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# Independent photovoltaic system

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*The paper presents an independent photovoltaic system. The photovoltaic installation is divided into two parts: the stationary and the follow up one. The stationary part of the system is composed of twelve modules, having a power of 660 Wp, turned towards the south and set up at an angle of 45°. The mechanic construction let a periodic change of the elevation angle of about 20°–75°. The follow up part of the system is composed of two identical mechanisms following the sun movement. Working in the azimuth-elevation scheme, those gears let the use of any sun-tracking system (in one or two axis). On each mechanism three modules have been installed. Total power of the follow up part in 330 Wp.*

*Because of searching and didactic character of the installation a parallel connection of the modules into aggregates of 165 Wp has been made. Each aggregate contains a separate cable system driven to the control chamber. It allows observation and comparison between several system elements (charge controllers and regulators, batteries, inverters, etc.). Observation can be made at the same lighting and temperature conditions. In the control chamber there are some measuring and control devices. They are in charge of supervising, the correct loading of the accumulator batteries protect them from overloading and assure proper division of power between several loads. For the goals mentioned above, Neste and Siemens products have been used. To convert 12 VDC tension of batteries to 220 VAC special inverters we use. Monitoring of the whole system has been built using equipment and software of the Advantech Company. During the research work it has been found that for monitoring of installation of this value the industrial DA&C modules (like the ADAM4000 family) are the best ones. According to them, a diffused control system related to a bus RS485 and working under the GENIE program has been elaborated. This system, apart from the main controlling functions, has to steer the move of the systems following the sun movement. Thanks to the constant measurement of the level and direction of the sun radiance, it was possible to use intelligent decision algorithms improving operation of the following systems.*

**Keywords:** photovoltaic, solar energy, control, sun tracking, installation.

## 1. Introduction

This article presents an independent photovoltaic system built for the Photovoltaic Laboratory in the Institute of Automatics. This institute is a part of the Faculty of Electrotechnic, Automatics, Computer Science and Electronic at the University of Mining and Metallurgy (UMM) in Cracow. The installation is still under construction and that is why the description will concern its final shape. The work that had been already done will be pointed, too. The electric energy coming from this system would be entirely used for the needs of the Lab. The research and educative goals of the Photovoltaic Lab caused a huge diversity of the equipment used. It also helps to compare several technologies and quality of products made by the best companies.

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## 2. System overview

The whole photovoltaic installation is situated in building C-3 by Czarnowiejska Str., the solar battery cells are located in a special "garden", south of the main building. The energy stock and the controlling system are in the Lab at the ground floor of building C-3. Functional aspect of the system is presented in Fig. 1.

### 2.1. Solar panels

The total power of the photocells is about 1 kWp. The solar battery modules have been parallely combined into 3-element blocs. It reduces the number of cables that were to be used and it let the freedom to experiment on different combinations. A certain part of modules (about 660 Wp) is a stationary system directed towards the south with the possibility of a temporary change of the elevation angle of about 20°–75°. The changes have to be done manually. The

 

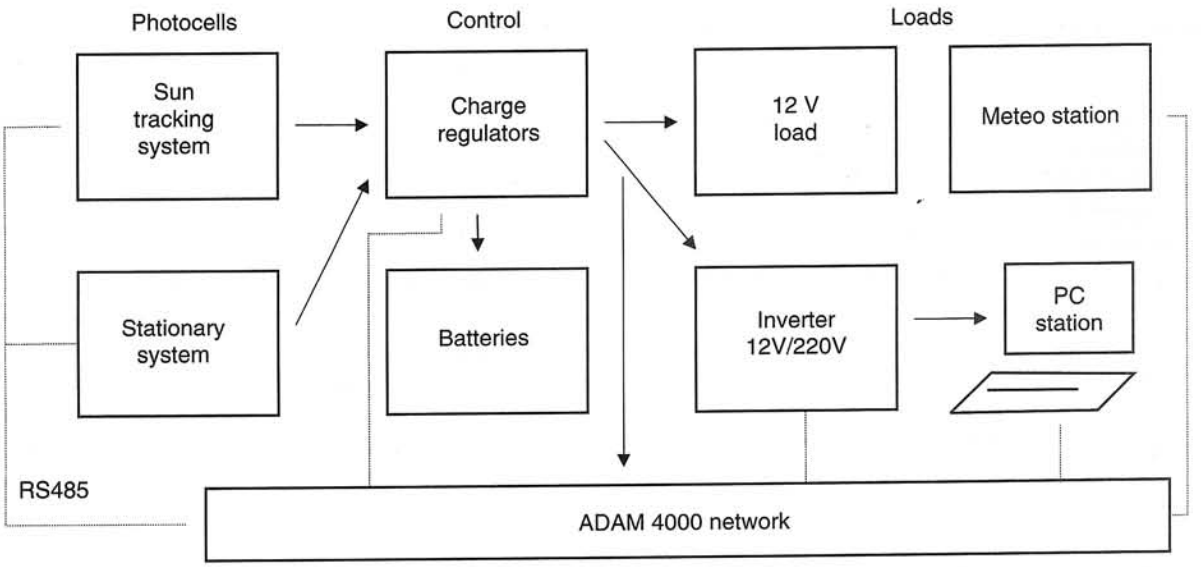


Fig. 1. Functional aspect of our installation.

