ISSN 1454 - 8003
Proceedings of 2017 International Conference on Hydraulics and Pneumatics - HERVEX
November 8-10, Băile Govora, Romania

HIGH EFFICIENCY ELECTRIC MOTOR

Mihail POPESCU[1], Constantin DUMITRU[1]

[1]National Institute for R&D in Electrical Engineering ICPE-CA Bucharest, office@icpe-ca.ro

Abstract: *Electric motors are a significant consumer of electricity, so over time they have been improved. From the point of view of energy consumption, the main parameter of an electric motor is the efficiency. This paper describes an electric motor that combines two electric machines, a transformer and an electric motor, in order to improve the efficiency.*

Keywords: *Electric machine, high efficiency, permanent magnet, reduced loss*

1. Introduction

Since the start of the industrial revolution, global energy consumption has been steadily increasing, thus encouraging and accelerating the growth of the human standard of living. One of the indicators of a nation's economic development is the per capita energy consumption index. For example, the United States, which accounts for about 5% of the global population, consumes about 25% of the world's energy.
At global level, the largest amount of energy is consumed by electrical machines (about 80% of the whole electricity that is used) used in the production, transport and distribution of electricity, the operation of industrial and household equipment and so on.

2. Existing legislation in the field of increasing the electric machines efficiency

With the reduction of the fossil fuels reserves and the increasing demand for electricity, an action to improve the efficiency of electromechanical conversion processes has been initiated. This approach led to a gap in European standardization (CEI and CENELEC) compared to the national standardization of some states (Canada and USA).
The comparison between the two approaches regarding the increasing of the electric motors efficiency is shown below:

USA-Canada	**European Union**
Written e - PACT laws Minimum efficiency for 2, 4 and 6 poles and 60 Hz motors is provided in the power range of 1-200 HP (0.75-150 kW):	Voluntary obligations developed by CEMEP for 2 and 4 poles and 50 Hz motors with short-circuit rotor in range 1.1-90 kW: - classification of yields (Eff3, Eff2, Eff1); - big discounts on the market for Eff3 engines.
The efficiency should be selected from the NEMA MG1 rough steps values.	There is no degradation of the exact value for efficiency.
The yield is an average value of a number of engines of the same construction. It is permissible that the output of a single engine to be down to 2 steps in the table.	Tolerances allowed after CEI 60034-1 - 15% loss on motors < 50 kW; - 10% loss on motors > 50 kW.
IEEE 112B Measurement Process with Modified Execution Conditions.	Verification by individual measurement according to IEC 60034-2 by the loss separation method.
Efficiency is proven through accredited measurement laboratories.	The proof based on the manufacturer's declaration is the Eff 1 ÷ 3 label.

Regarding the recommendations of CEI and CENELEC, the Technical Committee 2/CEI has developed the standard 60034-30-1: "Maşini electrice rotative. Partea 30-1: Clase de randament pentru motoarele asincrone trifazate cu rotor în scurtcircuit, cu o singură turaţie (Cod IE)".

