PERFORMANCE EVALUATION OF A SOLAR TRACKING PV PANEL

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This paper deals with the performance estimation of a solar tracking PV panel of single axis type. The studied device automatically searches the optimum PV panel position with respect to the sun by means of a DC motor controlled by an intelligent drive unit that receives input signals from dedicated light intensity sensors.

The solar tracking PV panel is compared with a fixed PV panel in terms of electric energy output and efficiency.

Keywords: PV conversion, solar tracking PV panel, performance estimation.

1. Introduction

The increasing demand of energy, the depletion of fossil fuel reserves, the unexpected events taking place on the international scene (local armed conflicts, natural disasters like earthquakes, tsunamis, floods, hurricanes, etc.) that have the potential to partially cripple the energetic systems, proves that the energy security and diversity is a serious aspect that the mankind should seriously consider when deciding the short and middle term energy policy. The general opinion shared by the most part of the specialists supports the idea that the exclusive dependence on the energy produced from fossil fuels (coal, oil, nuclear, etc.) is hazardous, unsustainable and harmful for the environment. In this context, many developed countries (e.g. USA, Germany, Spain, Denmark, France, Italy etc.) launched in the last decades ambitious programs for supporting the rapid development of alternative energetic technologies based on: solar energy, wind energy, tidal and wave energy, biomass etc.

One of the most promising renewable energy sources characterized by a huge potential of conversion into electrical power is the solar energy. The conversion of solar radiation into electrical energy by Photo-Voltaic (PV) effect is a very promising technology, being clean, silent and reliable, with very small maintenance costs and small ecological impact.

The interest in the PV conversion systems is visibly reflected by the exponential increase of sales in this market segment with a strong growth

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projection for the next decades. According to recent market research reports carried out by European PhotoVoltaics Industry Association (EPIA), the total installed power of PV conversion equipment increased from about 1 GW in 2001 up to nearly 23 GW in 2009 [1].

The continuous evolution of the technology determined a sustained increase of the conversion efficiency of PV panels, but nonetheless the most part of the commercial panels have efficiencies no more than 20%. A constant research preoccupation of the technical community involved in the solar energy harnessing technology refers to various solutions to increase the PV panels conversion efficiency. Among PV efficiency improving solutions we can mention: solar tracking [2-3], optimization of solar cells geometry [4-5], enhancement of light trapping capability [6-7], use of new materials [8-9], etc.

The output power produced by the PV panels depends strongly on the incident light radiation. The continuous modification of the sun-earth relative position determines a continuously changing of incident radiation on a fixed PV panel. The point of maximum received energy is reached when the direction of solar radiation is perpendicular on the panel surface. Thus an increase of the output energy of a given PV panel can be obtained by mounting the panel on a solar tracking device that follows the sun trajectory.

The main objective of this paper are to estimate the performance of a solar tracking PV panel of single axis type, designed and executed by University Politehnica of Bucharest in cooperation with Technosoft International SRL. The studied device automatically searches the optimum PV panel position with respect to the sun by means of a DC motor controlled by an intelligent drive unit that receives input signals from dedicated light intensity sensors [10].

2. Solar tracker description

Unlike the classical fixed PV panels, the mobile ones driven by solar trackers are kept under optimum insolation for all positions of the Sun, boosting thus the PV conversion efficiency of the system. The output energy of PV panels equipped with solar trackers may increase with tens of percents, especially during the summer when the energy harnessed from the sun is more important.

Several types of solar trackers are known so far and they can be classified according to various criteria such as rotation axes number, orientation type, activity type.

If we refer to the number of rotation axes we can distinguish solar trackers with one rotation axis or with two rotation axes. Depending on the orientation type solar trackers can have a movement based on a previously computed sun trajectory, or they can be equipped with on-line orientation system that updates the PV panel position according to the instantaneous solar irradiation. Solar trackers can be also classified depending on their activity type into active or passive ones.

