

Annex 2 – Forms/ B

Programme		CEEX/ Form B	
Module-I	Complex research&development projects	Type of Project	P-R&D
Proposal's Acronym	HIGH_EFF	No.	

Thematic Fields S/T*) (3 thematic fields)	Code 1	5	Title 1	Energy
	Code 2	5.8	Title 2	Energy efficiency and savings
	Code 3	5.9	Title 3	Knowledge for energy policy making
Technological Platform **)	Code	PT.13	Title	Manufature

*) according to Annex 1 – Activities / Thematic Fields S/T

***) according to Annex 1 – Activities / Technological Platforms (for complex projects)

B - PROJECT PROPOSAL DESCRIPTION

(max. 15 pages, Arial 10, 1.5 lines)

1. PROPOSAL'S TITLE IN FULL

Proposal's Title in full, and its acronym :

Increasing of the efficiency in the electromagnetic energy conversion process by means of a.c. electrical motors (HIGH_EFF)

1.1 Thematic fields S/T according to Annex 1: 5. Energy (5.8. Energy efficiency and savings)

1.2 Proposal's abstract (max. ¾ pages, Arial 10, 1.5 lines)

The oldest energy „source” is the *saving of energy*. The a.c. electrical motors are representing a big energy consumer: about 65% from the total electrical energy is converted in mechanical energy in all of the industrial fields via fans, pumps, compressors, machine-tools, elevators, a.s.o. Long time there was encouraged the tendence through reducing the active materials (electrical steel, copper, aluminium) in order to get lower delivery prices, to the prejudice of energy efficiency and power factor. *The increasing of the a.c. motors efficiency , i.e. the decreasing of the dissipated losses is representing a stringent necessity* both in Romania and Europe, having important effects not only on the final users expenditures but especially on the decreasing of the emissions associated by the burning of the primary fuel (generally hydrocarbons) to produce electrical energy in the power stations.

It is demonstrated in the proposal that turning a conventional set of 200.000 small power (up to 7.5 kW) standard electrical motors in the well defined eff-1 efficiency class, may lead to turning off a power station working on conventional primary fuel of 25 MW working 7500 hours/year, representing the losses that are no more producing, with all the adjacent consequences related to the environment protection, emissions and other effects.

The increasing of the a.c. motors efficiency may be generally done by decreasing of the electromagnetic loadings as flux and current densities. In case of *general application induction motors* the starting performances being normalised, the observing of correlation between power, speed and dimensions leads to the significant increasing in the material consumption and manufacturing costs. There are actual researches and tendencies to replace the induction motors in some industrial applications by so called line start permanent magnet synchronous motors, even there are no up to now catalogue data for three phase applications. These motors have the advantages of the higher efficiency in smaller volume and weight having similar costs with equivalent induction motors. These motors are suitable for so called *centrifugal applications* as fans and pumps which need no high starting torques and accidentally overloads are out of question. The researche of these type of motors in order to replace the general purpose induction motors are actually on the working table of some research teams from Europe and represent a main component of the proposal.

The proposed project is to define the high efficiency technical solution (eff-1 as is defined by CEMEP) for both type of motors, induction motors and permanent magnet synchronous motors with line-start capability. Based on theoretical and experimental researches, the project will be finalised by technical developed design of the two series of motors frame 90-132, establishing the constructive conception and the main elements of the normalised series of motors. The technical results will be wide disseminated to all the Romanian motors manufacturers in order to get started the manufacturing process.

2. PRESENTATION OF NATIONAL AND INTERNATIONAL CONTEXT WITHIN THE MENTIONED THEMATIC FIELDS:

The most of the industrial drives are using squirrel cage induction motors. Being manufactured in mass production, in special special locations, according to the noemalised power-speed-dimensions correlation, these motors are cheap, robust and reliable. Some applications regarding the pumps or fans drive are now provided by static inverter supply in order to save energy by speed control depending on the driven system parameters. The global economy of the inverter fed solution has to be analised from case to case because the total price of the investment is still high.

The permanent magnet (PM) synchronous motors were used up to now only in the well defined application such as machine tools spindle or adjacent drives, special processes in the chemical industry (synthetical fibres) a.s.o. It is known that the PM synchronous motors have the advantages of high rated power factor and efficiency due to the lack of the losses in the rotor armature. However, these motors have the difficulty of starting. If the induction motors are naturally started by simply line connection, the PM synchronous motors encounter difficultied to get started in load , even they are provided by starting squirrel cage. The reluctance torque, superimposed on the asynchronous torque during starting, is very annoying and the starting may fail. In some cases the PM synchronous motor may be supplied by inverter controlled by an incorporated encoder but the solution is expensive and are to be used only in high performance driving systems from the dynamic and static accuracy are in view.

The small power PM synchronous motors are used only in special applications being known as brushless a.c. motors, supplied by inverter and controlled by encoder. Replacing the small power general purpose induction motor (less than 10 kW) by PM synchronous motors may lead to important energy savings due the big number of these kind of motors (the induction motors up to 11 kW are consuming more than 65% from the total induction motors consumed power).

In Romania there were researches concerned to PM synchronous motors especially related to PhD thesis with good results. The used starting solution is generally with squirrel cage provided in the rotor and special changing connection of the stator winding, either by series-parallel connection of the phase colis or by half number of turns during starting. In this way the starting field will be bigger and the stator current density will be preserved in the usual range in order to avoid high overtemperature in the stator winding. However the solution was not applied because of the low value of the starting torque (only a fraction of the rated torque). The rotating magnetic field due to the stator a.c currents are to close through very reluctant paths of the permanent magnets in the rotor, where it is interfering with the PM's field leading to additional (parasitic) torques.

Many researches on this topic were performed abroad starting from 80'th in order to find the best construction to solve the compromise between the starting and rated load performance. There are also many patents regarding the way to change the winding connections in order to compensate the reluctance torques of hybride rotors (PM and squirrel cage). However it is clear that the technical solution solving all the problems is to be found. It would be very attractive a PM synchronous motor developing the starting torque of 1-1.4 (p.u.) for many applications such as fans and a wide range of pumps. The great number of recent requested and issued patents in USA and other countries are to prove that the problem is very topical and there are elements to be improved both as constructive conception and materials and technologies.