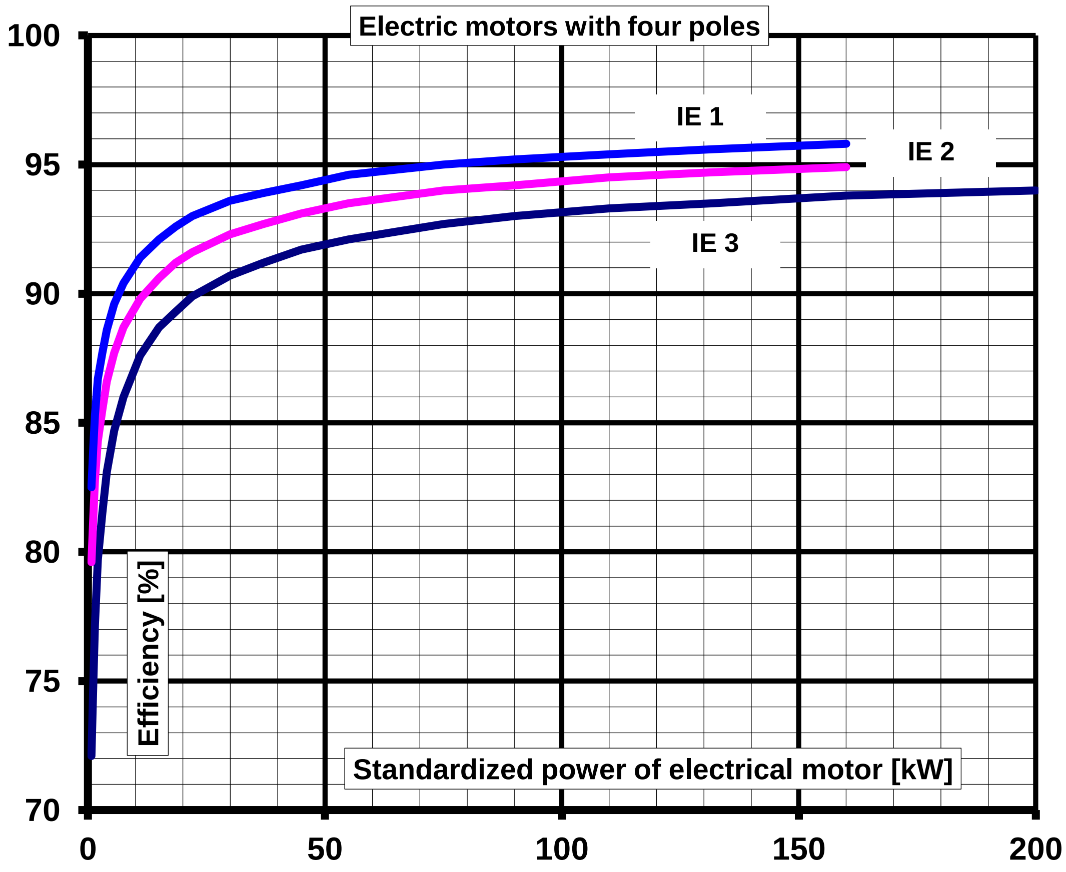


Fig. 1. The variation of the efficiency of electric motors according to efficiency classes IE1, IE2, IE3

3. Operating regimes of electric machines

An electrical machine can operate in several types of operating regimes:

a) In **motor regime**, the electrical machine absorbs power from the grid at the stator winding terminals and supplies mechanical power to the shaft. This mode of operation is the most used, the balance of power being shown in the figure below:

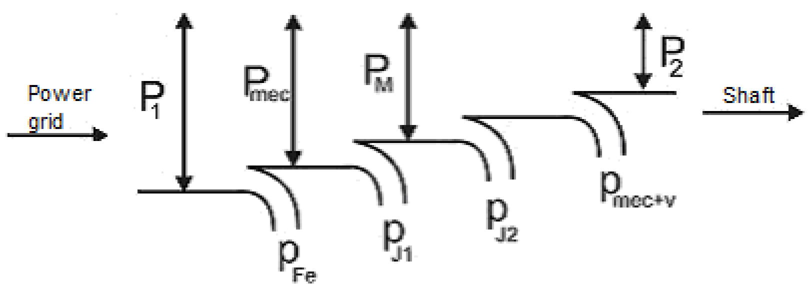


Fig. 2. The balance of power of an electric motor

where:
P_1 - the electrical power absorbed by the stator winding;

P_M – electromagnetic power (transferred to the rotor by electromagnetic field);
P_{mec} – mechanical power;
P_2 – power to the shaft;
p_{J1} – Joule effect losses from stator winding;
p_{Fe} – losses in the ferromagnetic core;
p_{J2} – Joule effect losses from rotor winding;
p_{mecv} – mechanical and ventilation losses.

b) Operation in the generator regime.
If the electric machine is driven by an auxiliary motor at a speed ***n*** and the magnetic circuit is driven by a magnetic field whose value can be changed by changing the value of the electric current through the inductor winding, than the operating regime changes. So, that electrical machine works in the generator regime.
In this operation regime, the machine receives mechanical power on the shaft (from auxiliary motor) and delivers electrical power to the stator winding terminals. The power balance is shown in the figure below:

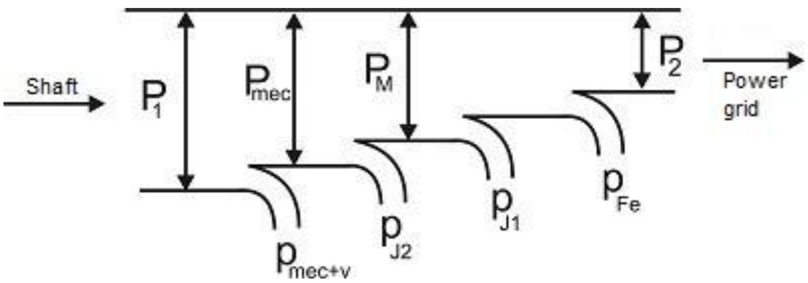


Fig. 3. The balance of power of an electric generator

c) Brake operation regime
In this case, an electromagnetic brake is applied and the machine is trained externally in the opposite direction to the stator field (W<0, s>1). The machine receives mechanical power on the shaft, electrical power on the stator winding terminals and, after the losses are covered, the entire output power is dissipated on the rotor.

