METODE ȘI SISTEME ELECTRONICE PENTRU CARACTERIZAREA CELULELOR FOTOVOLTAICE

Conf. Dr. COTFAS DANIEL TUDOR

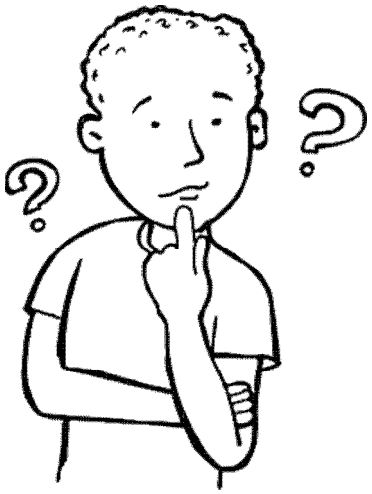
Domeniul:
Inginerie Electronică, Telecomunicații și Tehnologii Informaționale

Universitatea Transilvania din Brașov
FACULTATEA DE INGINERIE ELECTRICĂ ȘI ȘTIINȚA CALCULATOARELOR

Jeremiah Creedon a spus: „Ce ar putea fi mai grav decât epuizarea rezervelor de petrol? Mai grav ar fi ca ele să fie inepuizabile”.

Cuprins

- **Realizări științifice și profesionale**
  - Metode de determinare a parametrilor celulelor fotovoltaice
  - Sisteme de caracterizare a celulelor fotovoltaice
  - Aplicații
- **Planuri de evoluție și dezvoltare a carierei**

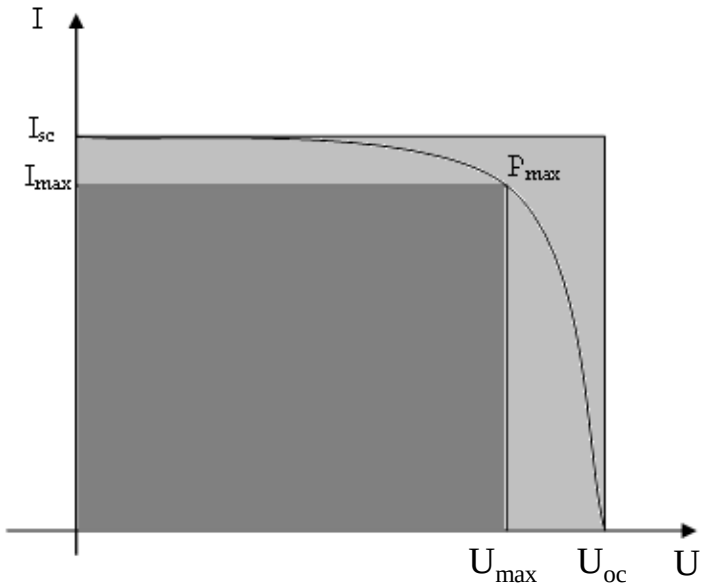


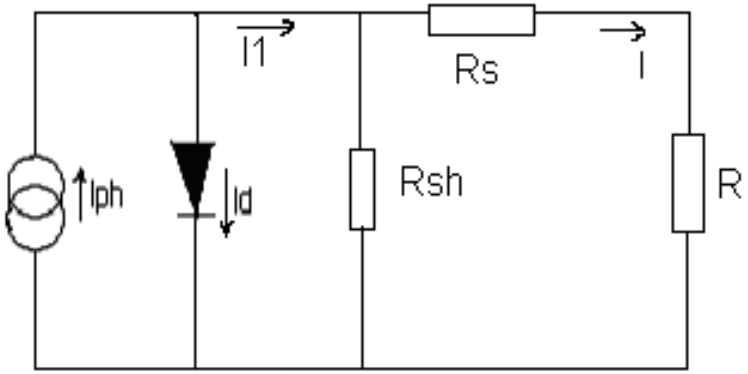
Determinarea parametrilor celulelor fotovoltaice

- Îmbunătățirea performanțelor celulelor și panourilor fotovoltaice
- Estimarea energiei electrice generate de fermele de panouri fotovoltaice

D. T. Cotfas, P. A. Cotfas, S. Kaplanis, *Methods to determine the dc parameters of solar cells: A critical review*, Renewable and Sustainable Energy Reviews, vol. 28, 2013, pp. 588–596, (FI-10.556).
D.T. Cotfas, P.A. Cotfas, O.M. Machidon, *Study of Temperature Coefficients for Parameters of Photovoltaic Cells*, International Journal of Photoenergy, 2018, (FI-2.026).

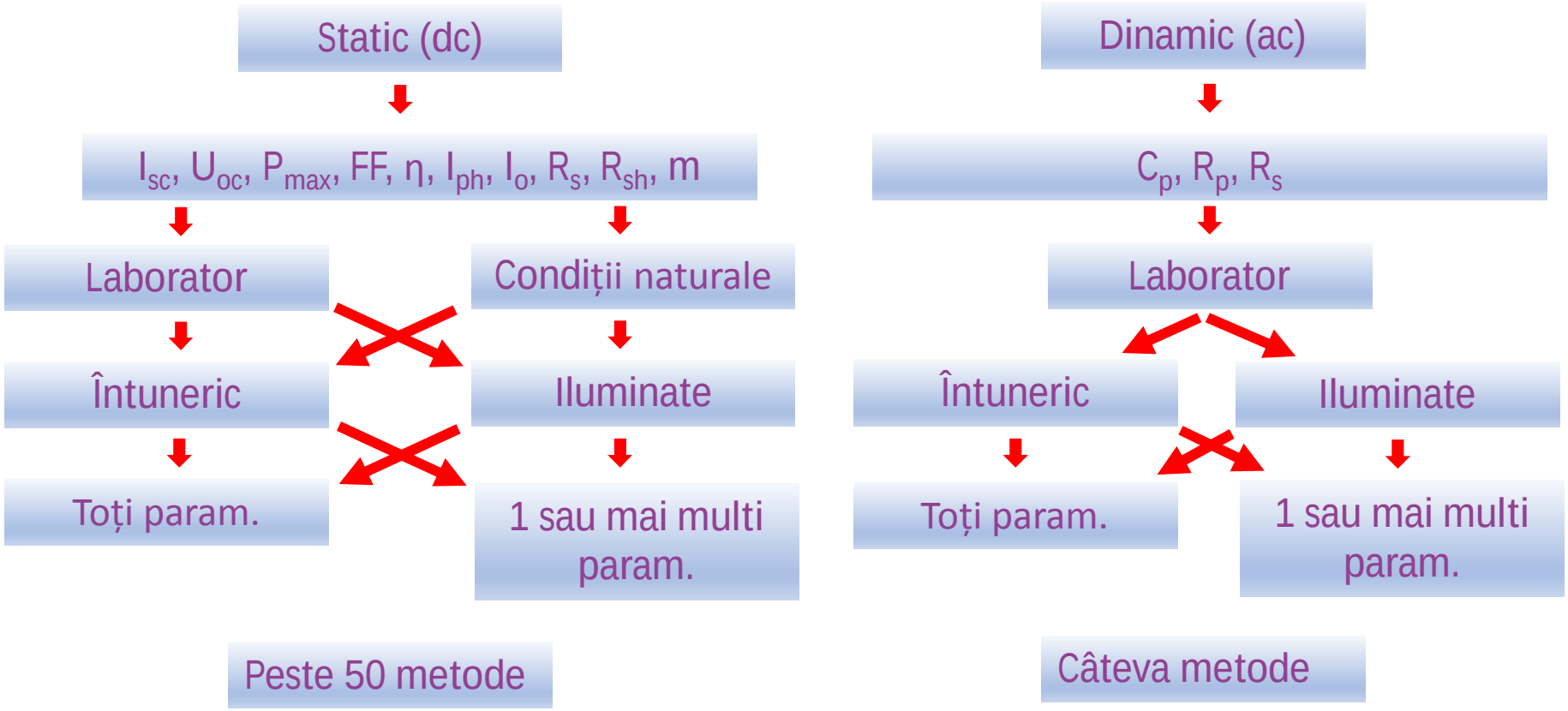
Caracteristica I-U





$$I = I_{ph} - I_o\left[\exp\left(\frac{q(U + IR_s)}{mkT}\right) - 1\right] - \frac{U + IR_s}{R_{sh}}$$

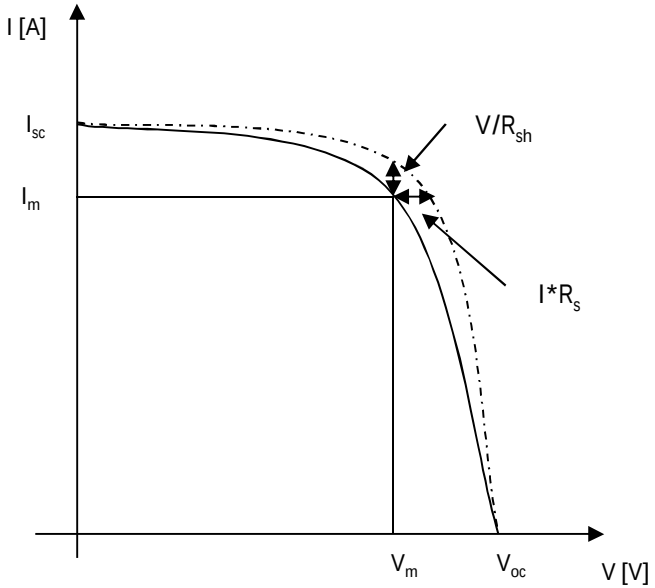
Metode

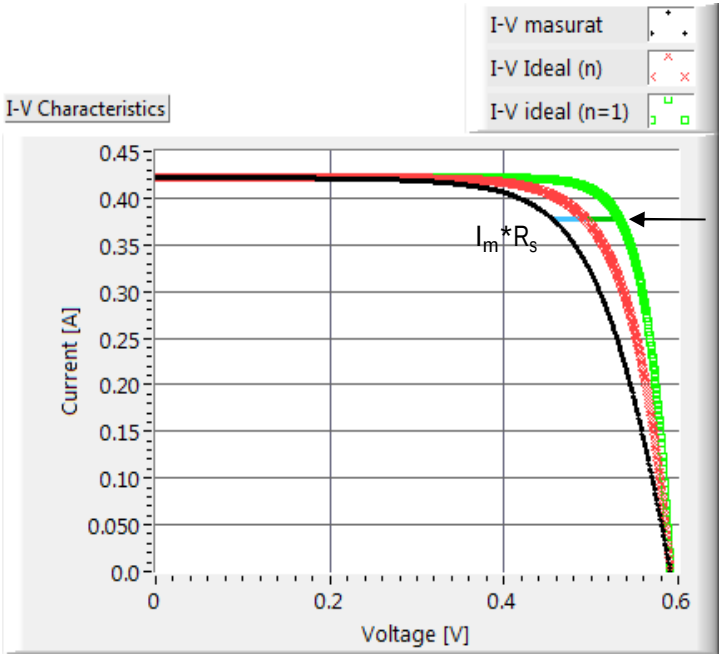


D. T. Cotfas, P. A. Cotfas, S. Kaplanis, *Methods to determine the dc parameters of solar cells: A critical review*, Renewable and Sustainable Energy Reviews, vol. 28, 2013, pp. 588–596, (FI-10.556).

D. T. Cotfas, P. A. Cotfas, S. Kaplanis, *Methods and techniques to determine the dynamic parameters of solar cells*, Renewable and Sustainable Energy Reviews, vol. 61, 2016, pp. 213-221, (FI-10.556).

Metoda Cotfas





$$R_s = \frac{\Delta V}{I_{\max}} = \frac{V_{ideal} - V_{\max}}{I_{\max}}$$

$$R_{sh} = \frac{V_{\max}}{\Delta I} = \frac{V_{\max}}{I_{ideal} - I_{\max}}$$

D.T. Cotfas, P. Cotfas, S. Kaplanis, D. Ursutiu, *Results on series and shunt resistances in a c-Si PV cell. Comparison using existing methods and a new one*, Journal Of Optoelectronics And Advanced Materials, vol. 10, No. 11, p. 3124 – 3130, 2008; (FI-0.588)

D. T. Cotfas, P. A. Cotfas, S. Kaplanis, *Methods to determine the dc parameters of solar cells: A critical review*, Renewable and Sustainable Energy Reviews, vol. 28, 2013, pp. 588–596, (FI-10.556).