Referring to general purpose industrial drives, there are no literature reference about PM synchronous motors replacing simply the induction motors. There are only application in single phase, most of them home appliances, but not in three phase drives. Researches are performed in research centers as "Speed Laboratory" from Glasgow (Prof. Timothy Miller), University of Manchester (Prof. B.J. Chalmers), but especially in the Royal Institute of Technology from Stocholm where the team of Peter Thelin and Hans Peter Nee obtained important results concerning design and testing of this kind of motors. From patented inventions point of view there are as reference the patents of John Boyd from GE-Motors (Wayne-Indiana, US 5,952,757), Kliman B. Gerald (GE-Corporate, Schenectady, US 5,548,172) and Toshihiko Satake (Japonia, US 5,796,233). As single phase applied PM synchronous motors can be mentioned the catalogue of RELIANCE (UK) and Baldor (USA) companies.

Taking into account the above mentioned data, the developing in Romania of the three phase PM line start synchronous motors could be an interesting achievement with economical effects to be taken into consideration. If these motor would develop the starting torque around 1 p.u. (or a little bit more) they could be used in a large number of centrifugal applications regarding the fans and some pumps. Using in these applications the general purpose induction motors is, from the point of view of the research team, a waste of both raw materials and electrical energy because the fans need no high starting torque (the load torque is proportional to the square of the speed). The development of different type of motor than general purpose induction motor (for general

application) is to be taken into consideration for fans drive even in case of induction motors¹.

Once getting started, the PM synchronous motors run at synchronous speed having the advantages of a little bit bigger speed, and power factor close to unity because of the fact that the PM are supplying the reactive power which will no more drawn from the line. If the magnetic field created by PM is big enough, there is even the possibility that the motor to supply reactive power in the line. Taking into account this fact there is the possibility to obtain in the volume of eff-2 induction motor an eff-1 PM synchronous motor with approximately the same cost of the materials.

As the induction motor are concerned, in Romania is covered structurally all the ranges of general purpose motors. The abusive politics imposed before '89 to the electrical machines manufacturers in order to continuously decrease both the raw materials (electrical steel sheet, copper, aluminium) and the costs led to the lower performance of the motors as the efficiency and power factor. This tendency was applied even by the other abroad manufacturers, being a consequence of the optimising criteria of minimum material and cost at given (low value) performance. In the last 15 years the problem was re-considered and the result is that some manufacturers have introduced eff-2 induction motors. However up to now there is no inner manufacturer to manufacture or deliver eff-1 induction motors even there are many applications (internal services of the power stations, chemical industry, agriculture irrigation pumps) where these kind of motors would be very useful. The analysis of the sold motors shows that the most manufactured and sold induction motors in Romania are of the eff-3 type as in Europe are of eff-2 type and only 6-10% are of eff-1 type².

Abroad in last years the energy politics regarding the electrical motors had an evolution with institutional aspects. In fact there was an evolution from leaving all the freedom to the motor manufacturer to design, to manufacture and to sell their products, through an institutional politics (in case of USA a Government politics) to constraint the manufacturers to increase the efficiency of the electric motors. In USA it is known the so called EPACT³ which established the minimum values of the efficiency of the motors to be manufactured and sold after one established dead line. In Europe the same politics was applied by CEMEP (European Consortium of Electric Motors manufacturers) being established the values of the efficiency of three classes of electrical motors of given rated power and also a time graphic to increase of efficiency. The main aim is to stop the manufacturing of eff-3 motors considered as wasting energy motors.

It has to be mentioned that in case there are recent modification in the international standards (EN 60034-1:2004 as IEC 60034-1:2004) regarding the methods of determining the efficiency of the electrical motors in order to avoid the differences between the national standards. These documents to which Romania has agreed make some clarifications regarding the limits of the running temperatures of the motors, rated voltages and methods of determining the efficiency at rated or partial load.

In this respect the research of the high efficiency (eff-1) induction or line start PM synchronous motors are justified from economical point of view. More important, the development of eff-1 motors will lead to the possibility of exporting of the Romanian motors on the international market, corroborated with the next years integration of Romania in the European Community.

Additional it has to be mentioned the activity of the Joint Research Center from Bruxelles which has created a data base of all the high efficiency series of motors manufactured in Europe⁴. All the electric motors manufacturers (including the Romanian's) are invited to contribute in order to get extended the data base by communicating the newest achievements in the field. There is also created at the level of European Community the so called "Motor Challenge Program⁵" (MCP), intended to recommend, to observe and to notify the introducing of the high efficiency motors in the drive systems, acting close as the European technological platform. It is shown in the studied developed by MCP that the final saturated effect of replacing the electrical motors by eff-1 motors in Europe can lead to 200 billion kWh yearly saved energy and 79 million tones less CO₂ emissions, which could be equalated by a forest having an area as of the Finland⁶.

¹ For example it could be mentioned the new series of induction motors of Leroy Somer (France) in the range of 0.55 – 55 kW designed specially for the fan drives as wood driers, rated as "energy saving", LS catalogue CPP-01.10.04

² Please see http://www.cemep.org/cemep/organization/lvac/monitoring_report_2003.pdf

³ Please see <http://www.acee.org/motors.epactapp.htm>

⁴ www.energyefficiency.jrc.cec.eu.int/eurodeem/index.htm

⁵ www.energyefficiency.jrc.cec.eu.int/motorchallenge/index.htm

⁶ Hans de Keulenaer, "Energy efficient motor driven system", http://energyefficiency.jrc.cec.eu.int/pdf/HEM_lo_all%20final.pdf

At the level of the European research programmes there was and still there are researches funded on the topic of increasing of the efficiency, for example it is the present in progress work developed by "Joseph Stephan" Institute from Ljubljana entitled "Promotion of high efficiency electric motors in Europe"⁷.

Taking into account the above considerations it is clear that the effort of introducing the eff-1 motors in Romania is not only justified by even imposed by the European tendencies in the field of energy saving. Following the general evolution it should have to create in Romania the legal frame of forcing the increasing the energy efficiency and savings, even if there will be a period of time when the state will give some incentives to the motor's manufacturers to compensate their increased expenditures.

3. OBJECTIVES

The general objectives of the project is related to the objectives of the frame „Excellence Research” programm referring to the European FP6(7), chapter 5 (Energy), more specific referring to the energy efficiency and savings (chapter 5.8). The specific objectives of the module nr.1 (Complex researche and development projects) are in close relation with the topic of introducing a new unified series of a.c. high efficiency induction /PM synchronous motors in order to increase the competitiveness of the Romanian manufacturers on the European market.

