THESIS ABSTRACT

In contemporary society conditions, the paper entitled "Contributions for establishing the performances of asynchronous traction motor", approaches a well-known, very complex and studied theme, examined from a new perspective, that of using the asynchronous motor, as an answer for solving transport problems within the general concern for a "cleaner surrounding environment'.

This research theme is directly included among the fundamental research concerns regarding the optimization of electric machines operation at the Department of "Electric Machines and Environment Engineering" and also uses the studies and experiments of the departments of "Electrical Engineering" (Electric Traction section) and "Electric Control" at the Faculty of Engineering in Electromechanics, Environment and Industrial Informatics of the University from Craiova.

The subject has established a new large bibliographic documentation upon the researches carried and published in the field of electric traction, electric machines and not only.

Why electric traction? Because railway transport can be a safe answer to the environment problems regarding the use of non-polluting power sources.

Why the asynchronous motor? The first reason is given by the classic advantages of the asynchronous motor, regarding its ruggedness and safety in operation, advantages that make it the most often used in various industrial applications. On the other hand, the higher energetic output, volume gain, provided by the application of the new technologies upon these motors and related inverters have made the asynchronous motor the ideal candidate for the optimization of electric traction. A significant competent for choosing the asynchronous motor as the object of study was the opportunity given by the development of available mathematic instruments and the increasing power of computers, which have allowed to pass from the pragmatic design of induction machine to its design and numerical modelling, due to a thorough knowledge of the phenomenon of synthesizing under the form of calculation tools and optimization.

Consequently, the working *objectives* of the researched theme, proposed and achieved were:

1. Synthesizing the knowledge regarding the transport problems within the context of current environment policies;
2. Reviewing the existing and future asynchronous motors traction systems;
3. Main theoretical synthesis necessary for the study of the asynchronous traction motor;
4. Applications of the numerical calculation in the analysis and simulation of some dynamics regimes of operation of the asynchronous traction motor.
5. The use of numerical calculation in the adequate design of the asynchronous traction motor;
6. Experimental trials which simulate a traction chain of the type "runway – asynchronous motor".

The *first chapter* makes a short description of the time evolution of asynchronous motor electric traction. Starting from the current international and national context of electric traction, this evolution was divided in stages, trying to underline the permanent connection between the social need it has to answer to, at a given time, a new solution and a possibility for its practical achievement.

The paper reveals four stages in the evolution of electric traction: electric traction with asynchronous motors powered directly from the contact line, electric traction with asynchronous motors powered through rotating converters, electric traction with asynchronous motors powered through inverters and high speed electric traction.

For the current stage, that of high speed electric traction, a synthetic analysis was made for the problems identified, accompanied by a classification of types of problems, by the description of negative effects identified for each problem and their solutions.

The next point of interest in the study of the traction system was the particularization of the asynchronous traction motor. The conditions imposed to the motor by operation modes, specific to electric traction were described and analyzed: operation with constant torque and constant power.

The bibliographic synthesis allowed to describe the general structure of the energetic circuit of railway electric vehicles driven by short-circuits rotor asynchronous electric motors, by revealing their related voltage inverters operation.

The last paragraph is dedicated to the traction system in general. It analyses the adherence phenomenon and the way in which, through the adequate control of the asynchronous machine, it can be used efficiently.

This chapter also makes a synthesis of the dynamic operation of railway traction (establishing the running regimes and running diagrams), in order to reveal the constraints of the traction motors from the point of view of moving speed.

The general conclusion of this chapter is that the structural circuits of the asynchronous traction machine illustrate the interactions between various variables describing the operation of the motor and are defined as a system of powerfully non-linear equations, whose solving requires the use of numeric calculation.

In *the second chapter* the accent moved on the asynchronous machine as a technical system modelled both mathematically and numerically.

Starting from the introduction of the representative phaser as instrument of analysis of the asynchronous machine, its generalized equations were defined along with their related unit equivalent circuits, for a *unitary theoretical study* of stationary and transient processes within an asynchronous machine, whose operation has to be optimized. *The analysis has revealed that unitarily and directly generalized equivalent circuits are found both in transient and in stationary operation.*

Because the asynchronous traction motor operates at variable speed, an analysis was made for the operation of the asynchronous machine at variable speed, in stationary operation, in order to determine the adequate technical and economic parameters for the operation of the machine at frequencies below the rated one in order to give analytical expressions that allow to describe all the sizes that define the behaviour of the machine.

