Innovative Technologies for Romanian Anti-hail System

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Abstract: - About 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 of crops. So, this is a 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.
The paper outlines the concerns of the research team at the University of Craiova, Innovation and Technology Transfer Centre - CITT on combating hail. Mainly, the researches concern the equipments and the innovative technologies for Romanian anti-hail systems.

Key-Words: - anti-hail, microcontroller, photovoltaic system, informatic system, monitoring information, environment.

List of symbols and abbreviations

ARL – automatic rocket launcher
ACPL – automatic center point launcher
B1, B2 – batteries
D_1, D_2- semiconductor diodes
ESRA - European Solar Radiation Atlas
EV- East West
Ga – solar irradiation
GIS – geographic information system
GSM – global system for mobile communications
K_1, K_2, K_3 – electric contacts
L_1..L_7 – static contactors
PC – personal computer
PI1, PI2 – threshold values of current
PU1, PU2, PU3 - threshold values of voltage
PV- photovoltaic
RT_1- radio telephone
SN- SouthNorth
SPI- serial port interface
Ta- ambient temperature
TC_1, TC_2- current transducers
TU- voltage transducer

1 Introduction

A national anti-hail system was established in our country in 1999, [24] and recently was established a National Authority against hail fall and for the stimulation of the rainfall. During the mentioned period were developed a lot of research activities supported by the government bodies or by businesses. Presently there are concerns for the extension of these activities through doctoral researches, through international, cross-border or regional partnerships researches. It can be said that the management of hail fall and the rainfall stimulation has become, in our country, a current preoccupation.

The achievement of an anti-hail system in Romania provides several advantages:
- the reduction of the losses produced by hail in agriculture, but also in economic and domestic areas;
- the creation of the premises for a rainfall (a ton of water obtained from an artificial rainfall is 3-4 times cheaper than the one obtained from the irrigation water);
- the regional integration of the national Romanian anti-hail system with similar systems from Ukraine, Moldova, Bulgaria or Hungary;

The University of Craiova, Innovation and Technology Transfer Center - CITT started the research regarding the powering of local points anti-hail missile launch from photovoltaic panels in 2000. The research was initiated with the Technical University of Moldova in Chisinau, since in Republic of Moldova the energy security is a very important problem. This research has been pursued on the request of the constructor of the electrical and mechanical part of the launch ramps for the anti-hail missiles - Electromechanics Ploiesti - to monitor further information, submitted by local weather radar to local launch points of anti-hail missiles. A complex team was involved in the work, consisting of professors, researchers and PhD students.

2 Main researches objectives related to suppression system

The climate changes in the last decades led to intensification of the hail falling processes, and also to the alternation in long periods of drought. In this context, several countries in the world practice simple solutions or have developed complex anti-hail systems to increase efficiency of action against hail fall. Anti-hail systems are used in 29 countries and several projects are ongoing.

The researches which take place in the world presently have the following objectives:

- the improvement of technological actions by studying micro and macro physical processes of formation and evolution of cloudy and condensation systems;
- the reduction of the response time by automating intervention systems (detection, determination of parameters of seeding, launching and monitoring of physical efficiency);
- the improvement of the monitoring criteria of physical and economic efficiency actions, the increasing of dispersion elements of active agents efficiency (by shortening the nucleation time and by the increase of the activities);
- the identification of new areas of systems' application, taking into account the progresses realized in influencing the weather phenomena.

The anti-hail informatic system is a assembly of hardware, software components, procedures, strategies, activities and people united and organized to process data related to combating hail, to fulfill the task of reducing / eliminating the damage caused by hail and the and achievement of through measurable performance criteria established (Fig.1).

In figure 1 is shown, generally, computer system architecture for monitoring anti-hail units launch points.

The hardware structure of the anti-hail computer system comprises the following subsystems:

- equipments for identifying the potential carriers of hail clouds;
- equipments for the coordination of the anti-hail rockets launching;
- automated equipment for launching anti-hail rockets;
- equipments for supplying electricity from solar panels.

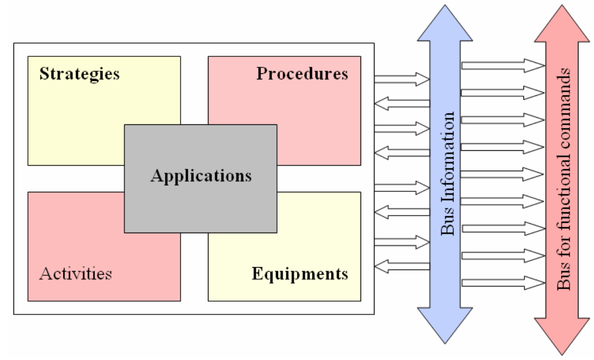

Fig. 1 Anti-hail informatic system

The informatic system integrates data related to: the weather data, the coordinates of protected crops, the coordinates of the launch points and central points, types of crops, range of release points, access roads, the presence of a missile launch point on the ramp, data about the positioning of the launch ramp, the selection methods, data on electricity supply system, record launches, missile stocks, etc.

The computer system has two main components (Fig. 2), [17]:

- the system for taking the decision of launching;
- the decision support system for launch.

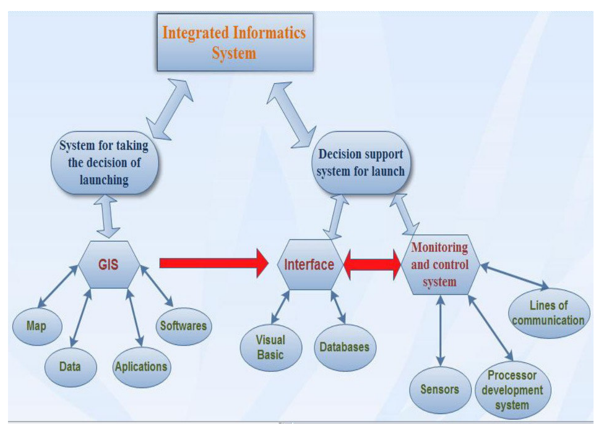

Fig. 2 Main components of the system

The system for taking the decision of launching addresses exclusively to the central control point. The system is a multifunctional GIS which can help the staff of the center point upon the decisions which must be taken in extreme situations. The current weather system from our country allows an update to about each 7-9 minutes, the information of clouds progress come at the central point in about every 15 minutes, [17].

