BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LVII (LXI), Fasc. 1, 2011
Secţia
ELECTROTEHNICĂ. ENERGETICĂ. ELECTRONICĂ

PERSPECTIVE RESEARCHES OF TRANSFORMERS AND ELECTRIC MACHINES OF SPECIAL APPLICATION

BY

TUDOR AMBROS*

Moldova Technical University, Kishinew, Moldova

Received, March 15, 2010
Accepted for publication: December 4, 2010

Abstract. Some present problems concerning the study of electrical power conver-ters of special application are analysed, such as: efficient use of electrical materials for producing small and welding transformers, development and implementation of three phase axial asynchronous motors, airtight motors with permanent magnet, using of axial generators in nonconventional sources of energy systems.

Key words: small and welding transformers; axial asynchronous motors and generators.

1. Introduction

The paper identifies some issues concerning the development of Electrotechnical industry and economy at national and international level as well. The oportunity of these problems is imposed by the global conditions of energy production and consumption in unconventional ways.

Depletion of energy production resources represents a great problem for modern Electromechanics which requires reducing the electrotechnical materials consumption, improving and simplifying the technology of

* *e-mail*: tudorambros@gmail.com

electroenergetical converters production, adapting the converters construction to the characteristics of the working machine, drafting and design time reduction.

In this paper some examples of converters for special application in the domain of the identified problems are presented.

2. Small Power and Welding Transformers

Nowadays Moldova imports natural gas, oil and fuel, mostly from the Russian Federation. These products are 95...97% of total Republican outfit (Arion, 2004), unfortunately the actual loss of energy in the present social and economic transition period represents 1/3 of the energy delivered to the system.

The operation of high power transformers at no- or low load reduces their power factor and efficiency. Therefore small power transformers (10... 160 kVA) may be used more efficiently.

For raising the efficiency of electric consumption it is necessary to install small power transformers for small private bureaus. But now these transformers must be imported, and their cost is high in foreign markets.

The present paper proposes solutions concerning this problem more advantageous from the economical and technological point of view.

It is known that transformers are calculated for a life time of 20...25 years. Materials used for the magnetic core and windings system include: electrical steel, copper, aluminum and insulation material. Among these materials, during the period of operation of the transformer, insulation modifies its chemical, dielectrical and mechanical parameters, being submitted to irreversible aging, which determines the life duration of the transformer.

Metallic materials (electrical steel, copper, aluminum) practically do not change their chemical and physical characteristics, and can be used after a certain treatment or after repair in production of small power transformers, including welding transformers.

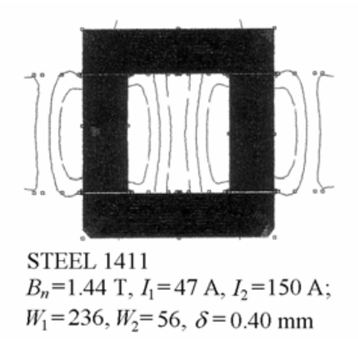


Fig. 1 – The magnetic field of a transformer in load-operation.

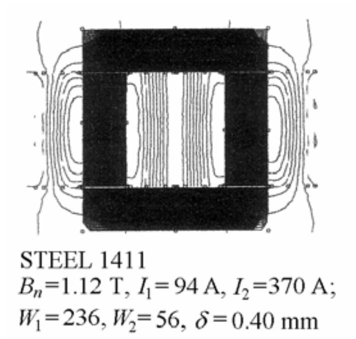


Fig. 2 – The magnetic field of a transformer working in short circuit operation.

These materials obtained from disassembly of large power transformers, except the function due to damage or to life expiration, can be used in producing of low power and special transformers. An electromagnetic calculation method was carried out with application of the finite element method. In Figs. 1 and 2 the magnetic field distributions determined with this method are represented.

Small power and welding transformers were developed at the Department of Electromechanics and produced in several North SA RED, Bălţi.

3. Electric Three-Phase Induction Motors with Two Rotors

The first electric car that was used in transport was equipped with a d.c. motor with axial magnetic flux. This construction, in terms of technology, was difficult at the initial stage of development of electric cars. But thanks to launching of new technologies for the production of active materials and devices, new technological processes were achieved, such as cold rolled electrical steel produced in rolls, stamping devices using variable pitch; the partial or total compensation of the unilateral attraction electromagnetic forces have improved the development and implementation of the axial flux electrical machines.

Study of axial electric machines, little studied in the past, is of theoretical and practical interest for the design and production to increase active material efficiency as compared to its use in cylindrical machines with radial magnetic flux. In this context the interest concerns the performance of axial magnetic flux in electrical machine compared with those of cylindrical machines.