Through the particularization of α parameter, in generalized equations, various machine operation situations were analyzed: operation at $U_1 / \omega_1 = ct$; at $\psi_m = ct$; at $\psi_{m\alpha} = ct.$ for every case, resulting mathematic patterns were numerically simulated using Matlab programming in order to provide qualitative and quantitative information upon the variation of inputs $(\psi_m(\omega_2), I_1(\omega_2), M(\omega_2), M_{kM}(\omega_1), M_p(\omega_1), \omega_{2k}(\omega_1),$ at $U_1/\omega_1 = ct$; $U_1(\omega_1)$ at $\psi_{sh} = ct, \omega_2 = ct$, $U_1(\omega_2)$ at $\psi_m = ct, \omega_1 = ct$, for machines of 100 – 1000kW). The analysis of mathematic patterns and numerical simulations was performed in order to reveal the advantages or disadvantages of using the asynchronous machine, described by them, in electric traction.

For the study of the dynamic operation of the traction motor mathematic patterns were drawn-up for the saturated asynchronous machine that can be used for the simulation of specific aspects of its operation (variable load, variation of the supply voltage, etc.). This had to be described because the high precision of asynchronous machine behaviour simulation during dynamic processes is given by the description of the magnetic saturation influence on the mathematic patterns used. Certain particularizations of the main patterns were made in actual cases that can occur in electric traction.

The chapter originality consists in the conception of the numerical programs for simulating the dynamic process of the asynchronous machine operate with variable frequency.

The third chapter describes the adequate design of the asynchronous traction, under the constraints of sizes, temperature, noise minimization, under the circumstances of sustainable development approaching aspects of recyclability. It follows an adequate design based both on traditional experience and on the use of mathematic and numeric tools. It is known that, for a long time, electric machines design was made based on experience capitalization. This pragmatic aspect was not neglected in the paper, but, because the increasing power of computers allowed more formal approaches that require good knowledge of physical phenomena occurring in electric machines, the adequate design shall be based on numeric calculation.

It follows the design and construction method of asynchronous traction motors. The most important stages and calculation relations are described here. References on the specialty literature are made, new aspects of designs and technologies existing at S.C. Electroputere S.A. are presented and personal contributions in this field are also described.

A significant extended paragraph is that of optimization. It starts from a brief and clear enumeration of the main optimization methods and criteria, with actual appliance possibilities, made available to designers by the mathematic calculation apparatus. Then, it refers to the optimal design of asynchronous traction motors using the selected criteria. In this way the objective function is established, as well as the main variables, constructive restrictions and the ones imposed to variables.

Local optimizations are made in order for chosen variables to result (power layer, electrical gap magnetic induction, power densities from stator and rotor windings) on the gauge, production and operation costs of the motors.

The results and conclusions of this chapter reveal the correction of solutions based on the aforementioned criteria, by comparison with an already existing continuous power motor at the electric diesel LDE 2100 locomotive in operation at CFR. This justifies the modernization proposal for this type of locomotive to replace old continuous power traction motors with new more performing asynchronous ones.

The final part of the chapter describes the alignment program with the help of numeric calculation performed for designed traction motors operation and mechanic characteristics, by exactly considering the parameters of the machine, the saturation phenomenon and the upsetting phenomenon at various frequencies.

Many graphic representations are described, by mainly analyzing costs and other secondary criteria: gauge sizes, starting and operation characteristics, active material consumption, main losses. These results are recorded in tables and reveal maximum, minimum and optimal values, by considering the significant criteria.

The 4th chapter proposes a new manner for including saturation effects in calculations, by using general equations as representative phasers. The high precision of asynchronous machine behaviour simulation during dynamic processes is provided by revealing the influence of magnetic saturation on mathematic patterns. Possible combinations of state variants are divided in two classes for which calculation algorithms are determined directly. Starting dynamic processes are considered along with the specific operation of a traction motor. It proves the extended possibilities provided by non-linear dynamic patterns, by electric, magnetic and mechanic stress predetermination, and practical valuable results are achieved in order to complete the design stage of machine’s parameters.

First of all, constant parameters are supposed, and secondly the saturation in the main field as well as upsetting processes in dispersion fields are considered.

All the characteristics defining its behaviour in dynamic operation are practically defined for the rated motor. The following types of operation are analyzed: dynamic starting operation by considering constant parameters and various inertia moments and null resistant torque; dynamic starting operation by considering variable parameters $L_m(i_m)$, $R_r(\omega)$, $L_s\sigma(\omega)$, $L_r\sigma(\omega)$ and $J = J_n$; dynamic spinning operation; oscillations dynamic operation of traction motor voltage.

The chapter ends with conclusions.