other modules (about 330 Wp) form the sun tracking system. The modules will be placed on two identical mechanisms, which give the possibility of an independent setting of the azimuth and elevation angles. The degree of rotation of the mechanisms will be 120° for the azimuth and 0°–75° for the elevation. It will let us follow the sun in the Cracow's geographic conditions from the sunrise to the sunset during the whole year. It will also let us assemble the modules into a resting position (a horizontal one) in the case of strong wind.

## 2.2. Battery

As a stock of energy we use the maintenance-free gel batteries produced by TUDOR and SONNENSHEIN. It is a very expensive solution but necessary for a room with systematic groups of people working close to the batteries. Experiments done on acid-lead batteries show that the level of vapours of the acids, during the charging process, is very harmful for the equipment (it provokes a quick process of corrosion). It is also harmful for people (it provokes strong headaches). This is important to underline the necessity of using batteries working differently than car batteries in the photovoltaic installation. The special work of the photovoltaic system doesn't need important moving streams but it is necessary to take big streams for a long period from the batteries. The best batteries to fulfil these demands are those dedicated to photovoltaic systems or the traction batteries. The capacity of those batteries is determinated for a 5- or 10-hour discharging current.

## 2.3. Charge regulators

Charge regulators control the right loading process of batteries. They also provide energy to the load. In the system we use one simple SIEMENS regulator and two NESTE GENIO microprocessor regulators. The SIEMENS element contains advanced loading algorithm based on PWM with making a difference between traditional acid-lead batteries and gel batteries. Apart from protecting against too deep discharging of the battery, SIEMENS regulator periodically makes a controlling gassing process (only for the acid-lead batteries). We can read battery voltage and current on the LCD display, too.

NESTE GENIO is the real energy distribution centre. It has two inputs for sticking solar batteries. The first is a typical relay one and the second is with a current amplifier. The work based on the MPP tracking let a maximum use of the power from solar elements. Several automatically selected loading algorithms prolong a period of the battery using. The LCD display of the element, presented in Fig. 2, shows all the system parameters like the streams going out of the photo units, the charging/discharging currents, the battery voltage and the degree of batteries loading. Above all, this instrument can estimate, for how long the energy accumulated in the battery would be sufficient (with the actual load current). GENIO has also a link named the NAPS LINK serving to exchange informations with other elements of the system.

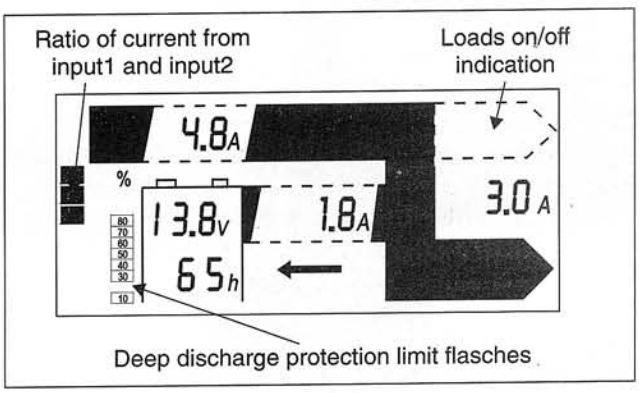


Fig. 2. LCD display of GENIO charge controller.

## 2.4. Load

The load in this system consists of the 12V DC devices (halogen lamps, controlling and measuring elements) and the 220 V AC units (for ex. the computer station). As a processor 12 VDC/220 VAC used the ATLAS inverter. It assures a constant power of 850 W and the peak power of 1500 W. It has an LED display to show a state of the work. There is also the possibility to supply control signals from another control instrument.

# 3. Installation control

The supervision of the whole photovoltaic system is made by the products of Advantech Co. Ltd Taiwan. The main control application is written in GENIE 3.0 environment and the access to the measurement signals is possible thanks to remote DA&C modules from the ADAM4000 family. They form a dispersed control system working with the RS485 bus. The main application, apart from the control function in the installation, also has to follow the sun in the tracking part of the system.

## 3.1. Model solution of sun tracking device

The easiest way to understand realisation of the sun-tracking task is presenting our model solution. Students in our lab for a test work use the device showed in Fig. 3.

Fig. 3. Model of a sun tracking device.

The measurement signals coming from the object to the application are:

- level of lighting from 4 directions (a sensor made by ourselves),
- present disposal of the photoelements in a horizontal and vertical position,
- arrival to the end of the range of moving in each axis.