3 Results researches regarding the anti-hail system from Romania

The researches made at the University of Craiova CITT are concerned with the realization of equipments for supplying power from photovoltaic panels of specific equipment in a anti hail station, monitoring of the information transmitted from the meteorological station at the local point and the automatic positioning of the rackets launch ramp and an integrated system to receive and process a large set of information [2], [3], [4], [5], [6], [7], [13], [23].

This paper will present the results for the power supply and for the coordination of the anti-hail rockets launch ramp.

3.1 Equipment for the coordination of the anti hail rockets launch

The equipment contains:

- Automatic Rocket Launcher - ARL;
- Automatic Center Point Launcher-ACPL connected as shown in figure 3.

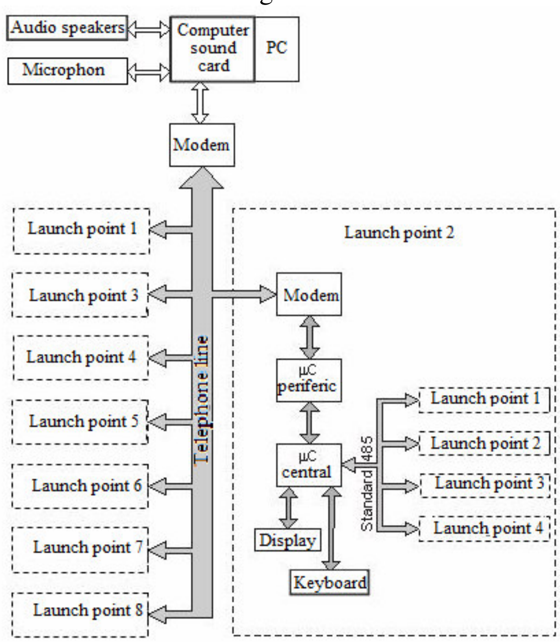

Fig.3 Structure of the system for monitoring information transmitted

The system for monitoring of the transmitted information (Fig.4) ensures:

- two-way voice link between the point of order and points of release;
- the transmission of data - orders from point of launch control points;
- data transmission – monitoring of launches from the launch points to the point of order;

Fig. 4 "MONIGRIN" automation

The maximum distance between the control point and the release point is of 120 km. The lines of communication accepted are wired telephone lines and GSM telephone channels. In exceptional cases such as cases where telephone services are not accessible, is accepted radio communications equipment. The control of the transmission system is made entirely from the point of order. The establishment of the communication link is performed by the request from the point of order and will last as long as necessary.

The voice contact assures the possibility of communication between the control point and the release point. Connection is initiated from the point of order and indicates the point of launch and the optical sound.

3.2 The equipment for supplying electricity from photovoltaic panels for anti-hail stations

The needed daily electricity for consumers of a anti-hail station is 1004 Wh/day, [4].

A Photovoltaic (PV) System must provide efficient energy available to different consumers.

The PV System should provide electricity to as many as possible consumers characterized by different nominal voltages. Also must by ensure a high degree of autonomy in the sunset or at night, low solar radiaţion.

In figure 5 the structure of Stand Alone photovoltaic system is shown.

The Stand Alone PV System consists of two PV panels, one fixed mounted with a tilt angle corresponding to the latitude location and the other is provided with a tracker system.

The two PV panels are charging batteries through load regulators.

Diodes D_1 and D_2 ensure the functioning of PV panels only in generator mode.

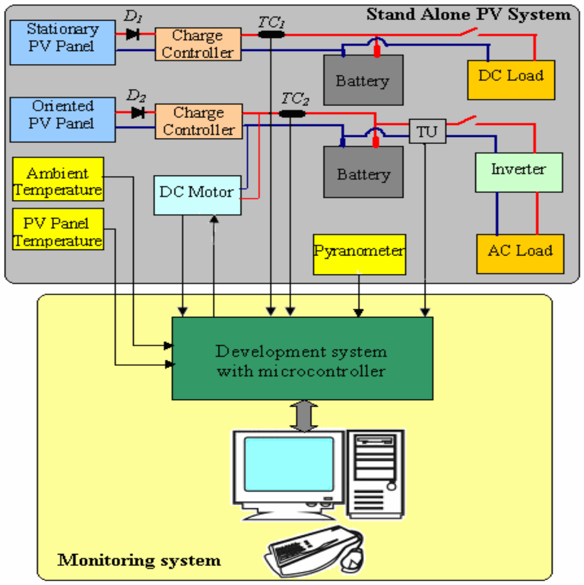

Fig.5 Principle scheme of a Stand Alone PV System

DC consumers are supplied directly from the batteries and the AC customers are supplied by inverter.

In order to monitor the status of Stand Alone PV system and the parameters for conversion are used sensors and transducers.

Monitoring system uses sensors to measure ambient temperature and PV cell temperature, the TC_1 and TC_2 current transducers, the *TU* transducer voltage, the pyranometer and the transducer position for DC motor.

The monitoring system allows local monitoring by means of development system with microcontroller or remote by way of PC.

The main components of the system are in accordance with the functional diagram from Figure 5. Both construction and auxiliary elements are mounted in the distribution box (Fig. 6).

Inside the box distribution shown in Figure 6 are fitted: battery charge controllers - 2; automatic fuses - 3; batteries - 4; inverter - 5, automaton for PV panel orientation and monitor the movement of energy -9; current transducers -10. Electrical connections between components is done using connections ruler - 6.

On the outer casing of metal box is mounted pyranometer - 7, which measures global radiation on a horizontal plane.

On the oriented PV panel -1, are mounted temperature sensors that measure ambient temperature - 8, and a PV panel temperature.

The batteries have a capacity of 55Ah and depending on the type of connection (serial or parallel) provide consumers supply of 12V or 24V DC voltages.

The inverter has a 1200W power, and provides power to consumers as a form of pure sine wave voltage, 220V amplitude.