The solar tracking PV panel analyzed in the paper is of single rotation axis type, electrically driven based on the signals received from light intensity sensors (with on-line orientation system).

Since solar tracking PV panels include moving parts and control elements relatively expensive, single-axis variant seems to be more cost-effective than the double-axis alternative, especially for small PV power plants. For a better performance, PV panels equipped with single axis trackers may include manual elevation adjustment mechanisms on the second axis, allowing thus an update of the PV panels position on a monthly or seasonal basis to increase the global energy output of the system.

The single-axis solar tracking system analyzed in the paper consists of a PV panel rotating around a tilted shaft, under the action of a DC motor controlled according to the real Sun position estimated by means of two light intensity sensors, Fig. 1.

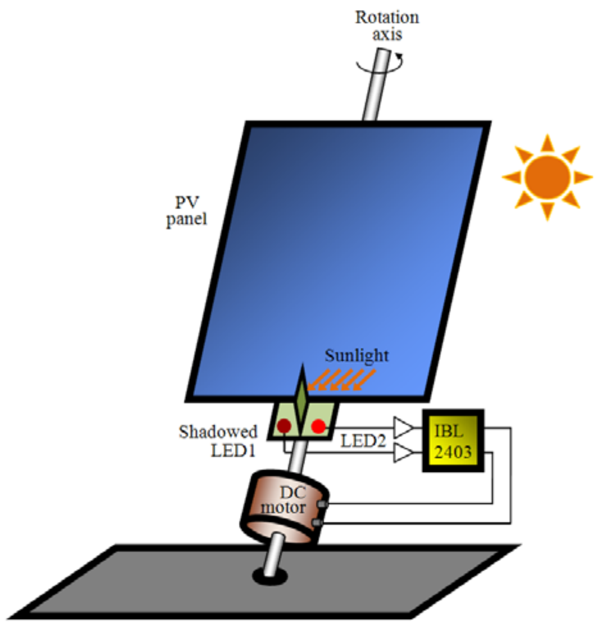

Fig. 1. Principle of the studied single-axis solar tracking PV panel

The light sensing solution consists of two luminescent diodes of LED type placed normal to the panel surface and separated by an opaque plate. Thus, depending on the solar light direction with respect to the PV panel, one of the two LEDs will be shadowed and the other illuminated. The LED that is lighted up will generate a stronger signal and the other LED a weaker one. This output voltage difference will indicate the movement direction of the PV panel, so as to bring it normally oriented to the incident sun light rays and thus to obtain a maximum conversion efficiency of light into electricity.

In the experimental model of the solar tracking system, Fig. 2, the voltage signals generated by the two LEDs are amplified so as to match the value range of the analogue input terminals of IBL2403 module for PV panel motion control.

IBL2403 is a flexible and completely digital drive unit, based on the DSP technology, dedicated to the command of DC electric motors, sinusoidal or trapezoidal DC brushless motors or stepper motors. This drive unit is a product (design and execution) of Technosoft®, being programmable in the high level language TML (Technosoft Motion Language) [11].

IBL2403 drive unit is used in our case to command the DC electric motor that ensures the PV panel movement. The main data of the DC motor integrated in the experimental model of the solar tracker are: rated voltage 24 V, rated current 3 A, maximum speed 3000 rpm, gear box with speed reduction ratio of 1: 20.

Fig. 2. Solar tracking PV panel and fixed PV panel used for comparison

The IBL2403 drive unit used to control the experimental model of the solar tracking PV panel was programmed by means of the Technosoft EasyMotion Studio platform. The proposed solar tracking system was designed and executed so as to satisfy specific technical requirements such as: small energy consumption, optimum performance-cost ratio, operation reliability, movement simplicity, possibility of system integration in a monitoring and control centralized structure.

The two signals produced by the two LEDs are both measured with the purpose to detect if:

- the light intensity is strong enough to justify the panel movement (any panel movement means additional energy consumption that reduces the overall efficiency of the PV system),

- the difference between the signals from the two LEDs is higher that an imposed limit so as to trigger a new movement of the PV panel, to the left or to the right, for a better position with respect to the sun (if the difference between the output signals of the two LEDs is very small that means the PV panel position is not far from the optimum one and the movement is not justified since it will not bring a notable energy output gain).

