Erasmus+

PV TRAINER

Project Erasmus+: Training and certification model
for photovoltaic trainers with the use of ECVET system
(EU-PV-Trainer). No 2016-1-PL01-KA202-026279

From the identification of competence requirements to the educational offer – good practices and outcomes of the EU-PV-Trainer project

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Editors:
Katarzyna Sławińska, Mirosław Żurek

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Editors: **Katarzyna Sławińska, Mirosław Żurek**

The contributors: **Alfonso Cadenas Cañamás, Adina Cocu, Luminita Dumitriu, Radosław Figura, Radosław Gutowski, Maria Knais, Kamil Kulma, Jose Enrique Val Montros, Emilia Pechenau, Stanisław Pietruszko, Katarzyna Sławińska, Ioan Susnea, Mirosław Żurek**

Reviever: **prof Daniel Kukla, Tomasz Magnowski**

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The paper presents the methods and procedures to develop results of the project "Training and certification model for photovoltaic trainers with the use of ECVET system (EU-PV-Trainer)" co-funded by the EU under the Erasmus+ programme.

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ŁUKASIEWICZ Research Network – Institute for Sustainable Technologies
6/10 Pułaskiego Street, 26-600 Radom; phone (+48 +48) 36-442-41
e-mail: instytut@itee.radom.pl http://www.itee.radom.pl

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Introduction

The publication summarises the results of the Erasmus+ project entitled "Training and certification model for photovoltaic trainers with the use of ECVET system (EU-PV-Trainer)" (project number 2016-1-PL01-KA202-026279).

The project was implemented in the period from 01/09/2016 to 31/08/2019 by international partnership:

1) Instytut Technologii Eksploatacji – Państwowy Instytut Badawczy (actually: Sieć Badawcza Łukasiewicz – Instytut Technologii Eksploatacji), Radom, Poland – Coordinator,
2) EDICT Ltd., Nicosia, Cyprus,
3) Universitatea Dunarea De Jos Din Galati, Romania,
4) Fundación Equipo Humano, València, Spain,
5) Stowarzyszenie Elektryków Polskich Oddział Radomski, Poland,
6) Polskie Towarzystwo Fotowoltaiki, Warszawa, Poland.

The idea of EU-PV-Trainer project is signed up into EU instruments based on practical and flexible learning paths and improving the quality of education due to the established European reference frameworks such as National Qualification Framework (NQF) related to the European Qualifications Framework (EQF) together with the validation system and European Credit System for Vocational Education and Training (ECVET) directly linked to national education and training systems and to EU tools for mobility and transparency and recognition of learning outcomes and qualifications.

According to the conducting analysis done before the application preparation, there is no doubt that in all partners' countries there's a clear lack of well-qualified PV trainers and there's a huge demand for them from the labour market needs:

1) Increasing demand on the PV trainers is linked to the growth of the PV labour market and the need of preparation of PV installers what is connected to priorities:
   - reduce greenhouse gas emissions by at least 20% – it is well over 1 million new jobs that are at stake (Europa2020 Strategy),
   - obligation of 20% of sharing the energy from OZE in the total produced energy stimulating the development of PV in EU (Market of photovoltaic in Poland, 2013),
   - in 2020-2025 there will be the beginning of the producing of energy with the use of the photovoltaic cells for the large scale (report PEP, 2013),

   - PV installers is one of the nine occupations related to the improvement of the use in the efficient way of the natural resources mentioned in the group of 8 countries EU (Cedefop, 2015),
   - valid legal solutions in EU require among others, the interim improvement of the competences by PV installers.
2) Increase number of accredited training institutions preparing PV installers (in Poland 57 accredited installers) (Office of Technical Inspection, 2016).
3) Vague qualification requirements for PV trainers (level of education and professional experience) are not conducive to the quality of training (PL, ES, CY, RO).
4) No training offers for PV trainers (PL,ES, CY, RO).
5) An increase number of vacancies for PV trainers (analysis www).
6) PV trainer are often the specialists who are not prepared for the trainers activities or specialists with the knowledge of PV (Interviews with the educational Institutions).
7) Lack of certification of PV trainers in the partners countries.

One of the objectives of the project was to increase the mobility of teacher/trainers in the field of photovoltaics (PV), through the introduction of specialised foreign language training elements.

The project results developed based on diagnosis and transfer of good practices of European project partner countries (especially Spanish, Polish, Cyprus, Romanian) in the field of PV are the contribution to the updating and standardization of professional competences, including the training and language of PV teachers/trainers in the partner countries.

Therefore, it is reasonable to take measures aimed at improving the quality of education and training of future PV installers by aligning and improving the quality of professional preparation of the persons conducting PV theoretical and practical classes, taking into account EQF,NQF,ECVET,EQAVET and specificity of the partner countries.

The specific objectives of the project included enhancing the quality of vocational teaching/training of PV installers by:

- levelling and improving the competence of VET teachers/trainers conducting theoretical and practical training for PV installers results in increasing the level of their competitiveness in the labour market and increasing employability or maintaining employment,
- building a blended learning course to gain wider coverage and better learning outcomes,
- recognition of non-formal and informal learning outcomes of educators conducting theoretical and practical training for installers of photovoltaic systems,

- the development of a modular training programme combining theory with practice and education packages based on the analysis of the work process (professional tasks and the skills, knowledge and competencies required to be able to perform them) of the PV teacher/trainer described by the standard of professional competences,
- the development of professional competence of teachers/trainer supplemented by the foreign language for practical use within the specific field of photovoltaics and teaching skills of PV trainer.

The target group of the project were persons conducting theoretical and practical PV vocational education and training or are interested in conducting such training and they comply with the legal requirements applicable in the partner countries. They might be employed people or at risk of losing their jobs (e.g. teachers and instructors of practical training in vocational schools, persons conducting professional courses in continuing education institutions or university teachers) as well as job seekers and employers providing services in the field of PV.

Chapter entitled *"From the identification of competence requirements to the educational offer presents"* is a general characteristics of the project. It gives details of individual tasks performed by partners, and describes the results achieved.

Partners from the University of Dunarea de Jos Din Galati analysed professional competence standards in a chapter „Building professional competence standards for vocational training" in which they explained what the professional competence standards are and explained the cornerstones of any national or sectoral qualification system or framework. This paper aims to describe the various paradigms that can be adopted when creating a professional competence standard. The two most common existing methods in development of competence standards are investigate, as well their conceptual basis and rationale, advantages and drawbacks.

The Romanian solution for competence standards' structure and content is further presented, as an example of a mixed approach in strategy of building norms for a professional qualification system. The PV-Trainer project approaches' in development of a competence standard was pointed out with their possible impact in building effective qualification programs for vocational education.

Romanian experts also composed a chapter entitled *"On-line systems for competences evaluation – methods and digital technologies"* in which they explained what a competence is, how it is formed and how it is measured. The competences that a person possesses and uses for the purpose of obtaining, processing and communicating knowledge, constitute the main behaviour of the person, but also of the society or organization of which he is a part. Nowadays, there are many psycho-pedagogical methods and digital technologies for verifying and validating the competences held by a person in a particular learning field. Choosing a test method and its implementation technology is a decision that is based on a number of factors. Among them, we mention the number of people who will benefit from the evaluation of the competences that would justify the investment in an eLearning system, the specificity of the domain of competences focused on theory or practice, the age group of the users. Depending on the technology chosen, the instructors can benefit from various tools that allow them to assess competences, to analyse the results, to update the system performances. In addition, the methodology and technology chosen also influence the efficiency of the eLearning system.

The involvement of students in any learning environment (e-learning or stationary training) is a decisive factor in achieving the intended learning outcomes in this article, was presented by Cyprus partners. Researchers defined engagement as a complex idea, consisting of behavioural, cognitive and emotional elements. They argue that instructors should participate in each of these components to effectively engage their students. According to the opinion of many scholars, the balanced involvement of the student facilitates his learning, leads to valuable results and prevents the student from resigning from the course and does not allow him to be bored.

Project partners from Spain in their article included among others, the description of provided activities by Fundación Equipo Humano. They tried to attempted to answer the question: How to implement a training plan in your company? By answering the question posed in this way, they presented experience related to the project implementation in the field of creating a joint training program for a PV trainer.

Chapter entitled *"Photovoltaic systems – history and current condition"* presents basic information on the development of photovoltaic systems and their popularity in partner countries: Poland, Romania, Spain and Cyprus.

The subject of photovoltaics is being continued in two subsequent chapters, in which the authors presented an analysis of the photovoltaic module operating parameters and cooperation of a hybrid inverter with a lithium-iron energy storage. The presented content supplements the educational packages developed under the project.

Katarzyna SŁAWIŃSKA, Mirosław ŻUREK

Katarzyna SŁAWIŃSKA, Mirosław ŻUREK
Sieć Badawcza Łukasiewicz – Instytut Technologii Eksploatacji, Radom (Poland)

From the identification of competence requirements to the educational offer on the example of the project "Training and certification model for photovoltaic trainers with the use of ECVET system”

Introduction

This section presents the justification for research within the area of competence improvement for trainers conducting training for photovoltaic installation fitters (PV trainer) under the project "Training and certification model for photovoltaic trainers with the use of ECVET system" funded under the Erasmus+ Programme. The research scope is presented, as well as its methods and developed outputs are indicated. Selection of the project partners is also justified here. To sum up, there are listed benefits to be brought by the project completion for the growth of education and professional development in the area of photovoltaics.

According to the assumptions of the 2014-2020 Erasmus+ Programme[1], initiatives for the growth of education and professional development conducted in the formal and informal education system are perceived as activities which may significantly contribute to meeting emerging social and economic demands, main challenges expected in the nearest decade in Europe.

It should also be mentioned that actions taken up in projects funded under the Erasmus+ Programme are supported by the application of tools supporting transparency and recognition of skills and qualifications acquired through the learner's participation in various forms of education and learning[2]. At the Institute for Sustainable Technologies – National Research Institute in Radom (now the Łukasiewicz Research Network – the Institute for Sustainable Technologies), in cooperation with domestic and foreign partners, completion of the project "Training and certification model for photovoltaic trainers with the use of ECVET

[1]Regulation (EU) No 1288/2013 of the European Parliament and of the Council of 11 December 2013 establishing 'Erasmus+': the Union programme for education, training, youth and sport (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0050:0073:PL:PDF), access: 19 October 2016.
[2] Erasmus+. Programme Guide. European Commission, Version 1 (2016): 20 October 2015.

system

(EU-PV Trainer)" was proposed, with use of the following tools:

1) European Qualifications Framework (EQF),
2) National Qualifications Framework (NQF),
3) European Credit System for Vocational Education and Training (ECVET),
4) European Quality Assurance in Vocational Education and Training (EQAVET).

The EU-PV Trainer project has received a positive assessment of reviewers and subsidy under the Action 2: Cooperation for innovation and the exchange of good practices for the Erasmus+ Programme.

It aims at the improved quality of education and training of future PV fitters through the alignment and improvement of quality of professional background of PV trainers conducting theoretical and practical courses, with consideration of EQF, NQF, ECVET, EQAVET and requirements applicable in the partner countries.

During the project completion in the years 2016-2019, partners were searching for answers to the following research questions:

1) What standardised qualification requirements should be met by the trainer conducting theoretical and practical courses in the area of photovoltaics in Poland, Romania, Spain, and Cyprus?
2) What structure should be presented by a description of a profession/standard of professional competence for the PV Trainer unified for the project partnership?
3) What learning outcomes and personal and social competence should be contained in the common modular training programme and educational materials (in a classroom and e-learning) for the PV trainer with consideration of EQF, NQF, ECVET, EQAVET requirements?
4) How should individualisation of the learning process be ensured through the consideration of acquired knowledge and skills of a trainee before starting learning?
5) How to increase prestige of PV trainers who completed the learning process according to the curriculum developed under the project and with use of prepared educational materials?

