IT'14
ŽABLJAK

XIX
naučno - stručni skup

INFORMACIONE TEHNOLOGIJE

SADAŠNJOST I BUDUĆNOST

Urednik
Božo Krstajić

IT'14

INFORMACIONE TEHNOLOGIJE

- SADAŠNJOST I BUDUĆNOST -

Urednik
Božo Krstajić

Zbornik radova sa XIX naučno - stručnog skupa
INFORMACIONE TEHNOLOGIJE - **sadašnjost i budućnost**
održanog na Žabljaku od 24. do 28. februara 2014. godine

Zbornik radova
INFORMACIONE TEHNOLOGIJE - sadašnjost i budućnost 2014

Glavni urednik
Prof.dr Božo Krstajić

Izdavač
Univerzitet Crne Gore
Elektrotehnički fakultet
Džordža Vašingtona bb., Podgorica
www.etf.ucg.ac.me

Tehnička obrada
Aleksandra Radulović
Centar Informacionog Sistema
Univerziteta Crne Gore

Tiraž
150

Podgorica 2014.

Organizator

Elektrotehnički fakultet Univerziteta Crne Gore

Skup su podržali:

* Ministarstvo za informaciono društvo i telekomunikacije
* Pošta Crne Gore
* Agencija za elektronske komunikacije i poštansku djelatnost
* Čikom

Programski odbor

Dr Novak Jauković, Elektrotehnički fakultet, Podgorica
Akademik Dr Ljubiša Stanković, CANU
Dr Zdravko Uskoković, Elektrotehnički fakultet, Podgorica
Dr Vujica Lazović, Ekonomski fakultet, Podgorica
Dr Branko Kovačević, Elektrotehnički fakultet, Beograd
Dr Milorad Božić, Elektrotehnički fakultet, Banja Luka
Dr Miroslav Bojović, Elektrotehnički fakultet, Beograd
Dr Zoran Jovanović, Elektrotehnički fakultet, Beograd
Dr Božidar Krstajić, Elektrotehnički fakultet, I. Sarajevo
Dr Milica Pejanović-Đurišić, Elektrotehnički fakultet, Podgorica
Dr Dejan Popović, Elektrotehnički fakultet, Beograd
Dr Božo Krstajić, Elektrotehnički fakultet, Podgorica
Dr Milovan Radulović, Elektrotehnički fakultet, Podgorica
Dr Budimir Lutovac, Elektrotehnički fakultet, Podgorica
Dr Igor Radusinović, Elektrotehnički fakultet, Podgorica
Dr Igor Đurović, Elektrotehnički fakultet, Podgorica
Dr Miloš Daković, Elektrotehnički fakultet, Podgorica
Dr Milutin Radonjić, Elektrotehnički fakultet, Podgorica
Dr Ramo Šendelj, Fakultet za Informacione Tehnologije, Podgorica
Dr Stevan Šćepanović, Prirodno-matematički fakultet, Podgorica
Dr Sašo Gelev, Elektrotehnički fakultet, Radoviš

Organizacioni odbor

Dr Božo Krstajić, Elektrotehnički fakultet, Podgorica
Dr Milovan Radulović, Elektrotehnički fakultet, Podgorica
Dr Ana Jovanović, Elektrotehnički fakultet, Podgorica
Dr Saša Mujović, Elektrotehnički fakultet, Podgorica
MSc Žarko Zečević, Elektrotehnički fakultet, Podgorica
Vladan Tabaš, dipl.ing., Čikom

Sekretarijat

Aleksandra Radulović, CIS Univerzitet Crne Gore

SADRŽAJ

JEFTINO PIC BAZIRANO REŠENJE ZA AUTO-TRAKING FOTONAPONSKIH PANELA AFFORDABLE PIC BASED SOLUTON FOR PHOTOVOLTAIC PANEL AUTO-TRACKING

Roman Golubovski, *Faculty of Electrical Engineering, University "Goce Delčev" - Štip, Republic of Macedonia*