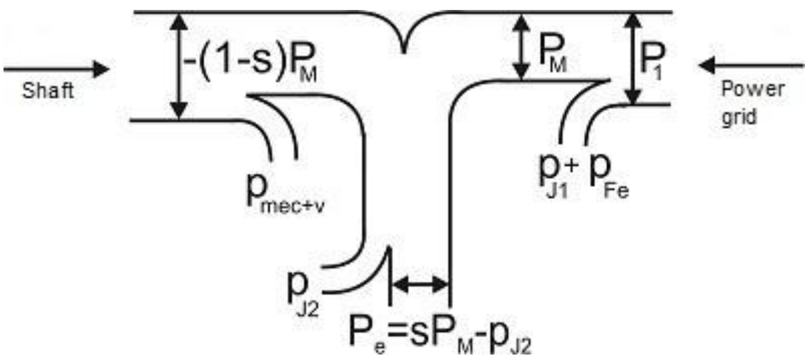
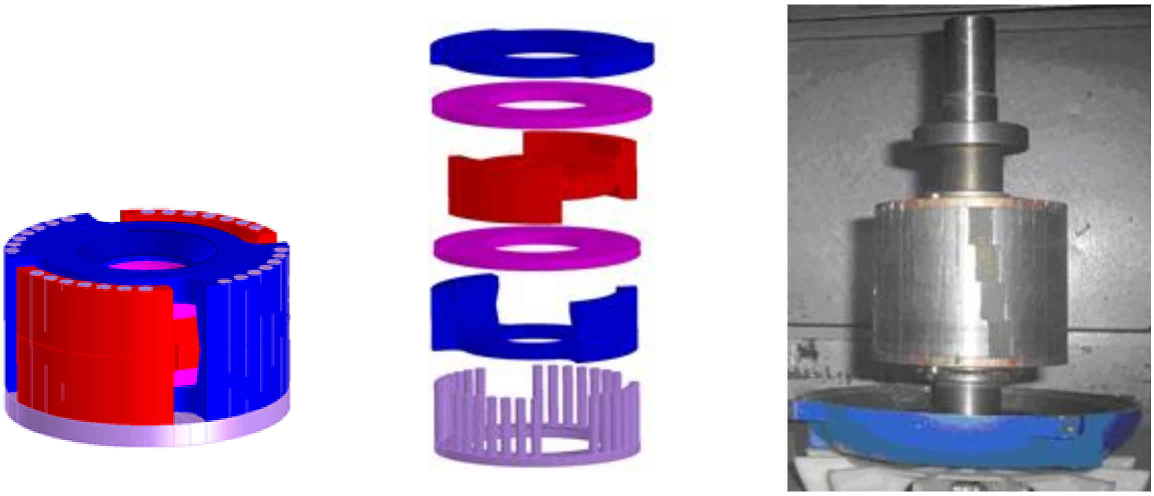


Fig. 4. The balance of power in brake operation regime

4. Solutions to reduce the losses in electric machines

Until now, a series of technical solutions have been developed to reduce the losses of the electric machines. Among them, the followings are presented:

- Use of copper in the asynchronous motors rotor winding; this solution leads to a decrease in the electrical resistance value in the rotor circuit and implicitly of the associated Joule effect losses;
- Insertion of permanent magnets into the rotor magnetic circuit, thus ensuring the magnetization of electric machines;



(a) (b) (c)

Fig. 5. Inductor construction details
Two assembled modules (a), expanded view (b) and physical construction (c)

The motor with permanent magnets has a squirrel cage that provides self-starting, combining the advantages of the synchronous motor, related to the absence of the main Joule effect losses in the rotor, with the self-starting advantages of asynchronous motor with the rotor winding in short-circuit. In this way, exploitation and production losses can be reduced.
Since is no longer necessary to provide reactive magnetizing current of the magnetic circuit, the presence of permanent magnets presents advantages over normal asynchronous motors. The load factor and Joule losses decrease.
- The use of special windings in the stator's electrical circuit adapted to the demands of the electric motors and made by combinations between the coils of each phase and multiple star / delta connections.

