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**FACULTY OF ENGINEERING IN ELECTRO - MECHANICS,**  
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***DOCTORATE THESIS***  
***-Résumé-***

**RESEARCH CONCERNING THE USE OF SOLAR ENERGY**  
**FOR SUPPLY THE ELECTRICAL CUSTOMERS FROM**  
**ISOLATE ANTI-HAIL STATION**

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## **1. Actuality and relevance of thesis**

The utilization of alternative energy sources is now one of the main world topics due to the fact that the World Energy Council estimates that the primary energy consumption will rise 40% by the end of 2020. This rise will be possible mainly by using those alternative energy sources; also it has to be taken into account that the world oil and natural gas reserves are estimated to finish off in tens of years and the coal reserves in 200 years. More else, the nuclear energy has taken almost 30 years of research and 20 years of implementation in order to satisfy nearly 10% of the world demand in primary energy. In this kind of respect it has to be mentioned that the nuclear energy production encounters a very strong opposition from public opinion in almost all developed countries.

Watching to the actual solar energy utilization level it turns out that in Romania are in fact very few significant and functional projects having real practical applications in the domain. So, the approach of the analyzed theme and generalization of results applied to the national anti-hail system are really justified. Recently released estimations reveals that the electric energy provided by alternative sources will reach some 8.3% of the entire national electric energy consumption by the end of 2010.

The importance of theme is related to solar energy utilization as well as to the destination of equipments driven by this energy (isolated ant-hail stations). The installed power of these equipments is small indeed and the utilization period of time can reach 6 months, on one hand, but, on the other hand, the alimentation network construction spending is quite big. More else, some of the isolated stations have to change their locations yearly. Also, we have to consider that the active exploitation of the anti-hail stations during a year starts early April and ends late September and that coincides with the maximum solar radiation period of time during the same year. It turns out that the utilization of the solar energy does represent a really successful solution and adds to the growth of National Anti-Hail System both in Moldova and Oltenia. The theme is important also because some 60% storms on the Romanian territory (during the march-September period of one year) are accompanied by hail falls and 40% of these hail falls lead to significant or even total losses in crops.

So, is this new and actual research domain that the present work is related to and its main goal consists in building up a study concerning the existing technical solutions and exploring some new ways in order to solve the identified problems.

Recent researches made in different countries reveal that, considering the price/efficiency ratio, the most part of anti-hail systems work by using rockets as carrying vector of the condensation germs. But in order to launch those rockets an electric energy source is needed in order to power the rockets' fuses.

Security reasons require that the launching stations of rockets have to be placed far out of reach of towns or villages, so, these launching stations simply cannot access the public electric energy network.

At least for now, the powering of rockets' fuses is made using electric accumulators that are periodically recharged using a Diesel generator; sometimes the accumulators are transported to the command centers.

This way the topic - on which the theme of this PhD thesis is based on - arisen. The utilization of photovoltaic module to directly power the accumulators will significantly reduce the spending level on liquid fuel as well as the number and size of those accumulators.

## **2. Thesis objectives**

The main purpose of this thesis consists in realizing a really performant autonomic system designed to power the anti-hail rockets local launching stations. In order to reach this purpose the next steps were required:

- building-up a mathematical model for the solar energy conversion system.
- realizing an automatic system designed to control the orientation of photovoltaic panels.
- realizing a system designed to monitorize the circulation of energy from photovoltaic panels to consumers having hierarchiezed priorities.

## **3. Thesis's volume and structure**

This PhD thesis has 202 pages and its structure consists in one introduction and 5 chapters. The results of research are materialized in 150 mathematical relations, 159 draw-figures, 11 tables, a chapter of conclusions and original contributions, 8 additional parts and a list of references containing 125 positions (in 19 of them I am the first author and in eight of them I am a co-author).

Chapter 1: Analysis of anti-hail station architectures.

Chapter 2: Contributions concerning the structure and analysis of autonomous photovoltaic system of a anti-hail station.

Chapter 3: Contributions on modeling and simulating the photovoltaic system designed to power the isolated anti-hail stations.

Chapter 4: Contributions concerning the build-up of the orientation system and of the of energy circulation monitorizing system.

Chapter 5: Experimental results on how the autonomous photovoltaic system does work.

Chapter 6: Conclusions and original contributions.

In the 1<sup>st</sup> chapter a full analysis of the worldwide found solutions for reducing the damages caused by hail is made. The PhD theme turns out as being actual and in line with the existing studies in the anti-hail systems domain of research. Indeed, such systems are used in 29 countries, 40 new projects concerning 87.4 millions ha are on the pipe and in U.S.A., only in the last two years, and some 741 new anti-hail related programs involving 22 billion US dollars did get financing.

It turns out that a solid majority of anti-hail systems are using rockets as carrying vector of condensation germs. The efficiency of those systems surpasses 90%.

Next, a comprehensive presentation of the anti-hail stations from Moldova and Romania is made. The particularities of the stations energy empowerment in both countries are pointed out.

The 2<sup>nd</sup> chapter contains the theoretical contributions concerning the utilization of the solar energy to empower the consumers of the anti-hail stations. First, an assessment on existing situation as well as on the future of using the photovoltaic energy – both from national and international perspective – is made. Next, the structure of the proposed system is presented and the mathematical models are written for each and every part of the photovoltaic system. The mathematical models are written starting from the solar radiation models and finishing with the consumers' models.