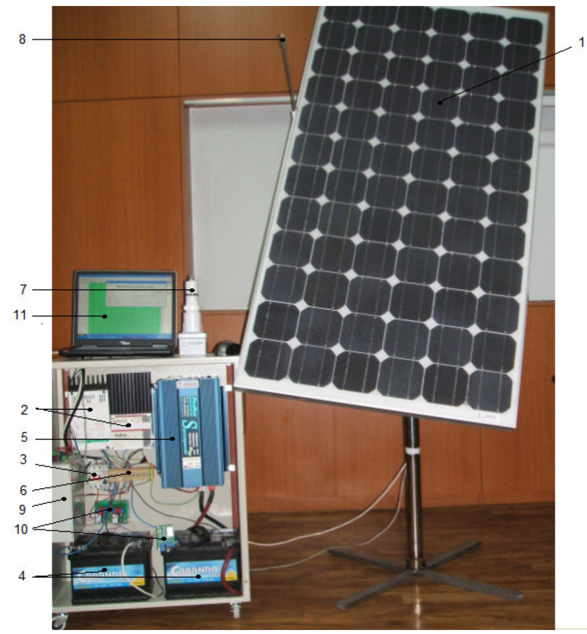

Fig. 6 Overview of Stand Alone PV System

To increase the efficiency of the stand alone photovoltaic system was made a pseudo-equatorial guidance system after two axes for the photovoltaic panel (Fig. 7), [2] .

Fig.7 "Pseudo-equatorial" system for PV panel orientation

The PV panel follows diurnal motion of the Sun in the direction of EV, and can be adjusted daily the angle of SN direction of the photovoltaic panel, so that the stand alone photovoltaic system to provide a maximum amount of energy.

Among the existing orientation systems in the literature [9], [14], the most suitable solution proposed for orientation of the PV panel, is pseudo-equatorial orientation system, because this system does not require a simultaneous combination of movements for the two axes.

3.2.1 The modeling and the simulation of equipment for power supply from photovoltaic panels

In order to validate the corresponding mathematical models of the solar energy conversion system the modeling and the simulation was done in Matlab Simulink [26]. With the aid of Homer programme it was simulated the process of production-consumption of energy for the proposed photovoltaic system.

For practical use, Simulink block models for each component of an autonomous PV system are grouped into blocks “Subsystem”. Subsystem blocks contain block models for PV generator, battery, inverter, charge.

Simulink model of the entire Stand Alone PV System is shown in figure 8.

The total system has thus as inputs the irradiation and the ambient temperature. These are used in the PV module together with the voltage from the controller to generate the PV current.

The basic blocks of the library can be used to build more specific structures, [1].

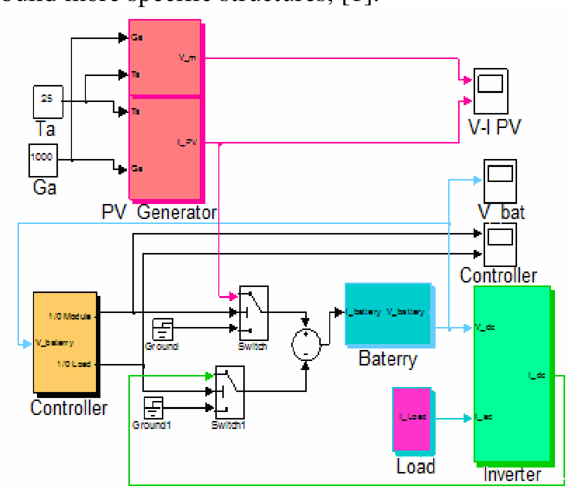

Fig. 8 Simulink model of the Stand Alone PV System

Another powerful feature of the Simulink, called masking, is that it can simplify the use of the model by replacing many dialog boxes in a subsystem with a single dialog box. Instead of requiring the user of the model to open each block and enter parameter values, those parameter values can be entered on the mask dialog block and passed to the blocks in the masked subsystem.

The most relevant parts of the series with particular events, from each of the set data of inputs, are chosen and analysed for understanding and modelling of the Stand-Alone PV system, [11], [15].

Figure 9 shows the simulation results, when the initial set data of inputs are: solar radiation