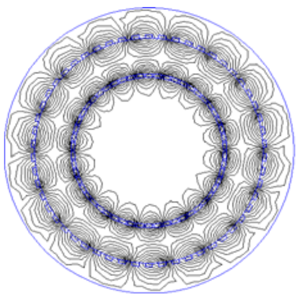


Fig. 3 – Distribution lines.

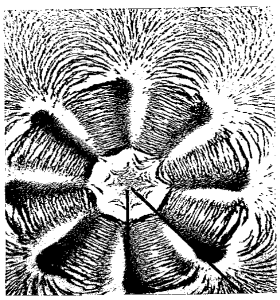


Fig. 4 – Physical picture of magnetic field flow dispersion.

One of these important achievements is materialized in the use of converters with axial magnetic flux used to drive electric centrifugal pumps, fans, ship propellers. When coupling axial machines with the above-mentioned mechanisms, the rotor can be incorporated with the drive mechanism or with the device involved. In these machines it can be obtained a reduced angular velocity because the large diameter allows to carry out a large number of poles. These machines are used today as electric generators, driven by wind engines or water turbines, without multiplying the angular velocity.

In the experimental examples (Figs. 3 and 4) the magnetic field study was carried out with the finit element method. In this context it was studied theoretically and practically the determination of the specific aspects concerning the magnetic induction distribution sectors of the magnetic circuit, the unilateral action of forces in the startup and in load operation of the axial machine (Figs. 5 and 6).

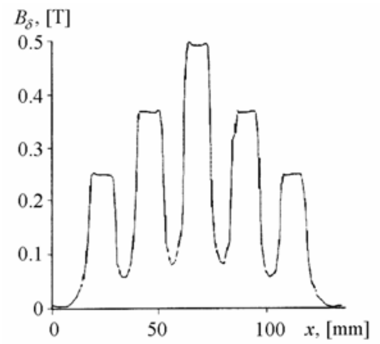


Fig. 5 – Magnetic flux density variation curve.

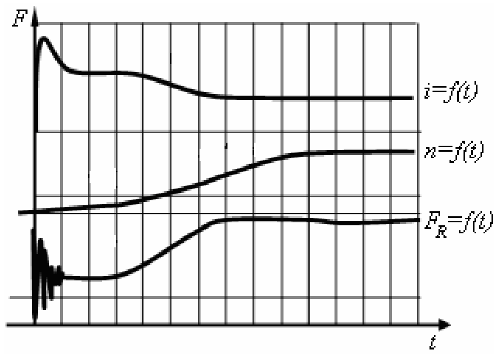


Fig. 6 – Variation oscillograms of the quantities, i_1 , n and F_R in the starting process.

4. Single-Phase Induction Motors with Axial Magnetic Flux

The total power consumed by electric motors used to drive mechanisms and domestic machines represents 20% of total power relative to the population.

In home appliances, in most cases single phase electric motors which are single-phase grid-dependent are used.

Ways of improving the construction and production of these machines can be achieved by cutting electrical steel without waste by using permanent magnets and insulating materials corresponding to modern technologies. Not less important is the conceiving of non-traditional constructions, providing more efficient cooling, coupling, working with the mechanism without auxiliary transmission. The single-phase motors with axial construction and ring or pan-cake stator winding have technical and economical performances higher than the traditional single-phase motors (Загрядский, 1988; Гусев и др., 1982; Ambros *et al*., 1994).

Usually, for the construction of axial electric machines, the problem of the stator and rotor package manufacturing was solved out by producing the electrical steel in rolls. Connected to this construction type there are many only partially studied problems, such as: establishing correlation between the sizes of the axial and centrifugal machine, studying the structure of stacked packages wrapped in electrical steel strip, determining uneven distribution of magnetic induction in the ferromagnetic volume, the influence of the nonlinear distribution load current in the ring-winding on the machine parameters, compensation of unilateral forces of attraction between stator and rotor. All these problems require a deeper study in the field of single phase motors and, generally, of axial electric machinery for proper design and operation. Modern computing methods of the magnetic field of these machines, such as finite element method, represent a way to obtain single-phase motors with improved electromagnetic qualities.

In (Ambros *et al*., 1992; Polard, 1979; ВНИР, 1984; Курбасов, 1985) it is shown that the constructive cylindrical type has lost its perspective, because in this machine were implemented standard technical elements appropriate for that time. The drawbacks of the axial machine diminished by partially solving them out namely: compensation of unilateral forces, construction of the magnetic system, conceiving the teeth configuration. The total or partial compensation of the unilateral forces can be achieved by placing the disk-rotor, fixed on the shaft, between two immobile packages: the stator package and the rotor yoke.