Metoda SDA

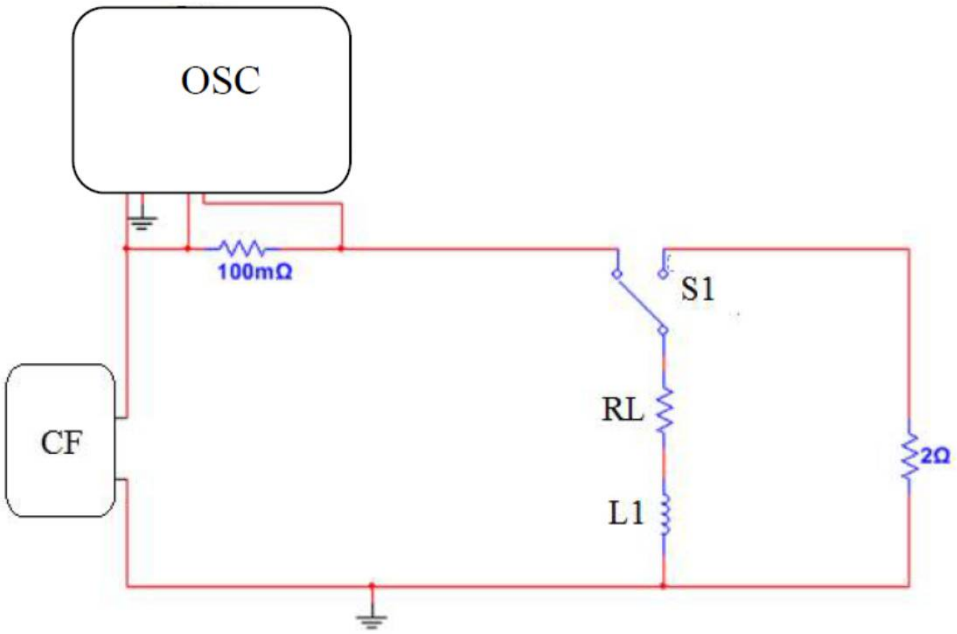
Algorithm	I_{ph} [A]	I_o [μA]	n	R_s [Ω]	R_{sh} [Ω]	RMSE	Rank
SDA	0.760773	0.3244462	1.48164	0.03636	53.842702	9.8598E−04	1
CWOA [24]	0.76077	0.3239	1.4812	0.03636	53.7987	9.8602E−04	2
CSO [14]	0.76078	0.3230	1.48118	0.03638	53.7185	9.8602E−04	2
NM-MPSO [48]	0.76078	0.32306	1.48120	0.03638	53.7222	9.8602E−04	2
STLBO [46]	0.76078	0.32302	1.48114	0.03638	53.7187	9.8602E−04	2
ABC-DE [47]	0.76077	0.32302	1.47986	0.03637	53.7185	9.8602E−04	2
ImCSA[29]	0.760776	0.323021	1.481781	0.036377	53.718524	9.8602E−04	2
ISCE [33]	0.76077553	0.32302083	1.48118360	0.03637709	53.71852771	9.860219E−04	3
EHA-NMS [31]	0.76077553	0.32302080	1.48118359	0.03637709	53.71852139	9.860219E−04	3
Rcr-IJADE [50]	0.76077553	0.3230208	1.4811836	0.03637709	53.718525	9.860219E−04	3

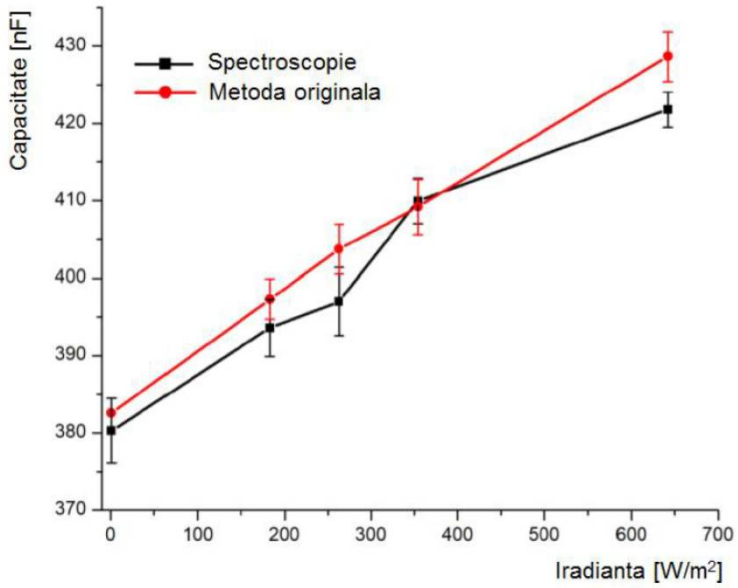
Whale Optimization Algorithm
Cat Swarm Optimization
Hybrid Nelder-Mead and modified particle swarm optimization
Improved Cuckoo Search Algorithm
Teaching–learning–based artificial bee colony

Algorithm	I_{ph} [A]	I_o [μA]	n	R_s [Ω]	R_{sh} [Ω]	RMSE	Rank
SDA	0.425752	0.5168535	1.679294	0.091316	99.136671	5.63097253E−04	1
GA	0.4256882	0.8383311	1.73926	0.0859435	123.3659	6.97414541E−04	2
5P	0.4255	0.30645567	1.618311	0.10352224	145.222	2.25639649E−03	3

D.T. Cotfas, A.M. Deaconu, P. Cotfas, *Application of successive discretization algorithm for determining photovoltaic cells parameters*, Energy Conversion and Management , vol. 196, p. 545 – 554, 2019; (FI-7.181)
D.T. Cotfas, Cotfas, P.A., Cataron, A. *Using the genetic algorithm to determine the parameters of photovoltaic cells and panels*, 2018 13th International Symposium on Electronics and Telecommunications, ISETC 2018, Timișoara - Conference Proceedings, IEEEXplore, ISI.

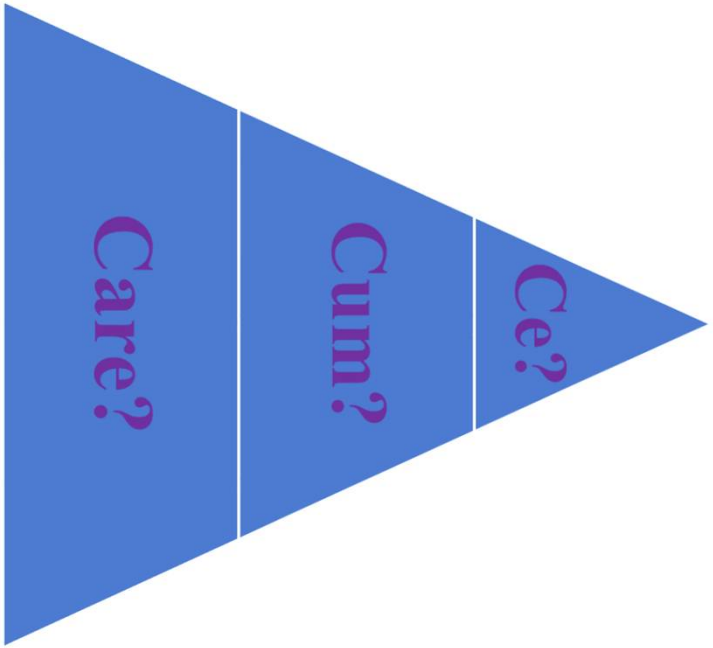
Regim dinamic



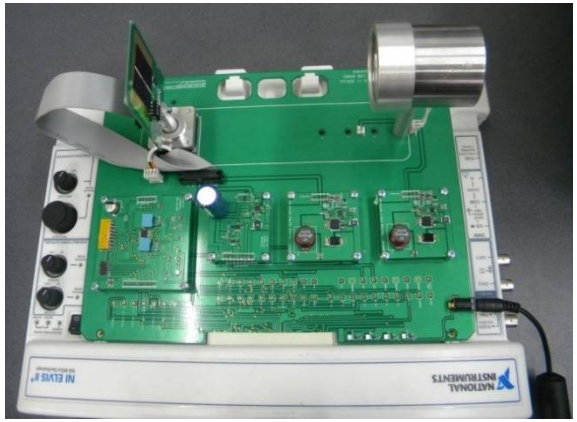


P.A. Cotfas, **D.T. Cotfas**, P. N. Borza, D. Sera, R. Teodorescu, *Solar Cell Capacitance Determination Based on an RLC Resonant Circuit*, Energies 11 (3), 672, 2018 (FI 2.707).

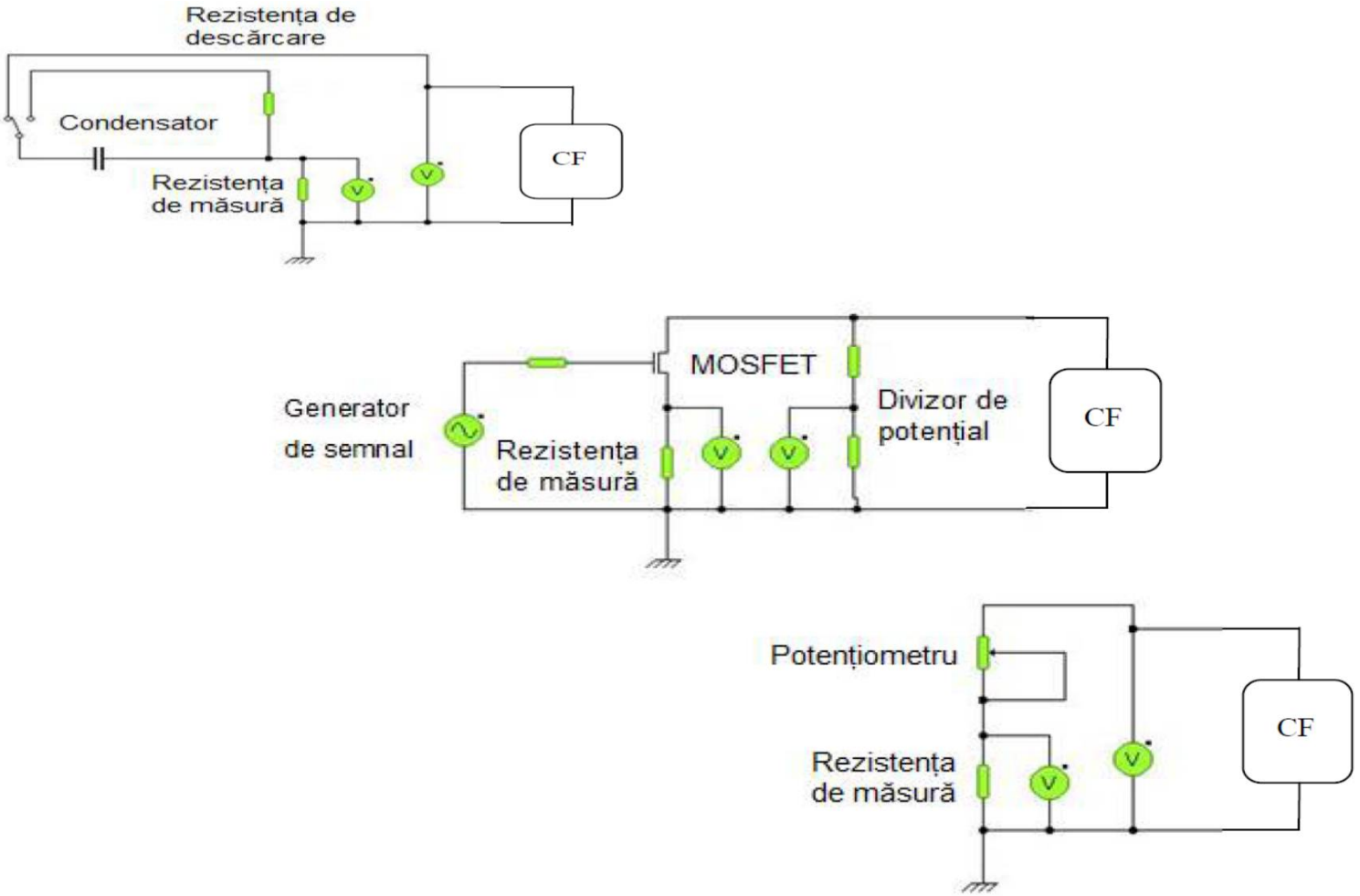
Sisteme de caracterizare a celulelor fotovoltaice



SolarLab

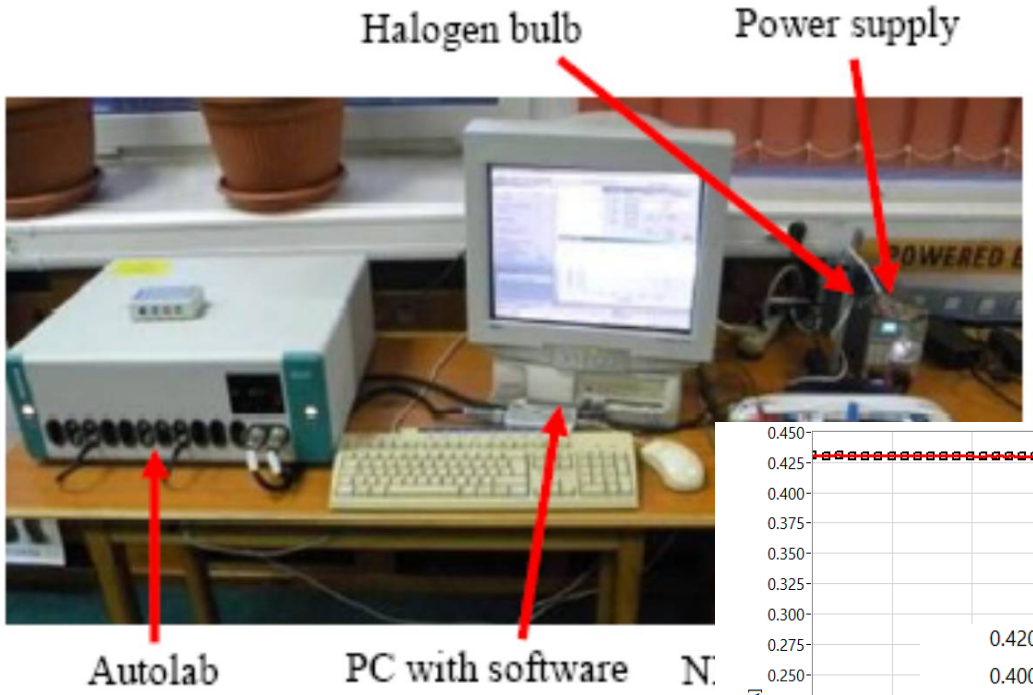


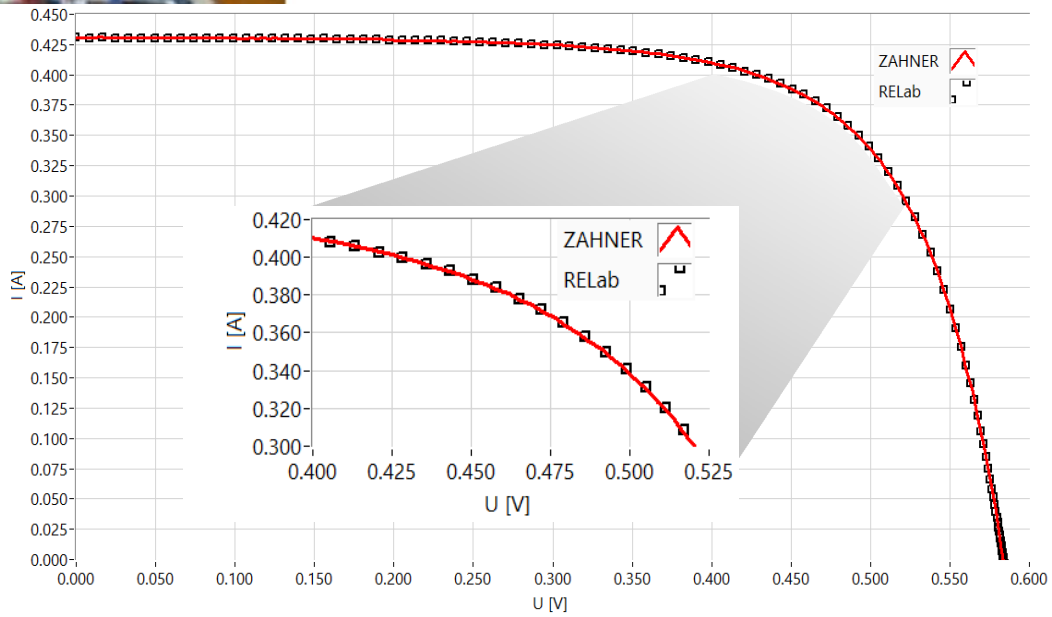
Tehnici de măsurare pentru caracteristica I-U