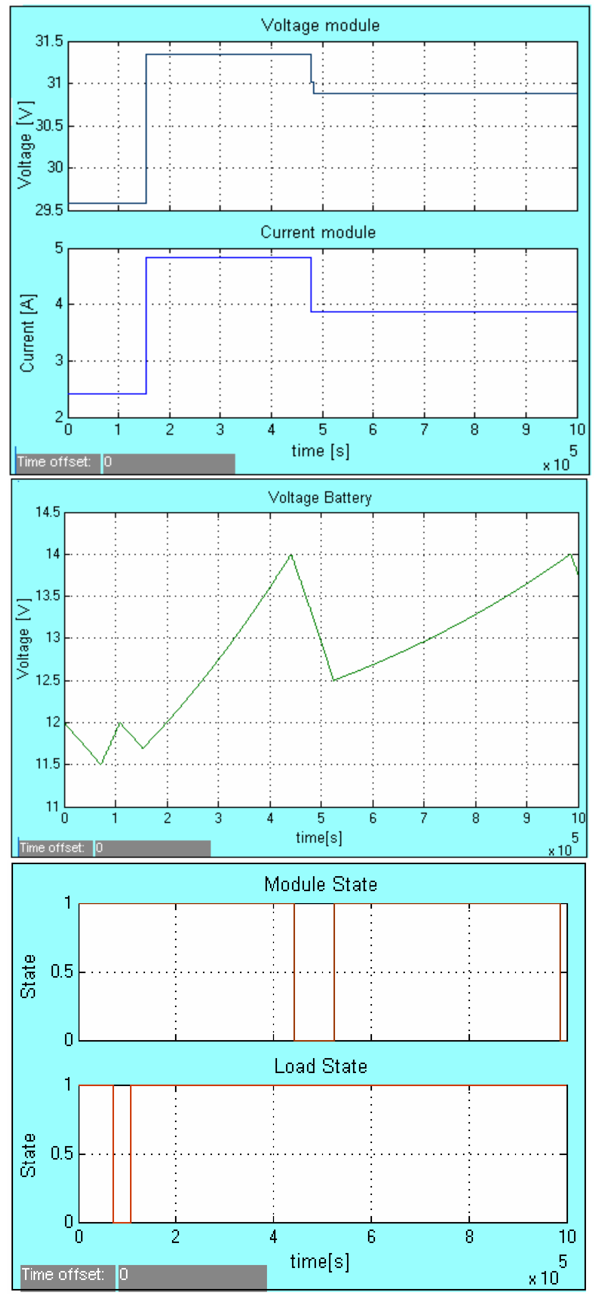

Fig. 9 Simulation results for several data set of input of PV system

ambient temperature Ta=15°C, the load is connected and the PV current is directly used in the charging of the battery, but the $I_{PV}<I_{Load}$ and the battery voltage decreasing until V_{min_off}=11.5V. In this time, the load is disconnected, and the battery voltage increasing until V_{min_on}=12V, when the load is reconnected on the Stand-Alone PV system.

In the moment when the set data of inputs are modified: solar radiation G_a=1000W/m^2, ambient temperature T_a=25°C, the battery is charging. In the moment when battery voltage reaches the limit of the charging voltage V_{max_off}=14V, the PV generator is disconnected by the PV controller of the Stand-Alone PV system, in order to avoid overcharging. The battery is discharging because the load is connected on the system.

When battery voltage reaches the limit V_{max_on}=12.5V, the PV generator is reconnected on the Stand-Alone PV system.

At a solar radiation G_a=800W/m^2 and an ambient temperature T_a=20°C, the battery voltage increasing, because $I_{PV}>I_{Load}$.

The whole Stand-Alone PV system has the solar radiation as input variables, the ambient temperature; these parameters are directly involved in converting solar energy.

In order to determine the energy production and the energy efficiency of Stand Alone PV System, it was developed the modeling and the simulation of this system, [18]. It was used a specialized software for simulation of renewable sources named HOMER [27].

HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system. For this system that includes batteries, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries.

In figure 10 are presented HOMER components of Stand-Alone PV system.

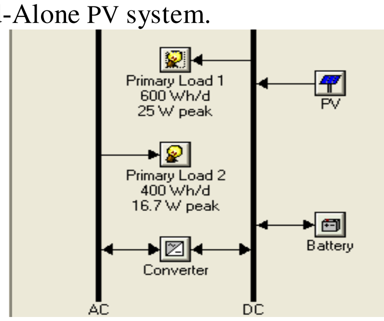

Fig. 10 HOMER components of PV system

In order to simulate the Stand Alone PV System, the Homer program requires information on input variables, such as geographical coordinates, namely solar radiation. Thus, there were introduced the corresponding value of coordinates of Craiova and the monthly average solar radiation calculated by the ESRA model, [10].

The simulation results provide information regarding the daily operation of the system over the year (Fig. 11), the energy produced by the PV generator, the energy consumed by load, and the excess of energy, (Fig. 12).

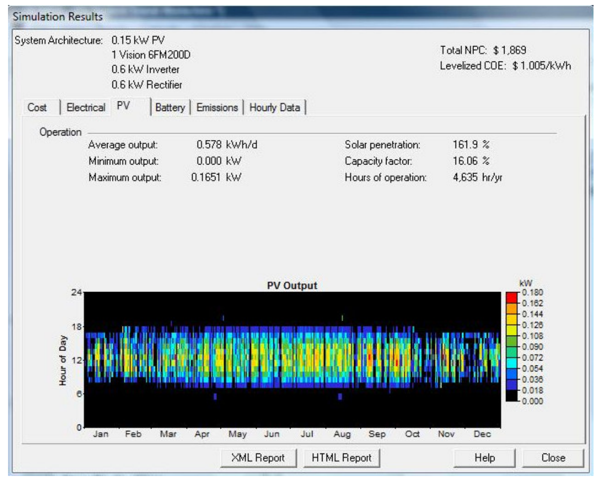

Fig. 11 Hours of operation and the annual produced energy by the PV generator

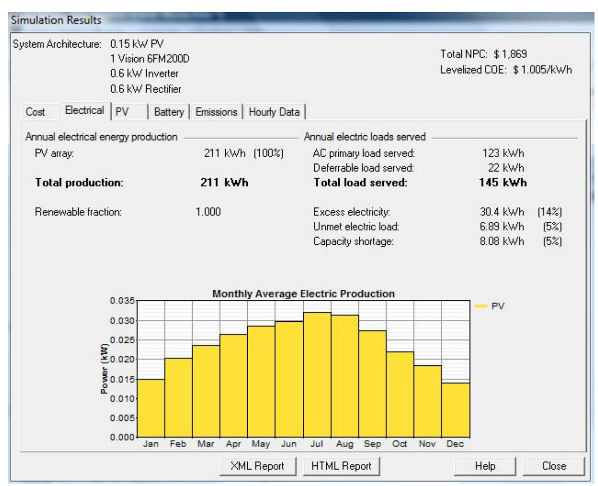

Fig. 12 Energy rating system

The simulation results shown in figure 13 reflect the annual evolution of photovoltaic power generator, the evolution of the power load, but also the evolution of the battery charge status.

A quantitative analysis on the evolution of these variables which characterizes the PV system in terms of energy, involves the following aspects:

- the active power generator available PV power is higher than that required consumers;
- the energy stored in battery deficit recorded during January to March, respectively from October to December period, during which the anti-hail stations are in operation.