The more concrete objective of the project are related to the perspective of obtaining in about 36 month of new series of motors of high efficiency, based on exepirical modells with the aim of getting started the manufacturing of eff-1 induction and line start PM synchronous motors in Romania at the level defined by CEMEP. There will be considered first the 4-poles motors in the frame 90-132, these motors being the most important consumers of electrical energy and most solicited by the users. The development of the PM line-start synchronous motors as three industrial motors for centrifugal application may be a new fact even on the international level.

In the table 1 there are shown comparatively the values of the efficiency recommended for the 4-poles motors in the frame 90-132 as they are manufactured today in the classes of eff-3 (standard motors), eff-2 (improved motors) and eff-1 (best available motors). The eff-3 motors are manufactured using the design data of more than 20 years ago as cheap but wasting energy motors. The eff-2 motors were developed a few years ago by the research team and they are partially produced by the Romanian manufacturers. The eff-1 motors are the objectives of the actual project, they will be analysed, developed and tested experimentally in order to demonstrate the best possibilities to obtain these motors in the same frames but using increased outer diameters. Of course the actual rated power, speed and mounting dimensions correlation will be observed as it is imposed by DIN-CENELEC norms

Based on the representative experimental tested modells there will be carried out the final technical design which will be used by the manufacturers in order to starting the manufacturing. It is to be mentioned that there will be found the technical solution for seven types of induction and PM line starting synchronous motors with high efficiency (eff-1) for general and centrifugal applications, in the frame 90-132. For each motor will be given all the design data including the diameters (outer, inner), the length of the lamination stack, the transversal geometry, the cooling and ventilation elements, the bearing solution and other technological factors such as the efficiency, the total losses, the overtemperature, the slot filling factor, the length of the end-windings to be in the prescribed limits. It is important to mention that the choise of developing this series of motors is that the motors in the range including the frame 90-132 is consuming more than 65% from total energy consumed by all of the industrial motors.

The necessary and sufficient reasons for including the project in the National Program CEEX and introducing in the financing scheme are the following:

- (1) the aim of the project is to develop a complex product (unified series of high efficiency motors at the European level) as induction motors, and PM synchronous line start motors respectively, having clear consequences regarding the saving of the energy, with all of the adjacent effects on the environment
- (2) the project will be based not only on theoretically but also experimentally facts and will be finalised in the developed technical documentations (designs) allowing the starting of high efficiency motors in Romania in the range 90-132; it is an answer of the market brequest regarding the general and centrifugal application

⁷ Contract no. NNE5/2002/52: OPET CHP/DH (Energy, Environment and sustainable development – part B: Energy Programme)

- (3) the project will be developed having in view the new technical solutions of the design team which will be protected as industrial property
- (4) in order to start the project there is established a well defined public/private partnership including researchers having long research experience from Universities, Research Centers and other research institutions being active at the international level
- (5) there is a close connection between the research team and industrial manufacturers of the electric motors from Romania

In the table 2 there are underlined the concrete objectives as they will be developed during the project. One can see that one can apply the obtained results immediately they appear in order to save time in manufacturing the high efficiency motors. There will be developed one experimental motor (both induction and PM synchronous line start motors), usually the biggest motor in each frame, the second motor (if any) being obtained by extrapolating the results.

Table 1. The efficiency of the a.c. motors., IP-44, 4 poles, (CEMEP)⁸

Putere, kW	1,1	1,5	2,2	3	4	5,5	7,5
Gabarit, mm	90S	90L	100L	100L	112M	132S	132M
Eff-3	0,73	0,76	0,79	0,805	0,82	0,84	0,855
Eff-2 (≥)	0,762	0,785	0,81	0,826	0,842	0,857	0,87
Eff-1 (≥)	0,828	0,841	0,856	0,867	0,877	0,886	0,895

Note: For the electric motors in classes eff-2 and eff-1 the values in the table are minimum values. For eff-3 the values are typical for the Romanian manufacturers.

Table 2. Measurable objectives, problems to be solved

Year	Problems to be solved	Measurable objectives
2005 (3 months)	<ul style="list-style-type: none"> -Technical analysis and experimental study in order to draw up the concept -Development of the optimal analysis and synthesis software - Development of the computational methods with application to the electrical machines having permanent magnets - Development and study of the experimental testing methods for PM machines with technical high performance special equipments 	<ul style="list-style-type: none"> - Preliminary study for critical analysis at the national and international level of the theme (single phase and three phase motors, induction and PM synchronous motors, constructive concepts of the PM inductors, surface and imbedded magnets, patented solutions, actual state of the art of the efficiency in the Romanian manufacturing, available electrical and magnetic materials) - Analysis of the energetical efficiency of the motors as defined classes of efficiency (eff-3, eff-2, eff-1) at European level (CEMEP) and of the technological and material effort to obtaine it - Aspects regarding the European and national standardization in the field of electrical a.c. motors (performances, correlation between dimensions-power-speeds, testing methods and related equipments, rated values)
2006 (12 months)	<ul style="list-style-type: none"> - Establishing of the design theme and the technical document containing the main performances -Electromagnetic design of the PM experimental modells - Verification using advanced numerical methods of the adopted technical solutions - Testing of the 	<ul style="list-style-type: none"> - Establishing of the design theme (defining the series of motor's power, frame, speeds) considering the economical criteria of reducing the losses and the user expenditures as equivalent of the reduced losses in the electromechanical conversion process - Development of the initial reference document of the series of tmotors and establishing of the main technical conditions for some family of the industrial drives (general applications, centrifugal applications) - defining the base concept of the series of motors as induction motors and PM synchronous line start motors respectively (constructive and functional concept, justification of the adopted technical solution)