S. Kaplanis and E. Kaplani, *Renewable Energy Systems: Theory, Innovations and Intelligent Applications*, **D. T. Cotfas** and P. A. Cotfas: *Chapter IX: PV Innovative Techniques and Experimental Test Sets*, Nova Science Publishers, USA, 2013

Sistem comparativ



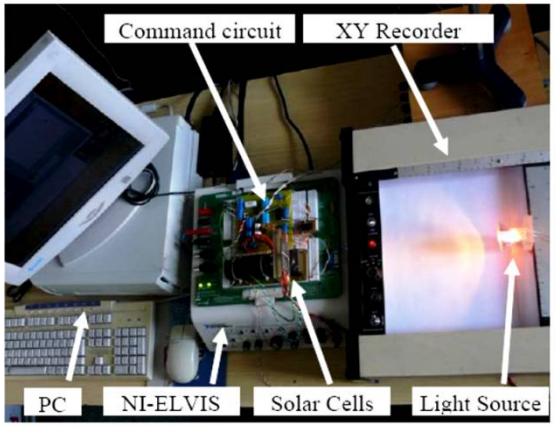


D.T. Cotfas, P.A. Cotfas, D. Ursutiu, C. Samoila, *Current-Voltage Characteristic Raising Techniques for Solar Cells. Comparisons and Applications*, Optimization of Electrical and Electronic Equipment (OPTIM), 2010, IEEEXplore, ISI

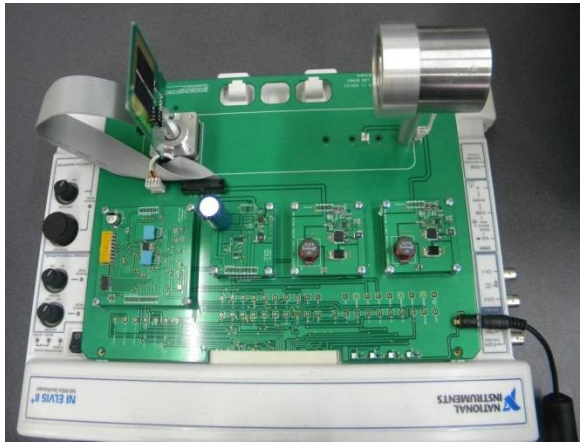
P.A. Cotfas, **D.T. Cotfas**: Design and implementation of RELab system to study the solar and wind energy, Measurement 93, 94-101, 2016 (FI 2.791)

Evoluția SolarLab

Prima versiune



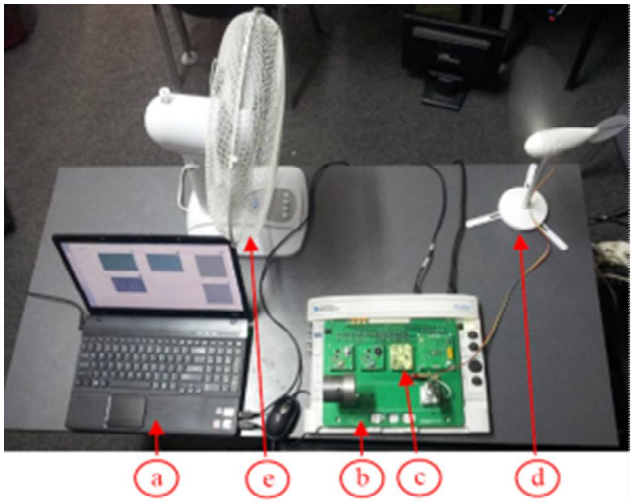
Versiunea finală

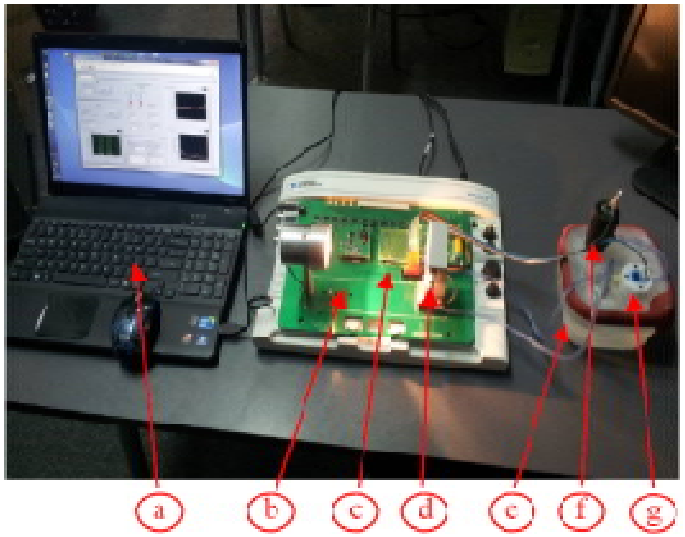


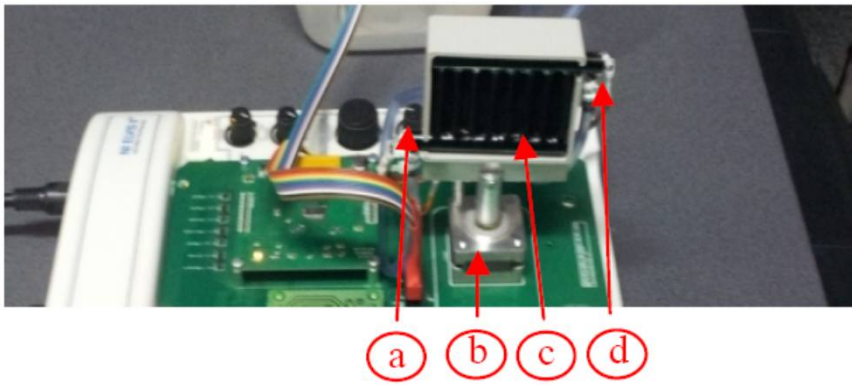
A doua versiune

A treia versiune

RELab

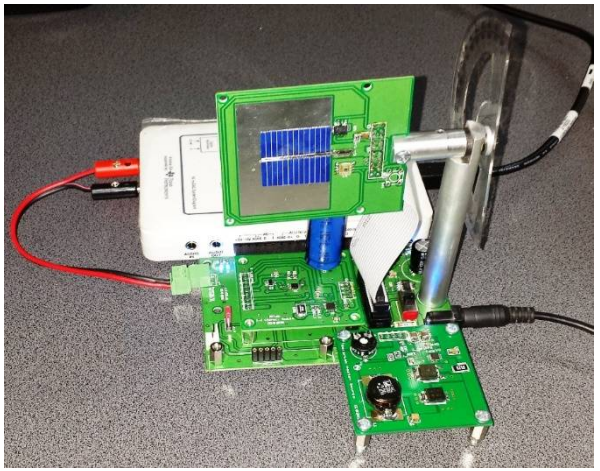






P.A. Cotfas, **D.T. Cotfas**: Design and implementation of RELab system to study the solar and wind energy, Measurement 93, 94-101, 2016 (FI 2.791)

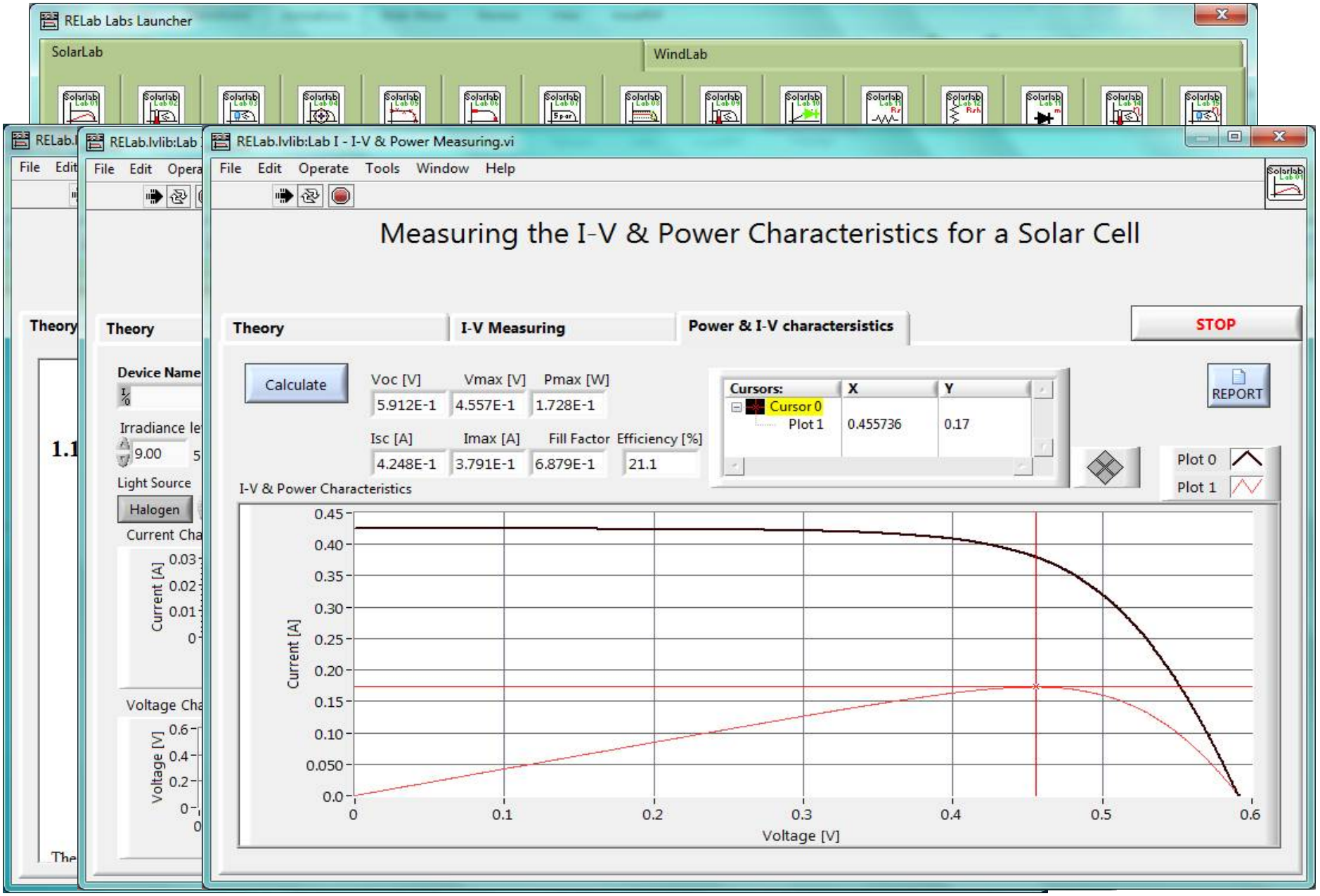
miniRELab



P.A. Cotfas, **D.T. Cotfas**, C. Samoila, *Mobile virtual laboratory for renewable energy*, Remote Engineering and Virtual Instrumentation (REV), 2013 10th International Conference on, Sydney (IEEE Xplore)

Vendor Master Services Agreement National Instrument (2014)

Laborator


RELab Labs Launcher
SolarLab
WindLab
RELab.lvlib:Lab I - I-V & Power Measuring.vi
File Edit Operate Tools Window Help
Measuring the I-V & Power Characteristics for a Solar Cell
Theory
I-V Measuring
Power & I-V charactersistics
STOP
Calculate
Voc [V]
Vmax [V]
Pmax [W]
5.912E-1
4.557E-1
1.728E-1
Isc [A]
Imax [A]
Fill Factor
Efficiency [%]
4.248E-1
3.791E-1
6.879E-1
21.1
Cursors:
X
Y
Cursor 0
Plot 1
0.455736
0.17
REPORT
Plot 0
Plot 1
I-V & Power Characteristics
Current [A]
Voltage [V]
Device Name
Irradiance
Light Source
Halogen
Current Cha
Voltage Cha

Romanian University Wins 3 Prizes at the Graphical System Design Achievement Awards at NIWeek 2013

Dr. Daniel Tudor Cotfas and Dr. Petru Adrian Cotfas with Dr. T.