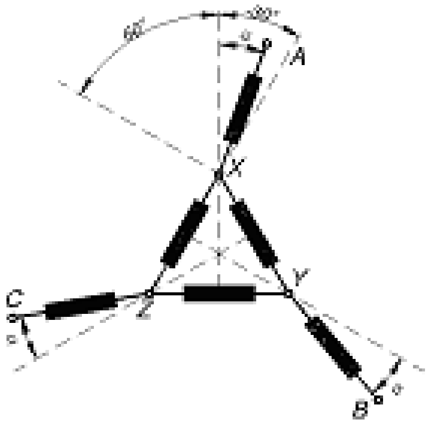


Fig. 6. Combination star-delta winding. Defining the spatial relative position

Combined star – triangle windings had long been used to reduce triangular start - up current for step - wise start - up of asynchronous motors, especially fast 2 - pole motors, which drive large inertial loads.

For achieving this winding, it is assumed that in the notches uniformly distributed at the periphery of the electrical machine armature, two distinct winding systems are located - one connected in a triangle and the other connected in a star. It is also considered that the phases of the star are connected in series with the triangle. Otherwise, there are extreme demands in the electric machine.

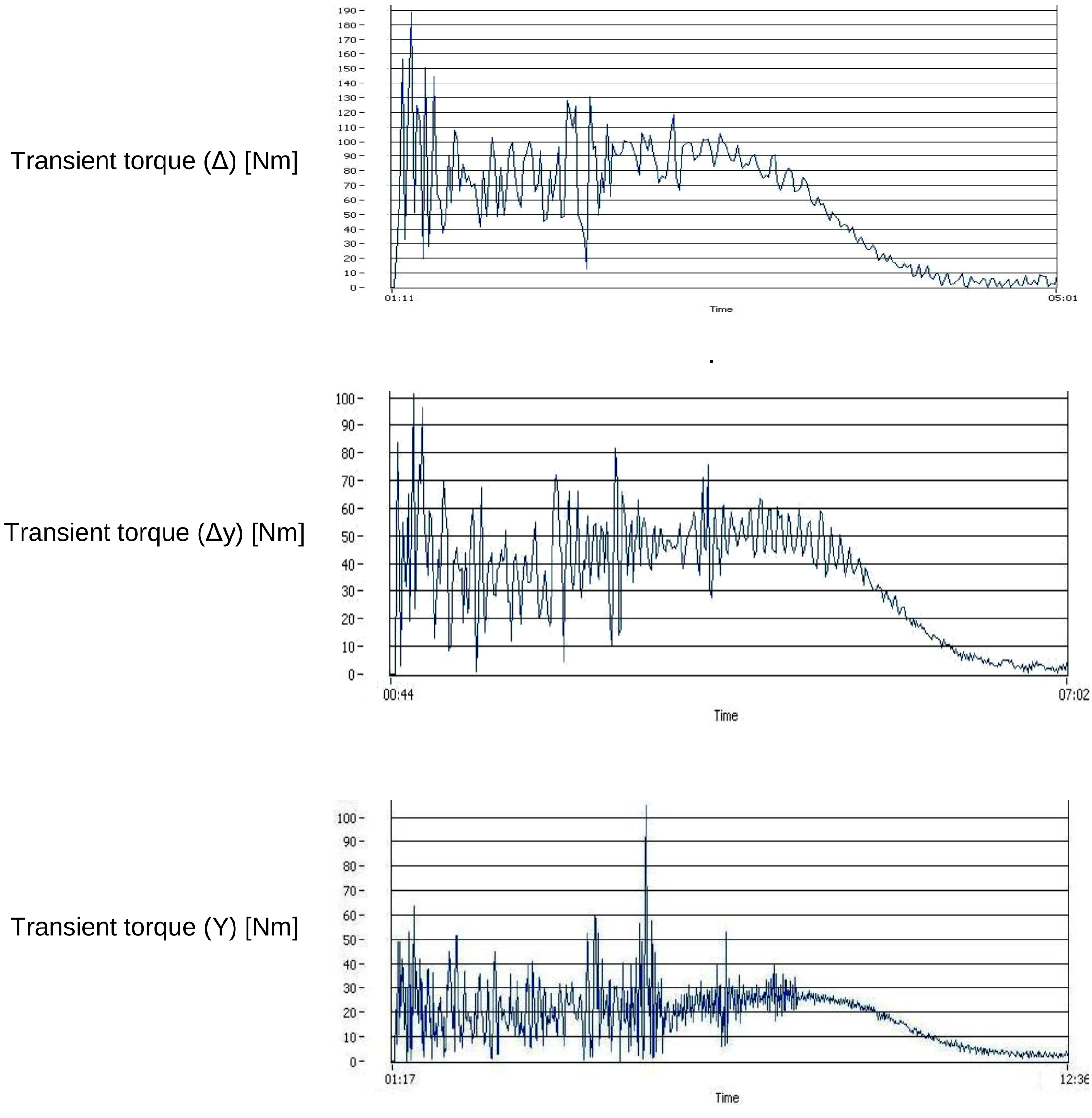


Fig. 7. Transient start-up regime for three combinations

For a 4 kW - 1500 rpm electrical motor provided with such windings, by using these 6 connection, were obtained in load function 4 / 3.25 / 2.5 / 2 / 1.75 / 1.35 kW.

5. The proposed solution for transverse geometry

A group of researchers from INCDIE ICPE - CA proposed and achieved within a research contract (NUCLEU no. PN 16110102/2016 contract) a new transverse geometry of the electrical machine.
The technical solution has several advantages, as follows:
- the active materials used in its construction are those currently marketed and used in the manufacture of electric transformers;

- the ferro-silicon sheet has smaller thicknesses of 0.1 ... 0.3 mm than the one used in the current electric machines, namely 0.5 mm;
- due to the reduced sheet thickness, the hysteresis losses and eddy currents are lower;
- the sheets used have oriented crystals and presents a higher value for magnetic saturation, namely 1.85...2T, compared to the classic values of 1.6 to 1.8T.

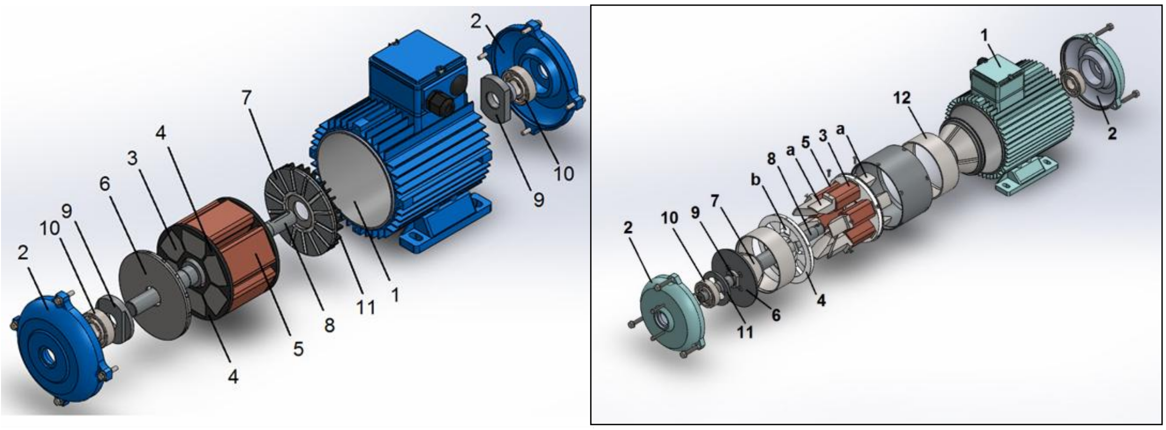


Fig. 8. The exploded machine assembly with modified transverse geometry with axially and conically air gap

The magnetic circuits have the form of columns while the stator windings are in the form of cylindrical coils along the columns. This solution has also the advantage of removing the front ends of the coils; as it is known, they do not contribute to the creation of mechanical torque in the shaft in the case of motors, and respectively to the increase of the supply voltage in the generator operation regime. At the same time, for winding operations, the winding is not inserted into the slots, so a significant number of device, tools and verifiers are eliminated, and the execution time is reduced.