Sadržaj: *Fotonaponska konverzija je medžu najbitnijim aplikacijama obnovljivih izvora zbog direktne konverzije solarne energije u električnu. Iako su fotovoltaici skuplji od ostalih tipova energetskih konvertora, oni imaju prednosti kao mala težina, i skalabilnost i za manje aplikacije. Zato je bitno da se postiže veča efikasnost maksimirajuči absorpciju solarnog zračenja. Sama Absorpcija je nekompletna uglavnom zbog napadnog ugla radijacije na površinu PV panela (sunčeva putanja tokom dana i razlike u sezonskim trajektorijama), kao i zbog refleksije istih. Jedan od načina podizanja efikasnosti je optimizacija napadnog ugla kontinuiranim trakingom. Ovaj trud predlaže jeftnu PIC realizaciju trakinga sa četiri LDR (light dependent resistor) senzora za planarnu prostornu orijetaciju sa dva stepena slobode i steperskim pogonom.*

Abstract: *Photovoltaic (PV) conversion is one of the most important applications of renewable energy sources because of the direct conversion of solar energy to electric energy. Although PVs are more expensive compared to other types of energy converters, they have some advantages such as low weight and feasibility of small scales. Therefore, it is important to absorb the maximum solar energy in order to increase the efficiency of the energy converter. PV's absorption of the solar energy is incomplete mainly due to angle of incidence (resulting from both the daily sun motion and the seasonal trajectory differences) as well as the partial loss due to reflection off PV's surface. One way to increase efficiency is to optimize the angle of incidence by employing continuous solar tracking. This paper proposes a cheap PIC based embedded design calculating next optimal spatial orientation by using four LDR (light dependent resistor) sensors, and tracking that optimal orientation with a two-degrees of freedom stepper drive.*

1. INTRODUCTION

Solar energy is a type of renewable energy source that is relatively easy to convert directly into electrical energy by the use of photovoltaic (PV) converters [1], [2]. Solar cells convert the energy of light's photons to electric energy with efficiency between 5% to 25% without using thermodynamic cycle or active fluid. Solar cells can be light collector directly or can use light concentrators like mirror or convex lens.

The PV has advantages like light weight suitable for transport and installation, silent operation, little maintenance, etc. However, it is still more expensive than most of the rest energy converters like diesel generators. So efficiency in terms of optimal operation with maximized solar absorption is essential. Beside the high costs, another problem is the low efficiency of the solar cells themselves (14%-17% for monocrystalline silicon, 13%-15% for polycrystalline silicon and 5%-7% for amorphous silicon). Therefore an optimal PV conversion efficiency requires optimal angle of incidence for as long as possible during daylight radiation.

This paper depicts an affordable (PIC based) concept with four cheap LDR sensors that can accurately and timely follow the sun providing best solar absorption. The algorithm can adjust the daily rate of corrections taking into account the cost of driving the moves against the efficiency loss due to incidence angle's deviation from its optimum. The analysis behind the algorithm is a typical set of power-voltage characteristics recorded for movable and fixed (reference) PV arrays during a sunny summer day.

2. PV OUTPUT POWER DEPENDENCE OF THE SOLAR RADIATION INTENSITY AND ANGLE

Typical current-voltage-power characteristic of a solar cell is given on figure 1:

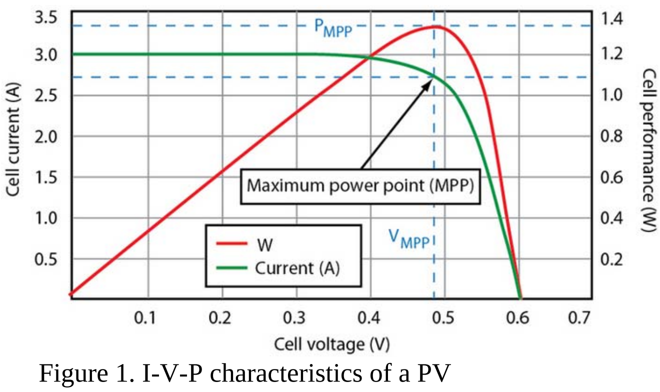

Figure 1. I-V-P characteristics of a PV

Figure 2 shows how generated current varies with light intensity changes thus resulting in output power changes, which can go below its nominal value.