1. Justification of the need for research

The EU-PV-Trainer project's concept refered to the EU instruments based on practical education and flexible learning paths, oriented towards the improvement of quality of education supported by systems of validation and certification of participants' competence and the European Credit System for Vocational Education and Training (ECVET).

The initial diagnosis conducted in Poland, Romania, Spain and Cyprus showed that in partner countries competence gaps were experienced in the area of preparation of qualified trainers fitting future PV installation fitters. While justifying the need for the project completion, special attention was paid to:

1) Increase in the demand for highly qualified PV trainers on the market of educational services, which is related to the extension of the market of renewable energy sources and to the concurrent increase in demand for qualified fitters, in particular resulting from:
   - decrease in greenhouse gas emissions by at least 20% by the year 2020, which may translate to the creation of over one million of new jobs in the area of renewable energy sources[3];
   - introduction of an obligation to obtain 20% of produced energy from renewable energy sources, which may constitute an important stimulus for development of photovoltaics in the EU member states[4];
   - high dynamics of growth of the Polish market of photovoltaic installations in the years 2014-2015[5];
   - forecasts of "massification" of energy production from photovoltaic installations in the years 2020-2025[6];
   - general data showing that by the year 2018 approx. 43,400 persons should be trained within the scope of renewable energy sources[7]. It is confirmed also by the Vocational

[3] Communication of the Commission. Europe 2020. A strategy for smart, sustainable and inclusive growth. European Commission, Brussels 2010, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:PL:PDF, access: 19 October 2016.

[4] Rynek fotowoltaiki w Polsce – diagnoza [*The Photovoltaics Market in Poland – Diagnosis*], Park Naukowo--Technologiczny Euro Centrum, Katowice 2013.

[5] Rozwój polskiego rynku fotowoltaicznego w latach 2010 – 2020 [*Development of the Polish Photovoltaic Market in the Years 2010-2020*]. Raport, Stowarzyszenie Branży Fotowoltaicznej Polska PV, Kraków 2015.

[6] Idem.

[7] Professional qualifications and staff for green construction. Assessment of the current situation in the construction and vocational education sectors in Poland with regard to the accomplishment of objectives for the

Training Centre data, showing that in the years 2014-2017 it was expected that the architectural and construction industry would increase employment with regard to the application of photovoltaic installations[8];

- classification of the PV fitter occupation as one of nine occupations contributing to an improvement in use of natural resources to produce energy in a group of eight EU countries[9];
- introduction of mandatory legal solutions in the EU oriented towards continuous improvement of competence by PV fitters already operating on the market.

2) An increasing number of accredited training institutions preparing PV fitters in the EU states.
3) The lack of precise qualification requirements for PV trainers in valid legal regulations in the EU and member states that does not contribute to the quality of conducted training.
4) The lack of an offer of improvement of PV trainers' competence on the market of educational services in the project partner countries.
5) An increase in the demand for PV trainers (analysis of job offers published on websites in the project partner countries).
6) The fact that PV trainers are often specialists not prepared for conducting classes or that there are issues that courses are conducted by trainers having gaps in theoretical knowledge and/or practical skills connected with the installation of photovoltaic systems (interviews of representatives of training institutions hiring PV trainers).
7) The lack of the PV trainer certification system in the project partner countries.
8) Introduction of the content of education within the scope of PV installations to curricula in vocational schools, which requires the preparation of vocational education teachers conducting classes with students.

One of the project purposes includes an increase in mobility of PV teachers/trainers through the development of specialist linguistic training.

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year 2020 within the scope of an increase in energy efficiency and in the use of renewable energy sources conducted under the project Build Up Skills – Poland, Warsaw 2012.

[8] Analysis of a demand for occupations related to green economy in the Płock subregion. Final report conducted under the project "Green potential of the Płock subregion as an opportunity for the labour market growth", ZDZ Płock, 2012.

[9] Theocharis Tsoutsos, Training of photovoltaic installers in Europe. The PVTRIM training and certification scheme. Final report. 2013.

Specific objectives of the project are oriented towards an increase in quality of vocational education/training of PV fitters through:

- improvement of quality of competence of vocational education teachers, trainers conducting theoretical and practical training for PV fitters, which may contribute to an increase in their competitiveness on the labour market, thus increase in their fitness for employment or keeping their job;
- development of a modular training programme, combining theory and practice and preparation of educational packages based on effects of an analysis of working process described through e.g. professional tasks, skills, knowledge and competence required for the PV teacher/trainer;
- development of educational enclosure for vocational training for the PV trainer;
- development of mechanisms of recognition of non-formal and informal learning outcomes of potential trainees for the PV trainer;
- development of linguistic competence of PV teachers/trainers.

2. Selection of the project partners

The EU-PV-Trainer project team was selected by the project coordinator – the Institute for Sustainable Technologies – National Research Institute (now: Łukasiewicz Research Network – the Institute for Sustainable Technologies). It is composed of the following institutions:

- Institute for Sustainable Technologies – National Research Institute (now: Łukasiewicz Research Network – the Institute for Sustainable Technologies), Radom (Poland);
- EDITC LTD, Nicosia (Cyprus);
- Universitatea Dunarea De Jos Din Galati, Department of Computer Science and Information Technology, Galati (Romania);
- Fundación Equipo Humano, Valencia (Spain);
- Association of Polish Electricians Branch in Radom (Poland);
- Polish Society of Photovoltaics, Warsaw (Poland).

Under the consortium, particular institutions shall be responsible for:

1) Łukasiewicz Research Network – the Institute for Sustainable Technologies:
   - development of the research methodology, including comparative research on competence requirements of PV trainers, development of the methodology of creating a unified description/standard of professional qualifications for the PV trainer;

- design and development of a modular training programme, including its evaluation and development of methodological assumptions of creating educational packages supporting the PV trainers' improvement;
- performance of activities for the benefit of improved quality of qualifications of teaching staff and development of new methods ensuring high quality of training under the Polish Network of Modular Education, including accreditations of institutions and programmes, as well as certification of trainees' competence.

2) EDITC, Association of Polish Electricians Branch in Radom, Polish Society of Photovoltaics, Universitatea Dunarea de Jos Din Galati, Fundación Equipo Humano:
   - development of training programmes and materials with application of innovative learning methods and modular education technologies,
   - development of a set of tests to diagnose competence gaps of PV trainers allowing, on the one hand, for consideration of acquired knowledge, skills by a potential trainee and, on the other hand, individualisation of its learning process.
3) Universitatea Dunarea De Jos Din Galati:
   - for development of e-learning training.
4) Polish Society of Photovoltaics:
   - development of a model of environmental certification of the PV trainer with consideration of requirements of the standard EN ISO 17024:2012.

To sum up, while considering the Erasmus+ Programme criteria, we may state that the project partners were selected purposefully and their personnel potential shall allow for efficient performance of tasks posed for them in the project.

3. Target group in the project

The target group of the project are persons conducting theoretical and practical PV vocational education and training or are interested in conducting such training and they comply with the legal requirements applicable in the partner countries. They may be employed people or at risk of losing their jobs (e.g. teachers and instructors of practical training in vocational schools, persons conducting professional courses in continuing education institutions or university teachers) as well as job seekers and employers providing services in the field of PV.

4. Tasks completed under the project

Under the EU-PV-Trainer project, the following eight tasks were planned (intellectual outputs, Fig. 1):

1. In-depth diagnosis of qualifications requirements for a trainer conducting theoretical and practical training in the field of photovoltaics and a methodology of development a professional competence standard.
2. Standard of professional competences for the photovoltaic trainer.
3. Modular training programme for the photovoltaic trainer with regard to ECVET requirements.
4. Bank of training modules for the photovoltaic trainer with regard to ECVET requirements (stationary learning).
5. E-learning training bank for the photovoltaic trainer.
6. Bank of tests in the form of IT tool to check the level of professional competences for the photovoltaic trainer.
7. Development of community certification model for the photovoltaic trainer with regard to the requirements of EN ISO 17024.
8. Publication showing good practices and outcomes of the project.

Taking into account an international specificity of the partnership, in the project there was adopted a principle that performance of every task was preceded with development of common methodological assumptions with consideration, on the one hand, of EU guidelines (EQF, ECVET, EQAVET) and, on the other hand, of specificity of every partner country (including, among others, NQF).

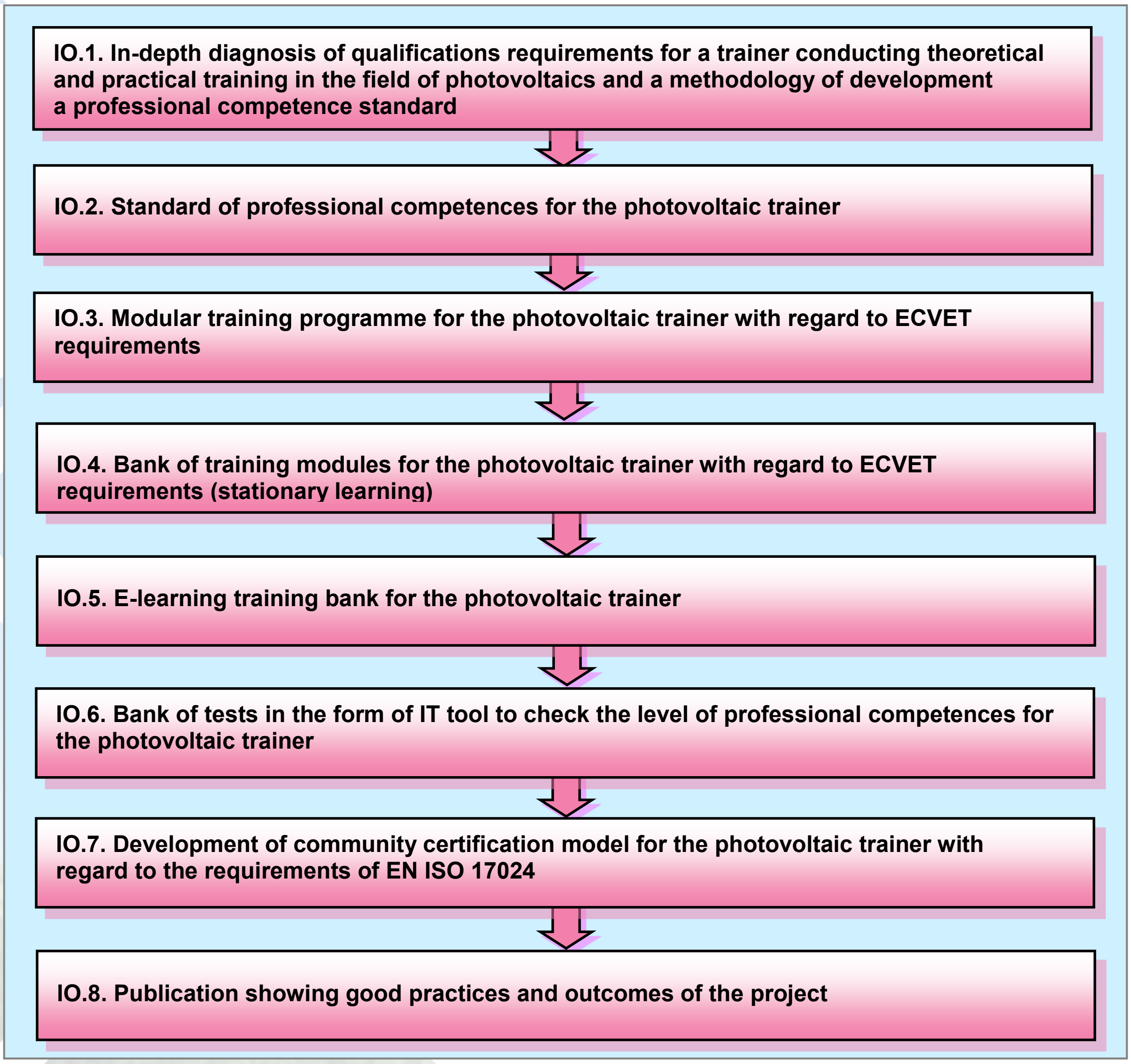


Fig. 1. Tasks completed under the project

5. IO.1. In-depth diagnosis of qualifications requirements for a trainer conducting theoretical and practical training in the field of photovoltaics and a methodology of development a professional competence standard

Preliminary analysis carried out at the stage of the project preparation indicated that in the EU there is no commonly accepted standard methodology for describing the professional competence of workers in specific occupations in the labour market. Therefore, it is justified to identify, in each of the partner countries, competence requirements necessary to perform the work as a trainer conducting training in the area of photovoltaic installations.

