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SYSTEMIC ANALYSIS FOR THE USE OF RENEWABLE SOURCES OF ENERGY FOR THE ELECTRIC AUTOMOBILE. CASE STUDY FOR ROMANIA

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Abstract: ***The introduction of the electric energy in more and more diverse applications currently represents an evolution which is considered normal, taking into account the durable development concept, which are required among the decision makers, and also due to the fact that the oil and gas resources are not evenly distributed in the world, and those who do not have these resources look for solutions to provide them a certain independence over those who have resources. One of the technical solutions, available on Earth, is currently represented by the renewable energy sources. Their usage in the field of the electric automobile charging, is both an economic and technical challenge. Technical solutions are available, and they are developing, but their industrial application is related to an economic strategic approach and a systemic one, which are treated below.***

Keywords: renewable energy, energy, systemic, automobile, electric.

1. INTRODUCTION

Electric vehicle's energy charging problem has as main support the durable development concept, but for this to be applied on industrial scale, we must solve several technical and economic problems, structured by - what we currently call – a systemic approach [1-2].

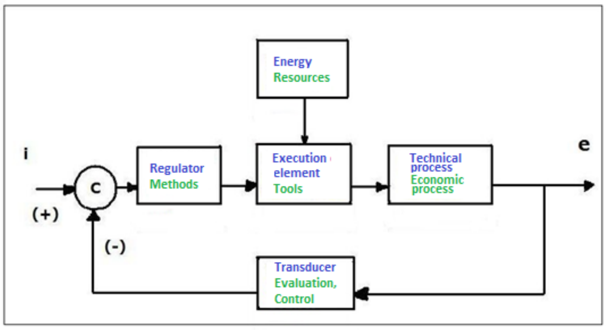

Figure 1. The systemic modelling of an economic strategy.

The proposed goal, the use of the electric energy from renewable sources, represents the prescribed value of the system, the mission, on strategical terms. Other relations between the technical terms and the economic terms are show in Figure 1, where is pictured with black colour for technical process and with blue colour for economic process. Once this similarity is accepted, all the mathematic instrument of the system theory can be transposed by analyse of economic strategies, which represent an important methodological gain. The systemic errors can be analysed for strategies as well as for systems, reaching at the substantiated conclusions mathematically [3]. To reach these conclusions, we need to identify all the components of the system.

2. THE EVALUTION OF THE IMPLEMENTATION CONTEXT FOR THE ELECTRIC AUTOMOBILE

The number of automobiles currently used in Romania is about 5.5 million [4]. If we have an average consumption of energy about 15 kW/automobile [5], the result is an installed power requirement, only for this application, about 82500MW. The average consumption in the country, currently, is about 7500 MW, which means a necessary investment volume about 11 times more than the installed power from the current National Energy System (SEN), which isn't a promising result for future. Such a rhythm of investment growth is virtually not available to those who are active in the energy field even in the next 50 years. It follows that the solution of the large-scale use of the electric automobile, namely, the alimentation of electric automobile from SEN can't be taken account exhaustively, and only partially, for the certain socio-economic fundamental cases.

For the general application of the solution, we must find decentralized production variants which are based on the solar energy, the wind energy, the hydro energy etc, or even biomass and biogas, these converted in electric energy. Coupling these decentralized sources on national network is not recommended, whereas for the charging of the electric automobile, the current conditions of energy quality from SEN are not necessary, bringing them to these standards would have as consequence a more expensive energy, which is unnecessary, and would decrease the attractivity of the electric automobile.

3. THE AVAILABLE RESOURCES OF RENEWABLE ENERGU IN ROMANIA

In order to appreciate the fact that the electric automobile represents a feasible solution from energetical point of view, we must refer to the existing potential, for the renewable sources of energy. Detailed studies for their integration at national level were the basis of the Strategy for the recovery of the renewable sources of energy, approved by the Government Decision No 1535/2003 [6]. According to them, the potential of renewable sources of energy in Romania is:

- The solar energy, thermal exploitation: 60 million GJ = 16000 GWh;
- The solar energy, electrical exploitation: 1200 GWh;
- The wind energy: 23000 GWh;
- The geothermal energy: 7 million GJ = 1900 GWh;
- The energy of falling water: 40000 GWh;
- The energy from biomass: 318 million GJ = 88000 GWh.