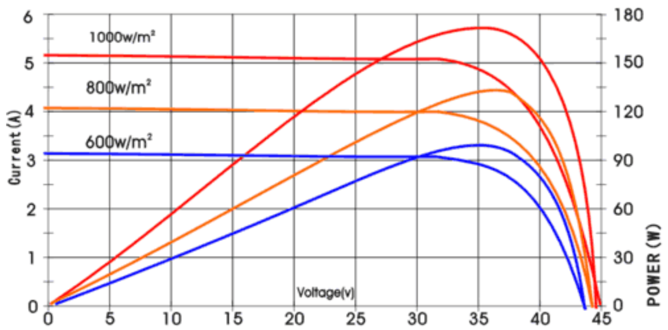

Figure 2. Current variations due to radiation intensity

Daily motion of the sun changes the radiation angle constantly, so the required perpendicular angle of incidence can be achieved only for movable PV arrays. Seasonal trajectory changes also imply need for angle adjustment so 2D planar freedom is required, as depicted on figure3:

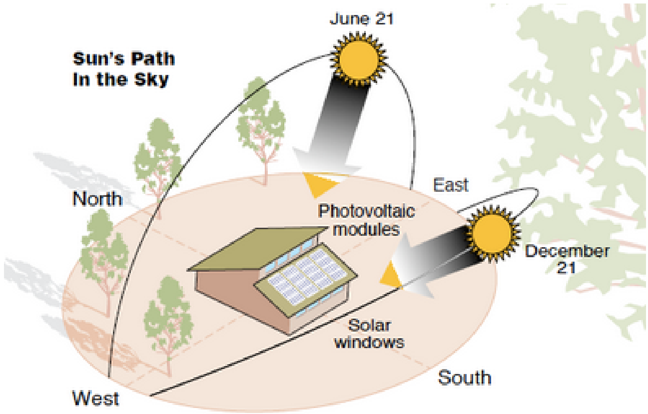

Figure 3. Variation of sun motion path during the year

The angle affects not only the direct absorption of radiation photons by the PV cells, but also the PV panel surface reflection which increases proportionally, thus lowering the effective absorption.

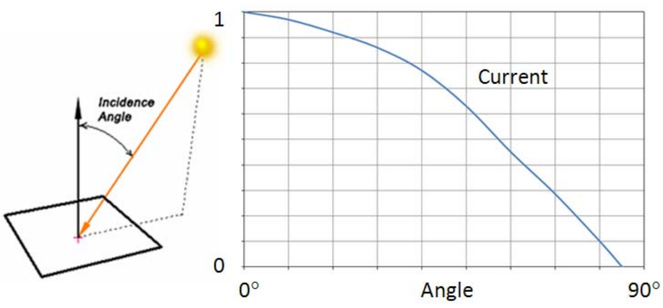

Figure 4. Radiation angle and its effect on the current

3. COMPARISON OF EFFICIENCY BETWEEN MOVABLE AND FIXED PV

The presented output power characteristics on figure 5 are typical and recorded on two identical PV panels - one being fixed in its optimal orientation, the other being movable and following the sun in two degrees of freedom (azimuth and latitude) [3]. The movable PV tracker locks on the MPP (maximum power point).

The comparative study is made on a sunny July day in the north hemisphere, hourly, from 0900h (AM) to 1800h (PM).