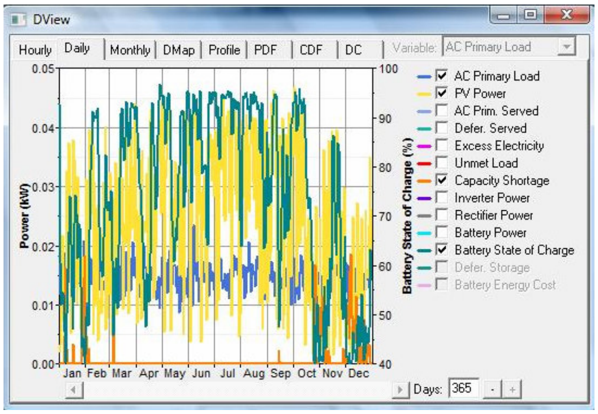

Fig.13 Evolution parameters of PV system for a year

4.2.2 Modeling of the monitoring system for the movement of energy for ranked priorities consumers

Monitoring and control algorithm was developed taking into account the principle electrical diagram shown in figure 14.

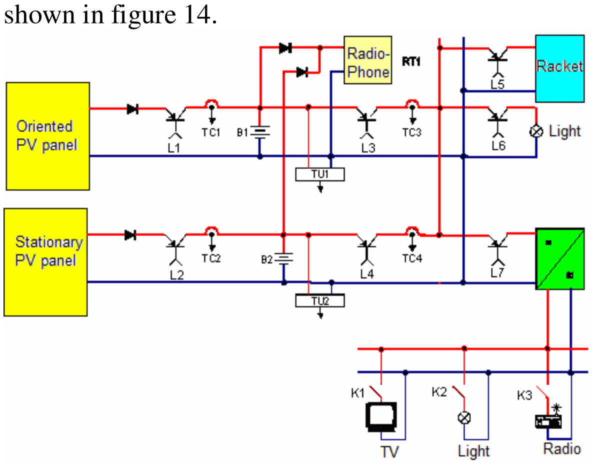

Fig.14 Electrical diagram of principle of the energy movement monitoring system

Notations from the figure above have the following meanings: TC3…TC1 - current transducers; TU1 ... TU2 - pressure transducers; L1 ... L7 - static contactors; K1 ... K3 – contact.

In order to develop the consumer monitoring system model and to implement the algorithm according to priorities set by consumers are established the following categories [7]:
- category "0" radio-phone RT1, rocket;
- category "1" stand lighting;
- category "2 " lighting, radio and television;

The principle of charging batteries

The batteries B1 and B2 are connected to solar panels: in the same time, if the charging current is greater than the PI1, TC1> TC2 PI1 and> PI2; successive if the charging of one battery is between thresholds PI1 and PI2, i.e. PI2<TC1 < PI1 and PI2 <TC2 < PI1 (Fig.15).

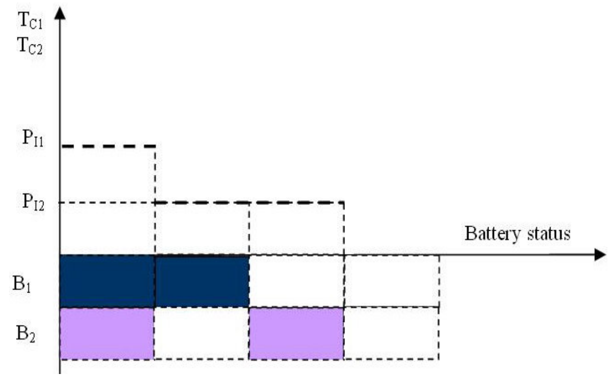

Fig.15 Current levels depending on the decision taken by coupling / decoupling panels

It is chosen which battery charging current is greater B1 if TC1> TC2, B2 if TC2> TC1. This represents a measure of the unloading degree.

The principle of connecting consumers

As shown in figure 16 it is allowed to connect all the consumers if the battery terminals reaches the PU1 voltage, consumers of the category zero and one are allowed if it is reached PU2, and it is allowed only the connection of consumers to the category zero if the terminal voltage decreases to the threshold PU3.

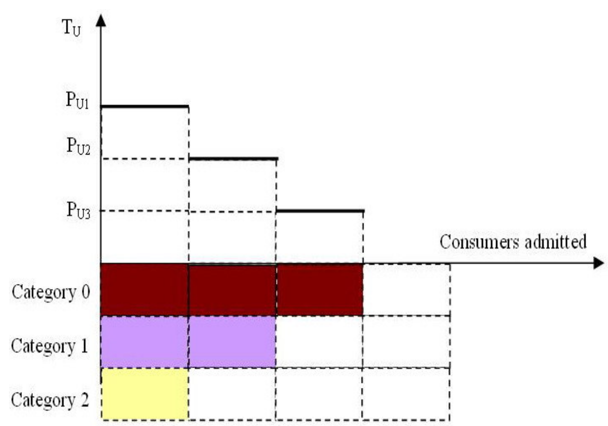

Fig.16 Voltage levels according to there are taken decisions of consumers connection

3.2.3 Simulation of the monitoring system for the movement of energy for consumers with ranked priorities

Based on the monitoring algorithm already presented it was developed a Simulink model for the monitoring of the movement of energy circulating in the Stand Alone PV System (Fig. 17).

Simulink model allows automatic connection and disconnection of the consumers according to the voltage levels of accumulators.

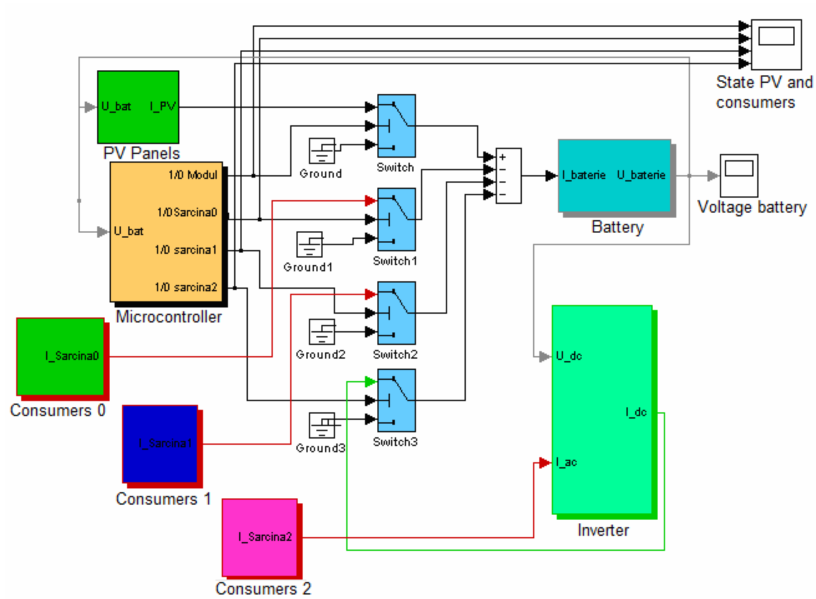

Fig. 17 Simulink model of the monitoring system for the movement of energy

The simulation results reveal the state of the photovoltaic panels respectively the categories of consumers according to the energy available in battery terminals, thus in Figure 18 is presented the evolution of battery terminal voltage and in Figure 19 are shown the states of the PV panels respectively the state for each category of consumer.