If we cumulate all the renewable forms of energy enumerated above, we should arrive to the total sum 170100 GWh, of available energy per year. Considering that the total installed power required (82500 MW = 82.5 GW) must be working about 4 hours per day, the time a charging lasts, we obtain the necessary of energy per year:

$$W_{na} = 82.5\ x\ 12(months)x\ 30(days)x\ 4(hours\ per\ day) = 118800GWh \quad (1)$$

Hypothetically, if we used only renewable energy for the charge all automobiles, from Romania, this would mean about 69% from all identified potential by now, remaining available for other categories of applications. A similar analyse made for the electric heating of residences show that this application would need 84.65% from the national energy potential [7]. We notice that the potential of Romania's renewable sources does not cover the exhaustive use of renewable sources for the entire park of automobiles, simultaneously with the electric heating of residences, with the need for partial preservation of perishable sources.

4. TECHNICAL AND ADMISTRATIVE METHODS FOR FULFILLING THE MISSION

Considering only the application for electric automobile, the solution is feasible, the necessary of renewable energy for this is under the known potential level by now, and for the desiderate to became reality, technical and economic models must be found and these should lead to the satisfaction of this social requirement, namely, the use of the vehicle without the boundaries under conditions of sustainable development, without leading to environmental pollution.

A very well know method, applied in many big cities, consist in the organization after the principles of sustainable mobility. This means the organization regulation of the transport so that the energetical needs are met by local facilities, these respecting the principles of sustainable development, relating to the environment and human resources. The sustainable mobility is a **sustained** concept at the level of European Union [8], where there are established definitions and procedures, the periodical reports are made, and measures are proposed to continuously improve the situation. The European Union, by the Directive 2001/77/EC established the strategy for the promotion of the electric energy from renewable sources in the unique European market. It also introduced the promotion tool "Intelligent Energy for Europe". In the future, the European Union could take additional measures through incentives and recommendations, introducing the urban mobility dimension into the Mayors Convention, to promote a common approach to link the energy and climate change of transport [9]. This will encourage the cities to introduce the problems of transport and sustainable mobility issues into Sustainable Energy Action Plans.

5. THE TECHNICAL TOOLS FOR THE ECONOMIC IMPLEMENTATION OF THE ELECTRIC AUTOMOBILE

The components of the electric automobile that matter both in the performing of the technical performances, as well as for the establishment of the cost are: the battery, the motor, the electronic system of control, monitoring and protection.

5.1. The battery of the electric automobile

The battery is the critical technology for the electric automobile and for it to achieve maximum performance under certain conditions, it is necessary to have a management of the batteries.

The battery can enable hybridization or electrification, provides power to motor and acceleration, provides energy for electric range and other auxiliaries, helps downsizing or eliminating of the traditional motor, enables regenerative braking.

The problems which appear at the battery construction are: additional cost, weight and volume, which could decrease reliability and durability, the decreased performance with aging, there appear safety problems.

One of the conditions required to have high performance batteries is to find a temperature management system (Battery Thermal Management System – BTMS) which should lead to the most effective thermal behaviour of the battery.

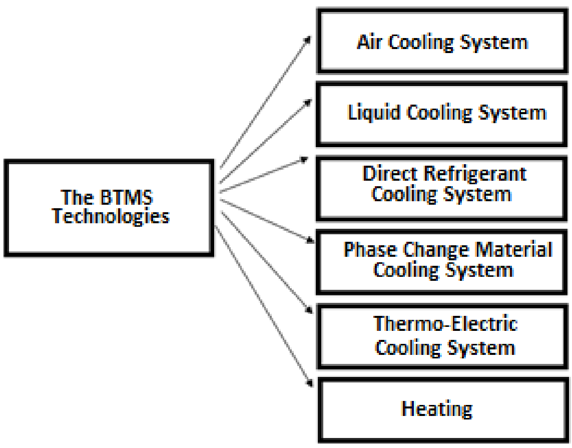

Figure 2. The BTMS technologies

The technologies which are used for BTMS are analysed from the point of view of the performance, weight, cost, reliability, safety and energy consumption, so that all this can reach a compromise, which should be as advantageous as possible. The BTMS technologies are shown in Figure 2.