The dimensioning of the structure of the proposed photovoltaic system was made starting from the necessary amount of electric energy and considering the consumers nature.

The theoretical contributions to the mathematical models of individual components of the photovoltaic system consist in particularizing some general models to the proposed system. In this kind of respect, the mathematical models of the solar radiation are particularized, in order to describe the Craiova location. The models are built up starting from the extraterrestrial radiation model and continuing with some parametric and empiric models of solar radiation (clear and mixed sky) and finishing with the model of solar radiation absorbed by an arbitrary oriented photovoltaic panel.

Following the analysis and comparing each-other the simulation results for the parametric and empiric models the most appropriate method to determine the solar radiation corresponding to the chosen location was established – and that because dimensioning the photovoltaic system means to know the solar radiation in the place where the system is to be placed.

Mathematical models for elements of photovoltaic systems are also particularized for the proposed system. In this kind of respect there are built up mathematical models for the photovoltaic generator (models for the cell, for the photovoltaic modulus and for the photovoltaic panel), the accumulators' model, the regulator's model, the inverting device's

model and the model for the charge.

The 3<sup>rd</sup> chapter is dedicated to mathematical models and simulation of the photovoltaic autonomous system of isolated anti-hail stations. All models and simulations were made using the Matlab Simulink program – distinct blocks for each and every component of the system were made. Accessing such a block drives to the apparition of a dialog window in which we can put the input parameters and that allows us to use this block for some other applications.

By using the HOMER program, the process of energy consumption-producing for the proposed photovoltaic system was simulated.

In order to increase the efficiency of the photovoltaic system, an orientation device for the photovoltaic panel is proposed. Modeling and simulation for the energy conversion system as well as for the orientation device of the photovoltaic panel are presented. The model for the energy circulation monitorizing system designed for consumers having hierarchiezed priorities is also presented as well as its validation by simulating it.

The 4<sup>th</sup> chapter consists in building up the physical models for the orientation device and for the energy circulation monitorizing system. There are presented the hard structure for each and everyone component as well as the software structure of the released system.

The 5<sup>th</sup> chapter presents the experimental results concerning the functionalities of the proposed system. These results are demonstrating the accuracy and the efficiency of the proposed solutions. The correctness of signals between the PC and the developing system is proved as well as the correctness of signals between the developing system and the sensors' system. More else, the quality of energy provided by the photovoltaic system was also verified by visualizing on oscilograph the wave form of electric tension and electric current at the exit of the inverting device. The process characterizing issues' online acquisition and their numeric and graphic affichage forms prove that the released developing systems for the orientation of the photovoltaic panel and for the monitorization of energy circulation really do work.

#### **4. Contributions**

From theoretical point of view, some contributions concerning analysis of methods and technologies used all over the world in eliminating the hail fallings was added.

Some existing mathematical models for the solar radiation were particularized for a certain location. In this kind of respect, the appropriate mathematical model corresponding to this location was chosen.

Also, the mathematical models of the existing autonomous photovoltaic systems elements were particularized and adapted to the conceived photovoltaic system.

In order to increase the efficiency of the autonomous photovoltaic system, an orientation

device of the photovoltaic panel was proposed. This way, the modeling and simulating of the electric „part” of the orientation system was released. Also, an optimization of the orientation system was released by building-up an imposed-time based mathematical model.

The monitorizing mathematical model concerning the circulation of energy from the photovoltaic panels to consumers having hierarchized priorities. The mathematical model's validation was made both by numerical simulation and experimentally.

A really important contribution brought by this PhD thesis consists in building-up the structure of the autonomous photovoltaic system. It turned out that the realized system is a truly performant one in all of its parts: the energy conversion equipments, the monitorizing, acquisition and communication equipments. Each and every one of these equipments has its own especially developed software the way that the entire system can be handled as a whole.

Strictly concerning the software issues – a lot of contributions were added in order to develop some monitorizing especially designed applications by using ultimate generation software technologies having easy-to-handle graphic interfaces. This way, the computing programs become easy to handle even by average computer users.

The software contributions consist mainly in realizing some programs for the Atmega 128 microcontroller which assures the automatic orientation of the photovoltaic panel, allowing in the meantime the consumers to connect and disconnect depending on how much energy the accumulators have at their disposal. Also, some PC programs were released in order to acquire informations from the Atmega 128 microcontroller and to present them (in real time) both numerically and graphically.

Concerning the functionality of the autonomous photovoltaic system and the monitorizing system, all experimentally obtained results are proving the rightness of the proposed solutions of all identified problems.

Some of practical contributions were utilized in order to get solutions for issues related to other applications like the monitorizing system that was part of the research in the excellence grant No. 21/2004: "*Research Bio-technologies for achievement of functional food from the Pleurotus mushrooms and preparation for industrial exploitation*". I was a member of the research team of this grant.

The obtained results will be very useful in solving some problems raised by the alimentation of the equipments for the anti-hail stations produced by S.C. Electromecanica S.A. Ploiesti who seems to be already interested in these results.

Also, the realized photovoltaic system presents an applicability of general kind and can be really useful in the alimentation of low power isolated consumers as well as in some research activities and in education.