Axial phase motors allow to save copper and to reduce the mechanical coupling auxiliary transmission mechanisms involved.

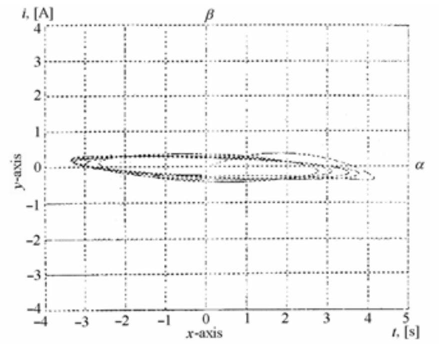


Fig. 7 – Hodoscope phasor of statoric current, C = 3 mF.

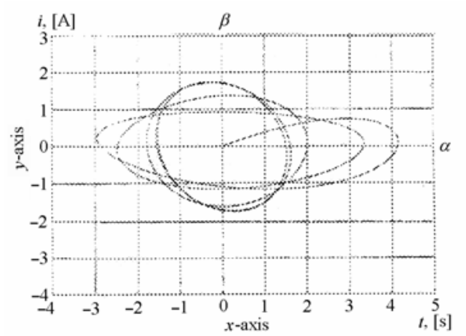


Fig. 8 – Hodoscope phasor of statoric current, C = 8 mF.

It is very important to obtain in these motors a circular rotation magnetic field in all operating modes.

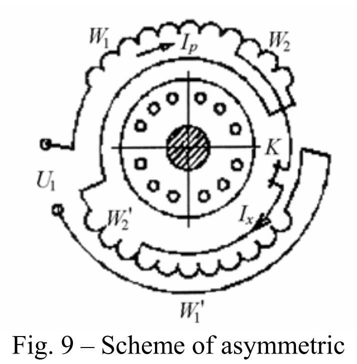


Fig. 9 – Scheme of asymmetric phase induction motor.

In Figs. 7 and 8 the phasor hodoscopes of the stator current are represented at optimizing the start-up process of the single-phase motor.

A special interest represents the starting of single-phase motor without a supplementary element of phase-shifting. In this context it is proposed the scheme of the induction motor with one phase, which excludes this shortcoming (Fig. 9).

Starting-up is achieved by shortcutting a part of the stator winding during starting process, and after that, by connecting it in series with the rest of the winding.

5. Special Electric Motors for Centrifugal Pumps Driving

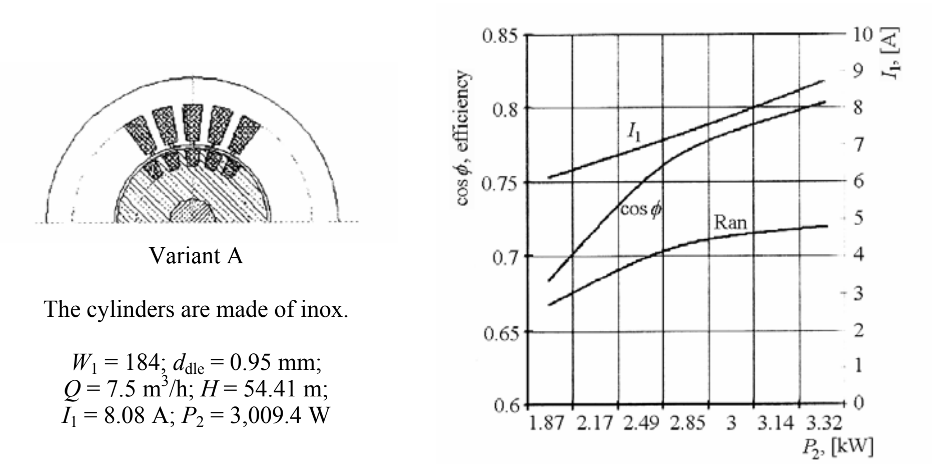
Modern hermetic electric pumps are constituted from one piece, which includes the electric motor, usually asynchronous, and the centrifugal pump. The pumped liquid used for cooling the motor is aggressive and penetrates into its air gap.

Using of electric induction motor drive is advantageous from constructive reasons. The induction motor with shortcircuit rotor excludes electrical contacts, allows the protection of the stator, rotor and windings against the aggressive liquid by means of the protection cylinders pressed on the inner side of the stator package and the outer side of the rotor package (Буренин, 1977; Синеев и др., 1967).

Protection cylinders are made from stainless steel (0.5...0.7 mm), in some cases cylinders can be made from ferromagnetic stainless steel. Pomped liquid serves as a lubrifiant for the bearings.