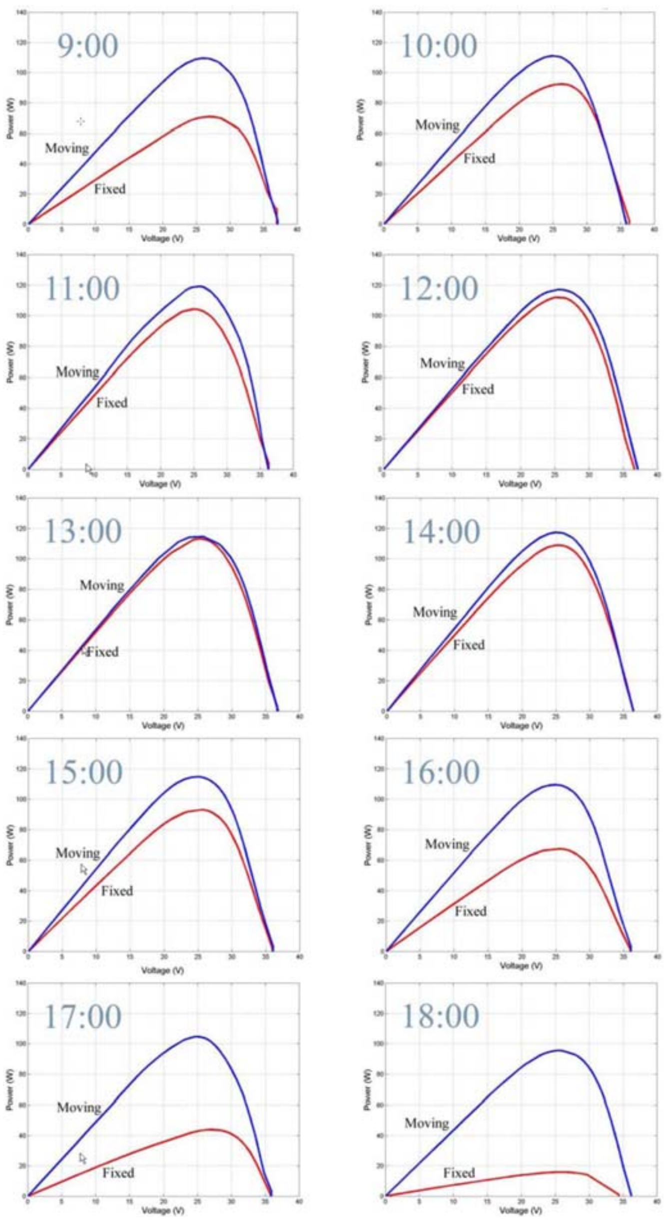

Figure 5. Power characteristics of fixed and moving PVs

At 0900h the movable PV (MPV) is 55.2% more efficient than the fixed (FPV). At 1000h FPV's output power raises significantly compared to MPV's which changes a little. Still MPV is 19.5% more efficient. From 1100h to 1400h FPV's output power approaches the MPV's, as their orientation matches. MPV is still more efficient (4% to 13%). After 1400h sun height starts decreasing and so is the FPV's output power. MPV also decreases its output power but slower as it still tracks best orientation. MPV's efficiency compared to FPV's raises from 7.5% to 61.4% at 1600h. As sunset approaches both MPV and FPM decline in their output power, but MPV is much more efficient - 236% at 1700h and 605% at 1800h.

This comparative analysis shows that a tracker can improve daily energy production of a fixed PV array significantly.

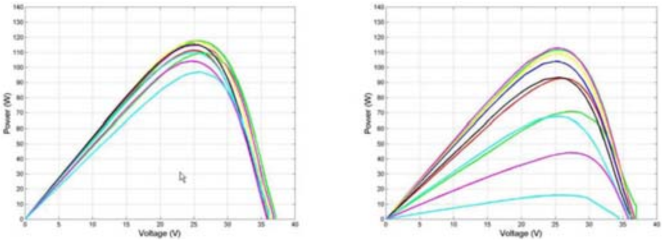

Figure 6. All-day curves for moving and fixed PVs

Figure 6 shows the power curves of both MPV (left graph) and the FPV (right graph). Obviously, during the day the moving system has less variations in the generated power than the fixed. Therefore, it can be concluded that in terms of electric power supply, by using the movable photovoltaic array the power quality will be higher and by using the fixed array, the large power variation should be dumped due to a larger energy storage unit.

4. EFFICIENT AUTO-TRACKING WITH TWO DEGREES OF FREEDOM

A PV tracker is consisted of three components:

- sensor
- controller
- actuator drive

As stated above, its goal is to lock on the sun maintaining minimal angle of incidence (hopefully 0°) by driving panel's actuators accordingly. Objective problem are the latitude (effecting the light radiation angle) and the average count of sunny days around the year. A significant parameter is actuators drive's own power consumption against the generated power, effecting the orientation update rate. Of course, fundamental for bringing the decision of automating a PV array with a tracker is the economic viability.