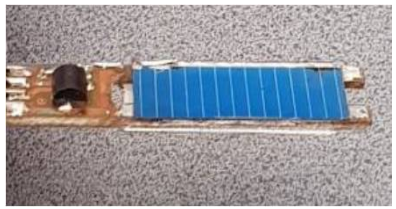
“The case study from the Transylvania University of Brasov, Romania, titled “Developing a Renewable Energy Laboratory Using NI ELVIS, NI LabVIEW, and NI myDAQ,” has been selected as a finalist in the Education category as one of the best examples of graphical system design, so Petru and Daniel travelled to Austin to take part at the conference and the awards ceremony to be recognized as finalists and so find out if they have won in their category. The awards ceremony was a huge success for the brothers as they came in as winners of the **Education category** as this year’s most innovative project in the world in the field of Education. What is more, they succeeded and won two more awards, namely the **Editor's Choice Award** which is based on the votes of the editors attending NIWeek as well as the **NI Community Choice Award** which reflects the preference of the engineering audience of the NI community who voted on their favourite projects online. With these 3 awards the Romanian project finished the contest as the most successful one this year in the world.”

Aplicații


Dispozitive de măsurare a radiației solare
Metodă rapidă de determinare a timpului de îmbătrânire
Lampă solară inteligentă
Utilizarea inteligentă a panourilor fotovoltaice
Sisteme hibride
Modele estimare a radiației solare
Celula fotovoltaică

Dispozitive de măsurare a radiației solare

ALBEDOMETRE



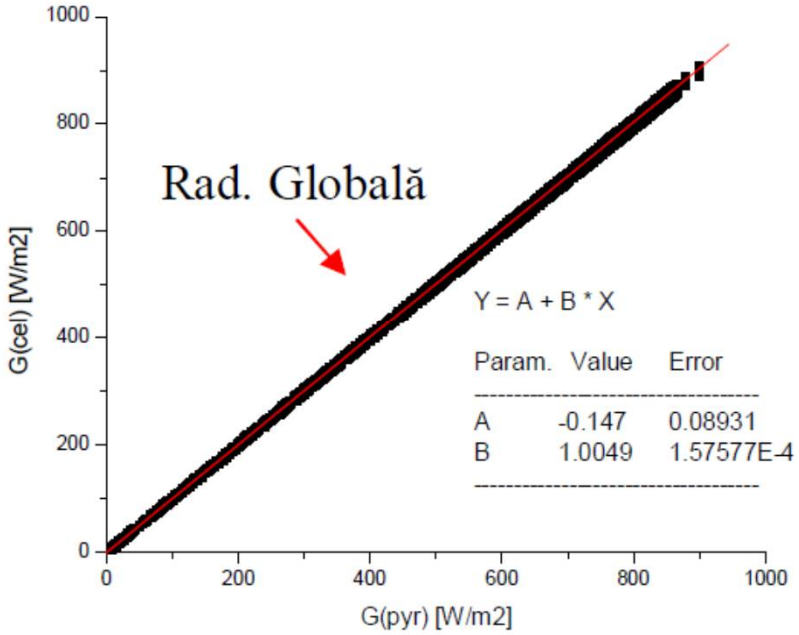
D. T. **Cotfas**, S. Kaplanis, P. A. Cotfas, D.Ursutiu, C. Samoila, *A new albedometer based on solar cells*, Proc. World Renewable Energy Congress X. Glasgow, 2008.

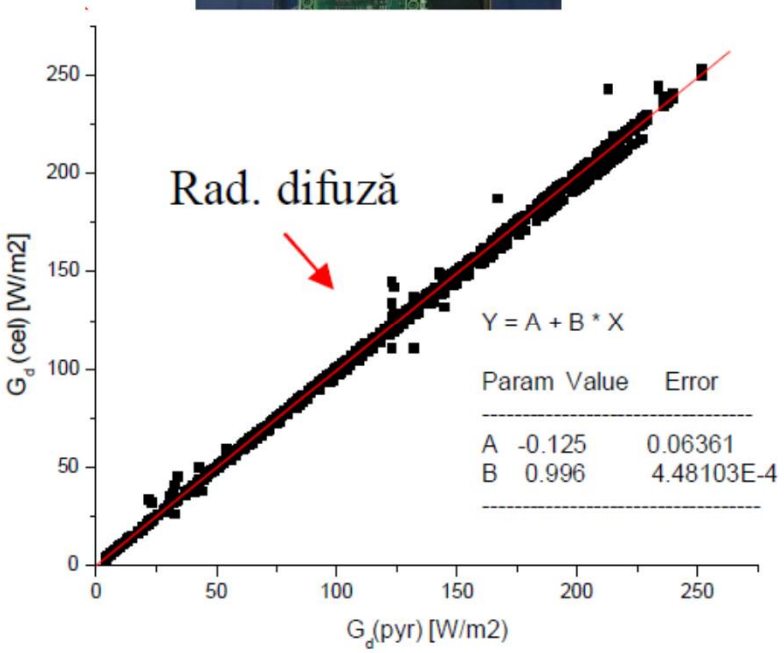
G. Şerban, **D. T. Cotfas**, P. A. Cotfas, *Crop albedo measurements after anthesis reveal significant differences among romanian wheat cultivars*,ROMANIAN AGRICULTURAL RESEARCH, NO. 29, 2012, ISSN 1222-4227; (FI-0.469)

G. Şerban, D. T. **Cotfas**, P. A. Cotfas, Significant differences in crop albedo among romanian winter wheat *cultivars*, ROMANIAN AGRICULTURAL RESEARCH, NO. 28, 2011, Print ISSN 1222-4227.

Dispozitive de măsurare a radiației solare

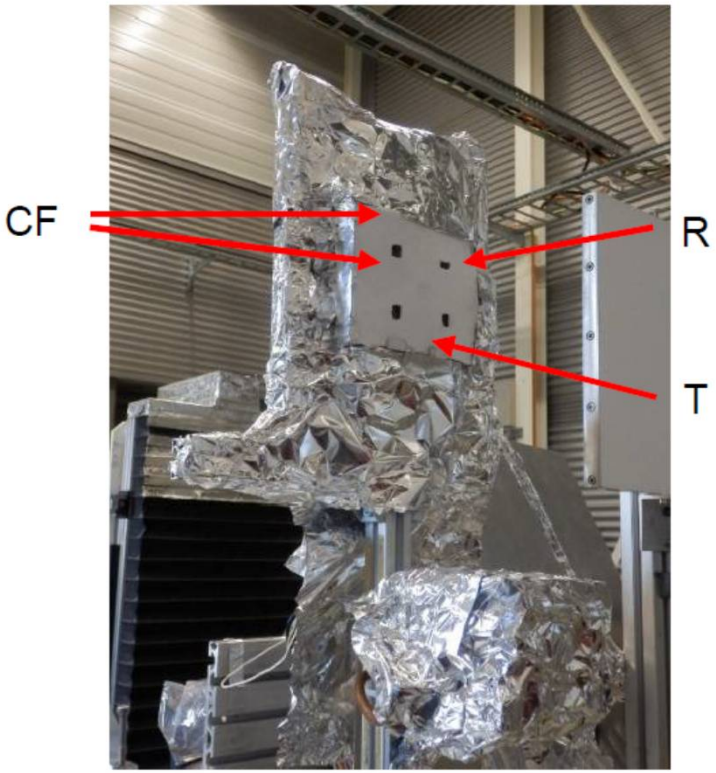
RADIAȚIA SOLARĂ GLOBALĂ ȘI DIFUZĂ

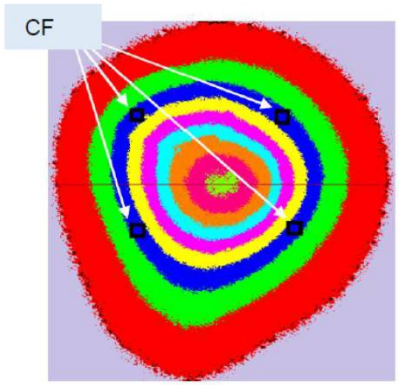




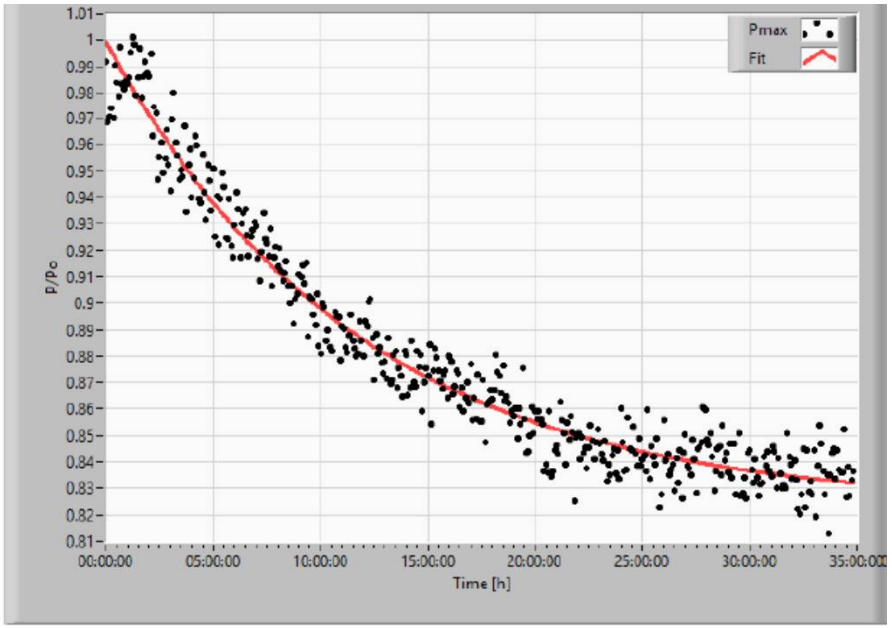
D. T. Cotfas, P. A. Cotfas, P. Borza, D. Ursutiu, C. Samoila: Wireless system for monitoring the solar radiation, Environmental Engineering and Management Journal, Vol.10, No. 8, pp.1133-1137, 2011(FI-1.186)

Metodă rapidă de determinare a timpului de îmbătrânire





Color	Suns
	50 suns
	125 suns
	190 suns
	260 suns
	320 suns
	370 suns
	410 suns
	450 suns

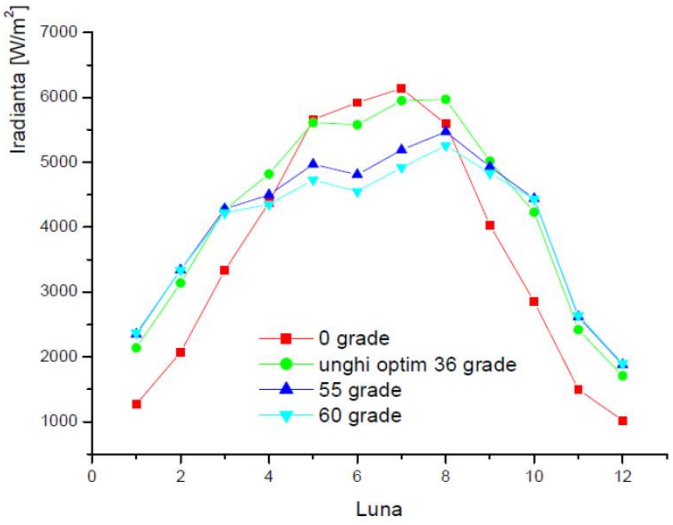


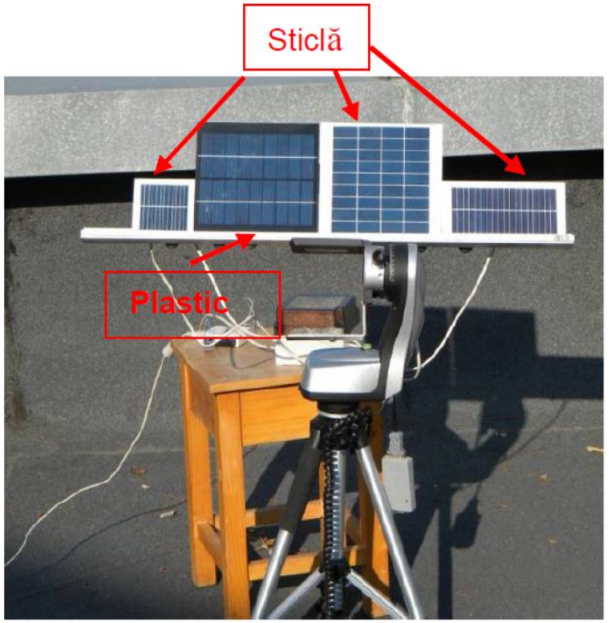
D.T. Cotfas, P.A. Cotfas, D. I. Floroian, L. Floroian: Accelerated life test for photovoltaic cells using concentrated light, International Journal of Photoenergy, 2016 (FI 2.026).

