:

$$C_t = \Delta E \cdot f_c \text{ [kg } CO_2\text{/an]} \qquad (6)$$

Where f_c (kg/kWh) is the pollutant emissions factor for different resources are shown in the below table.

Tabel 3 ***The values of emission factor f_c***

Resources	**f_c (kg/kWh)**			
	CO_2	**SO_2**	**NO_x**	**CO**
coal	1,18	0,0139	0,0052	0,0002
petroleum	0,85	0,0164	0,0025	0,0002
natural gas	0,53	0,0005	0,0009	0,0005
hydro	-	-	-	-
Wind, photovoltaic	-	-	-	-

To reducing of the principal losses in the stator winding was achieved by reducing the stator winding resistance. To this aim the winding diagram with concentric coils was replaced with a winding diagram with equal, displaced coils. The losses in the magnetic core are the main losses (which are taking place only in the stator) and supplementary losses. For the reducing of the losses in the core the use of electromagnetic steel sheet, having lower specific losses ps=1.1W/kg (M270-50) and ps=1.7 W/kg (M400-50) instead of that with specific loss of ps=3.6 W/kg (M800-50).

By adopting certain constructions and design methods, one can obtain motors with high energetic indexes.

The supplementary losses in the core appear both at no load and full load status of the machine. According to the literature, the supplementary losses can reach up to 8-25% from the total losses.

The supplementary losses in the induction motor are [6]:

- surface losses (representing 40%from the total supplementary losses);
- losses caused by transversal currents between the rotor bars (30% from the total supplementary losses;
- pulsation losses (represent 17% from the total supplementary losses);
- losses produced by the high frequencies (10%); losses produced by the stray fluxes.

Therefore, in order to reduce the supplementary losses and implicitly to increase the efficiency, first of all must be reduced the surface losses and the losses produced by the transversal currents between the rotor bars.

It was shown above theoretically that the decreasing of the supplementary surface losses and of those produced by the transversal currents can be achieved by the increasing of the resistivity of the rotor surface respectively by the increasing the resistance between the bars. [7]

This treatment is made as follows: the rotor (with machined shaft, but not finished on the bearing-seats) having the surface of the rotor core machined, is introduced in an oven and the temperature is increased at 400 ^{o}C and then maintained for 2 hours.

Then the rotor is cooled suddenly in water up to maximum 30°C. Using copper instead of aluminum in the execution of the squirrel cage leads to the decreasing of the rotor resistance, of the losses in cage and, also, leads to increasing of efficiency. For increasing the efficiency, it was worked on the ventilation losses by using fans with smaller external diameter.

3. CONCLUSIONS

The energetical efficiency growth in the electrical drives could determine a reduction of energy necessary with 6,5%. If estimate that every saved kWh leads to reduce the CO_2 emissions with one kg of CO_2 , for Romania, to a energy production of 45TWh/year , the gross energy necessary is less with 3,25% and is corresponding about $1{,}45\cdot 10^6$ tons of CO_2.

Worldwide, electric motors represent around 50% of electricity consumption. Promoting market uptake of efficient motors and drives is an important contribution to the fight against climate change.

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