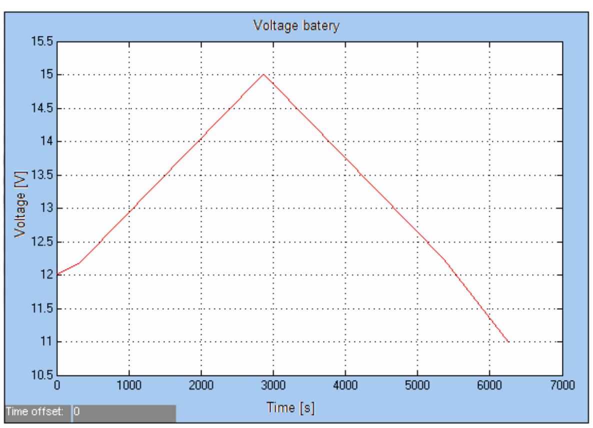

Fig.18 Voltage evolution on battery terminals

Analyzing the simulation results, it can be stated that consumers are connected to the system according to a threshold required for the remaining battery power. Thus the 0 class consumers are connected to a terminal threshold voltage of 11V, 1st class consumers are connected to the minimum of 12V, while those of category 3 to 13V, PV panels are disconnected from a maximum of 14V.

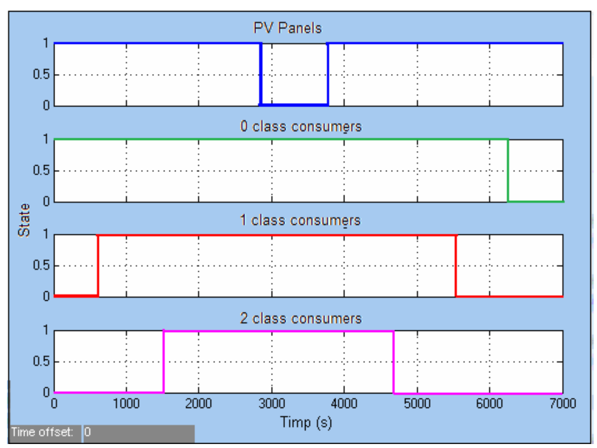

Fig.19 Categories consumers and the PV panels state

3.2.4 Structure of the automaton for panel orientation and for monitoring the movement of energy

The automatic orientation of the photovoltaic panel and the monitoring of energy movement require the design and the construction of a development system based on a numerical type structure Atmega 128 microcontroller from the AVR family, produced by ATMEL Company, made in SMD technology (Fig. 20), [28].

From the design stage, the development system with microcontroller was structured on three separate modules, for a better flexibility and an easier troubleshooting. The modules are structured as follows:
- CPU module;
- process interface module;
- power supply module.

Fig. 20 Automaton for panel orientation and for monitoring the movement of energy

The CPU module is shown in figure 21 and it consists of the following blocks: microcontroller Atmega 128; memory RAM; memory Flash, high sizes for data storage; LCD with 2x16 characters; clock for real time RTC 72421; battery for RTC and RAM; serial communication port RS232; integrated circuit 691; eight digital inputs from the interface; eight digital outputs for the interface.

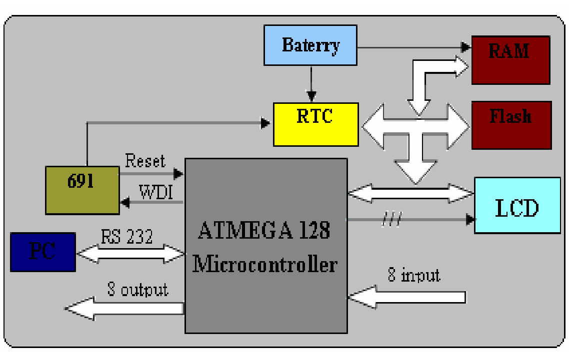

Fig.21 CPU module block diagram

The ATmega128 microcontroller provides the following features: 128K bytes of In-System Programmable Flash with Read-While-Write capabilities, 4K bytes EEPROM, 4K bytes SRAM, 53 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), four flexible Timer/Counters with compare modes and PWM, 2 USART's, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain, programmable Watchdog Timer with Internal Oscillator, an SPI serial port.

The Process Interface Module assures the data acquisition and adapts signals in order to be processed by the Central Unit.

The Process Interface Module with the photovoltaic system (Fig. 22) must enable:
- galvanic separation of the modules with the help of optocuplers;
- conversion and signals adaptation provide of the sensors;

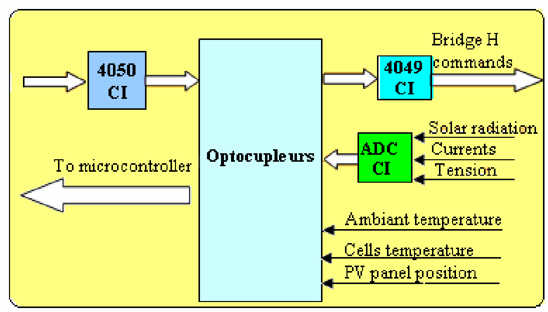

Fig.22 Interface block diagram

- PWM control with optocuplers for the orientation motor supply;
- control for the orientation motor revolution direction;

For supplying the actuators and the development system are used a DC-DC source with galvanic separation (Fig. 23), which are fed by the batteries and provide the output voltage 5VDCand 12 VDC.