Cerere de prevet, Metodă și dispozitiv de testare accelerată a timpului de îmbătrânire a celulelor fotovoltaice – ARCL

Director Proiect, The study of the evolution of the photovoltaic cells parameters during the ageing process using the concentrated light and the temperature, (2014) Sfera II (CORDIS FP7-INFRASTRUCTURES)

Lampă solară inteligentă

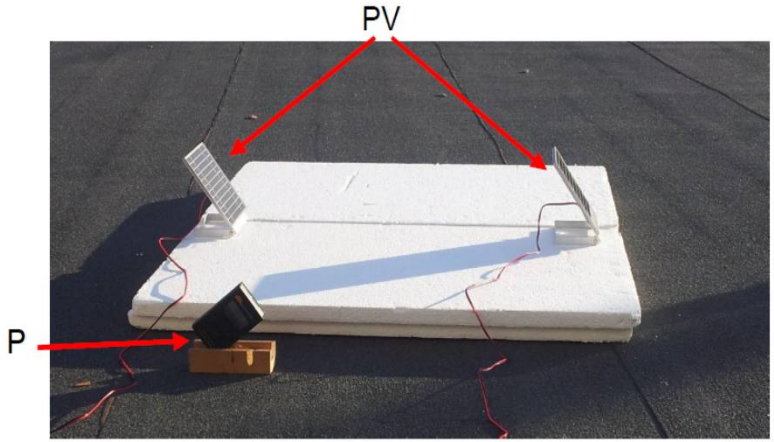


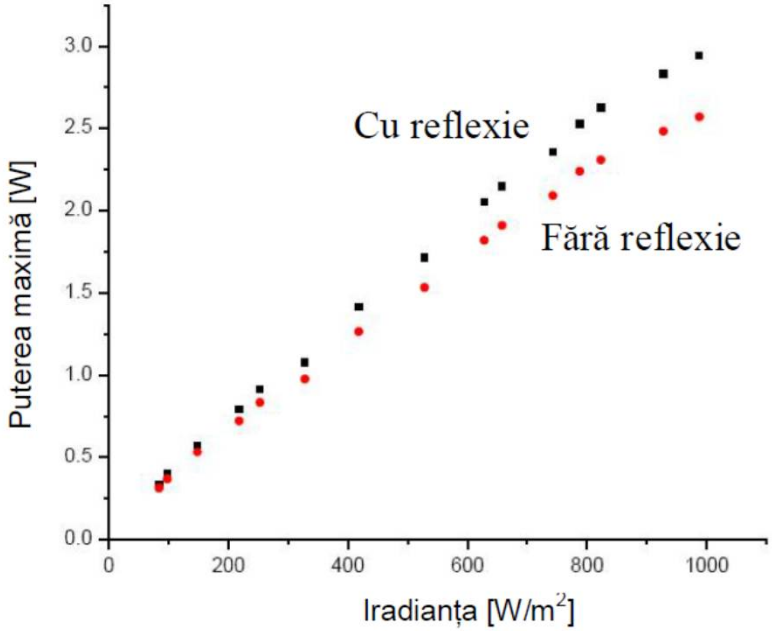


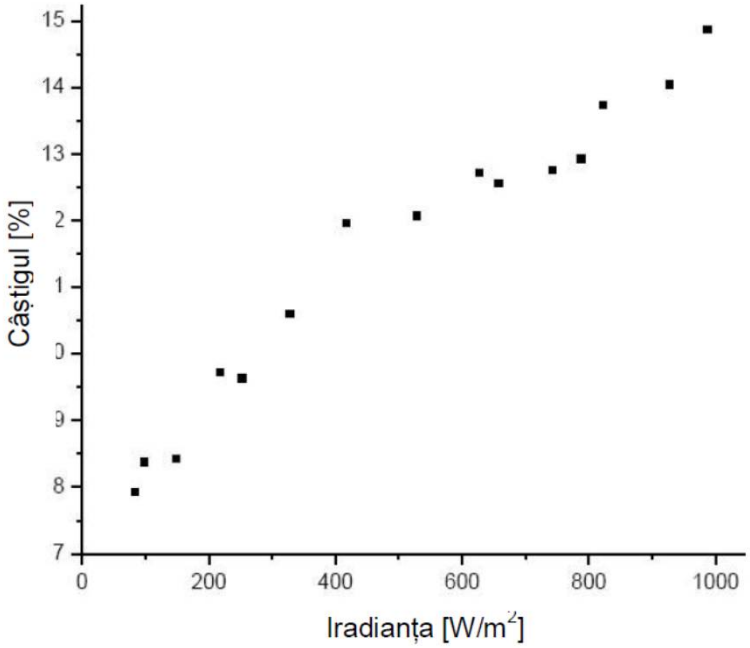
Membru Proiect, Sistem inteligent pentru managementul energiei oferite de panourile solare la alimentarea lămpilor cu senzori de infraroșu perioada:2011-2013 finantator:Steinel NrContract:7640/27.11.2011

http://www.steinel.de/en/Sensor-Switched-Floodlights/New-Products/Sensor-LED-light-XSolar-L-S-silver.html

Utilizarea inteligentă a panourilor fotovoltaice

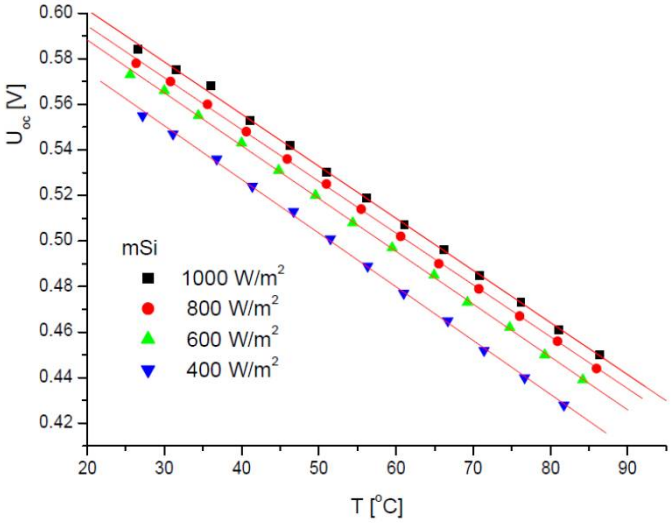


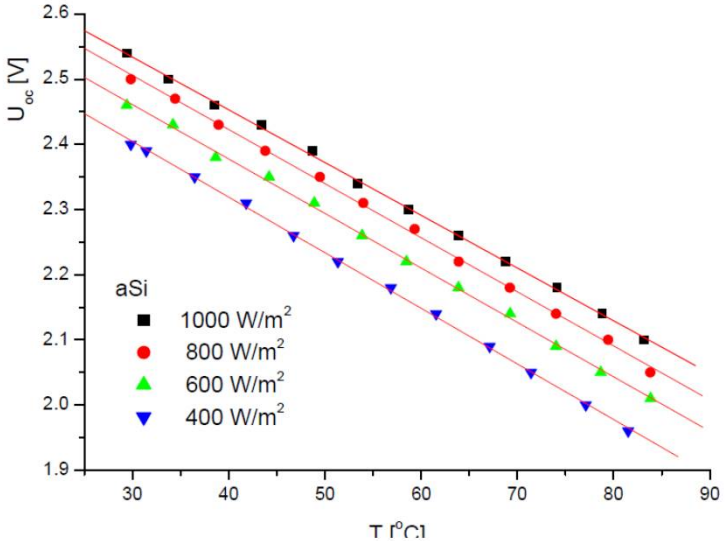


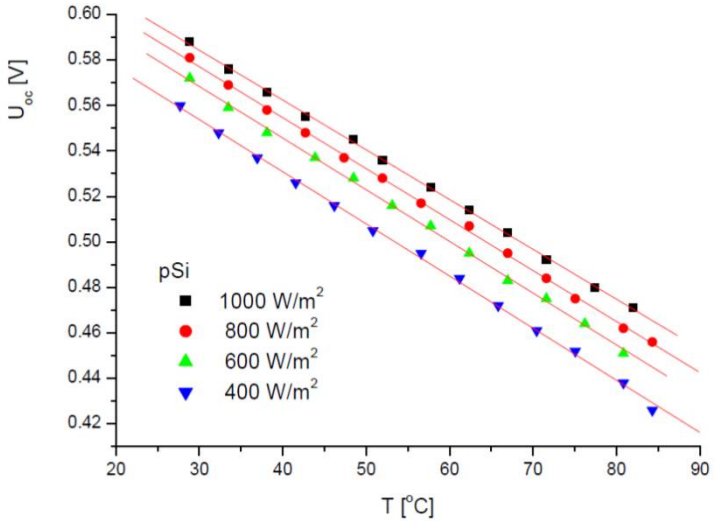


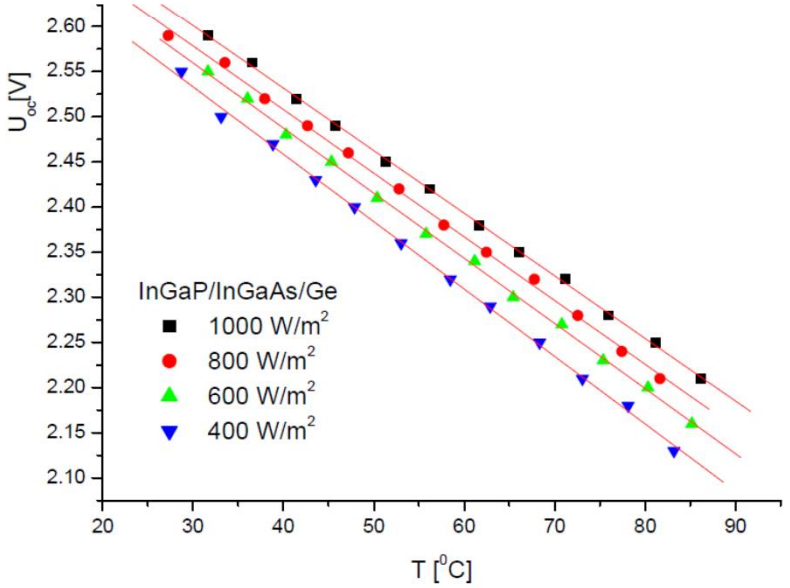
D.T. Cotfas, P.A. Cotfas, *A Simple Method to Increase the Amount of Energy Produced by the Photovoltaic Panels*, International Journal of Photoenergy, 2016 (FI 2.026).

Influența temperaturii



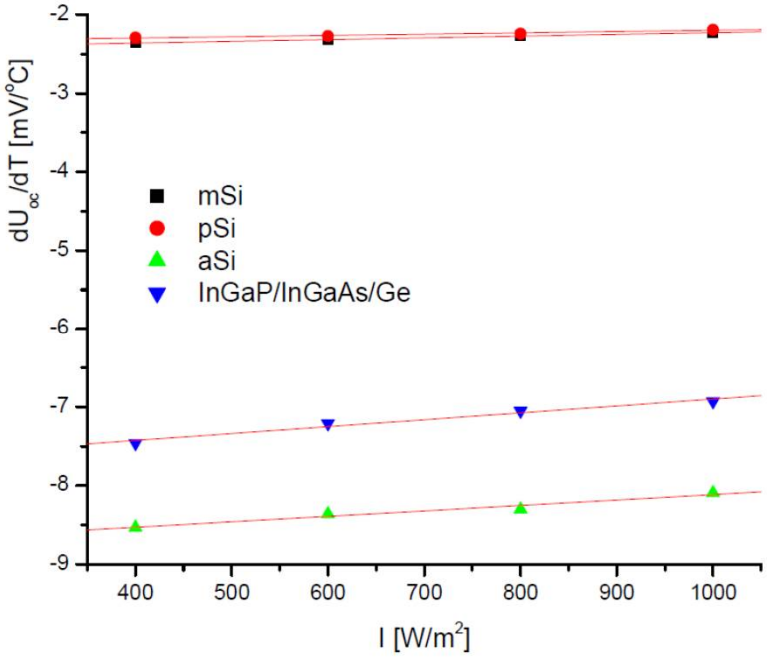


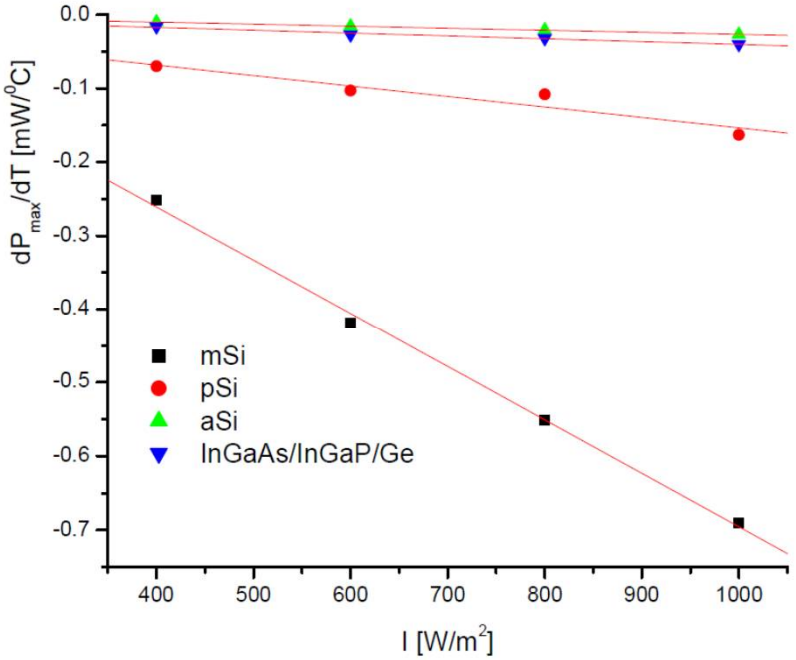




D.T. Cotfas, P.A. Cotfas, O.M. Machidon, Study of Temperature Coefficients for Parameters of Photovoltaic Cells**,** International Journal of Photoenergy, 2018 (FI 2.026).