In order to minimize the energy consumption of the tracking system, the power circuit of the IBL2403 drive unit can be completely disabled during the inactive periods of the DC motor. By the adopted solution we prevent the intermittent, frequent and un-necessary movements of the PV panel that would entail a higher consumption of energy, decreasing in this way the conversion efficiency of the system.

3. Experimental investigation

The experimental investigation is carried out in order to compare the performance of the solar tracking PV panel in comparison with a fixed PV panel of the same type, Fig. 2. The two PV panels will be subject to the same solar irradiation conditions in the same time and the energy output of each panel will be monitored and compared. The experimental measurements will be carried out in various meteorological conditions with the purpose of comparing the supplementary output energy obtained in case of a PV panel equipped with a solar tracking mechanism.

The experimental study of the solar tracking prototype will use a modern Data Acquisition System (DAS) [12-13] composed of a USB type data acquisition board (Advantech USB 4711 with a frame-rate of 150kS/s, 12-bits and 16 channels), a signal adaptation module and a laptop, Fig. 3.

The software interface for the management of the measurement system was developed using NI LabView development platform since it is characterized by a high compatibility with many types of data acquisition boards [14-15].

The developed software front panel is presented in Fig. 4 and it is designed for four measurement channels (two voltages and two currents). The recorded data can be saved in ASCII files (MS Excel compatible format, TAB delimiter), that can be analyzed separately. Since the studied application could entail very long data acquisition running time (hours, days) the software interface has the possibility to adjust the time delay between successive readings.

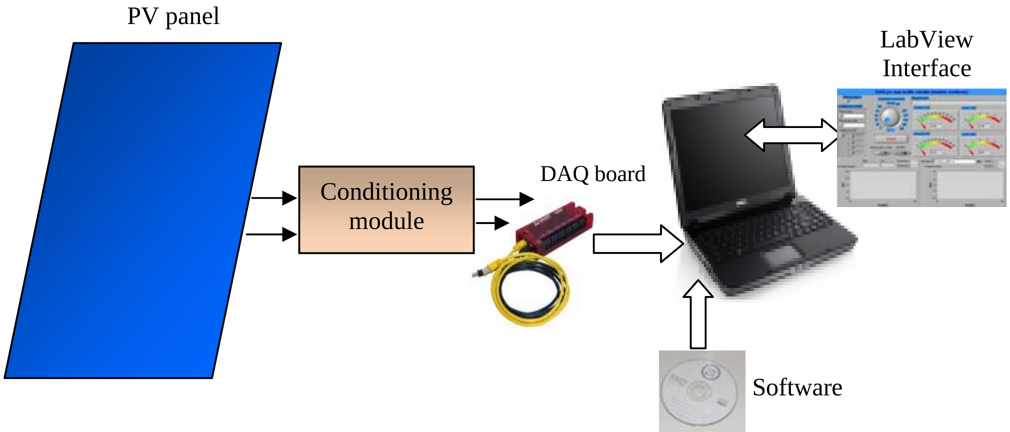

Fig. 3. General overview of the measurement system

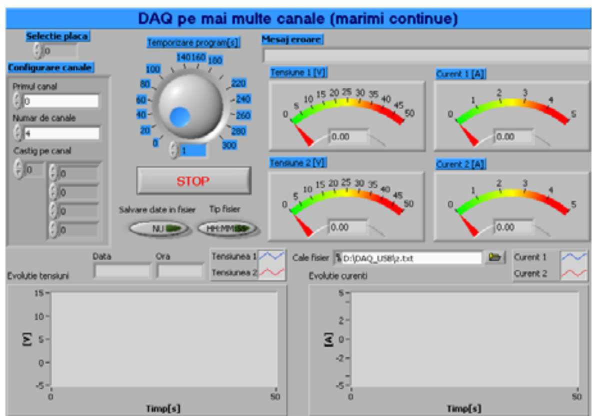

Fig. 4. Front panel of LabView software interface

Another functionality of the developed interface is represented by the possibility of calibrating the output signals by using high precision measurement apparatus.