In the project, a uniform methodology for the study in all partners' countries was used (Poland, Spain, Romania and Cyprus) that focuses on a comparative analysis of selected documents that describe, among others, profiles, job training, qualifications, which may be reference point for building the description of the professional competence standard for PV trainers. In the frame of the methodology the following elements were described:

1) The aims of the research

The aim of the international comparative research in the partner countries (Poland, Spain, Romania and Cyprus) was the analysis of intentionally selected documents describing, among others, profiles, job training, qualifications, which could be a reference point for building the description of the standard of professional competence for a PV trainer.

It was assumed that the competency requirements in the comparative analysis will take into account requirements for the competence areas:

- training;
- appropriate qualifications for PV installers.

2) Subject of the research

The subject of comparative studies was a structure and substantive content of the description of the competence requirements contained in official national documents which could serve as a point of reference for the development of the standard of professional competence for a PV trainer. It was assumed that competency requirements in the comparative analysis will take into account:

- the area of the requirements for the trainer competence,
- the area of the requirements for the competence appropriate for PV installers.

3) Research problems

Described purpose of the research will address the following issues:

- In what national documents are there descriptions of trainers' and expertise requirements including industry data relating to installation PV systems?
- On what levels of the EQF and NQF in the partner countries operate qualifications related to the competence of PV trainers?
- What are the existing similarities and differences in the structure of the description of the competence requirements in documents related to a new classification of "PV trainer"?

- What principal areas of professional activity should be done in the area of trainers and specialized (industry) competencies"?

4) Methods, techniques and research tools

In order to verify formulated research problems it was necessary to explore the appropriate research methods and techniques.

The method of desk research was used to identify and analyse selected documents describing, among others, profiles, job training, qualifications, which are a reference point for building the description of the standard of professional competence for a PV trainer in the construction industry.

The expert method was used in formulating conclusions and recommendations. During the studies, the experts service was used – specialists in creating descriptions of competency requirements and specialists – experts in the training competences and PV installations.

Partners carried out a qualitative research, considered as a discursive approach of reformulation, explanation and, to a certain extent, theorisation of institutional testimonies, practical experiences and human phenomena having progressively become interpretative and based on the criteria of credibility, transferability from one professional context to another, from one sector to another and from one country to another. The partners were sensitive on the problematic related to the mechanisms of macro regulation (governance of the systems) and micro automatisms (behaviour of operational organisations and VET providers), in permanent interaction and sources of potential tensions. Thus, the authors of the present report opted for the axiomatic and inductive method of analysis, where perceiving and understanding take more importance at this stage than conceiving and evaluating. Therefore, this qualitative and interpretative approach, aiming at a better understanding of meanings attributed by institutions and organisations to their own injections and by individuals to their own perceptions, has been intended to prepare the next phases of the project, especially the development of certification and validation model for the professional competences of PV trainers in the countries concerned. Of course, we admit that social and political interest and priorities have an impact on interpretations and choices made by the institutions, professional organisations and individual institutions engaged in the project.

5) Organisation and the area of the research

The research in Poland, Spain, Romania and Cyprus was conducted between September 2016 and February 2017 with the participation of experts from partner institutions. Each partner has prepared a national report which was submitted to the leader of the operation (ITeE-PIB). Individual four national reports have been analysed at an angle similarities and differences in describing competency requirements aimed at "PV Trainer".

The analyses carried out confirmed that there is no PV coach in official uneducated documents in Poland, Romania, Spain and Cyprus. It can be created by submitting two professional competencies. The first one is specific for the installer of the PV installation and the other for the trainer (pedagogical).

The comparative analysis shows that the following common elements (table 1) can be distinguished in the descriptions of competence requirements of a PV trainer:

1. Synthetic description of profession / competence.
2. List of professional tasks.
3. List of required knowledge.
4. List the necessary skills.

In the case of Spain and Poland there are additional elements common to the description of competence requirements, which describe:

1. The job description and the manner of its execution, the areas of the profession occurrence.
2. Work environment (working conditions, machinery and tools, risks, work organization).
3. Education and powers necessary to work in the profession.
4. Opportunities for professional development, validation of competences.

The collected data from the comparative analysis (Table 1-2) will be used to draw up a description of the professional qualification standard for the PV trainer, which will consist of two professional competencies: necessary for assembling PV installations and conducting classes with trainers.

National reports of the project partner under the task 1 were presented in English in the book titled *In-depth diagnosis of qualifications requirements for a trainer conducting theoretical and practical training in the field of photovoltaic and a methodology of development a professional competence standard* (Fig. 2).

Additionally, under the task, outputs of the IO1 task was summarised in five languages of partner countries and in English (Fig. 3).

Fig. 2. Book cover "In-depth diagnosis of qualifications requirements for a trainer conducting theoretical and practical training in the field of photovoltaic and a methodology of development a professional competence standard"

Fig. 3. Research reports carried out as part of the task „In-depth diagnosis of qualifications requirements for a trainer conducting theoretical and practical training in the field of photovoltaic and a methodology of development a professional competence standard"

Table 1. Comprehensive set of competency requirements for PV installation in partner countries

	Directive PEiR NR 2009/28 /WE	Description of the profession - Poland	Professional competences standard - Poland	Description of the profession – Romania	Occupational Standard for a job in Romania	Vocational/ Professional Trainer Occupational Profile Cyprus	Spanish Organic Law	Professional competences standard - Spain
Synthesis		X	X					X
Professional tasks		X	X			X		X
The job description and the manner of its execution, the areas of the profession occurrence			X					X
Work environment (working conditions, machinery and tools, risks, work organization)			X					X
Psychophysical and health requirements, including contraindications to professional practice			X					
Education and powers necessary to work in the profession			X				X	
Opportunities for professional development, validation of competences			X				X	
Knowledge	X		X	X	X	X		X
Skills	X		X	X	X	X		X
Competences			X	X	X	X		
Units of competence					X			
elements of competences					X			

Table 2. Comprehensive set of competency requirements for the trainer in partner countries

	Professional competences standard – Poland	Occupational Standard for a job in Romania	Vocational/Professional Trainer Occupational Profile Cyprus	Spanish Organic Law	Professional competences standard – Spain
Synthesis	X				X
Professional tasks	X	X	X		X
Components of professional qualifications	X		X		
The job description and the manner of its execution, the areas of the profession occurrence	X				X
Work environment (working conditions, machinery and tools, risks, work organization)	X				X
Psychophysical and health requirements, including contraindications to professional practice	X				
Education and powers necessary to work in the profession				X	
Opportunities for professional development, validation of competences				X	
Knowledge	X	X			X
Skills	X	X	X		X
Competences	X				
Units of competence		X			
elements of competences		X			

Conclusions on the analysis of competency requirements for trainer PV:

1. In Poland, Romania, Spain and Cyprus there wasn't introduced the profession of PV trainer into any classification, therefore there is no direct description of the professional competence.
2. Professional competence of PV trainer will be described on the basis of the pedagogical and professional competence related to the installation and service of the PV devices (Poland, Spain, Romania, Cyprus).
3. Training of the PV installations are providing by the accreditation training centres (Poland, Spain, Romania, Cyprus).
4. In Cyprus, PV trainers based on the CV sent are approved by The Energy Service of the Ministry of Energy, Commerce and Tourism.
5. Training centre is responsible for the picking of the trainer (Poland, Romania, Cyprus).
6. Spanish partner has described the whole requirements for PV trainer.
7. The training programme for PV installers are available for people who has electrician or plumber's qualifications.
8. The content of the competence requirements for the PV trainer vary in separate countries.
9. The common part of the profession competence description is presented by knowledge, skills and social competence.
10. It is recommended to prepare the professional competence in scope of the PV installation on the basis of the requirements of knowledge and skills mentioned in the annex IV Directive of the EU Parliament and Council No. 2009/28/WE from 23 April 2009 as the promotion of the renewable energy.

As part of the **recommendation**, a description of the structure of the proficiency profile of the PV trainer is presented, which should include:

1. The name of the profession, the link with EQF/NQF levels;
2. Synthetic description of profession/competence;
3. The job description, the areas of the profession occurrence;
4. Work environment (working conditions, machinery and tools, risks, work organization);
5. Education and powers necessary to work in the profession;
6. Opportunities for professional development, validation of competences;
7. List of professional tasks;
8. List of professional competencies;
9. List of required knowledge;
10. List of necessary skills.

The above elements of the profession description should be components of the professional competence standard for the trainer. Therefore, the collected data from the comparative analysis will be used to draw up a description of the professional qualification standard for the PV trainer, which will consist of two professional competencies: necessary for assembly of PV installations and conducting classes with trainers.

6. IO.2. Standard of professional competences for the photovoltaic trainer

The final product of the IO2 task was the standard of professional competence for the PV trainer.

Fig. 4 presents the procedure for development of the standard of professional competence under the partnership.

During a working meeting, there was discussed the proposed methodology of research oriented towards the development of a standard of professional competence for the PV trainer. The project partners presented their national examples concerning development of descriptions of information on occupations in the form of standard. The partnership established that a diagnostic survey method would be the main research method, while the questionnaire would constitute the research tool. The expert method would be applied as a support (agreement on methodology, structure of the questionnaire, final version of the standards of professional competence of the PV trainer).

At the stage 2, employees of the Łukasiewicz – IST developed an initial structure of the standard of professional competence for the PV trainer and the research tool – questionnaire concerning the standard of professional competence for the PV trainer. Proposals of a structure of the standard of professional competence for the PV trainer and of the research tools was consulted with other team members completing the project. Notes reported by partners (stage 3) in the form of national reports were taken into account after their analysis.