⁸ <http://www.cemep.org/cecep/organization/lvac/English.pdf>

	experimental models of PM motors; conclusions on the adopted solutions	- Proiectare electromagnetica prin metode numerice avansate (analiza FEM, analiza multicriteriala, analiza interdependentelor dintre dimensiuni, proprietati de material, performante)
Anul 2007 (12 luni)	<ul style="list-style-type: none"> - Establishing of the design theme and the technical document containing the main performances -Electromagnetic design of the IM experimental models - Verification using advanced numerical methods of the adopted technical solutions - Testing of the experimental models of IM motors; conclusions on the adopted solutions 	<ul style="list-style-type: none"> - Analysis of the methods to decrease the parasitic torques and ripple torques and their effects on the total losses of the motors during the electromechanical energy conversion -Manufacturing and testing os some experimental models in order to demonstrate the functionality - Analysis of the energy efficiency on the representative sets of motors within a defined class of electrical drive system - Development and forwarding to the Ministry of Economy and Trade of the substantiation project of law regarding the obligatory manufacturing and selling the eff-1 motors in Romania after a well defined dead line associated with an state incentives scheme
Anul 2008 (9 luni)	<ul style="list-style-type: none"> - Developed technical design of the two series of motors (induction motors, PM synchronous line start motors) having increased efficiency (eff-1) -Large scale dissemination of the results in order to be used by Romanian manufacturers 	<ul style="list-style-type: none"> - Developed technical design of the two series of motors (induction motors, PM synchronous line start motors) having increased efficiency (eff-1) based on the testing results obtained on the experimental models -Large scale dissemination of the results in order to be used by Romanian manufacturers -Workshop organization to disseminate the results

4. SCIENTIFIC AND TECHNICAL PRESENTATION OF THE PROJECT:

In the following will be presented some computational results regarding the efficiency of the eff-1 electrical motors taking into account the so called "real cost" obtained by adding together the initial investment and the operation cost during the life of the motors. In table 3 there are presented synthetical results applied to 4 types of motors (small power motors) without any difference if they are induction or PM synchronous line starting motors. The only criteria is that the level of the efficiency to be obtained by the 4 motors of 1.1 kW (100,000 pcs), 2.2 kW (50,000 pcs), 4 kW and 5 kW (25,000 pcs each), all of them 4-poles motors (synchronous speed 1500 rpm). The set of choosed motors can be considered as a representative one for the electrical motors in the frame 90-132. It will be compared the losses of energy during one year of different types of efficiency level, taking into account the operating time as 4000 hours/year and the energy price as 51 EURO/MWh (average multi-year price of the low voltage, three phase electrical energy).

The values of the new efficiency are up to ten "points" bigger than the case of standard motors, in some cases even bigger than those imposed by American EPACT document. It was determined the surplus of active materials (mainly electrical sheet and copper) to be incorporated in the each motor in order to be obtained the new efficiency. The saved energy due to the decreasing of the losses was counted during one year running of the motor taking into account the investment rate. The results in the table 3 show the total energy savings of the set of motors (200,000 pcs) and also the saving in operation cost to the user. During the research will be more clear the amount of increasing in the manufacturing costs of the new motors so that the pay-back time should be calculated more exactly. However it is clear that this time is less than 2-3 years.

The results at the level of the 200,000 motors clearly reveal that yearly using eff-2 motors the savings in operation cost are 3.3 MEUR/year and for eff-1 motors the savings are 9.2 MEUR/year. As saved energy, in first case will be 64,700 MWh/year and in the best case (eff-1 motors) will be 180,3 MWh/year. Analysing more deeply, in case of 5.5 kW motor, it is difficult to understand why the first order user of the motor would save as primary investment about 150 EUR/motor to buy a cheap motor and after that to loose yearly 70 EUR instead of buying a eff-1 motor which will pay-back the additional costs in about two years and after that will save more than 850 EUR during its 12 year supposed life.

The project is aimed to obtaine a new series of electric motors taking into account the European imposed

efficiency levels according to the a.c. general purpose and specialized motors market. The concrete elements determining the solution from scientific and technical point of view are related to:

- the constructive concept in order to obtain the imposed energetical performances (efficiency, power factor) and also starting performances (starting torque, starting current)
- increased reliability by decreasing the overtemperature of the windings
- low running noise taking into account the recent prescription in the international standards (to see IEC 60034-9:2003)

The main objective is the development of the constructive system to best fulfill the technical and economical requests of the application (general or centrifugal). Analysing the advantages and disadvantages of the existing solutions it will be chosen the best way to use the existing lamination of the series MA, 2MA and 3MA of the inner motors manufacturers, including the existing tools for the rotor squirrel cage die cast tools. For experimental modelling there will be used the maximum possible outer diameter in order to a proper using of the existing frame space and to obtain the imposed value of the efficiency.

More concrete, it is known that at given outer diameter the inner volume of the motor and the efficiency can be increased only by lengthening the stack of lamination. The procedure is limited in application because of the limited space of the frame of the motor. Also, longer the rotor, less quality in the squirrel cage casted aluminium. The developed solution will be based on the upper step in the outer diameter, the only technical solution to obtain really motors in the eff-1 class in the condition of Romanian manufacture. The previous experience of the research team, which was designed many electrical motors series from Romania, including the formerly constraints regarding the conception of double correlated motors (under DIN-CENELEC and under RS where bigger power should have been obtained in the smaller frame), will be creatively used in obtaining bigger efficiency in the same frame.

Once the main dimensions (diameters) of the motors has been established, one can point out the scientific objectives as follow:

- (1) the dimensioning of the electro-magnetic circuit of the motors in the unified construction such as the total leakage to be strictly controlled because of their important influence on the overload capacity
- (2) the establishing of the magnetic material quality and optimum saturation levels in the different portions of the magnetic circuit (teeth and yokes, slot top bridges), in order to be controlled the iron main and additional losses, the shape of the airgap flux density and the armature reaction
- (3) the right dimensioning of the rotor bars and shortcircuit ring cross sections to control the rotor Joule losses and starting and breakdown torque, taking into account the possibility to obtain some special shape of the torque-speed characteristic as some drives are requesting
- (4) the study of the magnetic and electric circuit of the motor and associated losses versus the cooling and ventilating system in the new condition where the losses being substantially reduced, also the cooling fan will have to be modified with favourable effects on mechanical losses and ventilating noise
- (5) solving the problem of the sealings, mechanical strength and bearings taking into account all the possible mounting possibilities (foot or flange fixing) including the necessity for the motors to run in overspeed either due to working with inverters or accidentally
- (6) defining the optimum winding solution from the point of view of the space harmonic content of the air gap magneto-motive force, taking into consideration some actual patents held by the research team regarding the sinusoidal windings with application to three phase a.c. motors

Realization of the above mentioned objectives will lead to a new, modern series of a.c. motors having high efficiency (eff-1) as it is requested by European market and imposed by the energy savings constraints. All the types of the application will be covered, the general application by induction motors and the centrifugal applications (fans and some pumps) by PM synchronous, line starting motors. From the main series of motors other derived series can be obtained from other special technical conditions. As general rule the insulating material in class will be provided but the overtemperature of the motor will be lower, in this way being improved the reliability.