A type of battery used for an electric car is the lithium-ion battery whose performance depends directly on temperature, voltage and operating mode. If the cells formed from lithium-ion batteries do not operate between certain voltage and temperature limits, it leads to their irreversible damage.

If there is a charge voltage in the cell that exceeds the bearable cellular voltage (overvoltage), there appear excessive current fluxes which create problems of failure for electrode materials and there can even arrive at short-circuit between electrodes. And the lower voltage (undervoltage) is a problem, the copper current collector may break down.

In the case of temperature, there appear more requests: to not exist overheat, to not exist underheat, to not exist the uneven temperature distribution.

Typically, the uneven distribution of the temperature is caused by excessive local temperature, by variation of the current inside the cell and by thermal conductivity, as well as by the location of the negative or positive terminals [10]. The uneven distribution of temperatures has as result the local deterioration and even the thermal scattering with reducing battery life.

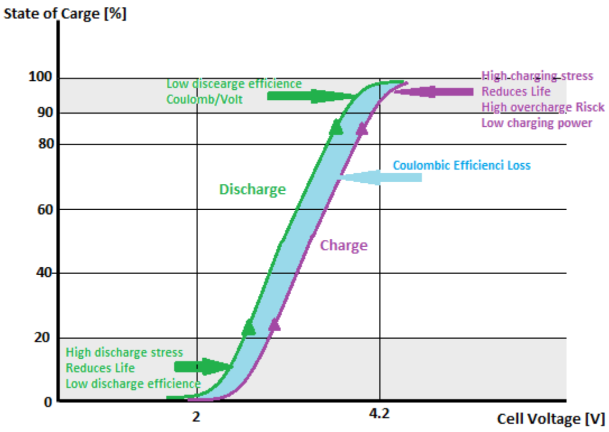

Figure 3. The voltage restrictions

The voltage restrictions which are required are shown in the Figure 3, and the functioning over limits negatively influences the lifetime the battery cells.

The power of battery is maximum, between 20ºC to 40ºC, as we can see in Figure 4.

The temperature of battery must be controlled within the limits of temperature, in order to avoid the thermal problems and to improve performance. The power of battery and the battery life are influenced on the temperature range. Figure 5 shows the life cycle of the battery according to the temperature at which it is subjected.

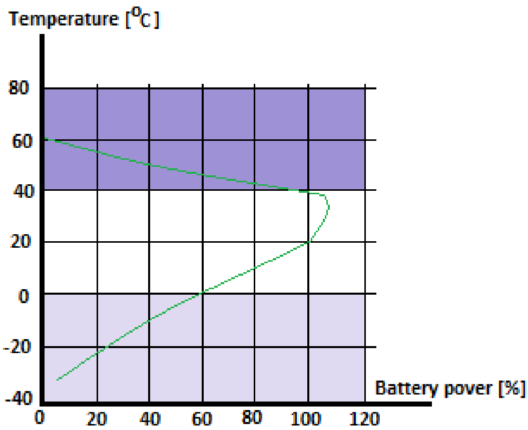

Figure 4. The battery power function of temperature

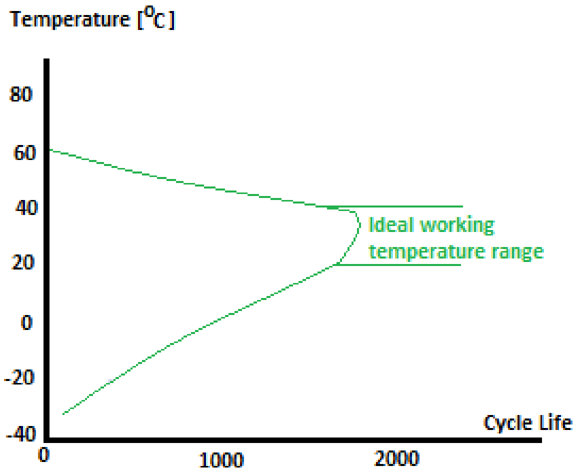

Figure 5. Life cycle time depending on battery temperature

The safety, the performance (power and capacity), the battery life, all must be kept in a controlled environment, and for this, BTMS must be equipped by four essential functions: the cooling function, the heating function, the isolation for extreme temperature conditions, the ventilation [10].