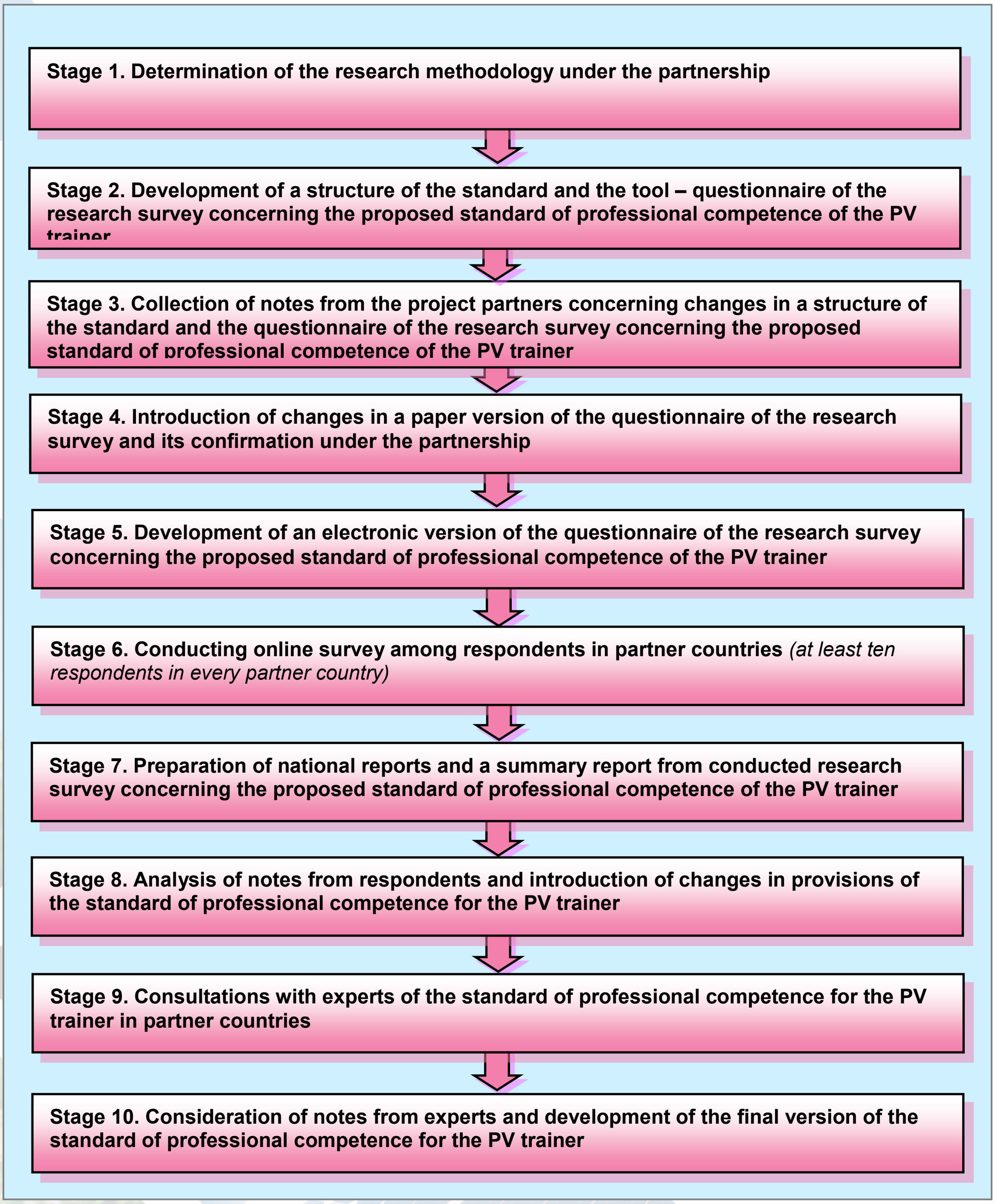


Fig. 4. Research procedure of development of the standard of professional competence for the PV trainer accepted in the project

As a result, it was assumed that a description of the standard of professional competence for the PV trainer would include the following elements:

INTRODUCTION
PROFESSIONAL COMPETENCE STANDARD FOR THE PHOTOVOLTAIC TRAINER
1. Position of a profession (competences) in classifications
1.1. Planning, organizing, conducting and evaluating of the vocational training (VET trainer)
1.2. Planning, installation, modernization and maintenance of photovoltaic installations (photovoltaic installation fitter) 7126
2. Description of the profession
2.1. The profession synthesis
2.2. The job description and the manner of its execution, the areas of the profession occurrence
2.3. Education and permissions necessary to work in the profession
2.4. Possibilities of professional development, recognition/validation of competence
2.5. List of professional competences / qualifications and units of learning outcomes
2.6. Relations between professional competence and the level of skills in the EQF / NQF
3. Description of the professional competence / qualifications
SOURCES

The proposed standard of competences / qualifications for a PV trainer contains minimum requirements in terms of knowledge, skills and personal and social competences which should be possessed. What is also consistent with the definition of QUALIFICATION adopted for the project implementation definition as a set of learning outcomes in terms of knowledge, skills and social competences acquired in formal education, non-formal education or through informal learning, consistent with the requirements for a given qualification that have been achieved checked in validation and formally confirmed by an authorized certifying entity.

The partnership agreed that the research tool – the questionnaire – would contain the following elements:

1) **INTRODUCTION**
2) **RESPONDENT'S DATA**
3) **In respondent's opinion, if you describe the profession of a PV trainer in the form of a professional competence standard, the following information should be taken into account:**

1. Identification of the profession
1.1. The name of the profession and position of the profession in the classifications
2. Description of the profession
2.1. The profession synthesis
2.2. The job description and the manner of its execution, the areas of the profession occurrence
2.3. Education and permissions necessary to work in the profession
2.4. Opportunities for professional development, validation of competences
2.5. List of professional competence
2.6. Relations between professional competence and the level of skills in the EQF / NQF
3. Description of professional competence
3.1. Professional competence Kz1
3.2. Professional competence Kz2
3.3. Social competence KzS
4. Profile of key competences

After consideration of notes from the project partners, the final version of the questionnaire of the research survey was developed and applied for the development of an online version of the research survey questionnaire (Fig. 5).

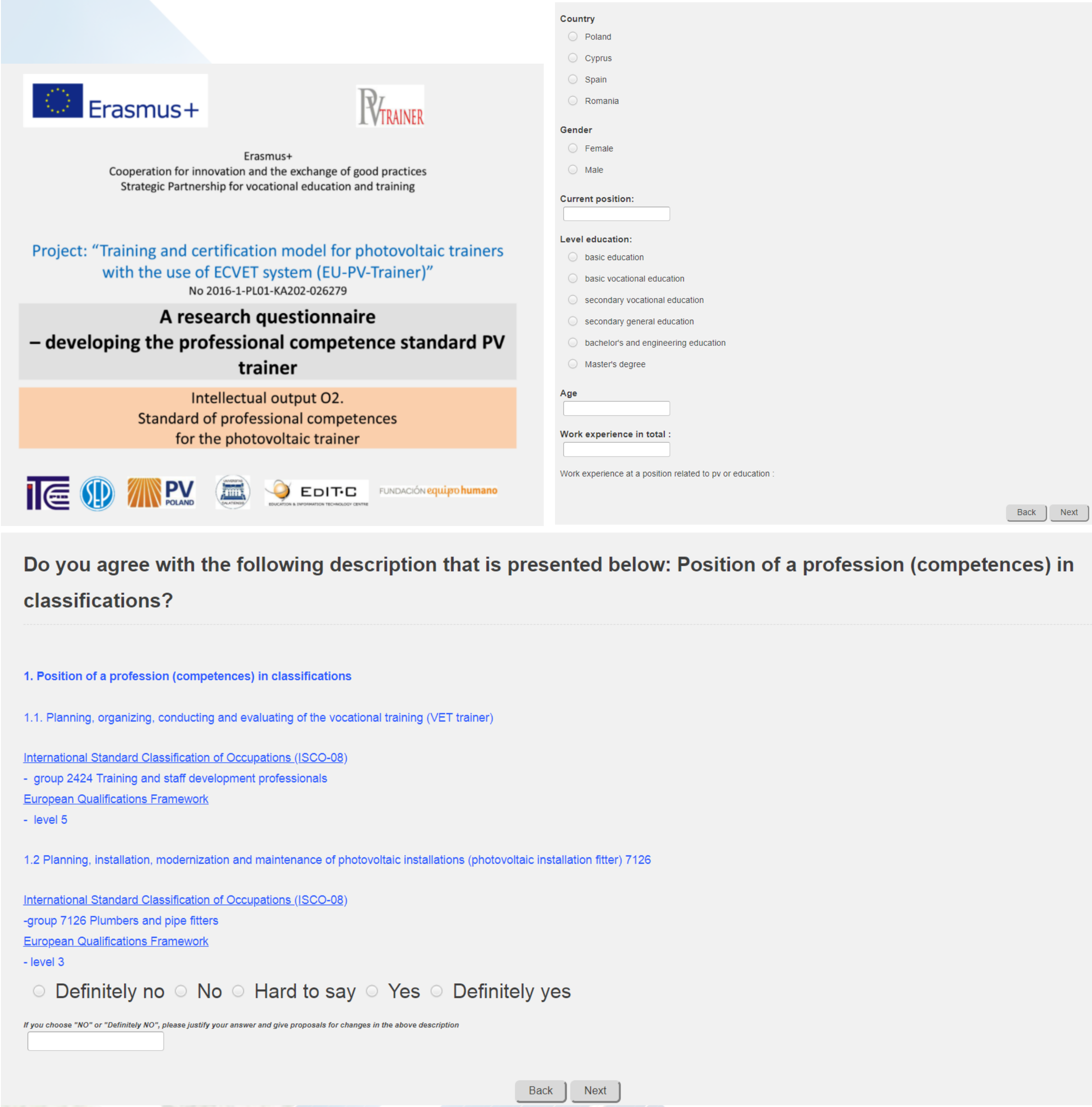


Fig. 5. Exemplary screenshots of the research survey questionnaire in English

An online version of the questionnaire was translated into languages of partner countries and applied for research in four countries: Poland, Romania, Cyprus, and Spain.

The draft standard was discussed, among others, by persons conducting training for fitters of photovoltaic installations, training organisers as immediate superiors of PV trainers, representatives of employers hiring PV installation fitters, associations and foundations related to renewable energy sources and teaching qualifications.

As an effect of conducted research, opinions were acquired from 50 respondents, including

17 from Poland, 10 from Spain, 13 from Romania, and 10 from Cyprus.

The gained data show that over 70% respondents was constituted by experts with more than ten years of professional experience connected with renewable energy sources or teaching qualifications. Approx. 70% of respondents has higher education in the area under research. The majority of respondents (indices exceeding 70%) assessed positively the content of particular elements included in the standard of professional competence of the PV trainer. Single notes reported by respondents were considered in the subsequent version of the draft standard of professional competence of the PV trainer.

According to the adopted methodology, an initial standard version takes into account a reference to European instruments referring to the development and quality of qualifications (including EQF/NQF, ECVET, EQAVET) and specific elements for every partner country.

At the stage 9, a version of the standard of professional competence of the PV trainer developed in such a way was subject to content-related and methodological assessment by experts in particular partner countries. The project partners, in cooperation with the task leader, organised in every partner country one meeting each with at least two external experts with experience in the occupation of PV trainer. During the meeting, there was presented the draft standard of professional competence to experts and they discussed the content of particular standards parts. The assessment process was documented in a form of written report, including proposed changes reported by experts. Every partner passed the report to the task coordinator, who introduced notes to the standard.

Fig. 6. Brochures with descriptions of the standard of professional competence of the PV trainer in five language versions

After consideration of notes, an English version of the standard of professional competence of the PV trainer was handed over to the project partners who translated it into their native language.

7. IO.3. Modular training programme for the photovoltaic trainer with regard to ECVET requirements

The Association of Polish Electricians Branch in Radom coordinated the task no. 3.

Here, the methodology of creating a modular training programme for the PV trainer was developed under the project partnership, with particular consideration of a structure and programme of training for the PV trainer, taking into account the ECVET requirements.

Under the adopted research procedure in the task 3, firstly a structure of the modular vocational training programme was established with consideration of the ECVET, EQAVET, EQF/NQF guidelines through references to the standard of professional competence.

Then, an initial version of the modular training programme in English was developed. It constituted the subject of consultations with all project partners under the project.

Results of an analysis of competence, professional tasks included in the standard of professional competence of the PV trainer constituted the starting point to develop the training programme.