For the permanent magnets to be incorporated in the rotor (a new arrangement of imbedded magnets) the NdFeB material will be used. The main performance requested for the motors to be designed are:

- remanence (flux density in case of zero mmf): 1.12 – 1.15 T
- coercitivity (magnetic field intensity at zero flux density): 8300-8600 A/m
- running temperature: 100-120°C

Finally, from the technological point of view, the objective to be solved are related to the design and realization of some tools and devices necessary for experimental model to be built. There are to be

mentioned not only the specific tools such as dies and punching tools but also some necessary tools and devices for mounting the permanent magnets into the rotor armature and also the mounting the rotor having inside magnets into the stator armature.

Concluding, it may be stated that the technical solutions had in view, covered by patents at least as the windings of the a.c. motors and PM configuration are concerned, will lead to the undeniable improvements in the a.c. induction and PM synchronous motors. The new series of motors will fulfill all the technical conditions imposed by the market and will be energy saving motors as it is requested by European CEMEP.

The raw materials to be incorporated in the motors have to be more deeply analysed taking into account the aim of the design. The shortcircuit die cast rotor using copper instead of aluminium represents a recent novelty as series production is concerned and has to be studied considering the economical efficiency of supplying the technical equipment. The raw materials produced in Romania do not cover entirely from the quality point of view the necessary materials for high efficiency motors. For example, having the electrical sheet in view, the improved quality is needed for the new motors as losses and magnetizing capacity are concerned. For normal motors in the frame 90-132 the electrical sheet having 3.6 W/kg at 50 Hz and 1.58 T flux density at 25 A/cm magnetic field intensity (a.c. maximum values) are normally used. For the new motors it will be recommended the improved materials having 2 – 2.3 W/kg and 1.62 T, this quality is not obtainable from the inner electrical sheet manufacturers (COS Targoviste) and will be supplied from abroad by selection.. As conductive and insulating materials there is covered in Romania all the needed quality and also for the structure (frame, housing and shields) where the light alloy will be chosen in order to keep the weight of the motors in a defined range.

5. PROJECT JUSTIFICATION:

The project is relevant for the field of general purpose and specialised a.c. electrical machines. The increasing of the inner necessity of electrical motors, predictable in the near future, has to find the Romanian industry ready to manufacture new energy saving series of motors. It would be not a singular case when a company, not necessary small or average, starting from a new design, will be launched based on the satisfying the inner necessity but also for export. It is difficult to point out how the project is integrated in the national politics specific to the electrical energy saving field because there are not enough elements to identify this politics. The project could be one of the strong point for the substantiation of such politics: a complex product (series of high efficiency electrical motors for general and centrifugal applications) to be manufactured for Romania but also to be exported, in the conditions of technical and economical competitiveness, with the final aim to drastically saving the energy and the operating associated costs.

Having a more deeply insight in the operating costs it is to be mentioned that the electrical motors are electro-mechanical energy converters having the most important parameters the speed and the end shaft torque. The failure of the motor is judged simply from this point of view. The efficiency is a little bit more hidden and it is difficult to be observed and studied when the energy costs are paid "in bulk", even the efficiency would be written on the nameplate of the motors or in the manufacturers data sheets. The fact that the motors are running many times not at rated load but in partial loads (variable load), in services different from S1, make difficult to watch the operating cost on each motor it means the energy wasting is very probable. Another forms of wasting the energy (for example the thermal energy, via temperature in houses) are simpler to feel, to limit or to correct. In case of electrical motors it is necessary a particular technical culture and it has to go up to coercive, legislative measures to impose some constraints as the minimum values of the efficiency of the new manufactured or sold motors are concerned. As in case of the auto-cars where there are imposed by state or local communities some levels of emissions by reasons of environment protection, in case of the efficiency of electrical motors the institutional rules should become compulsory by the reason of energy saving. Any energy saving goes to the same final target, limitation of emissions in the environment by the primary fuel burning in the power stations.

Again, the American model given by EPA (1992-1997) should be a good example, like the European "Motor Challenge Program" which is acting like an European Technological Platform. The research team has as subsidiary aim of the research to prepare the substantiation of the legislative initiative to be forwarded to the responsible forum in Romania regarding the "waste" energy, the Romanian Ministry of Economy and

Trade.

As in other country the chance of the project to be applied is depending on some “incentives” given to the manufacturers because in the chain of introducing the new motors they are less motivated⁹

To appreciate the project viability one has to consider the technical, technological and economical risks and also the strictly observing the established dead-lines. An analysis of these risks point out that (in a so called three stage classification) they are small or average and the degree of possibility to controll the evolution of the project is quite high. In this respect in any stage of the project there will be observed the distance between the imposed and realised parameters in order to make corrections.

To appreciate the project viability it also to be mentioned the previous experience and achievements of the research consortium. The project leader has sustained a PhD thesis in the field of optimal design of the unified series of motors related to three phase squirrel cage shortcircuit induction motors. The research team from ICPE-ME has as endowment one of the best and complete testing platform for electrical motors and has previously designed many series of electrical machines which are manufactured today in Romania. ICPE-ME is the holder of many Romanian patents in the field of a.c. motors with or without permanent magnets and has published many scientific paper related to the topic. The other partners from the well known University Research Center (UPB, UTCN) are the holder of many technical information and experience in the field of electrical machine computaion based on developed PhD thesis and also advanced equipments for testing electrical machines. Last but not the least, the Romanian Electrotechnical Committee is an international recognised institution being the interface between the International Electrotechnical Committee and inner industrial, research and educational institutions, dealing with the harmonisation of the romanian standards in the electrical engineering fields with the IEC norms.

6. DIAGRAM OF PROJECT EXECUTION:

The final results of the peoposed project are the developed technical designs (necessary and suffiecient for the Romanian manufacturers to start the preparating activities to manufacture) for two new series of motors, i.e. induction motors and PM synchronous motors with starting capability in the frame 90-132, the both of them being developed in the high efficiency class (eff-1) as CEMEP prescriptions are concerned. The series can be extended in the both of direction, through bigger and smaller power motors. At the basis of the designs will be experimentally activities on designed and manufactured modells tested on the special proof equipments.