5.2. The motor of the electric automobile

The electric automobile must be equipped with the motor of the best performing constructive category, from the point of view of the energy indicators (efficiency, power factor). It must have the minimum specific mass and volume it must be easy and it to occupy as little space as possible for it to be energetically efficient. The constructive type of motor which has all these qualities is the synchronous motor with permanent magnets from rare earths [11].

In the Figure 6 there is shown a motor with external ventilation, which helps to increase the specific power: (1 – shaft, 2 – rotor yoke, 3 – permanent magnets, 4 – air gap, 5 – stator winding, 6 – stator teeth, 7 – stator yoke, 8 – housing, 9 – space for air circulation of ventilation, 10 – fan cover).

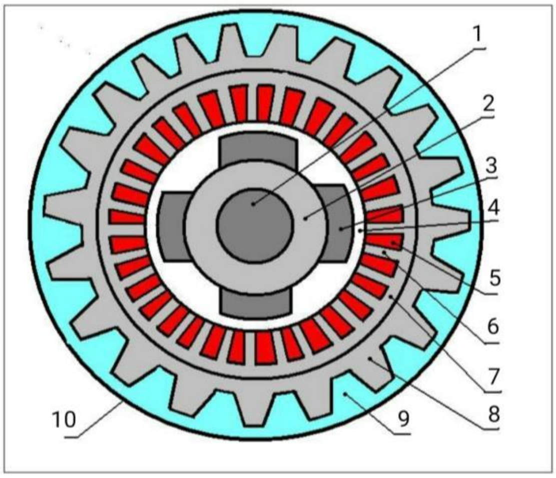

Figure 6. The synchronous motor with permanent magnets with external ventilation

To increase the motor power, this is usually cooled by water, which circulates into a loop, which is incorporated in the motor housing, see Figure 7 (1 – shaft, 2 – rotor yoke, 3 – permanent magnets, 4 – air gap, 5 – stator winding, 6 – stator yoke, 7 – stator teeth, 8 – housing, 9 – space of the circulation of the cooling liquid).

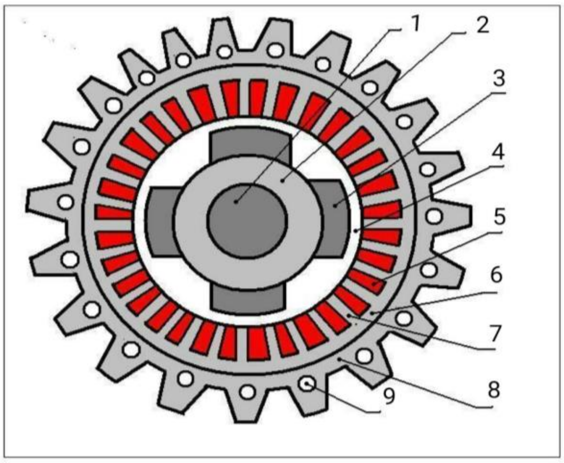

Fig. 7. The synchronous motor with permanent magnets which are cooled with water

In Figure 8 we can see a section of a synchronous motor with permanent magnets cooled with water, for an industrial application, produced by ICPE SA Bucharest.

Figure 8. The synchronous motor with permanent magnets cooled with water, for industrial applications