The modular programme was subject to assessment of two external experts – reviewers (specialist from the area of renewable energy sources – vocational education teacher conducting classes concerning the given subject and an academic teacher from the pedagogical university preparing, among others, teachers to conduct classes).

After consideration of notes made by reviewers, the task coordinator provided other project partners with an English version so that it was translated into their native languages.

The modular training programme was also subject to assessment on four events disseminating the project outcomes, remarks from which were also considered in final programme versions.

The developed modular programme for the PV trainer constituted the basis for preparation of educational packages (tasks IO4) and e-learning training (IO5 task).

While creating the methodology of developing the modular programme, one referred to the MES methodology (Modular Employable Skills) drawn up by the International Labour Organisation.

Within the framework of consultations in the partnership, there were introduced simplifications to the MES methodology, consisting in the modification of documentation with consideration of the best practice identified in the partner countries.

The modular training programme was developed based on the analysis of employers' requirements included in the description of the standard of professional competence for the PV trainer. Proposals of changes submitted by participants of training organised under the project in four partner countries were also taken into account.

By connecting the modular training programme with the standard of professional competence of the PV trainer, the modular programme has taken into account guidelines of the EQF (European Qualification Framework), NQF (National Qualification Framework, ECVET (European Credit System for Vocational Education and Training), in particular:

- reference to the EQF/NQF qualification levels as tools allowing to understand and compare qualifications granted in various countries and various education and training systems,
- consideration of the language of learning outcomes in the standard provisions, i.e. presentation of professional qualifications included in the standard through the prism of components such as knowledge, skills, and social competences,
- translation of the standard provisions as a competence description into the category of learning units together with associated points,
- consideration of trainees' self-assessment of professional competences acquired during training.

As a result of works conducted under the partnership:

- professional competences distinguished under the professional competence standard were assigned to the modules,
- occupational tasks distinguished under the competences in the professional competence standard of the PV trainer were assigned to the modular units,
- components of occupational tasks, i.e. knowledge, skills and social competences, were grouped and assigned to subjects of particular training units.

Two modules were distinguished under the modular programme for the PV trainer:

1) **M1. Planning, organizing, conducting and evaluating of the vocational training** – a vocational education and training specific for the trainer, i.e. taking into account the pedagogical and methodological aspects of conducting classes, andrology (working with adults), organization, implementation and evaluation and quality assurance of training;
2) **M2. Planning, installation, modernization and maintenance of photovoltaic installations** – a PV installation specific for a fitter.

In every module, three modular units each were distinguished with equivalents of occupational tasks performed at work (table 3).

Training units constituting subjects of particular courses were distinguished in modular units (table 4).

Tab. 3 Modular training programme for the PV trainer – division into modules and modular units

Module	Modular units	Approximate number of hours per implementation	Number of points ECVET[1]
M1. Planning, organisation, execution and assessment of professional training	M1.U1. Planning and designing vocational training and other forms of improving professional competence of employees	18	1
	M1.U2. Organisation and provision of teaching activities and consultation related to the training offer	18	1
	M1.U3. Promotion and provision of the quality of training services and awarding the qualifications	12	1
	Together M1	**48**	**3**
M2. Planning, installation, modernization and maintenance of photovoltaic installations	M2.U1. Planning installation of photovoltaic systems	28	2
	M2.U2. Assembly of photovoltaic installations	20	1,5
	M2.U3. Modernization and maintenance of photovoltaic installations	16	1
	Together M2	**64**	**4,5**
	Together	**112**	**7,5**

[1] *Within the framework of partnership, it was assumed for the calculation of ECVET points in the project that min. 15 teaching hours were assigned to one point. It results from the fact that in the vocational school approx. 900 teaching hours are provided per year, which, converted into 60 points, gives 15 teaching hours per one point.*

Tab. 4. Example of division of training units for the modular unit M1.U1. Planning and design of professional training and other forms of improving professional competence of employees

Educational (learning) outcomes		**Training units**
Knowledge (it knows and understands):	**Skills (it can):**	
– Directions and trends in the development of professional competences in the industry in which he conducts classes. – Documents describing competency requirements for employees in the industry in which they conduct classes. – Legal basis for the organization and implementation of training in the industry in which it conducts classes. – Fundamentals of andragogy – adult education.	– Analysing of available reports on researches and projects concerning the development of qualifications and competence required in a specific industry. – Use of open resources concerning the knowledge of occupations, describing the qualification and competence requirements for the employees experts in a specific industry. – Adjustment of the curricular offer to the legal requirements. – Identification of training needs of	– M1.U1.S1. What competence requirements must be met by the renewable energy source industry trainer? – M1.U1.S2. How can employees' training needs be identified in enterprises? – M1.U1.S3. How to develop a training offer in cooperation with the training organiser and employers and what should be covered by the training curriculum? – M1.U1.S4. What organisational

Educational (learning) outcomes		Training units
Knowledge (it knows and understands):	**Skills (it can):**	
– Methods and tools of identifying the training needs of the employees. – Methodical fundamentals of the development of professional training program for the experts in a specific industry. – Principles and tools of diagnosing the competence of training candidates. – Methods and organizational forms of vocational training in a specific industry. – Principles and forms of cooperation with organisers of professional training in a specific industry. – Principles of validation of the vocational training program at the pre-implementation stage. – The rules and regulations of health and safety, fire protection, ergonomics and environmental protection in a specific professional sector and during conducting didactic activities.	individuals, enterprises, as well as local labour market. – Application of methods and development of tools to identify the training needs of the employees training in a specific industry. – Analysis of results of the educational needs research in the context of developing the curricular offer. – Development, in cooperation with training organiser and employers, of curricular offers for qualifying courses and professional skill courses. – Design of the professional training program with use of learning outcomes (knowledge, skills, competence). – Selection of a method of didactic work and organisational forms of classes relevant for a given training course. – Recognition of interests and expectations of training participants. – Assessment of the quality of a training offer with participation of external experts. – Definition of the principles and prerequisites of participation in training and other classes. – Plan and development of the schedule of training and classes. – Identification of the resources required for designing and implementing a training program. – Diagnosis of the competence of candidates qualified for professional training. – Care about safe and hygienic conditions of the course of training and classes.	forms of classes and methods of the didactic work with adults are recommended to be applied? – M1.U1.S5. How interests, expectations and competences of training participants can be identified? – M1.U1.S6. Who can participate in the assessment of training curriculum and materials prior to the training commencement? – M1.U1.S7. To what dangers may training participants be exposed?
Social competence: – Operates independently and cooperates in organised conditions during the training and classes designing. – Accepts responsibility for the quality of designed training and classes programs. – Assesses the impact of prepared educational projects on potential participants and their work environment. – Is able to critically assess its own actions as a designer and organiser of training and classes.		

The following elements were included in the modular training programme for the PV trainer:

INTRODUCTION
GLOSSARY
CURRICULAR AND ORGANIZATIONAL ASSUMPTIONS OF A TRAINING
1. Description of the occupation/qualification – selected elements
    1.1. Position of a profession (competences) in classifications
2. Description of the profession
    2.1. The profession synthesis
    2.2. The job description and the manner of its execution, the areas of the profession occurrence
    2.3. Education and permissions necessary to work in the profession
    2.4. Possibilities of professional development, recognition/validation of competence
3. Training schedule
4. Requirements concerning the teaching and learning process organisation
5. Didactic map of vocational training programme

MODULAR TRAINING PROGRAM FOR PV TRAINER – MODULAR AND TRAINING UNITS
1. M1.U1. Planning and designing vocational training and other forms of improving professional competence of employees
2. M1.U2. Organisation and provision of teaching activities and consultation related to the training offer
3. M1.U3. Promotion and provision of the quality of training services and awarding the qualifications
4. M2.U1. Planning installation of photovoltaic systems
5. M2.U2. Assembly of photovoltaic installations
6. M2.U3. Modernization and maintenance of photovoltaic installations

The program's modular structure consists of:

- program and organisational assumptions of training,
- curricula,
- vocational training modules, modular and training units.

The organisational assumptions present general methodological recommendations concerning training execution, exercises, applied educational methods and methods of verification and assessment of trainees' achievements.

With use of an educational map, the scheme of correlations between particular modular units was presented and the sequence of their performance was defined. Application of such an approach enables the trainee, in its education according to the MES modular programme, to undergo subsequent modular units, acquiring knowledge and skills necessary for the performance of professional tasks distinguished in the PV trainer's competence standard.
Under the programme, every modular unit was assigned with detailed learning outcomes, subjects of courses (training units).

The modular units distinguished in the programme were assigned with sets of learning outcomes composed of knowledge, skills and competences. At the stage of formation of the professional competence standard and the modular training programme for the PV trainer, it was made sure that learning outcomes constituting the qualification were:

- described in clear and understandable categories through the reference to knowledge, skills and competences constituting them;
- constructed and organised in the way consistent with the given competence;
- constructed in the way allowing for individual assessment and validation of learning outcomes included in the given unit.

Under the project, it was assumed that the curriculum should provide the qualification level compliant with the European Qualification Framework (EQF) and the National Qualification Framework (NQF), together with associated ECVET points.

While giving the ECVET points under the project, the Recommendation of the European Parliament and of the Council on the establishment of a European Credit System for Vocational Education and Training (ECVET) was applied. According thereto, points constitute a supplementary numerical source of information on qualifications and units. They do not have any value in isolation from acquired learning outcomes concerning the specific qualification to which they refer, but they reflect the fact of acquisition and accumulation of learning outcomes.

Assuming that learning outcomes acquired during one year of formal vocational education and training on a full-time basis corresponds with 60 ECVET points, which translates into approx. 900 teaching hours in the teaching process of vocational education, it was assumed for the project purposes that one point referred to approx. 15 teaching hours.

While assigning the ECVET points, it was recommended to ensure assignment in two stages:

1) firstly, assignment goes to the specific qualification as a whole,
2) then, to particular modular units.

In order to ensure comparability of qualifications in the professional competence standard and in the modular training programme of the PV trainer, the European Qualification Framework (EQF) level was indicated.

The modular training programme for the PV trainer proposed in the partnership contains the minimum requirements within the scope of knowledge, skills and personal and social competences that it should have. It is compliant with the definition of QUALIFICATION assumed for the project purposes as a set of learning outcomes within the scope of knowledge, skills and social competences acquired in formal education, non-formal

education or through informal learning, compliant with the requirements established for the given qualification, the accomplishment of which was verified in validation and formally confirmed by the eligible certification body.
A developed structure of the modular training programme is flexible. Modules and modular units may be updated (modified, supplemented or replaced) according to the changing needs of the labour market, technological progress and development of science, and adjusted to the trainees' level.

Implementation of a learning process based on the modular programme is described with the following features:

- teaching and learning process is oriented towards the achievement of specific, measurable learning outcomes in the form of knowledge, skills and social competences allowing for the performance of specific professional tasks assigned to the PV trainer,
- organisation of the learning process allows for the recognition of learning outcomes acquired by the training participant in the formal, non-formal and informal (e.g. in working environment, through one's own learning) education,
- learning process is supported by the application of activating teaching methods that trigger activity, creativity, student's self-assessment ability.

Under the project, the assumption was adopted that educational packages, in particular, support education in full-time mode, while for distance teaching purposes the training platform was developed. Therefore, when the participant, after the e-learning training completion, does not have fully acquired skills related to conducting courses or to assembling the PV installation, it is recommended to complete additional full-time training within this scope. It is also recommended that such training takes place in accredited training units within the given scope.