Influența temperaturii



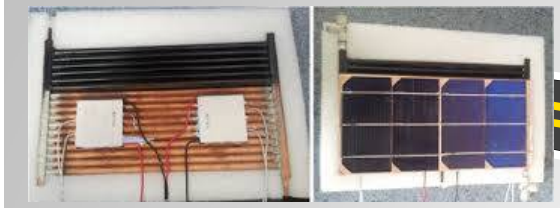


Tip	mSi	pSi	aSi	InGaP/InGaAs/Ge
Procente	-0.47%	-0.38%	-0.18%	-0.14%

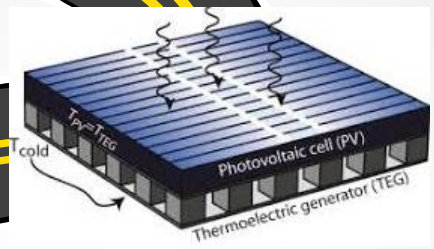
D.T. Cotfas, P.A. Cotfas, O.M. Machidon, Study of Temperature Coefficients for Parameters of Photovoltaic Cells**,** International Journal of Photoenergy, 2018 (FI 2.026).

Sisteme hibride

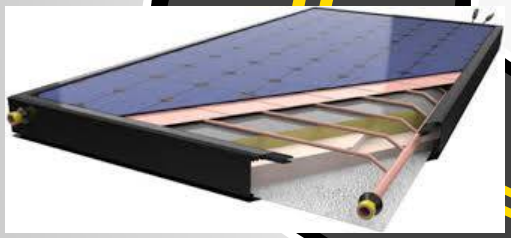
PV/TEG/STC



PV/TEG



PVT



Panou PV

Director proiect: Cercetări asupra sistemelor solare hibride fotovoltaice/termoelectrice/termice PV/TEG/STC pentru competiția „Tinere echipe de cercetare” din cadrul programului național PN-II-RU-TE-2014-4
http://fizica.unitbv.ro/rute/

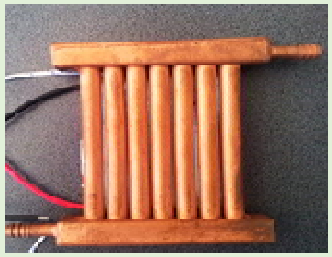
Sisteme hibride

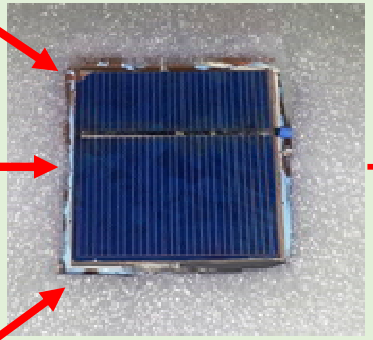
PV/TEG/STC

Celulă fotovoltaică

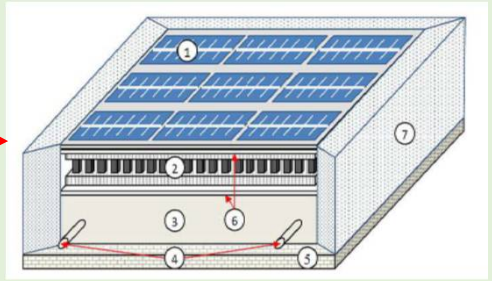
Generator termoelectric

Colector solar





Sistem hibrid PV/TEG/STC

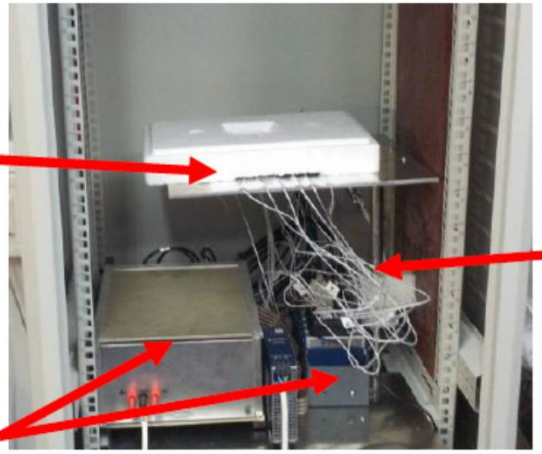


D. T. Cotfas, P. A. Cotfas, D. Ciobanu, O. Machidon, Characterization of Photovoltaic–Thermoelectric–Solar Collector Hybrid Systems in Natural Sunlight Conditions, J. Energy Eng., 2017, 143(6): 04017055 (FI 1.131).

Director proiect: Cercetări asupra sistemelor solare hibride fotovoltaice/termoelectrice/termice PV/TEG/STC pentru competiția „Tinere echipe de cercetare” din cadrul programului național PN-II-RU-TE-2014-4

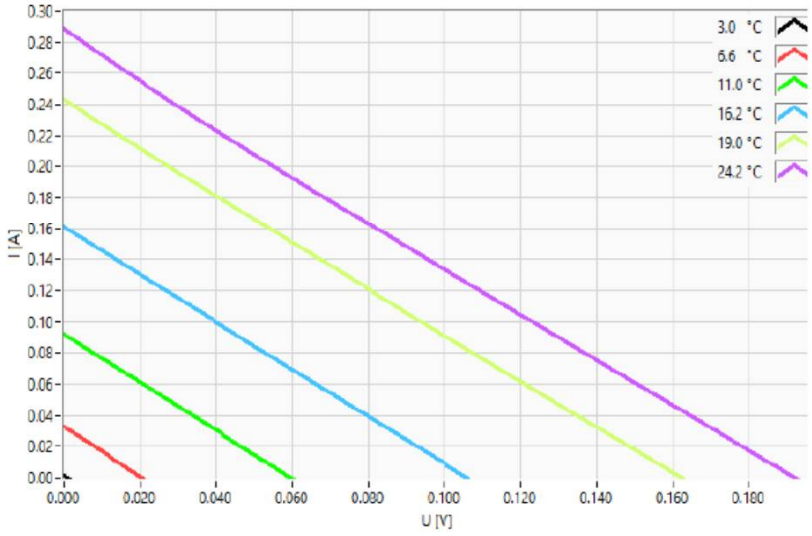
Sisteme hibride

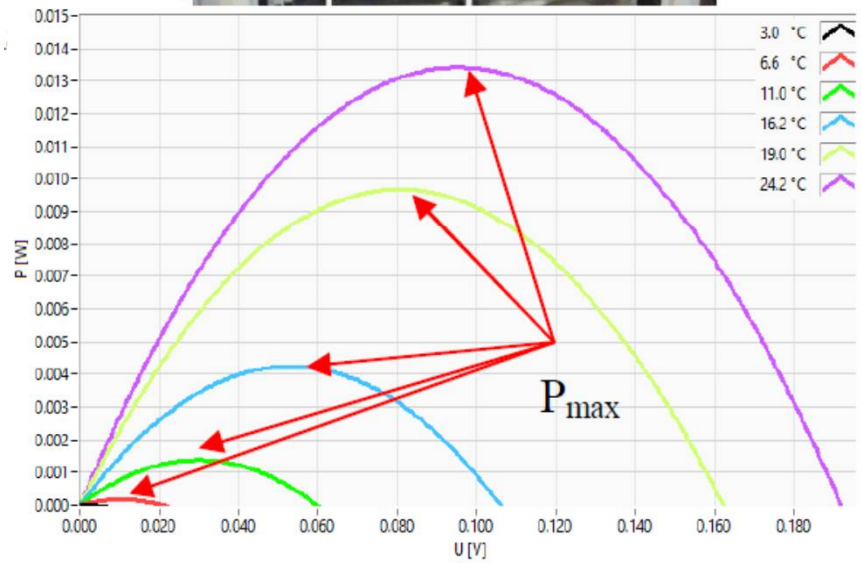
TEG-uri



Termocuple

Sistem de

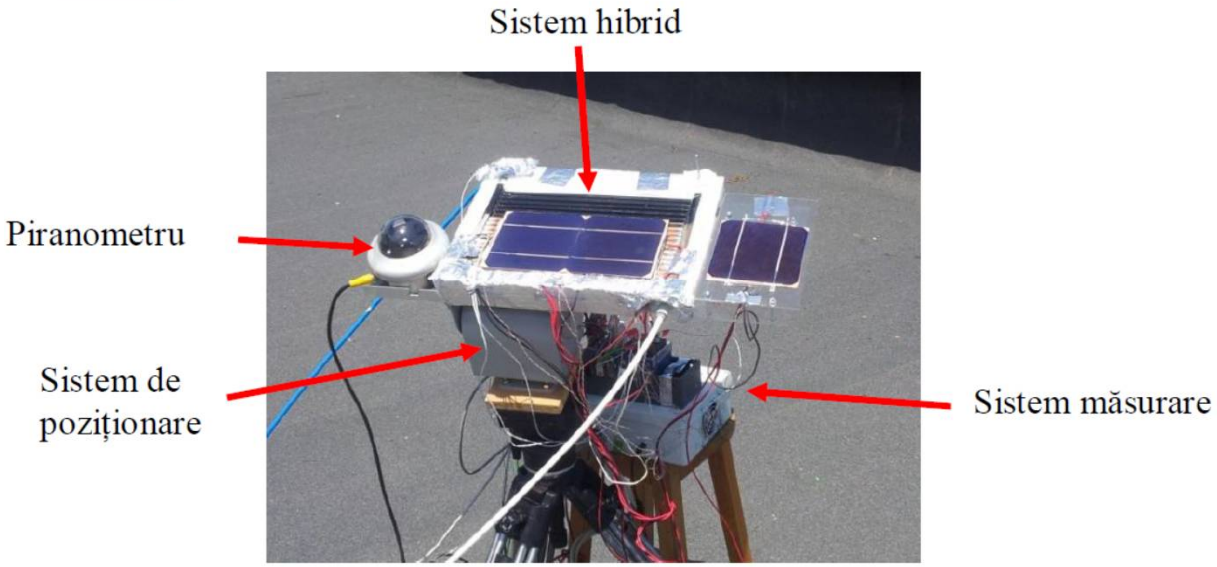


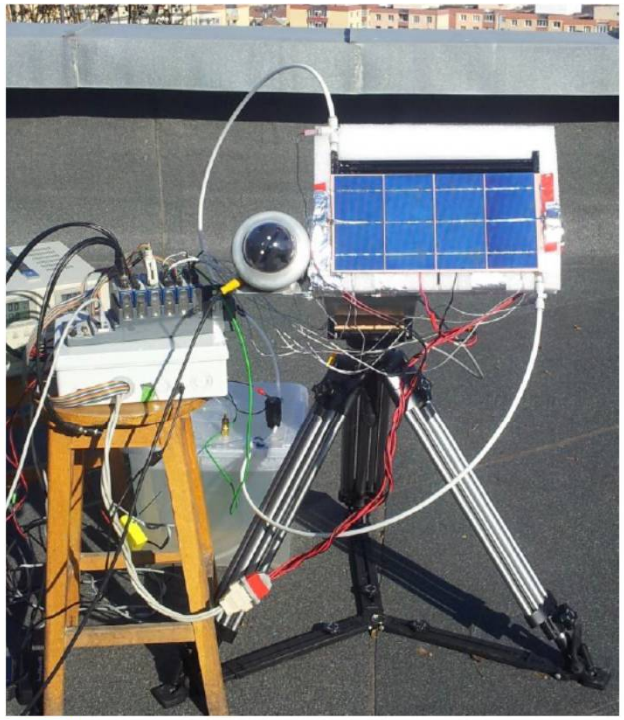


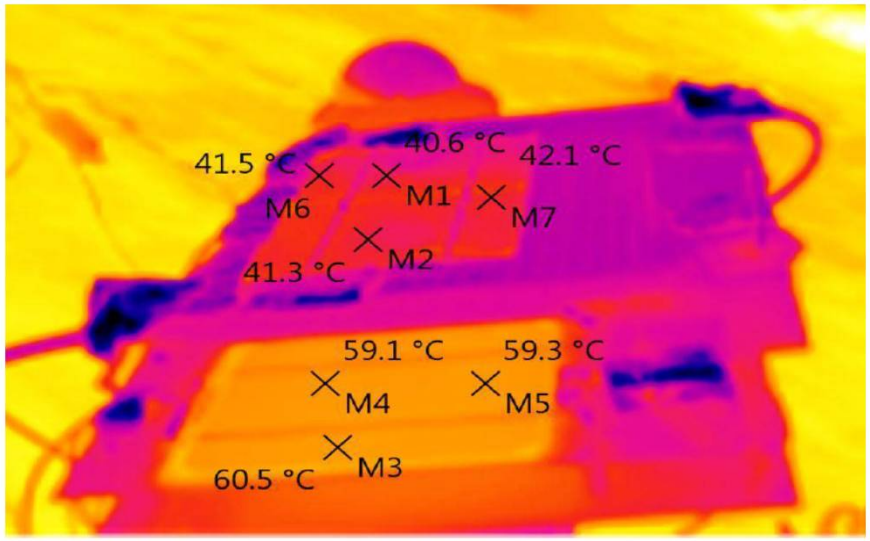
apă

D. T. Cotfas, P. A. Cotfas, O. M. Machidon, D. Ciobanu, Investigation of the photovoltaic cell/thermoelectric element hybrid system performance, International Conference On Innovative Research - ICIR EUROINVENT 2016 Book Series: IOP Conference Series-Materials Science and Engineering Volume: 133 Article Number: UNSP 012037 Published: 2016

Sisteme hibride







D. T. Cotfas, P. A. Cotfas, D. Ciobanu, O. Machidon, Characterization of Photovoltaic–Thermoelectric–Solar Collector Hybrid Systems in Natural Sunlight Conditions, J. Energy Eng., 2017, 143(6): 04017055 (FI 1.131).