After selecting the driver, the application configures the data acquisition board and the data recorded. Since the input quantities are DC voltages and currents, the application is not time critical. The developed software interface application is characterized by:

- easy signal interpretation and data mining,
- easy integration into a more complex system,
- possibility of extension with other signals when the initially proposed channels number is exceeded,
- possibility to start and stop the data recording process at predefined moments of time, e.g. sunrise time and sunset time.

The experimental data recorded on 14.07.2011 between 09:03:39 h and 13:03:39 h, on 1 sec. basis, are presented comparatively in Fig. 5 for the tracking PV panel (PV-T) and for the fixed one (PV-F). The recorded results are affected by inherent errors due to the temperature variation of load resistances, imperfect contacts and positions etc. The important fluctuations of the output power are due to the alternations of the sunny-cloudy periods during the experiment.

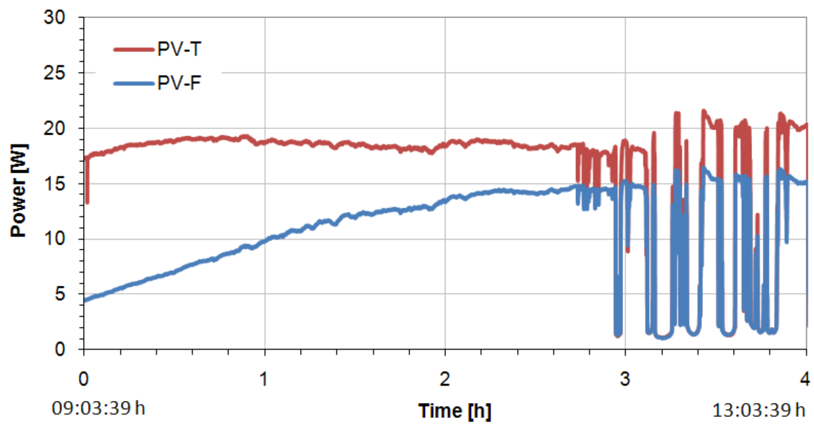

Fig. 5. Measurements data recorded on 14.07.2011;
tracking PV panel (PV-T); fixed PV panel (PV-F)

A higher energy output (57.55 % higher) can be noticed in case of solar tracking PV panel compared to the fixed one. On the other hand the approximate average power consumed by the electric drive system itself is about 10.17 W. If we take into account this consumption as well, the solar tracking PV panel becomes slightly less attractive than the fixed one. If we keep in mind that the electric drive system is oversized (it can be used to move much larger PV panels) we can conclude that the solar tracking PV panel becomes more attractive than the fixed ones only for larger PV panels, starting from around 35 W. For example a 100 Wp PV panel equipped with the same solar tracking mechanism may produce around 38% more energy than a fixed one in similar conditions. In case of cloudy days the net output energy generated by the solar tracking PV panel is expected to be close or even smaller than the fixed PV panel due to the energy consumption of the solar tracking mechanism.

5. Conclusions

This paper presents a single axis solar tracking PV panel designed and executed by University Politehnica of Bucharest in cooperation with Technosoft International SRL. The performance of the equipment was experimentally tested in comparison with a fixed PV panel.

The recorded data on 14.07.2011 day proved that the solar tracking PV panel produced more energy than the fixed one with about 57.55%. If we take into account the own energy consumption of the tracking mechanism, the mobile PV panel becomes less attractive than the fixed one, the tracking mechanism being oversized. If higher power PV panels are driven by the same tracking mechanism they may produce more energy than the fixed ones (e.g. about 38% more energy in case of a 100 Wp PV panel, in the same experimental conditions).

Acknowledgement

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