The squirrel cage induction motor series is to cover all the general applications, where the needed starting torque is in the range 2 - 2.2 (p.u.). The PM synchronous motor series is designed to cover the so called “centrifugal applications” (fans and some pumps) having the starting torques in the range 1 -1.2 (p.u.). The clasification of the driving system application is to be observed even on both the European market (governed by CEMEP) and American market (where is acting the Consortium of Efficiency Energy - CEE¹⁰).

As it can be observed from the diagram of t project execution, all the partners are involved in all of the project stages, the weight depending on the type of activity and the specific of each partner. Thus, the involving of the partners may be more specific detailed as follows:

ICPE-ME (Research Institute for Electrical Machines) has mainly the responsibility the study and technical analysis, establishing the constructive solution, the electromagnetic design, manufacture and testing of the experimental models anlysis of energetical efficiency on the sets of motors of given application, the integration of all the works during the project and co-ordination of the activities.

UPB and UTCN (Technical Universities from Bucharets and Cluj-Napoca) will be responsible on the problems related to technical analysis, development of specific methods of computation, non-conventional methods of testing the experimental models, participating to the development of the final technical solution.

CER (Romanian Electrotechnical Committee) will be responsible on the problems related to studies and analysis refring to the national and international standardization in the field of the project, development of the technical specification (data sheet) of the motors, the substantiation of the legislative initiative to be forwarded to the responsible forum in Romania regarding the “waste” energy and the proposal for type of incentives to be

⁹ For example in USA, state NY, for each motor sold as “premium efficiency” the manufacturer may apply to receive an incentives of up to 80\$ (the so called programm “NYSERDA”). Please see: <http://www.energysmartmotors.org/vendors/Guidelines.asp>

¹⁰ To see the web site where the performance system are imposed depending on speed, power and type of the application: www.cee1.org/ind/motrs-main.php3

given to the manufacturers of eff-1 motors as help from the state.

It is to be mentioned that, as it is pointed out in the recent European studies¹¹ not all the involved parts in developing the eff-1 motors (designer, manufacturer, seller and the human society in general) have the same motivation. As the manufacturer is concerned, it has normally to support the cost the design, of preparing the new series of motors taking into account the costs of the new tools and all the investment related to a new product. It is quite clear that the investment of the manufacturer to start the manufacturing of the new series of motors is the key point of the problem, this is why, like in other countries, it is compulsory that the institutions of the state to interfere in the actions by a combination of compulsory rules and some incentives.

In this respect the results of the researches that will be developed in the complex project will be large scale disseminated through all the Romanian manufacturers of electrical a.c. motors. Taking into account that the researches are developed by a consortium made by a research institute, two research centers from universities and one non-government non-profit institution, there are applicable the prescriptions of art.3, pt.2, paragraph c) from the application regulations of the law nr. 143/1999 with subsequently modifications regarding the help from the state. Considering the invoked prescriptions, the state help is not involved, that means the cost of the project will be covered 100% from the program budget.

The diagram of the project with the activities and dead lines is presented in the table 4.

Table 4.

Year	Stage/ Activities/ Partners	Dead line	Results/ Documents presenting the results	Needed financial resources *) (Millions lei)		
				Total	From which Budget	Other
2005	Etapa I: STUDIU, ANALIZA SI EXPERIMENTARI PE MODEL DE REFERINTA	30 NOV 2005	Studiu Buletin de incercare Raport tehnic	1.500	1.500	
	Activitate I.1 Studiu preliminar si analiza tehnica in raport cu situatia eficientei motoarelor de c.a. pe plan european si mondial.	30 NOV 2005	Studiu tehnic preliminar	500	500	
	Activitate I.2 Experimentari pe model de referinta motor asincron sincronizat cu magneti permanenti	30 NOV 2005	Buletin de incercare si raport tehnic	500	500	
	Activitate I.3 Analiza privind standardizarea europeana in domeniu (performante energetice si de pornire, metode de incercare).	30 NOV 2005	Raport tehnic	500	500	
2006	Etapa II PROIECT SI EXECUTIE MODEL EXPERIMENTAL MOTOR SINCRON CU MAGNETI PERMANENTI SI AUTOPORNIRE (eff-1)	15 IUN 2006	Proiect motor 2,2 kW/1500	1.900	1.500	
	Activitate II.1 Analiza metodelor de reducere a cuplurilor pulsatorii cu aplicare la proiectul de model experimental	15 FEB 2006	Raport tehnic	500	500	
	Activitate II.2 Aplicarea metodelor de analiza numerica (FEM) 3D in structuri cu poli "gheara" si magneti permanenti cu aplicare la proiectul de model experimental de motor sincron	15 MAR 2006	Raport tehnic. Metodologie si rezultate de calcul.	500	500	
	Activitate II.3 Proiect de model experimental 2,2 kW/1500 rpm gabarit 100L	15 MAR 2006	Proiect motor 2,2 kW/1500	700	700	
	Activitate II.4 Realizare model experimental 2,2 kW/1500 rpm gabarit 100L	15 IUN 2006	PV executie model experimental	200	200	
2006	Etapa III PROIECT MODEL EXPERIMENTAL SERIE DE MOTOARE ASINCRONE (eff-1) GAB.90-132 1,1 kW; 2,2 kW ;4 kW; 5,5 kW/1500 rpm	15 SEP 2006	Proiect model experimental 1,1 kW; 2,2 kW ; 4 kW; 5,5 kW/1500 rpm	1.900	1.900	

¹¹ To see the referred paper of Hans de Keunelaer, "Energy efficient motor driven system", http://energyefficiency.jrc.cec.eu.int/pdf/HEM_lo_all%20final.pdf, chapter 3, "Market barriers"