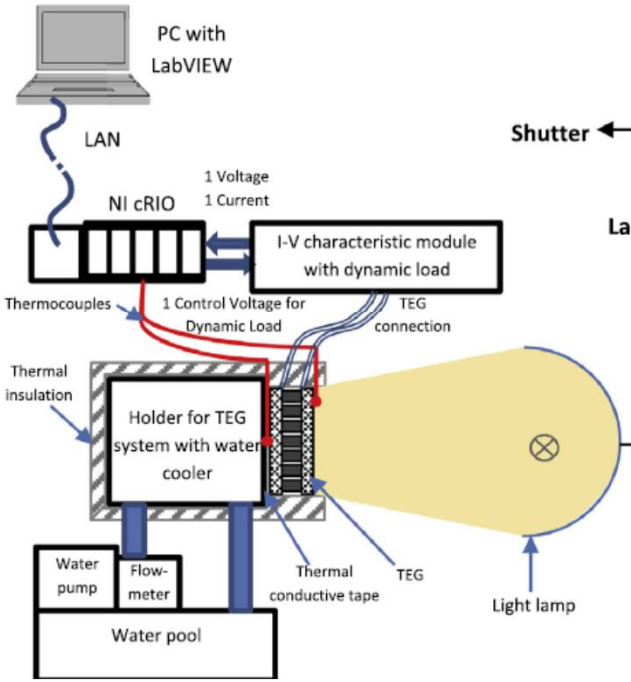
Sisteme hibride

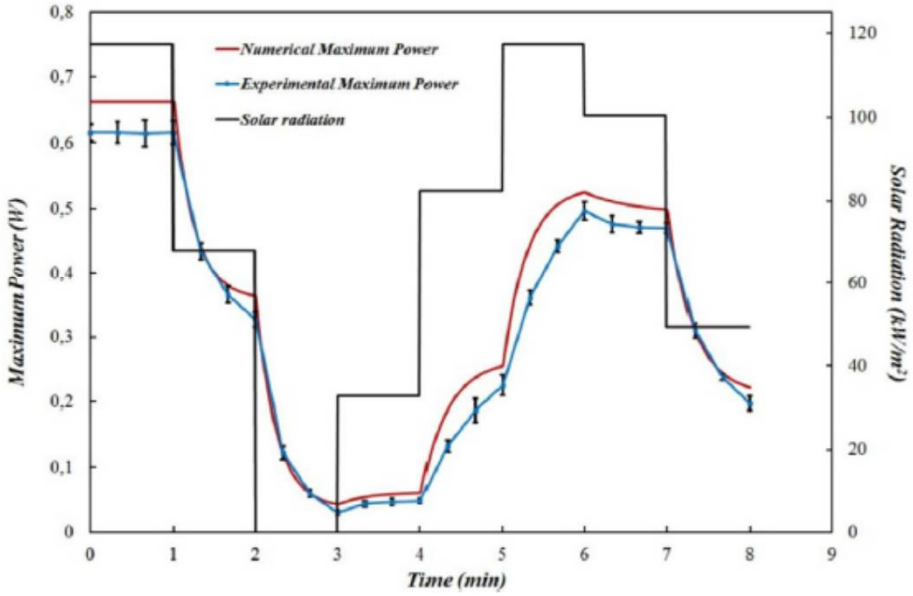
Rezultate

- 4 articole în reviste ISI
- 7 articole în proceedings ISI
- 6 articole în conferințe internaționale
- 1 cerere de brevet
- Keynote Speech: D. T. Cotfas, Hybrid systems - photovoltaic panel/thermoelectric generator/solar collector. Past, present and future, International Conference on Energy and Mechanical Engineering, 17-19.11.2017, Chengdu, China.
- O echipă dinamică
- Colaborări externe

D.T. Cotfas, P.A. Cotfas, Cerere de brevet 2017, *Sistem hibrid PV/TEG/STC pentru încălzirea apei dintr-o piscină*
http://fizica.unitbv.ro/rute/

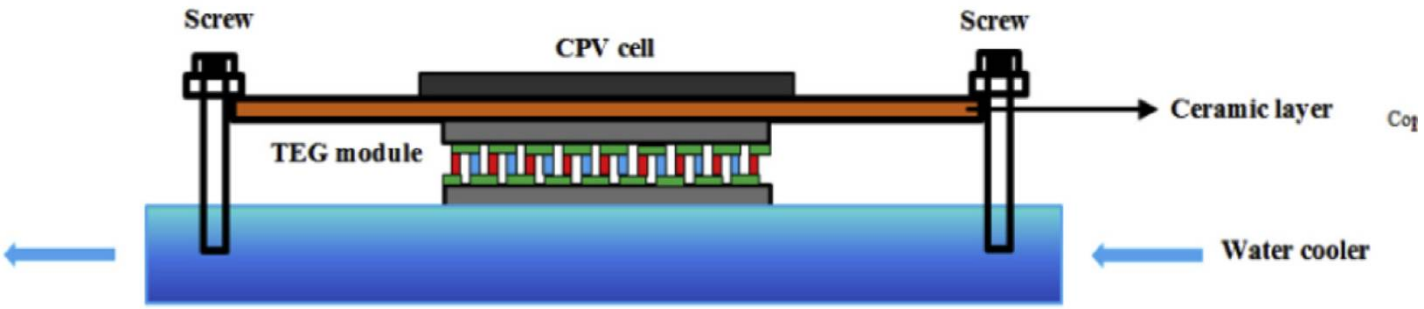
Sisteme Hibride - TEG

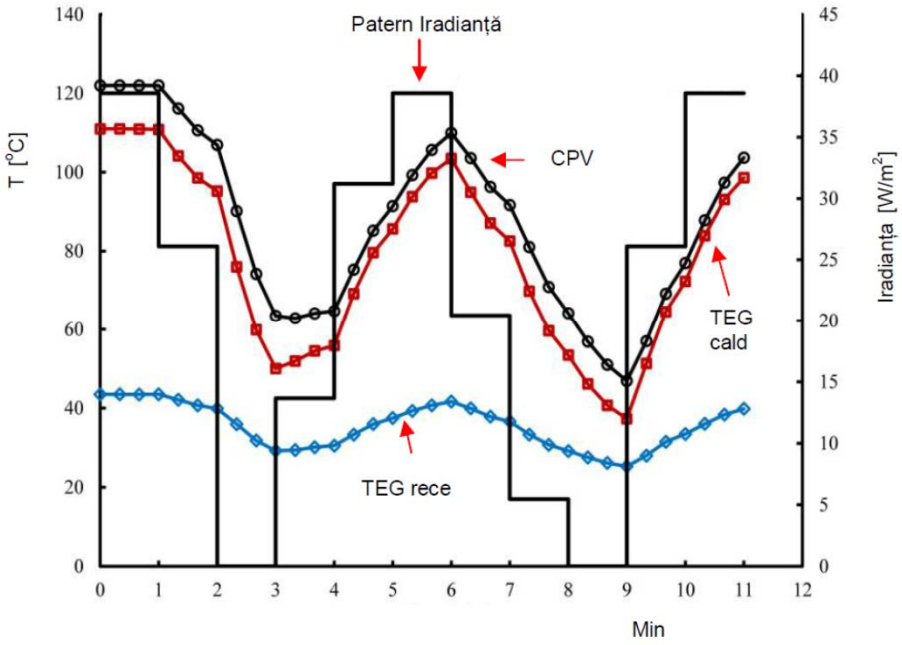


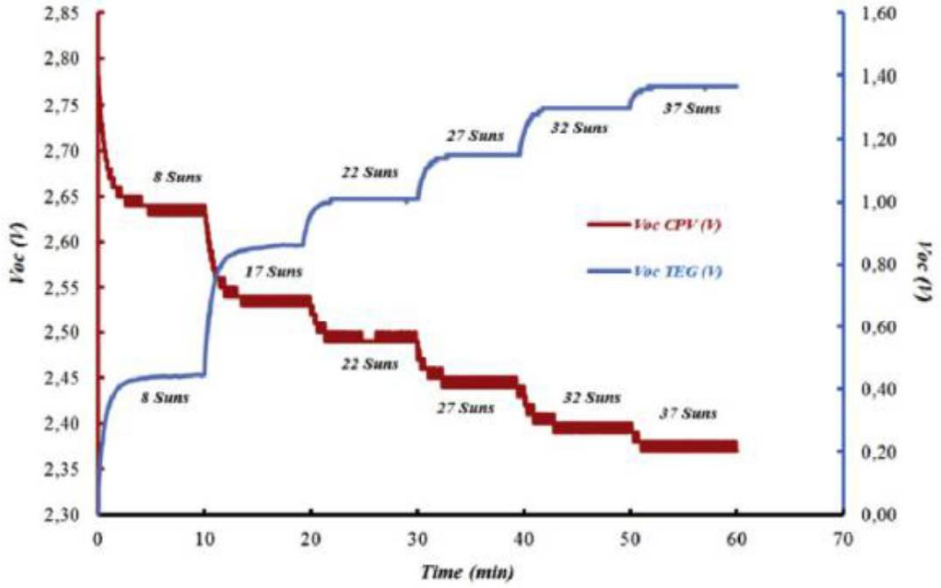


S. Mahmoudinezhad, A. Rezania, P. A. Cotfas, **D. T. Cotfas**, L. A. Rosendahl, Transient behavior of concentrated solar oxide thermoelectric generator, Energy 168, 823-832, 2019 (FI.5.537).

Sisteme hibride



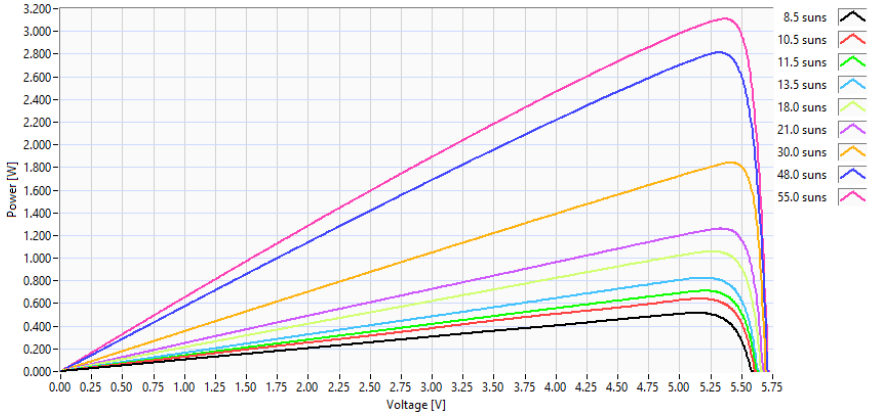


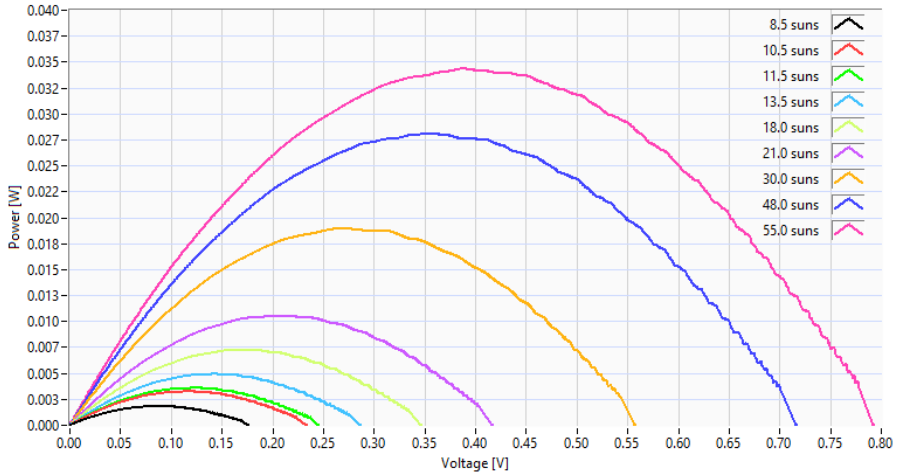


S. Mahmoudinezhad, S. Ahmadi Atouei, P.A. Cotfas, **D.T. Cotfas**, L.A. Rosendahl, A. Rezania, Experimental and numerical study on the transient behavior of multijunction solar cell-thermoelectric generator hybrid system, Energy Conversion and Management 184, 448–455, 2019(FI 7.181).

S. Mahmoudinezhad, A. Rezania, D.T. Cotfas, P.A. Cotfas, L.A. Rosendahl: Experimental and numerical investigation of hybrid concentrated photovoltaic–Thermoelectric module under low solar concentration, Energy 159, 1123-1131, 2018 (FI 5.537).