It is also allowed to confirm (with a separate certificate) modular units completed successfully unless a candidate finishes the entire course for ill-fated reasons. It shall enable to supplement the whole set of requirements included in the programme some other time selected by the participant or in the course of other training, without the necessity of repassing modular units confirmed with an independent certificate.

Outputs of the task 3 included, among others, the development of five language versions of the modular training programme for the PV trainer.

Fig. 6. Programme of the modular training for the PV trainer in five language versions

8. IO.4. Bank of training modules for the photovoltaic trainer with regard to ECVET requirements (stationary learning)

Outcome 4 covers the following activities:

1) **Development of a set of educational packages for the trainer and the trainee with consideration of the ECVET requirements**

At the first stage of the task performance, a common structure of an educational package was placed for the trainer and the trainee.

Under the partnership, it was established that there would be developed the common version of the package for the trainer and the trainee. It was justified with the fact that in the trainer's material there was initially planned the publication of tools for assessment of knowledge and skills of trainees in the beginning and after the end of training. These tools constitute the IO6 task outcome. However, as they constitute the basis for passing out particular modular units and entire training, under the partnership it has been decided not to make them public for trainers.

While considering the guidelines included in the task IO3. Modular training programme for the PV trainer, considering the ECVET requirements, educational packages were developed for six modular units.

Every educational package for a given modular unit includes:

1. **INTRODUCTION**
2. **PREREQUISITES**
3. **DETAILED LEARNING OUTCOMES**
4. **TEACHING MATERIAL**

4.1. Teaching material

4.1.1. Subject of the course 1 within the framework of the modular unit

4.1.2. Subject of the course 2 within the framework of the modular unit

4.1.3. Subject of the course 3 within the framework of the modular unit

………………

4.1.n. Subject of the course n within the framework of the modular unit

4.2. Exercises

4.3. Progress test

5. **GLOSSARY**
6. **LITERATURE**

In the "Introduction", the trainee and the trainer will find the following information:

1) Modules included in the given training.
2) Modular units included in particular modules.
3) Every modular unit includes teaching material, checklists, exercises and progress test.
4) Activities that should be performed by the trainee prior to training, in particular getting familiar with initial requirements and detailed learning outcomes, i.e. knowledge, skills and attitudes to be acquired after the end of learning in a given module.
5) Teaching material prepared under the package is supported with e-learning training.
6) Passing the test in an e-learning version constitutes the basis for passing the test placed in the modular unit.
7) Prior to the performance of exercises, check if you are properly prepared. Every subject is ended with a progress test that shall enable you define the scope of acquired knowledge and skills. If your results are positive, you can go to the next subject. If not, you should repeat the content necessary for specific skills.
8) In the case of teaching content including references to legal acts, it should be kept in mind that they are valid as at the date of study development and must be updated. The teaching content in the module is compliant with the legal status as at 15 August 2018.
9) The Guide has been developed under the project "**Training and certification model for photovoltaic trainers with the use of ECVET system (EU-PV-Trainer)"** co-funded by the European Union in the Erasmus+ programme Cooperation for innovation and the exchange of good practices Strategic Partnership for vocational education and training.
10) Materials included in the guide reflect only the position of their authors and the European Commission shall not be responsible for their content.
11) There is indicated a list of modular units and approximate number of teaching hours assigned to particular modular units.

Within the framework of "Initial requirements", there is information concerning knowledge and skills that should be acquired by the trainee to commence learning in a given modular unit, e.g. it should know:

– use various sources of information,
– determine your own rights and obligations,
– recognise basic legal acts,
– participate in discussion, presentation and defence of your own position,
– feel responsible for your and other's health (life),
– apply basic ethical principles (reliable work, punctuality, keeping one's word, honesty, responsibility for consequences, truthfulness),
– cooperate in a group with consideration of the division of tasks,
– use computer at a basic level.

In the chapter "Detailed learning outcomes", there is presented a set of learning outcomes, including knowledge, skills and social competences specific for a given modular unit. Below you may find the table with exemplary set of learning outcomes for the modular unit M1.U3. Promotion and quality assurance of training services and awarding of professional qualifications.

Tab. 6. Exemplary set of learning outcomes for the modular unit M1.U3. Promotion and quality assurance of training services and awarding of professional qualifications

M1.U3. Promotion and provision of the quality of training services and awarding the qualifications	
Knowledge (it knows and understands):	**Skills (it can):**
– Basic legal regulations concerning awarding qualifications in the in the industry in which he conducts classes. – Advantages and disadvantages of the model of validation and certification of professional competence based on the ISO/IEC 17024:2012 standard. – Procedures and criteria of quality assurance concerning the training. – Methods of validating the effects of non-formal learning through work experience. – Procedures, methods and criteria of validation and certification of competence. – Methods and tools of internal evaluation of a training process. – Validation principles of the professional training program. – Validation methods of informal learning outcomes through work experience. – Principles of quality assurance of the teaching	– Documentation of evidence confirming the training participant’s competence. – Participation in works of boards of examiners, validation boards and qualification awarding boards in the construction sector, chairing the board works if applicable. – Planning and designing the training evaluation. – Organisation of the evaluation process. – Provision of the class evaluation. – Evaluation of one’s own teaching work. – Monitoring of educational progress of the training participants. – Application of the quality assurance rules concerning the training and classes. – Use of evaluation conclusions for the improvement of one’s work and planning of one’s development. – Use of evaluation conclusions to improve quality of the teaching and training programs. – Adjustments of identified irregularities related to

and learning process. – Promotion and dissemination of professional training in the non-formal education and working environment.	the teaching and learning process and training performance. – Promotion and dissemination of professional training in the non-formal education and working environment. – Dissemination of the model of validation and certification of professional competence in the construction sector. – Improvement of one's own professional competence through the organised forms of non-formal education and self-learning.
Social competence:	
– Independently and in organised conditions assesses educational progress of the training participants in accordance with clear and objective criteria. – Assesses and examines while keeping its internal belief in justice and objectivity of made decisions. – Takes responsibility for effects of actions in which it participates, including the choice of forms and program of professional improvement, teaching methods, results of monitoring and evaluation of training and other educational activities. – Constructively responds to changes in legal regulations, requirements of training participants, commissioners, employers and work environment in the construction sector. – Voluntarily improves the vocational education and training trainer's skills and tools.	

"Progress test" for the trainee includes a list of questions referring to learning outcomes covered in a given modular unit to which the trainee answers within the framework of self-assessment. After stating that not all learning outcomes have been accomplished, it is recommended that the trainee should undergo repeated e-learning training, supplement its knowledge and skills on stationary training or read recommended literature.

Tab. 7. Fragment of the progress test for one of modular units

Can you:	Yes	No
1) Discuss potential threats when working with PV systems?		
2) List the activities necessary to perform before starting work?		
3) Discuss what the PV system installer is responsible for?		
4) Discuss the risk assessment?		
5) Describe the fire protection?		
6) Select the installation requirements?		
7) Explain safety work issues with electrical circuits?		
8) Discuss the dimensioning of DC components for PV systems?		

If you selected the answer "NO", we propose you returning to the teaching material and its repeated analysis in order to achieve intended learning outcomes (knowledge, skills).
If necessary, use additional source of information prepared to each topic.

The developed set of packages was the subject of reviews of external experts and within the framework of a multiplier event, all its participants in four partner countries got to know it. The reported comments by reviewers and event participants were provided to the task coordinator, as a result of which appropriate corrections were introduced to the content of educational packages.

Under the project, a set of educational packages was developed in five language versions for two modules and their six modular units. One language version includes approx. 350 pages.

Fig. 7. Covers of a set of educational packages for the trainee and the trainer for the module M1. Planning, organisation, conducting and assessment of professional training

Fig. 8. Covers of sets of educational packages in five language versions for the trainee and the trainer for the module M2. Planning, installation, modernisation and maintenance of photovoltaic installations

The developed educational packages constituted the basis for development of an e-learning course under the tasks IO5.

8. IO.5. E-learning training bank for the photovoltaic trainer

The task IO.5 aimed at the preparation of a fully functional module of e-learning training for the PV trainer on the platform, based on the content of training modules developed under the task IO.4.

According to the project assumptions, the following activities were performed to prepare a final version of modular training for the PV trainer:

1) There were developed common guidelines for creation of an e-learning course.
2) There were established the principles of developing teaching aids for particular training units, in particular related to the conducted exercises and films.
3) Particular modular units were split among the partners.
4) The first version of an e-learning course for the PV trainer was developed in English.
5) Under the partnership, the first version of e-learning training was tested. At least one person from every partner looked through the published materials, sent its comments

and observations to the tasks coordinator who, after consulting authors of particular modular units, introduced changes to the e-learning training.

6) E-learning training was translated into languages of the partner countries.
7) E-learning training was subject to the assessment of the multiplier event's participants. The event was conducted in four partner countries. Assessment considered versions in a native language of every project partner, comments reported by the event participants were noted down in the form of the report and sent to the task coordinator, who after consulting comments introduced changes in the course content.

For the purposes of performance of a given task, the expert method was applied as the main method, as well as guidelines of the task coordinator, describing principles of creating the e-learning training.

Within the framework of guidelines for the creation of e-learning courses, there was established e.g.:

1) Modular training structure (Fig. 9), covering:
   - **syllabus** with information on the organisation of training process (Fig. 10);
   - **introduction** in the form of presentation (Fig. 11) with basic course-related information;
   - **initial requirements** determining, as the name suggest, things that the trainee should be able to do before the e-learning training under the given module (Fig. 12);
   - list of **detailed learning outcomes** to be acquired by the trainee during training under a given modular unit (Fig. 13);
   - **introductory test** from the test bank – enabling the trainee to check its level of knowledge and skills prior to the commencement of learning under every modular unit (Fig. 14). Tests published in the course were developed under the task IO.6. Test bank and were described in detail there;
   - **training materials and exercises** for every modular unit – they cover materials in the form of presentation together with exercises to be performed by the trainee itself (Fig. 15-16). After exercise performance, the trainee obtains automatically information on its result. It may re-do the exercise to improve its result. It may also check the correctness of its results and obtain information on correct results;
   - **progress test** (Fig. 17) in the form of a list of questions referring to learning outcomes specified in every modular unit. Within the framework of the progress test, the trainee answers "yes" or "no" to questions connected with the acquisition of learning

outcomes in a specific modular unit. This test aims at the trainee's self-assessment in the area of acquired knowledge and skills. While answering "NO", the trainee obtains information encouraging it to repeat the material or reach some other sources of information to supplement its knowledge and skills;

– **final test** was developed under the task IO.6 Test bank to check the trainee's level of knowledge and skills after the end of learning in every modular unit (Fig. 18). The software selects ten random questions from the test question bank for a given modular unit. After answering correctly eight questions or more, the trainee has passed knowledge and skills included in a given modular unit.

2) Guidelines for preparation of training materials for the course.

The presentation template was prepared and the presentation content structure was established, including slides with:

– title of the module and the modular unit,
– title of the modular unit and the training unit distinguished under the module, according to the modular training programme developed under the tasks IO.3,
– training content for a specific training unit. In addition, it was established that every slide should hold the training unit's name, published information should be readable and possibly enhanced with graphic elements,

3) Guidelines for the preparation of exercises.

The partnership adopted the principle that the trainee might do exercises on its own, while their correctness would be checked automatically, i.e. it would not require an additional involvement of a course supervisor.

4) Instructional videos

In the course, instructional videos concerning the assembly and maintenance of photovoltaic installations were developed (Fig. 18).

E-learning course for the PV trainer is available on the website http://pvelearn.projectsgallery.eu/

To use it, the trainee must first log in (Fig. 19).

During the training, its participant may use the "Navigation" menu supporting the course use (Fig. 20).