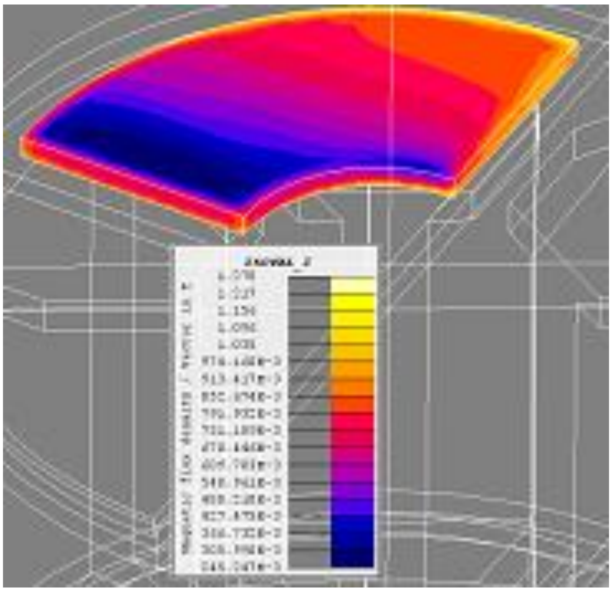


Fig. 9. Map of magnetic induction distribution inside the motor with axial air gap

Fig. 10. Electric motor with axial air gap

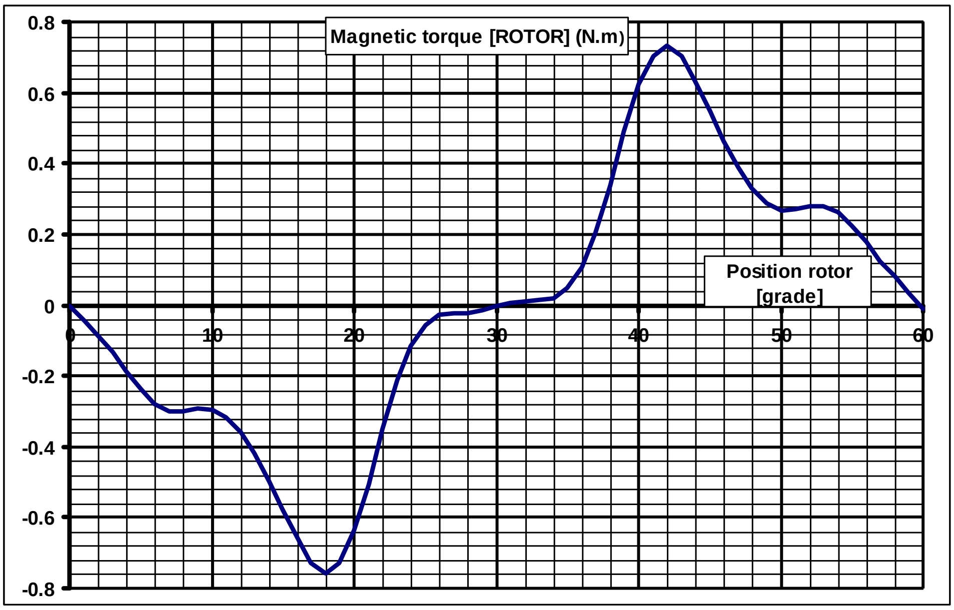


Fig. 11. Mechanical torque generated by permanent magnets at the shaft of axial drive machine with axial air gap

The magnetic rotor circuit, achieved of two subassemblies, is made of a number of magnets and possibly magnetic flux concentric pieces.

6. Conclusions

Over time, increasing electric motor performance has been an important concern for mankind. Different technical solutions have been applied, which generally refer to the increase of the consumptions of the active materials, respectively to the decrease of the electro - magnetic loads.
By comparing the solutions applied so far to the one promoted by INCDIE ICPE-CA, it was found that the value of the efficiency can be increased in the conditions of using existing active materials.
Taking into account the proposed transverse geometry and the advantages stated above, it results that higher-performance electric machines can be obtained. Eliminating the losses in the electric machine leads to obtaining a return in a higher class.

References

[1] “Geometrie transversala utilizata pentru masini electrice cu intrefier axial”, A/01020/ 19.12.2016;
[2] ”Maşina electrica cu magneţi permanenţi şi întrefier conic”, A/00887- 30.10.2017;
[3] http://www.novatorque.com;
[4] T. Tudorache, I. Melcescu, V. Bostan, G. Colț, M. Popescu, M. Predescu, “Electromagnetic analysis of a hybrid permanent magnet generator”, Revue Roumaine des Sciences Techniques, Editura Academiei Române.