	Activitate III.1 Elaborare metodici de analiza si sinteza optimala motoare asincrone cu rotor in scurtcircuit	30 IUN 2006	Raport tehnic. Metodica de calcul optimal	500	500	
	Activitate III.2 Aplicarea metodelor de analiza numerica (FEM) 2D in structuri cu simetrie circulara si circuite magnetice saturabile cu aplicatii la proiectarea motoarelor asincrone	30 AUG 2006	Raport tehnic. Metodica de calcul si rezultate cu aplicatie la motoarele din seria proiectata	600	600	
	Activitate III.3 Proiectare modele experimentale 1,1 kW/1500 rpm gabarir 90S 2,2 kW/1500 rpm gabarit 100L 4 kW/1500 rpm gabarit 112M 5,5 kW/1500 gabarit 132M	15 SEP 2006	Proiect model experimental 1,1 kW; 2,2 kW ; 4 kW; 5,5 kW/1500 rpm	800	800	
2006	Etapa IV INCECARE MODEL EXPERIMENTAL MOTOR SINCRON CU MAGNETI PERMANENTI SI AUTOPORNIRE (eff-1)	15 NOV 2006	Raport de incercare	1.800	1.800	
	Activitate IV.1 Elaborare referential si metodologie de incercare motor sincron cu magneti permanenti	30 SEP 2006	Document normativ de produs. Metodologie de incercare	300	300	
	Activitate IV.2 Incercari model experimental motor sincron cu magneti permanenti	15 NOV 2006	Raport de incercare	1.500	1.500	
2007	Etapa V REALIZARE MODEL EXPERIMENTAL SERIE DE MOTOARE ASINCRONE (eff-1) GAB.90-132 1,1 kW; 2,2 kW ;4 kW; 5,5 kW/1500 rpm	15 IUN 2007	PV de executie model experimental serie de motoare	600	600	
	Activitate V.1 Realizare modele experimentale motoare asincrone eff-1 de 1,1 kW; 2,2 kW ;4 kW; si 5,5 kW/1500 rpm		PV de executie model experimental serie de motoare	600	600	
2007	Etapa VI. INCERCARI EXPERIMENTALE SERIE DE MOTOARE ASINCRONE (eff-1) GAB.90-132 1,1 kW; 2,2 kW ;4 kW; 5,5 kW/1500 rpm	15 OCT 2007	Rapoarte complete de incercare	800	800	
	Activitate VI.1 Incercari modele experimentale motoare asincrone eff-1 de 1,1 kW; 2,2 kW ;4 kW; si 5,5 kW/1500 rpm	15 OCT 2007	Rapoarte complete de incercare	800	800	
2007	Etapa VII. ELABORARE INITIATIVA LEGISLATIVA PRIVIND FABRICAREA IN ROMANIA DE MOTOARE EFF-1 SI SCHEMA AFERENTA DE AJUTOR DE STAT	15 NOV 2007	Proiect de initiativa legislativa inaintata catre MEC; Proiect schema ajutor de stat inaintat la Consiliul Concurentei	600	600	
	Activitate VII.1 Elaborare initiativa legislativa privind fabricarea in romania de motoare eff-1 si schema aferenta de ajutor de stat	15 NOV 2007	Proiect de initiativa legislativa inaintata catre MEC; Proiect schema ajutor de stat inaintat la Consiliul Concurentei	600	600	
2008	Etapa VIII ELABORARE PROIECT TEHNIC DEZVOLTAT SERIE DE MOTOARE SINCRONE CU MAGNETI PERMANENTI SI AUTOPORNIRE GAB.90-132 (eff-1)	15 MAR 2008	Proiect tehnic dezvoltat	1.200	1.200	
	Activitate VIII.1 Elaborarea proiectului tehnic dezvoltat de serie de motoare sincrone cu magneti permanenti si autopornire gab.90-132 (eff-1)	15 MAR 2008	Proiect tehnic dezvoltat serie de motoare sincrone eff-1 gab.90-132	1.200	1.200	
2008	Etapa IX ELABORARE PROIECT TEHNIC DEZVOLTAT SERIE DE MOTOARE ASINCRONE CU ROTOR IN SCURTCIRCUIT GAB.90-132 (eff-1)	15 MAR 2008	Proiect tehnic dezvoltat	1.200	1.200	
	Activitate IX.1 Elaborarea proiectului tehnic dezvoltat de serie de motoare asincrone cu rotor in scurtcircuit gab.90-132 (eff-1)	15 IUN 2008	Proiect tehnic dezvoltat serie de motoare asincrone eff-1 gab.90-132	1.200	1.200	

2008	Etapa X DISEMINARE PE SCARA LARGA A REZULTATELOR SPRE TOTI FACTORII INTERESATI (FABRICANTII DE MOTOARE ELECTRICE DIN ROMANIA) SI CONSULTANTA LA PUNEREA IN FUNCTIUNE	15 SEP 2008	Documentatie de prezentare diseminata pe suport CD Raport de consultanta	500	500	
	Activitate X.1 Diseminare pe scara larga si consultanta la punerea in functiune	15 IUN 2008	Documentatie de prezentare diseminata pe suport CD Raport de consultanta Organizare masa rotunda, conferinta	500	500	
2006- 2008	Etapa XI (ACTIUNI SUPORT) – se vor preciza la perfectarea contractului (max. 5% din valoare contract) Participare la tirg international (Hanovra) 2006 si participare la Conferinta internationala (International Conference on Electrical Machines- ICEM'2006, 2008)	2006- 2008	Rapoarte de deplasare	600	600	
	TOTAL VALOARE CONTRACT (2005-2008)		36 luni	12.600	12.600	

7. RESULTS/ PROFITS AND DIAGRAM/CAPITALIZATION PLAN/ DISSEMINATION

The results will not appear immediately after the ending the research. The implementing of the results in the Romanian electric motors manufacturing needs more expenditures to cover the additional costs of preparing the specific tools and also the additional investment costs to the final user of the motors. Acceleration in the application of the final results may be obtained by a systematically politics with institutional character to press on the involved parts by the authorities responsible by energy savings and environment protection. The measures may be intensively and extensively too, and they are outlined at the European level where the problems are similar¹².

The results may be classified as "micro-economic" and "macro-economic". In the first acceptance, it is demonstrated that any user which is changing the standard motors to high efficiency ones, will be paid back in short time, generally between 1 and 3 years. At global level, if all the motors would be high efficiency motors, the saved primary energy (the energy which would be no more necessary to be converted due to the reduced losses) would be for Romania about 2.6 billion kWh/year, the equivalent of one 330 MW unit running continuously with all the subjacent consequences regarding the environment pollution by emissions.

The final results, based on experimentally models manufactured and tested, as induction motors and PM synchronous motors with line start capability, will be disseminated on large scale to all of the Romanian manufacturers following the financing the researches from the state budget.

In case of appearance, during the research, of elements which need classification or protection regarding industrial property, the problems will be solved observing all the legal prescriptions.