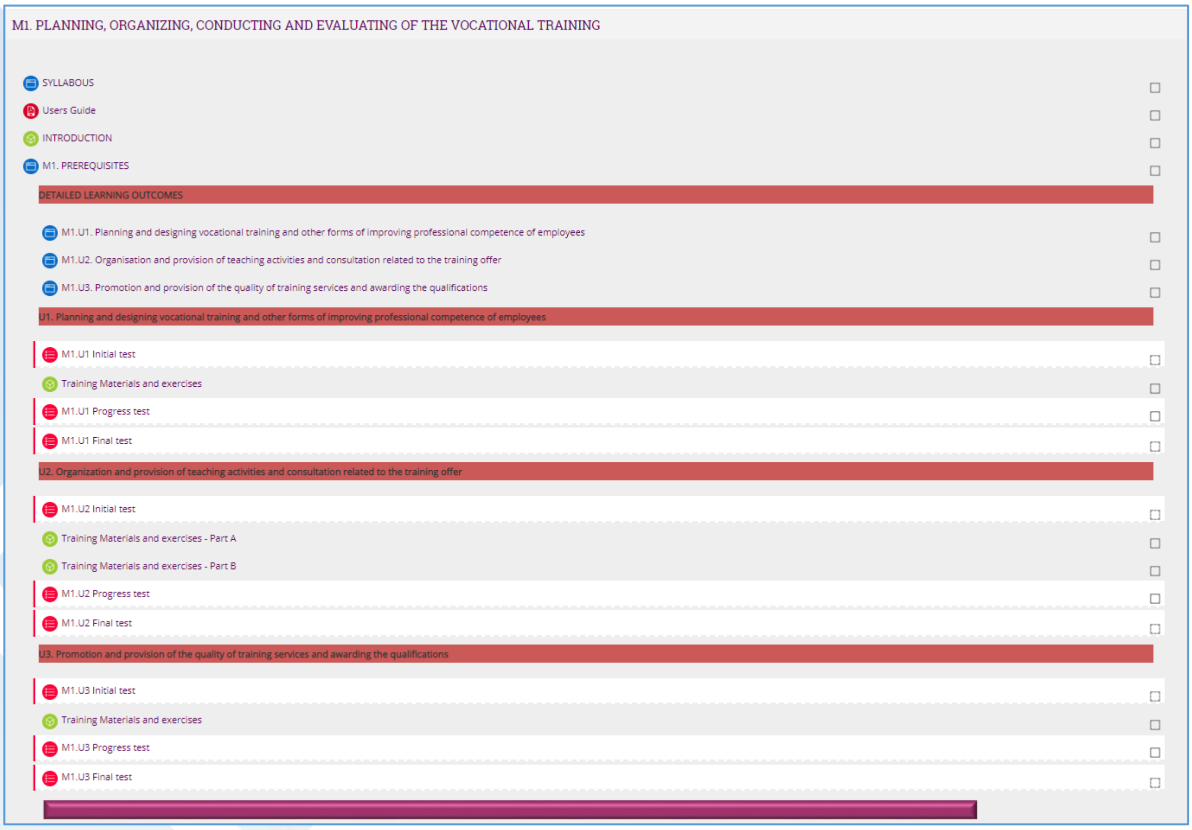


Fig. 9. E-learning training structure on an example of the module M1

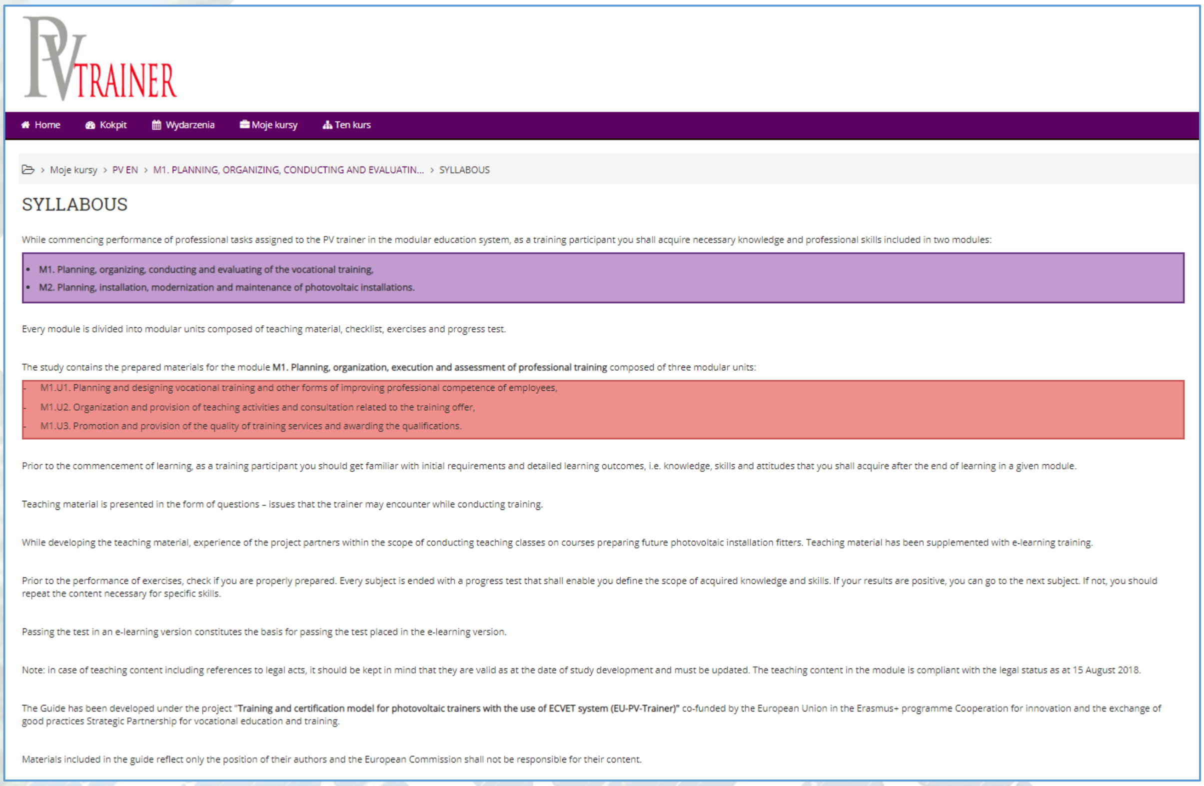


Fig. 10. Exemplary syllabus content

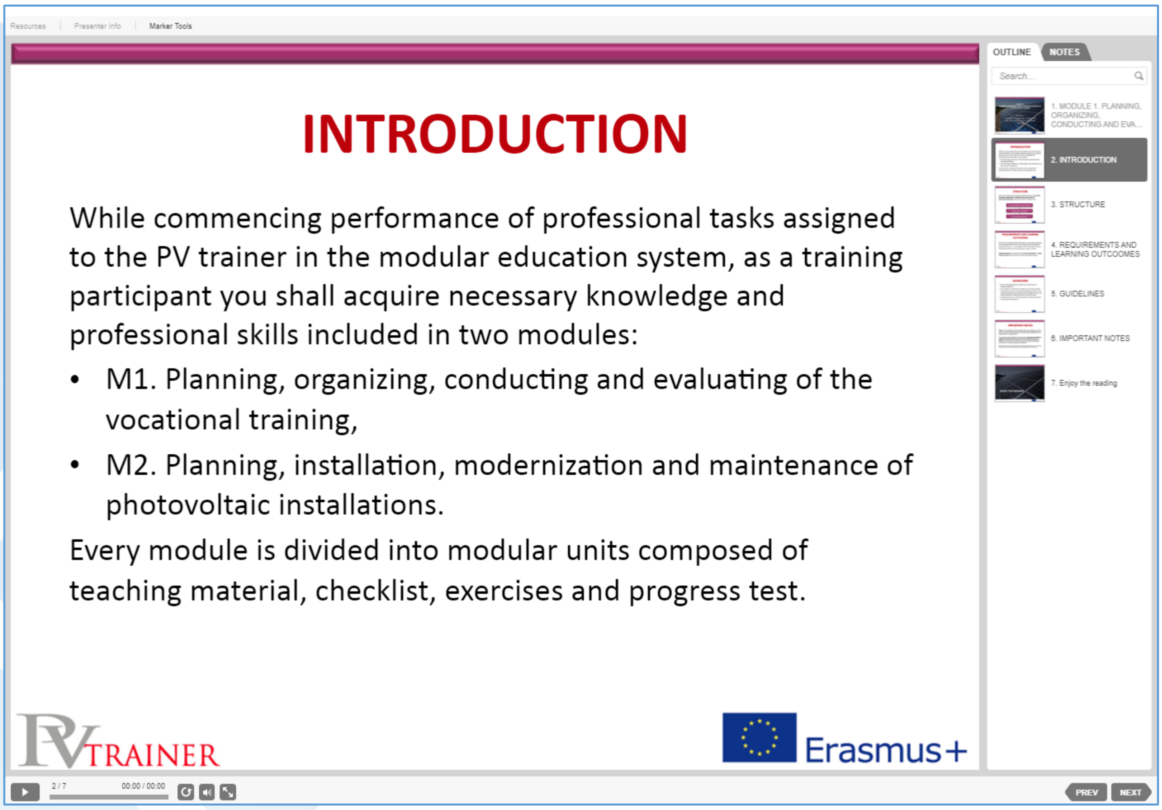


Fig. 11. Introduction to training

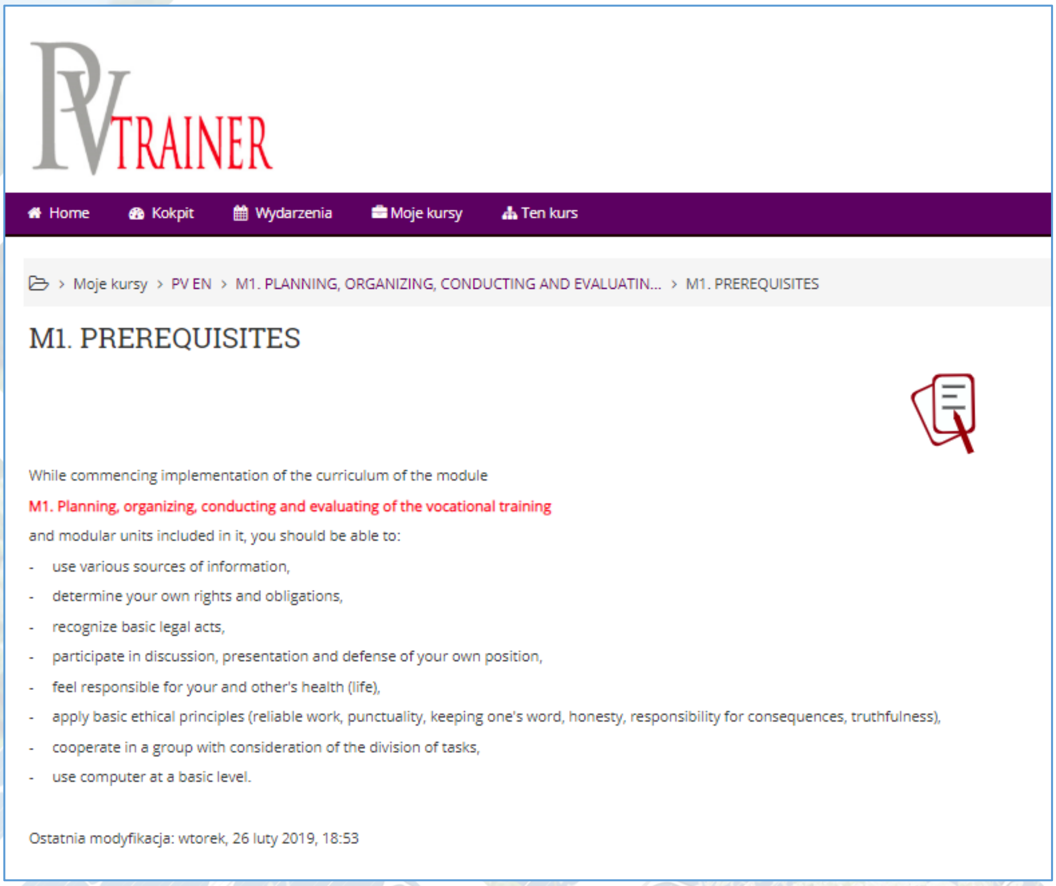
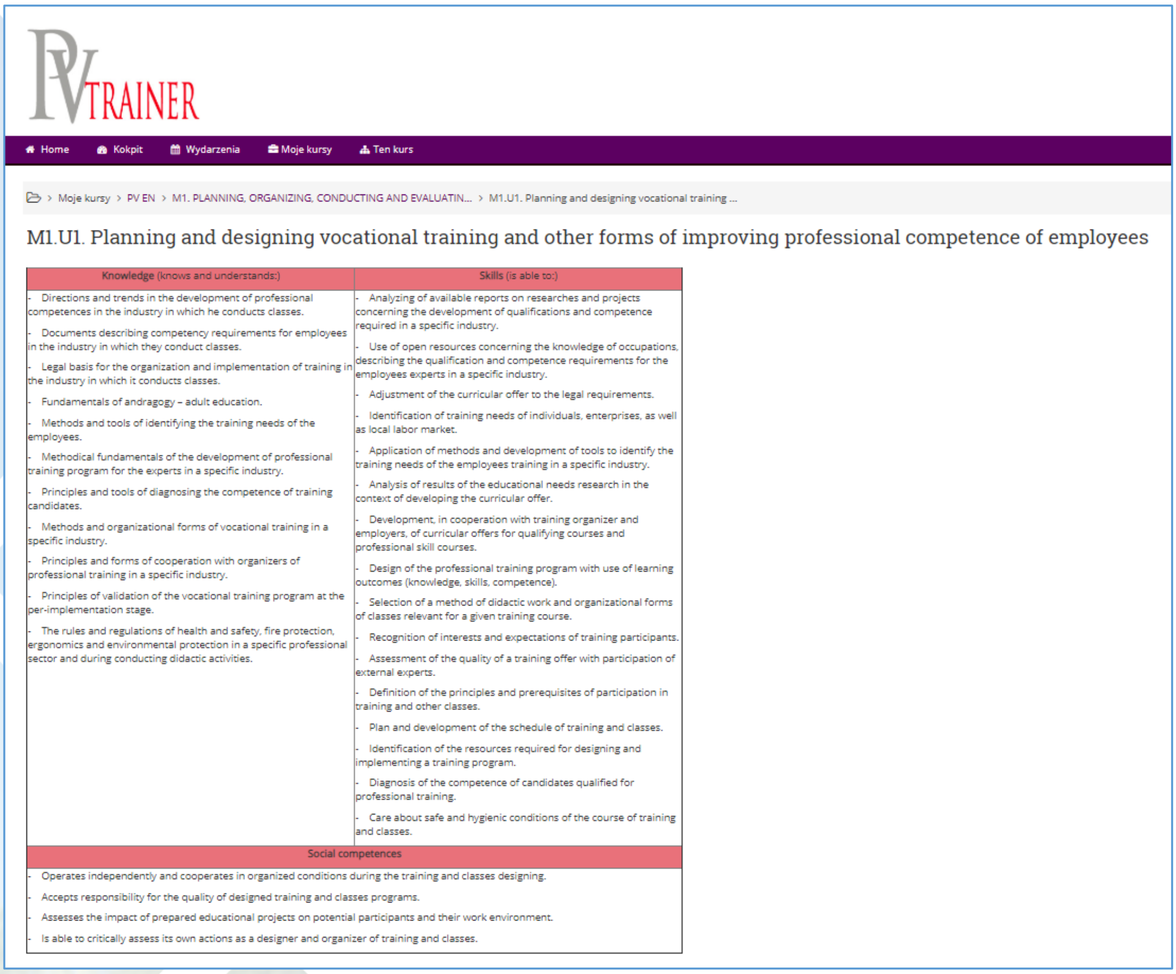


Fig. 12. Example of initial requirements for the module 1



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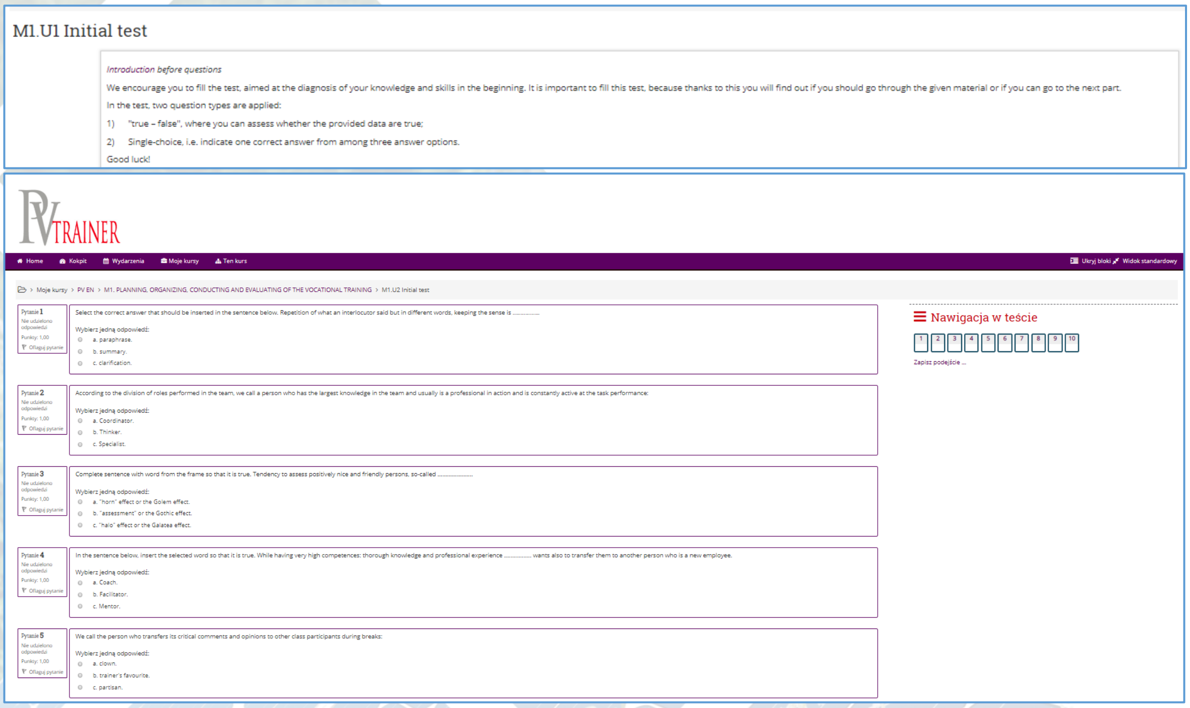
M1.U1. Planning and designing vocational training and other forms of improving professional competence of employees

Knowledge (knows and understands:)	Skills (is able to:)
- Directions and trends in the development of professional competences in the industry in which he conducts classes. - Documents describing competency requirements for employees in the industry in which they conduct classes. - Legal basis for the organization and implementation of training in the industry in which it conducts classes. - Fundamentals of andragogy – adult education. - Methods and tools of identifying the training needs of the employees. - Methodical fundamentals of the development of professional training program for the experts in a specific industry. - Principles and tools of diagnosing the competence of training candidates. - Methods and organizational forms of vocational training in a specific industry. - Principles and forms of cooperation with organizers of professional training in a specific industry. - Principles of validation of the vocational training program at the per-implementation stage. - The rules and regulations of health and safety, fire protection, ergonomics and environmental protection in a specific professional sector and during conducting didactic activities.	- Analyzing of available reports on researches and projects concerning the development of qualifications and competence required in a specific industry. - Use of open resources concerning the knowledge of occupations, describing the qualification and competence requirements for the employees experts in a specific industry. - Adjustment of the curricular offer to the legal requirements. - Identification of training needs of individuals, enterprises, as well as local labor market. - Application of methods and development of tools to identify the training needs of the employees training in a specific industry. - Analysis of results of the educational needs research in the context of developing the curricular offer. - Development, in cooperation with training organizer and employers, of curricular offers for qualifying courses and professional skill courses. - Design of the professional training program with use of learning outcomes (knowledge, skills, competence). - Selection of a method of didactic work and organizational forms of classes relevant for a given training course. - Recognition of interests and expectations of training participants. - Assessment of the quality of a training offer with participation of external experts. - Definition of the principles and prerequisites of participation in training and other classes. - Plan and development of the schedule of training and classes. - Identification of the resources required for designing and implementing a training program. - Diagnosis of the competence of candidates qualified for professional training. - Care about safe and hygienic conditions of the course of training and classes.