Induction motor drive is mounted in monoblock manner with centrifugal pump; in addition to the performance shown above, it also has some drawbacks which are the followings:

a) presence of losses in the rotor winding;
b) low efficiency and power factor, increased magnetising current;
c) decreased rotor angular velocity due to increased value of slip.



a *b*

Fig. 10 – Scheme design of induction motor (*a*); operating characteristics graphs (*b*).

Therefore it is necessary to seek new ways to improve the quality of motors for centrifugal pumps driving with low economic and technical indices (Fig. 10 *a*, *b*).

Pumps produced by "Moldovahidromas" are still required on the ex-Soviet market. To preserve and extend this market it is necessary to promote scientific research in this direction.

One of these directions (Ambros *et al.*, 2007; Дельман, 1977) refers to substitution of an induction motor with a permanent magnet synchronous motor or an induction motor with synchronous motor transformation. The first step of transformation can be done easily because the synchronous motor differs from the asynchronous one only by the rotor construction. It is necessary to change only the induction motor rotor construction.

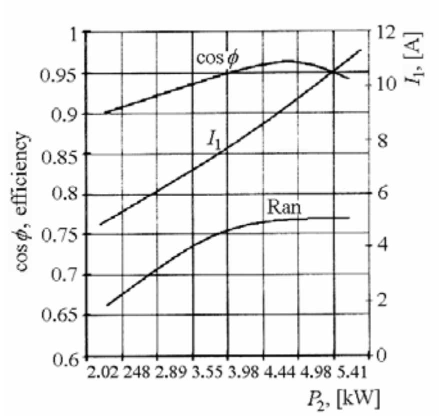
It was found that substitution of the rotor in short circuit in hermetic motors, produced by "Moldovahidromas" with a rotor which is equipped with permanent magnets, contribute to increase the power factor with 16% and the efficiency, with about 5%. Due to the increase of the air-gap magnetic induction and due to elimination of rotor losses, the power of the synchronous motor increases with 25...30% as compared to an asynchronous motor with same overall sizes.

Variant 4

The cylinders are made of permanent magnet

$W_1 = 184$; $d_{dle} = 0.95$ mm;
$Q = 15$ m^3/h; $H = 51.7$ m;
$I_1 = 8.25$ A; $P_2 = 3{,}978$ W

a



b

Fig. 11 – Scheme of synchronous motor (*a*); operating characteristics graphs (*b*).

Using permanent magnets mounted on rotor one can ensure: the increase of electromagnetic loading, *i.e.* magnetic induction and linear current load, excluding electrical losses in the rotor, increasing the angular velocity decrease of rotor noise and vibration in the engine, replacement of the common rotor with a ferromagnetic rotor, simplifying the technology of ferromagnetic solid rotor production, reducing losses in the power grid.

These and other performances of permanent magnet synchronous motor raise their domestic and external demand, being produced in series.

6. Electric Generators with Permanent Magnets and Axial Magnetic Flux

With global climate change and energy shortages exploitation started of new energy-sources which do not influence the climate and environment

(Амброс и др., 1974; Ambros *et al*., 1999). Among mostly spread non-conventional energy-sources the wind, sun and biomass energy are considered today. This tremendous amount of energy is dispersed and therefore difficult to be concentrated and turned into electricity. Wind and falling water energy can be converted directly into mechanical energy, usually rotary, and electric energy by means of electric power generators. In this context can be used axial permanent magnet generators without stator slots (Fig. 12) with a simple and cheap technology.

Fig. 12 – Assemblies of axial generators.

7. Conclusions

According to the theoretical and experimental research achieved on special electrical power converters, the following conclusions are drawn:

1. The problem of the development, design and implementation of small power transformers, including the welding transformers produced by means of low-cost reconditioned electrical steel and copper, is of present interest.

2. Researches concerning three phase and single phase axial motors demonstrate that they have a large application domain and also that their construction technology lead to active material saving.

3. The use of permanent magnets in synchronous sealed motors help to increase the power and the economic technical performances too.

4. The axial flux generators eliminate the gearred transmission when are coupled to the wind and hydraulic turbines. Research perspectives are opened in this domain.

REFERENCES

Ambros T., Nuca Il., *Mathematical Discriet of Axial Asinchronous Motor*. Devel. a. Appl. Syst., Suceava, 1992, 271-276.

Ambros T., Bumbu N., *Calculation of the Induction in the Axial Machine Air Gap*. The 4th Internat. Conf. of Optim. of Electr. a. Electron. Comp., Braşov, 1994, 201-202.