5.3. The system of control, monitoring and protection

In electric vehicles architecture monitoring and control are implemented through various management subsystems of the vehicle components. They are controlled by specialized electronic units driven by specific software, called ECUs (electronic control unit) that communicate with each other through various protocols: CAN, LIN, FlexRay, MOST, etc. Currently, in the electrical / electronic architecture of classic, hybrid or electric vehicles may be up to 100 ECU (in the case of top models). The architectural complexity due to the implementation of various hardware and software solutions required the development of a unitary software solutions development approach. As a matter of fact, AUTOSAR (AUTomotive Open System Architecture) was imposed as a standard that will support the development of electric vehicles in the future. On the other hand the complexity of functions and algorithms specific subsystems electric vehicles (but not only) has made complex architectures of the microcontrollers to be replaced by architectures FPGA (Field Programmable Gate Arrays). FPGAs are programmable hardware devices that deliver high-performance to the personalized hardware and which benefit from the rapid reconfiguration through software (software flexibility). FPGAs are powerful computing units which may be dynamically programmable, which gives them the advantage of being able to be reconfigured on the vehicle itself during operation or at rest. So, for those vehicle subsystems that operate on multiple strategies, automation and control can be much more easy made by dynamic reprogramming with different algorithms. In the context of electric vehicles, FPGAs have the advantage of running complex algorithms, have low energy consumption and reduced physical size (volume, weight) which make them compatible to be incorporated into electric vehicles.

Reducing the number of ECUs through the FPGA implementation allows the introduction of new and complex functions (for example, support systems, safety systems, multimedia systems, etc.) simultaneously with the reduction of the total cost of the car. With the FPGA, it is possible to combine intelligent electronic components in the electric car architecture, to implement a hybrid architecture that combines CPU (Processing and Computing Units), GPU (Graphics Processing Units) and SoC FPGA (system on a cheap). Figure 9 shows a car safety concept that can be implemented via FPGA.

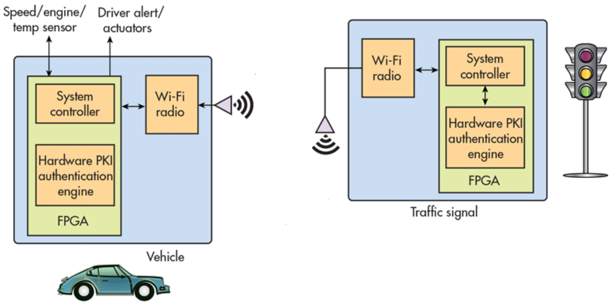

Figure 9. Road safety and security concept system that can be implemented on cars via FPGA (V2X - vehicle-to-everything) [13].

Regarding control systems, monitoring and protection, technological developments in fields such as electronics, computer, communications, has completely changed the car and created new development directions for the automotive industry. The trend to electrify as much the car (partly by creating hybrids or totally "full electric" models) generates major changes whose effects caused paradigm shifts such as automated mobility. In this way, the automotive industry is working to implement the necessary systems for the autonomous driving of vehicles by 2025. Although there are currently on some driving systems characterized by a lower or higher degree of autonomous driving, intended objective being that on certain segments of the travel routes to be possible total elimination of the human driver intervention and its complete replacement by the systems boarded on the vehicle - without the driver being always ready to intervene to correct the path and the way of travel.

Engineers from the Automotive and from support industry are implements the latest technologies created both in vehicle development and in building and expanding infrastructure, such as the network of stations and charging points for electric vehicles. Charging stations will be equipped with intelligent control and monitoring systems capable of communicating with the car's computer and the smart grid's of the electricity supplier to choose the optimum charging regime, to provide the energy needed to charge at the best rates and to operate in fast-charging mode. Regarding the fast charging mode, concerns are focused on implementing "fast charge DC" to support the next generation of electric vehicles.

In the case of electric vehicles, a special attention is paid to the various energy sources that can be considered to increase vehicle autonomy (batteries, regenerative braking, solar panels, superchargers), which makes the task of monitoring, control and energy management to be problematic.

6. CONCLUSIONS

The electric automobile represents a technical and economic problem of great importance, and its approach must be done strategically.

For the charge of the battery, the energy quality doesn’t have to be the same with the one from National Energy System, and the quality must reflect in the price.

The minimizing of the battery and of the motor represents desiderata with direct influence on the autonomy and the price.

Considering that the components of the system exist, the main renewable energy resources, expressed as potential, are sufficient, and the necessary will depend only on the national authorities and on the existing regulations of the European Union, we believe that there are realised the conditions for the implementing of the electric automobile in Romania, in a significant extent from economic point of view.

Using FPGA, the implementation of command, monitoring and protection systems becomes easy to implement and is scalable by minimal hardware changes.

FPGA and AUTOSAR will provide the hardware and software support needed to develop applications for the implementation of complex functionalities in electric cars.

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