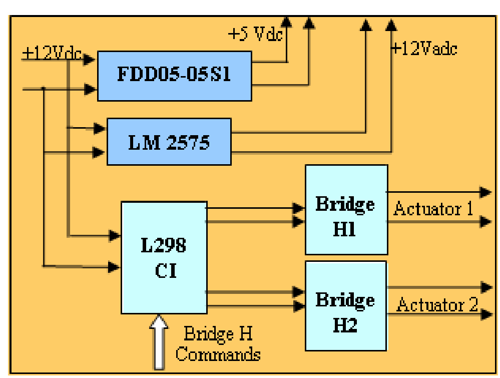

Fig. 23 Power supply block diagram

3.2.5 Development of software for the orientation panel system and monitoring energy circulation system

The microcontroller primarily program is designed in high-level language Visual C + +, [25] and requires working with functions and procedures which use variables of different types and which requires both an internal and external definition.

For a greater flexibility in tests achievement it was chosen the solution of storage data acquisitioned on the PC. Also, the switching commands are summarized at the PC level.

For ATMEGA128 microcontroller programming was used the software AVR3 Studio. The program was designed in "C", knowing that the ATMEGA family has been optimized for the use of high level languages.

The language chosen for the development of PC's software is Visual Basic, [8].

The main program window contains (Fig. 24):

- name of application „*Monitorizare sistem PV autonom*";
- menu of monitoring parameters of PV system;
- menu of PV Panel control "Control panou";
- menu of control data transfer "Control transfer date".

The menu of control data transfer contain three buttons for controlling data transfer ("Start transfer date", "Stop transfer date" and "Cerere date").

The menu of PV Panel control contain a button for the fast lock of panel drive motor ("Blocare c-dă panou") and a button to initialize the panel ("Inițializare panou").

The menu of monitoring parameters of PV system allows displaying the numerical information related to: currents to PV panel; current of battery discharge; voltage of battery; solar radiation; ambient temperature; temperature of PV cells; annual data (Y/M/D); hourly data (H/M/S); state of orientation motor; position of PV panel.

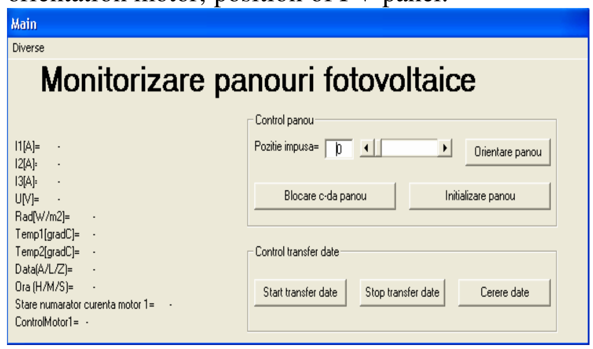

Fig.24 The main window of the monitoring program

The validation of physical model of the automation monitoring system achieved is given by the experimental results obtained on-line from this process. The facilities provided by Visual Basic program and increased flexibility of software modules Iocomp products have enabled a computer program capable of ensuring the control of photovoltaic panel, energy movement monitoring and storage of acquired data (Fig 25).

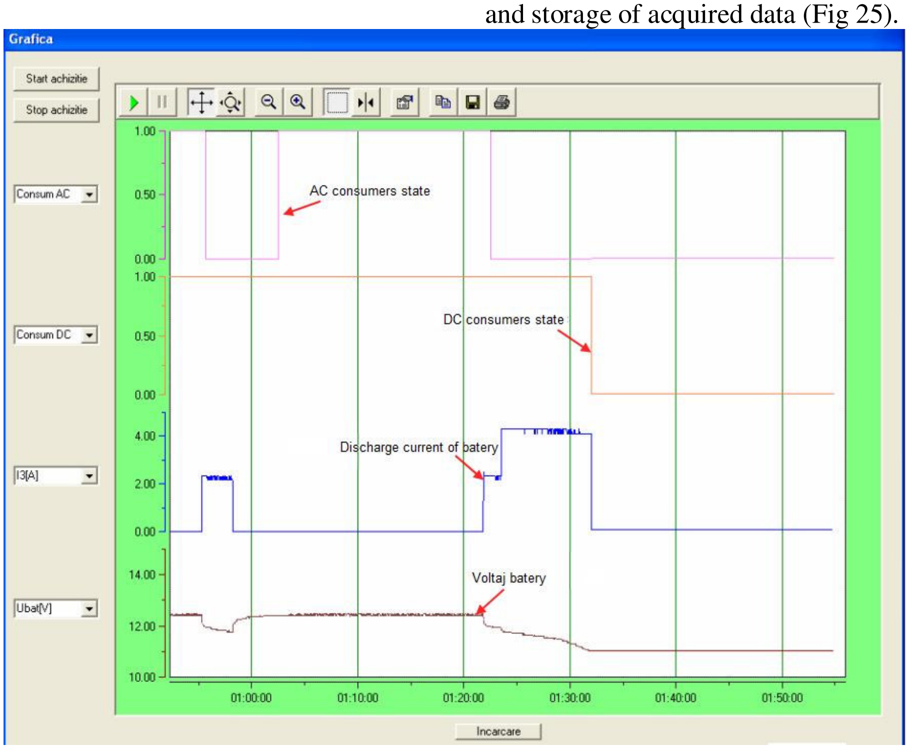

Fig. 25 On-line acquisition of signals from process

There are available four channels which can present the currents through panels, the current absorbed from the battery, the voltage at the battery terminals, the solar radiation, the ambient temperature, the temperature of a photovoltaic panel, the panel's current position (in number of parties to the origin), the consumers state of AC and DC current (Fig. 25).

The physical model allows disconnection of the two categories of consumers: Category 1 (consumers DC) and Category 2 (AC consumers). For consumers of category 0 (telephone and anti-hail rocket) due to protocol operation required, must be allowed to connect their continuous source of energy.

If the battery voltage rises above the threshold of 12.5V, the AC consumers are connected. Disconnect them from lowering blood is below 12V. DC consumers are connected until the voltage drops below 11V.