Sisteme hibride – sistem realizat pentru măsurare în lumină concentrată

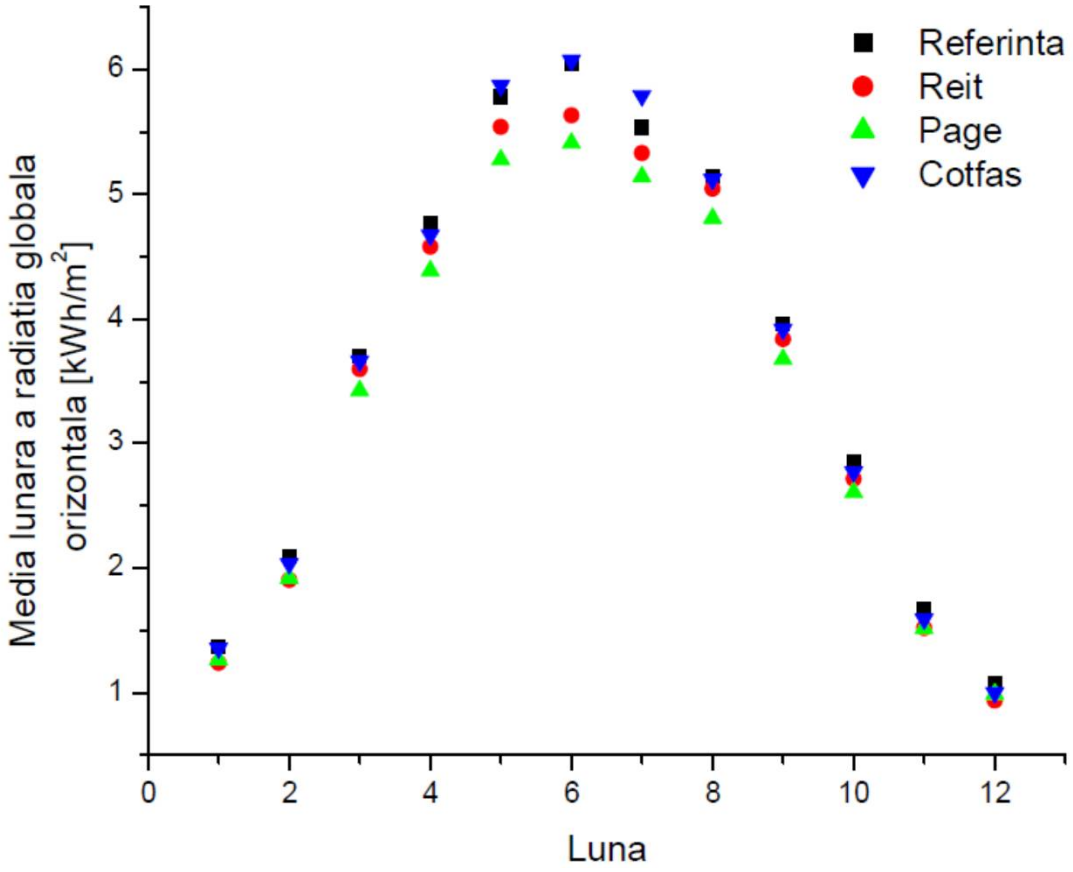




P. A. Cotfas, **D. T. Cotfas,** C Gerigan, O. M. Machidon, System design to study hybrid systems in concentrated light using Fresnel lens, 2017 International Conference On Optimization Of Electrical And Electronic Equipment (Optim) & 2017 Intl Aegean Conference On Electrical Machines And Power Electronics (ACEMP), 2017.

P. A. Cotfas, **D. T. Cotfas**, Hybrid system efficiency in concentrated sunlight, 7th International Congress of Energy and Environment Engineering and Management (CIIEM7), Las Palmas, Spain, 17th - 19th July 2017

Model de estimare a radiației solare globale



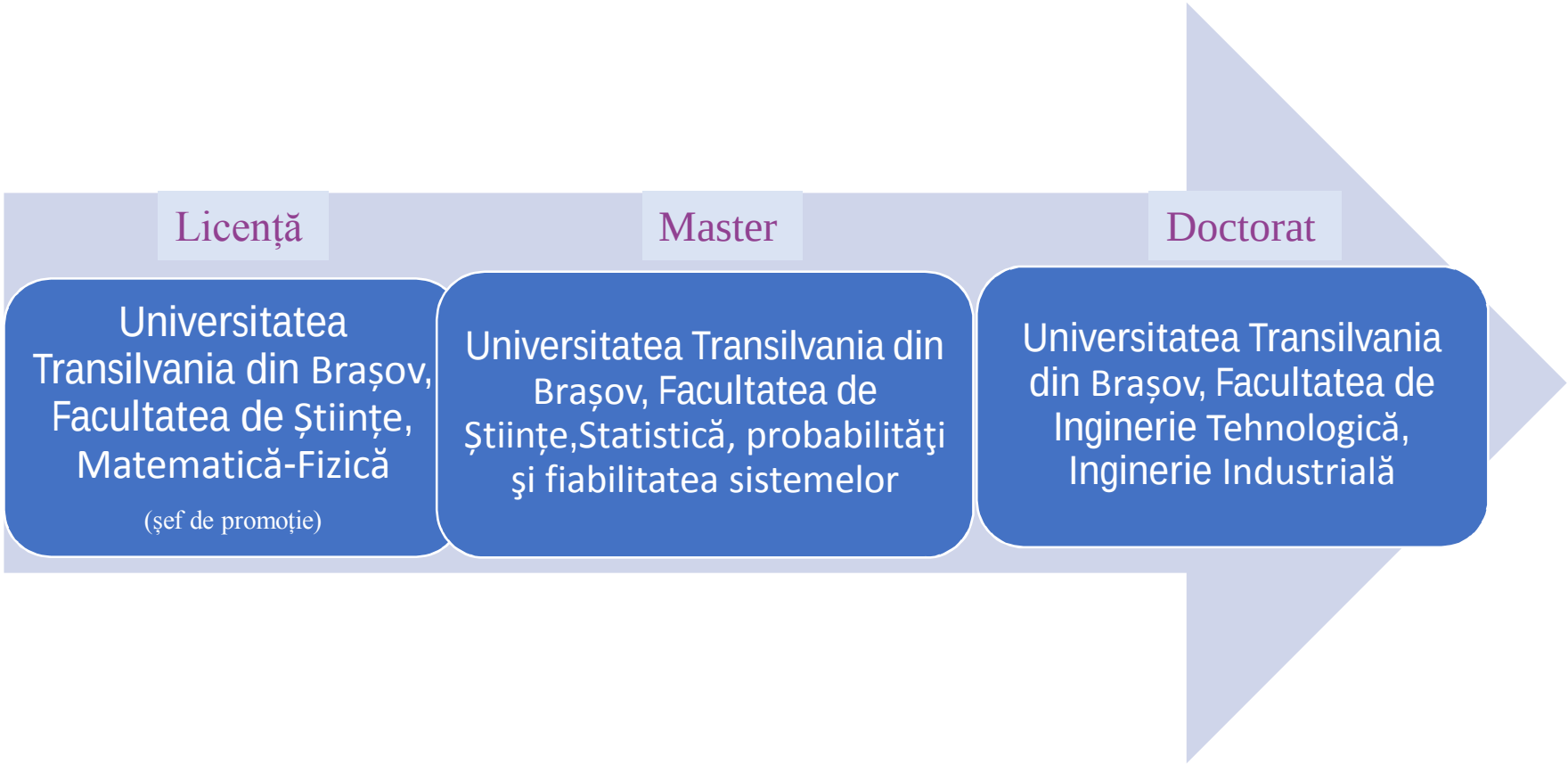
$$H = H_o\left(\begin{array}{l} -2.457 + 32.997\frac{n}{N} - 150.58\left(\frac{n}{N}\right)^2 + 336.64\left(\frac{n}{N}\right)^3 \\ -363.88\left(\frac{n}{N}\right)^4 + 152.512\left(\frac{n}{N}\right)^5 \end{array}\right) \quad for \quad August - April$$

$$H = H_o\left(0.325 + 0.41\frac{n}{N} + 0.0479\ln\left(\frac{n}{N}\right)\right) \quad for \quad May - July$$

D.T. Cotfas, P.A. Cotfas, Eleni Kaplani, Cornel Samoila, *Monthly average daily global and diffuse solar radiation based on sunshine duration and clearness index for Brasov, Romania*, Journal of Renewable and Sustainable Energy 6, (2014); (FI-1.511)

Planuri de evoluție și dezvoltare a carierei

EDUCAȚIE ȘI FORMARE



Titlu: *Investigation on parameters affecting the photoconversion efficiency in Pv-cells based on Si and CdTe,*

Coordonator științific: Prof. Dr. Socrates Kaplanis

ACTIVITATEA DIDACTICĂ

GRADE DIDACTICE

Cadru asociat	Asistent	Șef Luc.	Conf.
1997-2002	2002-2004	2004-2015	2015-prezent

Cursuri:

- Inginerie optică
- Fizică
- Fizica și tehnnologia sistemelor fotovoltaice
- Optoelectronică
- Fizică
- Surse de energie alternative
- Ecuațiile fizicii matematice

ACTIVITATEA DIDACTICĂ

Infrastructură

Laboratoare

- Realizarea lucrărilor de laborator pentru disciplinele
  - Surse de energie alternative
  - Optoelectronică
  - EMF
- Modernizarea unor lucrări de laborator pentru disciplinele
  - Fizică

Contract Idei - Cercetări interdisciplinare de stabilire a limitelor de potențial ale energiei solare. Corpuri solide pe intervalul încălzire- topire (2007-2010)

Sistem inteligent pentru managementul energiei oferite de panourile solare la alimentarea lămpilor cu senzori de infraroșu, (2011-2013)

Cercetări asupra sistemelor solare hibride fotovoltaice/termoelectrice/termice PV/TEG/STC (2015-2017)

ACTIVITATEA DIDACTICĂ

Predare ca profesor Invitat

- 2014 și 2015, predare la TEI of Western Patras, Grecia, Master (două săptămâni);
- 2013–predare la TEI of Patras, Grecia și școala de vară (două săptămâni);
- 2012–predare la TEI of Patras, Grecia și școala de vară (două săptămâni);
- 2011–predare la TEI of Patras, Grecia și școala de vară (două săptămâni);
- 2010–predare la TEI of Patras, Grecia și școala de vară (două săptămâni);
- 2009–predare la TEI of Patras, Grecia și școala de vară (două săptămâni);
- 2009-predare, University of Applied Sciences –Villach, (o săptămână);
- 2008-predare la TEI of Patras, Grecia și școala de vară (două săptămâni);

- Dezvoltarea continuă a direcției de cercetare creată
- Consolidarea prin evoluție și bun management a unei echipe de cercetare eterogenă și dinamică
- Îmbunătățirea procesului de diseminare a cercetării
- Dinamizarea atragerii de fonduri
- Menținerea și îmbunătățirea actualelor colaborări și dezvoltarea unora noi, atât cu mediul academic, cât și cu cel industrial
- Îmbunătățirea bazei materiale a laboratorului de cercetare

Cercetare și Didactic

- Implicarea studenților (toate palierele) în activitățiile de cercetare
- Implicarea studenților în procesul de diseminare
- Publicarea de noi cursuri, îndrumare, cărți având ca bază rezultatele cercetării, dar și necesitățile studenților
- Utilizarea rezultatelor cercetării în procesul de predare – accentul fiind pus pe metode interactive
- Menținerea și dezvoltarea colaborărilor cu liceele

ABILITAREA

Primii pași: S. Mahmoudi Nezhad, G. Șerban, A. Moraru, A. Machidon
F. Corciovă, I. Nartea, E. Blaga, D. Iordache

Direcții de cercetare
Posibile teme

Sisteme hibride și Energy harvesting

Dezvoltarea de dispozitive de caracterizare pentru diferite tipuri de energii regenerabile

Parametrii CF și a PV

Colaborări

- Aalborg University (Danemarca)
- University of Stuttgart(Germania)
- Technological Educational Institute of Western Greece (Grecia)
- University of East Anglia (Marea Britanie)
- West Pomeranian University of Szczecin(Polonia)
- Afyon Kocatepe University (Turcia)
- Universitatea Tehnică Gheorghe Asachi din Iaşi (România)
- Paul Scherrer Institute (Elveția)
- Deutsche Zentrum für Luft- und Raumfahrt (DLR)(Germania)
- Weizmann Institute of Science (Israel)
- Institutul National de Cercetare - Dezvoltare Agricola Fundulea(România)

Rezultatele cercetării

- 9 cărți/capitole de cărți
- 45 articole publicate în jurnale și proceedings ISI (două dintre articole fiind publicate în jurnale cu factor de impact mai mare de 10), 7 (Q1/Q2). FI.cumulat -57.44.
- 15 articole publicate în reviste și conferințe BDI
- 27 articole în conferințe internaționale
- 15 articole în conferințe naționale
- 4 proiecte câștigate prin competiție internațională ca director (membru în 7 proiecte internaționale)
- 2 proiecte câștigate prin competiție națională ca director (membru în 6 proiecte naționale)
- 8 proiecte cu terți
- 2 cereri de brevet depuse la OSIM.
- Peste 100 de citării în ISI, peste 430 citării în Google Scholar
- Idicele Hirsch: 5 - ISI Knowledge, 7 - Scopus și 10 – Google Scholar
- Referent
- 3 premii internaționale, 2 naționale
- Lead editor – International Journal of Photoenergy (Special Issue)

Îndeplinirea standardelor

Criteriu	Cerințe minimale (punctaj)	Realizat (punctaj)
Activitate Didactică și Profesională (A1)	100	230
Activitatea de cercetare (A2)	600	1073.4
Recunoașterea impactului cercetării (A3)	150	516.1
Total	850	1819.5

Criteriu	Cerinte minimale Nr.	Realizat Nr.
Cărți	1	5
Art. ISI	15 (3 in Q1 sauQ2)	45 +2 (7+2)
Director de proiect	2	6
Citări ISI	25	100
Factor impact cumulat	10	57.44+7.181+5.439

Vă mulțumesc pentru atenție !

=

Universitatea
Transilvania
din Brașov
FACULTATEA DE INGINERIE ELECTRICĂ
ȘI ȘTIINȚA CALCULATOARELOR