The proposed prototype tracker is biaxial (polar coordinates - azimuth and latitude) and it drives two step motors. The sensor is almost costless and made of four LDRs (light dependent resistor) which need to be equally calibrated for proper operation. They are planar and divided from each other with opaque plates for the purpose of highest accuracy in proper orientation (figure 7).

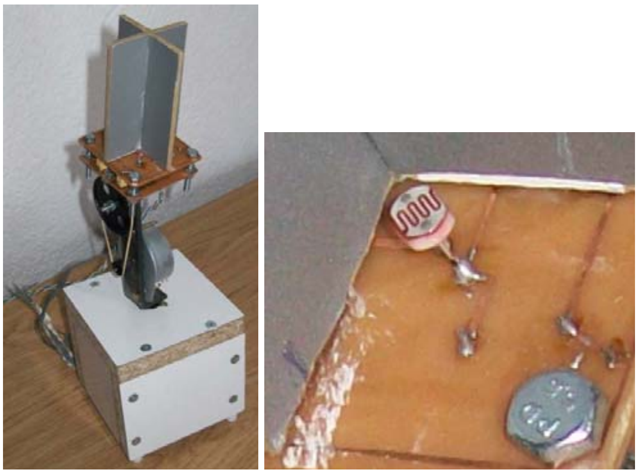
Figure 7. The 4x LDR sensor and a single LDR

The controller (figure 10) is PIC based, also very cheap. It acquires the four LDR inputs and generates command signals for the steppers drivers directly. For larger scaled applications different drivers (according to the actuators) can be used with the same controller.

The algorithm in the controller uses the sensors to calculate the adjustments of both axes for the next optimal position. Figure 8 shows the upper view of the sensor and figure 9 shows a side view of sensors LDR#1 (upper left) and LDR#2 (upper right):

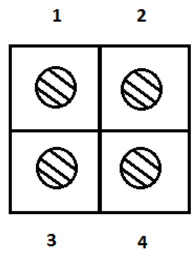

Figure 8. Upper view of the sensor

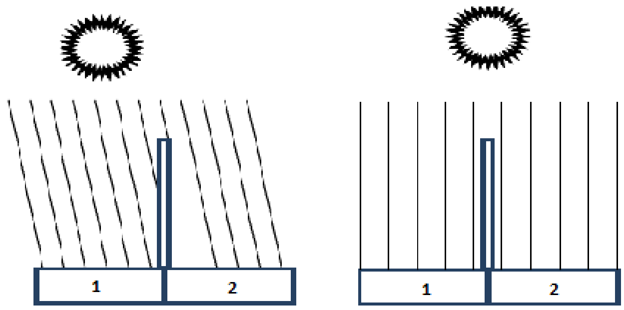

Figure 9. Side view of upper left-right LDRs

The high walls between the LDRs assure sensitivity to minimal differential excitation which allows for precise calculation of sun's azimuth and altitude above the horizon.

The azimuth is detected from the more excited pair of horizontal LDRs (the upper 1-2 or the lower 3-4). The principle is illustrated on figure 9. The microprocessor (PIC) acquires simultaneously all four LDRs and determines which one is most excited. Than it decides which horizontal pair to use for the azimuth correction. Figure 9 depicts the situation where LDR#1 is most excited, therefore horizontal pair 1-2 is used. The controller will then move horizontally in direction of LDR#1 until both LDR#1 and LDR#2 become equally excited, meaning the pair 1-2 is facing the sun perpendicularly.

The altitude is detected in the same manner, by determining the more excited vertical pair (the left 1-3 or the right 2-4). Once it is determined, the controller drives the sensor vertically (simultaneously with the horizontal movement) in the direction of the more excited LDR until both LDRs are equally excited.

Testing with ordinary lamps under daylight show that LDRs appear to provide a very stable (noiseless) signal which allows for smooth, fast and accurate response to small illumination changes.

Prototypes' schematics given in figure 10 is simple and affordable.