This piece of information let us to realise a control in an opened system (the position depends on the geographic situation, on the date, and time). It is also possible to work in a closed combination with using a lightning sensor. The measurement of lightning let the use of advanced decision algorithms which makes better efficiency of installation. The independent drive of rotary mechanisms of both axes is efficient for following in one or in both axes.

## 3.2. Hardware

Here, we would like to give some more details concerning the structure of the dispersed controlling system based on the RS485 bus and the remote DA&C modules ADAM4000. An example of the controlling network is presented in Fig. 4.

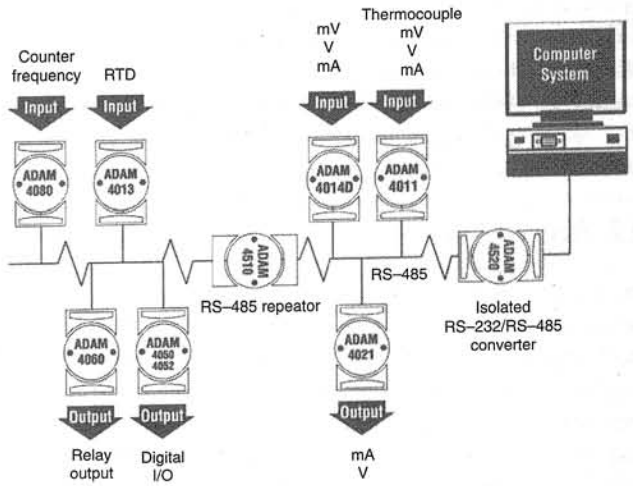


Fig. 4. ADAM4000 network diagram.

The controlling – measurement modules are situated just by the object. The function of the modules is to change the measured signals into a digital form and to transfer them on the common communication bus. Such a solution highly reduces influence of the disturbances. The RS485 bus uses a single par of twisted wires to transmit data. The maximal length of this bus is about 1.2 km. You can stick to it 32 ADAM modules. If there is a necessity to use more modules or a longer bus - repeaters should be used (e.g., ADAM4510). Physical combination of the network can be of a, so-called, "chain" or "star" type. Communication in the network is based on a question-answer system. All the modules have a slave status and the host computer has a master status. The master reads or sends control to specific module, making it available to this module to use the bus

 

for a moment. All the orders and data have the figure of ASCII characters, what makes it easier to test the system and to write our own applications. The wide range of the functions realised by the ADAM 4000 family modules make them very useful in industrial applications.

While projecting the dispersed controlling system based on the ADAM4000 modules, one should have care of several restrictions:

- maximum speed of transmission accepted by the modules is 38.4 Kbps,
- frequency of sampling at analog inputs is 10 samp./s.

Those restrictions are not so important in typical industrial use but they can stop realisation of a work in some specialised applications. In those cases, the Advantech Co. Ltd. proposed to use the ADAM5000 basing on the measurement "islands" which can be easily equipped with a wide range of modules – measurement inserts.

In the future, the dispersed control system will be used in a meteorological station in order to registrate the basic weather parameters, too.

## 3.3. Software

After describing the equipment aspect of our photovoltaic installation we will present shortly the supervision program looking after the proper work of installation. As a program environment we have chosen GENIE v. 3.0 package. This is a program for creating a direct digital control based on a PC, making it easy to present visually the controlled process. Developing the controlling algorithm by the right assembling of blocks-icons (representing advanced functions and procedures) makes the process of creating applications easier and shorter. The opened GENIE architecture makes

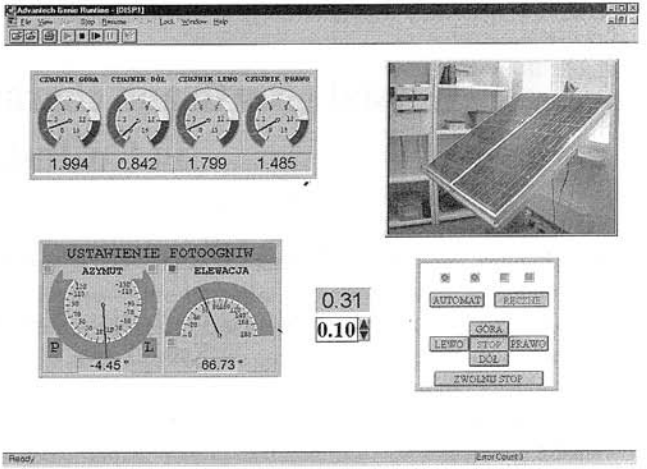


Fig. 5. Screen of our Genie application.

it possible to easily exchange the data between main application and other programs. The integral mechanisms of the Internet connections, make possible the co-operation of the distant applications. This is also important, that the package has drivers to almost all the instruments produced by Advantech. In this moment our application controls only the model tracking system (Fig. 5).

However, after completion of constructing works, the whole system will be under the control of application. We would like to show the basic work parameters of the photovoltaic installation and measurement from the meteo station on webside of our laboratory. We will do our best to measure at the same time the I–V characteristics of different photovoltaic modules working in natural lightning environment.