Ambros T., Arion V., Guțu A., Sobor I., Todos P., Ungureanu D., *Surse regenera-bile de energie.* Edit. Tehnica-Info, Chişinău, 1999, 434.

Ambros T., Câmpeanu A., Iazlovețchi L., *Generator sincron axial pentru minihidrocentrale.* Energetica, *1*, 33-35 (2004).

Ambros T., Iazlovețchi L., Lesnic I., *The Constructive Structures of Electric Generators with Axial Magnetic Flux*. Bul. Inst. Politehnic, Iaşi, **L (LIV)**, *5*, s. Electrot., Energ., Electron., 1177-1184 (2004).

Ambros T., Tofan Gr., *Metoda elementelor finite în calculul câmpului magnetic al transformatorului de sudare*. Conf. tehnico-ştiinţifică a studenţilor şi doctoranzilor, Chişinău, 17 nov. 2007, 324-325.

Ambros T. *et al.*, *Motoare electrice cu performanţe tehnice îmbunătățite pentru pompe ermetice*. Raport anual, Tema 12TC, Chişinău, 2007, 58 pp.

Arion V., *Strategii şi politici energetice*. Edit. Universul, Chişinău, 2004, 538.

Chalmers B.J., Spooner E., *An Axial-Flux Permanent-Magnet for a Gearless Wind Energy System.* Trans. IEE on Energy Conv., **14**, *2*, 251-257 (1999).

Chalmers B.J., Spooner E., *TORUS – a Slotless Toroidal-Stator Permanent Magnet Generator.* Proc. IEE B, **139**, *6*, 497-506 (1992).

Polard J., *La structure du moteur asynchrone face à l'évolution des méthodes du production*. Rev. gen. électr., *2*, 149-160 (1979).

Агеев В.Д., *Исследование потери мощностей в экранах экранированых двигателей*. Электричество, *12*, 63-65 (1974).

Амброс Ф.С. и др., *Самовозбуждение автономного асинхронного генератора с подмагничиванием статора. Оптимизация и расчеты электрических машин*. Сб. тр. АН МССР. Изд-во «Штиинца», Кишинев,1974.

Амброс Ф.С., *Автономный асинхронный генератор с подмагничиванием спинки статора*. Автореферат дисс., МЭИ, 1976, 24.

Арьянов С.А., *Определение параметров контуров вихревых токов асинхрон-ного двигателя*. Тр. МЭИ, *314*, 20-24 (1977).

Буренин В.В., *Конструкция и эксплуатация центробежных герметичных насосов*, Машиностроение, М., 1977, 151.

Гусев Б.Я. и др., *Асинхронные электродвигатели с аксиальным воздушным зазором*. Электрот. пром. СССР, Электр. машины, **3**, *133*, 18–22 (1982).

Дельман Р.Ш., *Расчёт пускового режима экранированных асинхронных двигателей с массивным ротором с короткозамкнутой клеткой*. Электротехн. промыш. серия электр. машины., *7*, 1-4 (1977).

Курбасов И.П., *Целесообразность и возможности использования электри-ческих машин дисковой конструкции*. Электричество, *2*, 29-32 (1985).

Лопухина Е., Сомихина Г., *Асинхронные микромашины с полным ротором. Теориа основы расчета и испытания*. Энергия, М., 1967, 488.

Поклонов С.В., *Асинхронные двигатели герметичных насосов.* Энергоатом-издат, Ленинград, 1987, 60.

Синеев Н.Н. и др., *Герметичные водяные насосы атомных энергетических установок*. Атомиздат, М., 1967, 174.

Загрядский В.И., Амброс Ф.С., *Исследование и разработка торцевых асинхронных двигателей для стиральных машин*. Отчет КПИ им. С. Лазо., NГР018700 инв.18409, Кишинев, 1988, 81.

* * * *Исследование встроенных торцевых асинхронных двигателей блочно-модульного типа, их разработка и внедрение*. Отчет ВНИР, гос. регист. № 01.84.0035360., М., 1984, 77.

CERCETĂRI DE PERSPECTIVĂ A TRANSFORMATOARELOR ŞI MAŞINILOR ELECTRICE CU APLICAŢII SPECIALE

(Rezumat)

Sunt analizate succint unele probleme actuale de cercetare ale convertizoarelor electroenergetice cu aplicaţii speciale. Din aceste probleme fac parte: utilizarea eficientă a materialelor electrotehnice recondiţionate în producerea transformatoarelor mici şi de sudare, elaborarea şi implementarea motoarelor asincrone axiale trifazate, a motoarelor ermetice cu magneţi permanenţi, utilizarea generatoarelor cu flux magnetic axial în sistemele surselor neconvenţionale de energie.