The fifth chapter, the experimental one proposed and achieved an experimental bench for the study of asynchronous machines in the regime of traction motor. Experimental bench conception was an original exercise of creativity, based on a detailed analysis of the synthesized theoretical support and on the existing laboratory equipment, being performed in the laboratory of “Electric Machines” at the Faculty of Electrical Motorering, Energetics and Applied Informatics within the “Technical University Gh. Asachi” from Iaşi. Its task was to physically simulate a traction chain consisting in the “runway system” and “the asynchronous traction motor”.

In the driving chain, traction conditions were creating by the working machine, which due to an adequate command, simulated the runway system, the movement resistance of the motor unit, respectively. Various simulation situations were created, acquiring the interest sizes for the study (mechanic torque or mechanic power, shaft revolution, power and supply voltage). Data were processed in LabView.

Experimental results regarding the influence of the convoy weight upon the movement resistance were validated in the laboratory of Electric Traction at the Faculty of Motorering and Electrical Motorering, Environment and Industrial Informatics within the University of Craiova, by using FERELEC didactic equipment meant for the analysis of various phenomena of electric traction.

The last part of the thesis is dedicated to general conclusions and perspectives. The paper closes with bibliography and annexes where various theoretical or experimental aspects are completed/ detailed.

Personal contributions

Treating a very complex research with multiple interrelations, the thesis is original due to its punctual description of theoretical bases used and due to its experimental solution proposed.

The subject analysed in this thesis is included in the author's concerns for several years regarding the use of mathematic calculation programs and numerical methods for the optimization of asynchronous motors design, especially of asynchronous traction motors, in order to reduce the consumptions of active materials, production cost and operation costs.

The matters described in this thesis, its results and conclusions provide originality to the thesis, by opening new perspectives for the use of modern calculation means in the design and achievement of the necessary documentation.

From practical point of view, the paper provides designers and manufacturers of asynchronous traction motors a new calculation technology based on electronic computers.

This thesis aims to answer current and further requirements regarding traction motors design and production with high economic and technical indicators.

Although a dominant place is held by the information provided by literature, the thesis is marked by originality from many points of view, and this is why the author's original contributions will be presented next on chapters:

- determining a mathematic pattern and achieving the calculation program for the optimal design of asynchronous traction motors with predetermined gauge sizes;
- determining the objective function (total minimum cost) for performing optimization;
- studying the influence of main variables which are considered the most important in design: A –power layer, B –electric gap magnetic induction, r, *J*1 –power density in

stator winding , J 2 –power density in rotor winding (rotor rod), on the objective function and on the most important criteria considered;
- determining the mathematic pattern and achieving the calculation program for calculating and determining the operation and mechanic characteristics of asynchronous traction motors;
- designing a calculation program in order to perform optimal construction and characteristics or the ones requested by the beneficiary;
- calculation and graphic representation of static and dynamic useful inductivities in relation to the magnetization power, in order to be able to study the influence of magnetic saturation of locomotive specific dynamic operation;
- calculation and graphic representation of stator and rotor dispersion inductivities in spinning relation in order to accurately represent mechanic characteristics;
- checking traction characteristics for the two motors: designed asynchronous motor proposed for the modernization of diesel electric LDE 2100 locomotive and the existing continuous power one;
- designing and developing a simulation chain of the "runway" – "asynchronous traction motor" system and determining operation methods;
- using MATLAB and LABVIEW programs in order to solve certain problematic aspects like: study on the asynchronous motor starting; calculation of asynchronous motor parameters based on experimental data; numeric calculation in order to chose the electric traction motor for the carriage operation simple chain; numeric calculation of running times and space for the traction chain.

Designed programs allow a wide range of stating the optimization problem and thus cover a great part of asynchronous traction motors manufacturing factories' needs.
- it proposes a new method for including saturation effects in calculations, by using general equations with representative phasers;
- the high precision of asynchronous machine behaviour simulation during dynamic processes is provided by the introduction of variable parameters in mathematic patterns used;

- possible combinations of state variables are divided in two classes for which the original calculation algorithms are directly determined;
- the wide possibilities provided by non-linear dynamic patterns are proved along with electric, magnetic and mechanics stress predetermination under conditions of traction and valuable practice results are achieved in order to complete machine parameters during the design stage;

As a whole, the studies performed herein have applied in the development of several scientific research contracts, in which I have participated as a member of the team.

I dare to say that the development that I personally performed in this period has opened new perspectives and I hope that I could continue to make a contribution to complete them.

I express my gratitude and my sincere thanks to all the persons that have contributed to this research, through useful direct advice and discussions, who may be sure that they have left a mark on this doctoral thesis.