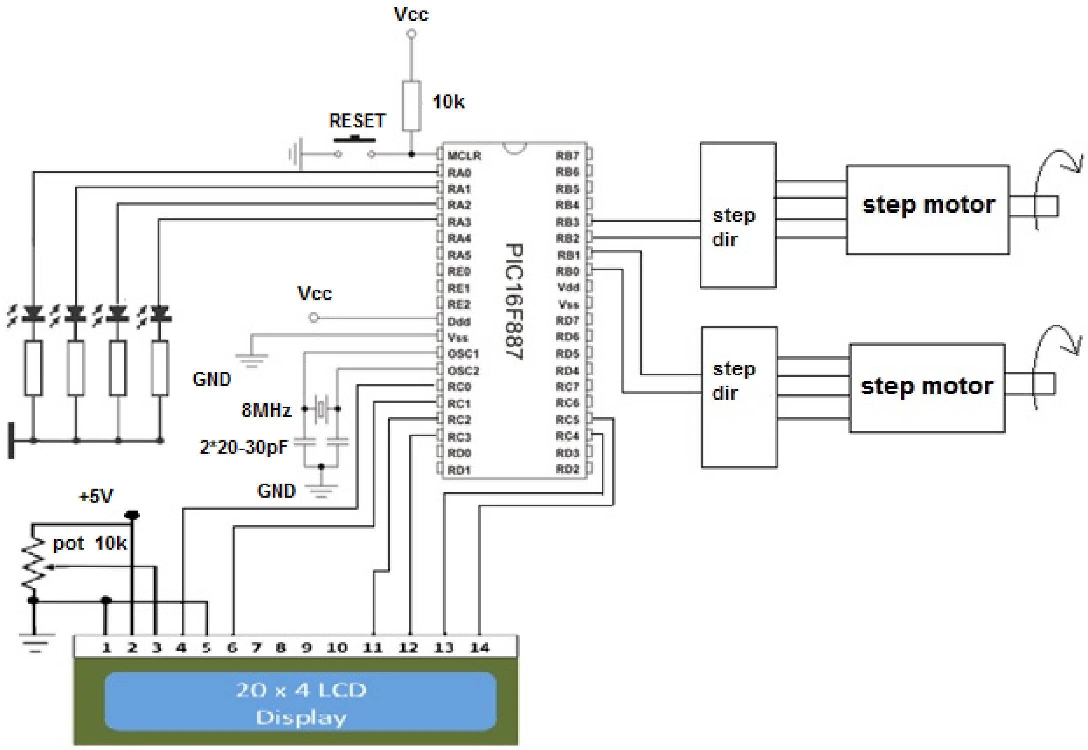

Figure 10. The PIC based controller

The microprocessor is PIC16F887 with sufficient functionality for acquisition of four 10-bit analog channels (LDRs) and four digital outputs for driving the two steppers.

Depending on the drive's power consumption an optimal strategy for the update period can be calculated so that the cost of the tracking remains insignificant against the power production.

5. CONCLUSION

The preliminary assessment of the proposed auto-tracker prototype shows some advantages that seem significant if taken into consideration:

- ability to maintain optimal performance/cost ratio achieved with the simple mechanical design and intelligent control strategy
- minimized self consumption of both the simple electronics and the fast and short lasting updates
- maximized productivity of the PV array by continuous maintenance of the optimal orientation
- the presence of the microprocessor allows both software modifications and upgrades, as well as implementation of communication protocols for networking with other controllers of large PV arrays
- ability for continuous monitoring of significant parameters and algorithm optimization

REFERENCES

[1] L.D. Partain, "Solar Cells and Their Applications", *John Wiley & Sons, New York, 1995*

[2] M.R. Patel, "Wind and Solar Power Systems", *CRC Press, 1995*

[3] H.Moghbelli and R.Vartanian, "Implementation of the Movable Photovoltaic Array to Increase Output Power of the Solar Cells", *Proceedings of the International Conference on Renewable Energy for Developing Countries, 2006*

CIP - Каталогизација у публикацији
Национална библиотека Црне Горе, Цетиње

ISBN 978-86-85775-15-4
COBISS.CG-ID 24749840

ISBN 978-86-85775-15-4

9 788685 775154 >