8. TECHNICAL, ECONOMICAL AND SOCIAL IMPACT

The technical impact is defined by introducing in manufacturing in the next years of the new series of low power (frame 90-132) induction and PM synchronously motors having high efficiency (eff-1) as it is requested by the European tendencies and prescriptions related to the CEMEP consortium of electrical motrs manufacturers and the European "Motor Challenge Program". The impact will be also the association of the Romanian manufacturers to the "European Joint Research Center" from Bruxelles by including the high efficiency manufactured motors in the data base EuroDEEM. It is clear that the implementing costs, sometimes with dimmed character, have to be distributed to all of the involved parts. The impact on the environment for example, considering the improvement in the quality of the life due to the less CO₂ emmissions have to be supported by the society and in this respect the state has an important role.

The research has also the aim to put in value the existing distributed scientific potential in the different research centers in order to work together for better results; tis could be an impact on the future research and on the

¹² Ibidem, http://energyefficiency.jrc.cec.eu.int/pdf/HEM_lo_all%20final.pdf, chapter 5, "Ongoing programmes"

research market in Romania.

The economical impact, as it was previous shown by calculations in nthe table 3 includind the additional note, the users of high efficiency motors will gain important amount of money after 1-3 years as the initial investment will be paid back.

9. PROJECT MANAGEMENT

The management of the project will be mainly a task of the research unit (ICPE-ME) which has a long time experience in designing the unified series of electrical motors. The research team is deeply specialised in the field of optimal design of electrical motors and also in the economical analysis and technological design.

It is stipulated that monthly the research team will analyse the steady state of the researches compared to the diagram of the project and discrepancies will be immediately solved. Measures will be taken as the results to be put in value as soon as possible inner the team but also in order to disseminate them.

Having in vue the colaboration between the research and execution compartments of the research team, the responsibility will be distributed depending on the stage of the research. Any time will be performed corrections in order to obtaine the proposed results as soon as possible. The team involved in the research activities is an heterogeneous one, having specialists in electrical machines, power electronics, electromagnetic design, mechanical design, the quqlity engineering and technico-economical analysis.

In order to be informed regarding the other manufacturers products as technical conditions, it was stipulated in the project's activity list some „support actions” (up to 5% from the total financing amount) representing expenditures for participating to the international fairs (example Hanover fair) or international conferences (example „International Conference on Electrical Machines”, ICEM-2006, 2008).

10. DESCRIPTION OF REQUIRED RESOURCES FOR PROJECT EXECUTION

Taking into account the execution plan of the project presented before considering all the eligible activities and deadlines, it is requested from the programme's budget the total amount of 12,600 milion lei covering the material and human resources necessary for developing the analysis, experimental modells design, manufacturing and testing, also the final design elements for two series of motors (induction and PM, line starting synchronous) in the frame 90-132.

As the endowments are concerned, it is to be mentioned that there exist the main equipments necessary to test experimentally the new designed motors taking into account the standard's prescriptions such as sources, dynamo-brakes, measuring equipments, computing equipments in ICPE-ME and in the research center of UPB and UTCN.

However, in order to improve the quality of the specific testing equipments it is necessary to take into account some new endowments to be bought from the project's budget such as data acquisition systems working on line with personal computers, oscilloscope “Tektronix” type THS 720P including additional equipments, torque transducers type “Hottinger-Baldwin” and also two computing systems for electromagnetic design including an A3 printer.

Table nr. 3. Elements for economical justification of the project –energy savings by high efficiency motors

a.c. Motor	1,1 kW/1500 – set of 100,000 pcs.			2,2 kW/1500 – set of 50,000 pcs.			4 kW/1500 - set of 25,000 pcs..			5,5 kW/1500- set of 25,000 pcs.		
	Eff-3	Eff-2	Eff-1	Eff-3	Eff-2	Eff-1	Eff-3	Eff-2	Eff-1	Eff-3	Eff-2	Eff-1
Efficiency	0.73	0.762	0.828	0.79	0.81	0.856	0.82	0.842	0.877	0.84	0.857	0.886
Individual losses [W]	407	344	228	585	516	370	878	751	561	1048	918	708
Yearly lost energy kWh/year	1628	1,376	912	2,340	2,064	1,480	3,512	3,004	2,244	4,192	3,672	2,832
Yearly savings per motor, compared to eff-3 motor kWh/year	-	252	716	-	276	860	-	508	1268	-	520	1,360
Cash saving to the user, per motor EUR/year	-	12.85	36.51	-	14.08	43.86	-	25.91	64.67	-	26.52	69.36
Yearly saved energy by the set of motors MWh/year	-	25,200 (100,000)	71,600 (100,000)	-	13,800 (50,000)	43,000 (50,000)	-	12,700 (25,000)	31,700 (25,000)	-	13,000 (25,000)	34,000 (25,000)
Cash saving to the user, per set of motors MEUR/year	-	1.285 (100,000)	3.651 (100,000)	-	0.704 (50,000)	2.193 (50,000)	-	0.648 (25,000)	1.617 (25,000)	-	0.663 (25,000)	1.734 (25,000)

Notes and conclusions:

- In the table there was counted only the losses in the electromechanical energy conversion process; the useful energy can be found in the driven load
- It was considered the assumption of running at rated power; during research may be analysed other hypothesis of different partial loads or other types of services as S1
- It was considered the motors working between one and two shifts (**4,000 running hours/year**)
- The price of the active energy was considered as average multi-year value of **0.051 EUR/kWh**, three phase, low voltage supply
- For the entire set of motors conventional structured (please see the head of the table: 100,000 pcs. 1,1 kW; 50,000 pcs. 2,2 kW; 25,000 pcs of 4 and 5,5 kW each) it can be summarised as energy saving, compared to the standard motor:
 - In case of eff-2 motors: **64.700 MWh/year, the equivalent of a 8.6 MW unit working 7,500 hours/year**
 - In case of eff-1 motors: **180.300 MWh/year, the equivalent of a 24 MW unit working 7,500 hours/year**
- The cash saving to the final user (important to be counted the pay back time of the initial investment) are:
 - In case of eff-2 motors: **3.300 MEUR/an**
 - In case of eff-1 motors: **9.195 MEUR/an**
- The effects of introducing eff-1 motors is much more bigger than introducing the eff-2 motors. Correspondingly the payback time will be different