Acknowledgment

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4 Conclusions

The results presented demonstrate the experience, the continuity and the coherence of action, but also the degree of competence at which the team arrived in the automation and monitoring of processes specific to anti-hail systems.

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.

Using a microcontroller for automation and monitoring system made a PV solution that can significantly reduce the number of electronic components and cost of design and development of the made equipment.

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.

Using an oriented system after two axes, for photovoltaic panels, it is increased the energy efficiency with about 30%.

The proposed algorithm for monitoring the movement of energy from photovoltaic panels to consumers with hierarchized priorities has been verified by both numerical simulation and experimental.

Research results obtained can be extended to other isolated applications.

References:

[1] Alboteanu L., Ivanov S., Manolea Gh., *Modelling and simulation of a stand-alone photovoltaic system,* Proccedings of the 8th WSEAS International Conference on Power Systems, Santander, Spain, 2008, pp.189-193, ISBN 978-960-373-006-2.

[2] Alboteanu L., Novac Al., Ravigan Fl., Gh. Manolea, *Automation and supervision for orientation of the autonomous photovoltaic panels*, Buletinul Institutului Politehnic Iasi, Tomul LIV, 2008, pp.473-478, ISSN 1223-8139.

[3] Alboteanu L., Manolea Gh., Ravigan Fl., *Automatic System For Orientation Of The Autonomous Photovoltaic Panels*, Proccedings of the 13th National Conference on Electrical Drives, Tom 43(67), 2008, pp.1-6, ISSN 1482-7193.

[4] Alboteanu L., Ravigan Fl., Alboteanu D., Manolea Gh., *Research on antihail stations power supplay from the photovoltaic panels*, AGIR Bulletin, no. 4 oct.- dec., 2008, pp. 2-6, AGIR Publishing House, ISSN 1224-7928.

[5] Alboteanu L., *Research concerning the use of photovoltaic energy for supply the isolate anti-hail station,* Project CNCSIS PN II TD-31. Contract no. 232/2007.

[6] Alboteanu L., *Research concerning the use of photovoltaic energy for supply the isolate anti-hail station,* Project CNCSIS PN II MD-6 (PhD mobility). Contract no.8/2008.

[7] Alboteanu L., Novac Al., Manolea Gh., Nedelcut C., *Traffic monitoring system energy from solar panels to consumers ranked priority*, Patent application no. A-0069/22.01.2009.

[8] Braicu L., Limona L., Visual Basic 6.0-Programming Guide, Teora Publishing House, Bucuresti, 2002.

[9] Burduhos, B., Diaconescu, D., *The Optimization of the Pseudo-Equatorial Tracking Mechanisms for Increasing the Conversion*

Efficiency of Individual Photovoltaic Panels, CNSNRE - Conferinta Nationala de Surse Noi si Regenerabile de Energie - Editia a VIII-a, Bucuresti, Romania, 01 - 03 Noiembrie 2007.
[10] *European Solar Radiation Atlas*: Springer Verlag Berlin 1996, ISBN 3-430-61179-7.
[11] Metwally Aly Abd El-Aal, *Modelling and Simulation of a Photovoltaic Fuel Cell Hybrid System*, PhD dissertation, Kassel, Germany, 2004.
[12] Messenger R, Ventre J, *Photovoltaic System Engineering,* CRC Press, 2004, Sec. Edition.
[13] Novac Al. *Computerized system for monitoring a rocket launch point anti-hail,* Research contract E4/2001, CITT-S.C. Arsenal Ploieşti.
[14] Perez Richard, *To Track… or not to Track*, Home Power, no 101, june & july, 2003.
[15]Plangklang Boonyang *An Embedded interactive Monitoring System for PV-Diesel Hybrid Plants in Rural Areas*, Doctoral thesis, Kassel, Kassel university press GmbH, 2005.
[16] Sobor I., Kobîleaţkii N., Gherţescu C. *Autonomous system for power supply to consumers anti hail station using solar energy*, Scientific report, Chişinău, 2003.
[17] Sulea C., *Manolea Gh, Informatic system used for combating hail*, Annals of the "Constantin Brancuşi" University of Târgu Jiu, Engineering series, Issue 3/2010, "Academica Brâncuşi" Publisher, ISSN 1842-4856, pp. 143-153.
[18] Ulleberg O., S*tand-alone power systems for the future: optimal design, operation & control of Solar-Hydrogen energy systems*, Ph.D. dissertation, NorwegianUniversity, Trondheim, 1998.
[19] Xinjing Zou, Li Bian, Yonghui Zhai and Haitao Liu, *Performance Evaluation of Small Photovoltaic Stand-Alone Systems*. Proceedings of ISES World Congress 2007 (Vol. I – Vol. V), 4, Pages 1468-1472.
[20] Wei Deng, Wei Pei, Zhiping Qi and Li Kong, *Design and Implementation of Data Acquisition, Communication and Monitoring System for Photovoltaic Power Station in Microgrid*. Proceedings of ISES World Congress 2007 (Vol. I – Vol. V), 4, Pages 1538-1542.
[21] Waldemar Nawrocki, *Measurement Systems and Sensors*, London, ARTECH HOUSE, 2005.
[22] Zugravescu D., Manolea Gh., Alboteanu L., Sulea C., *Anti-Hail System - Geonomic Component of Modern Science***,** Proccedings of the International Conference on Risk Management, Assesment and Mitigation (RIMA'10), Bucharest, Romania, 2010, pp. 70-74, ISBN 978-960-474-182-3, ISSN: 1790-2769.
[23] *** *Automated Systems-autonomous power supply sources to service anti-hail, using solar and wind energy.* Contract CIITT 575/2000 - ANSTI, in collaboration with Technical University of Moldova.
[24] *** Nr.604 DECISION of 28 July 1999 on the approval of achieving the anti-hail national system and its financing.
[25] *** Microsoft, *MSDN Visual Studio 6.0.*
[26] *** MathWorks Inc. *Matlab Simulink software*.
[27]*** National Renewable Energy Laboratory, *Getting Started Guide for HOMER, Version 2.1*, April 2005.
[28]*** www.atmel.com.