Social competences	
- Operates independently and cooperates in organized conditions during the training and classes designing. - Accepts responsibility for the quality of designed training and classes programs. - Assesses the impact of prepared educational projects on potential participants and their work environment. - Is able to critically assess its own actions as a designer and organizer of training and classes.	

Fig. 13. Detailed learning outcomes for the modular unit M1.U1



M1.U1 Initial test

Introduction before questions

We encourage you to fill the test, aimed at the diagnosis of your knowledge and skills in the beginning. It is important to fill this test, because thanks to this you will find out if you should go through the given material or if you can go to the next part.

In the test, two question types are applied:

1) "true – false", where you can assess whether the provided data are true;

2) Single-choice, i.e. indicate one correct answer from among three answer options.

Good luck!

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Pytanie 1 — Nie udzielono odpowiedzi — Punkty: 1,00 — Oflaguj pytanie

Select the correct answer that should be inserted in the sentence below. Repetition of what an interlocutor said but in different words, keeping the sense is ....

Wybierz jedną odpowiedź:
- a. paraphrase.
- b. summary.
- c. clarification.

Pytanie 2 — Nie udzielono odpowiedzi — Punkty: 1,00 — Oflaguj pytanie

According to the division of roles performed in the team, we call a person who has the largest knowledge in the team and usually is a professional in action and is constantly active at the task performance:

Wybierz jedną odpowiedź:
- a. Coordinator.
- b. Thinker.
- c. Specialist.

Pytanie 3 — Nie udzielono odpowiedzi — Punkty: 1,00 — Oflaguj pytanie

Complete sentence with word from the frame so that it is true. Tendency to assess positively nice and friendly persons, so-called ....

Wybierz jedną odpowiedź:
- a. "horn" effect or the Golem effect.
- b. "assessment" or the Gothic effect.
- c. "halo" effect or the Galatea effect.

Pytanie 4 — Nie udzielono odpowiedzi — Punkty: 1,00 — Oflaguj pytanie

In the sentence below, insert the selected word so that it is true. While having very high competences: thorough knowledge and professional experience .... wants also to transfer them to another person who is a new employee.

Wybierz jedną odpowiedź:
- a. Coach.
- b. Facilitator.
- c. Mentor.

Pytanie 5 — Nie udzielono odpowiedzi — Punkty: 1,00 — Oflaguj pytanie

We call the person who transfers its critical comments and opinions to other class participants during breaks:

Wybierz jedną odpowiedź:
- a. clown.
- b. trainer's favourite.
- c. partisan.

Nawigacja w teście

Fig. 14. Introductory test for the modular unit M1.U1

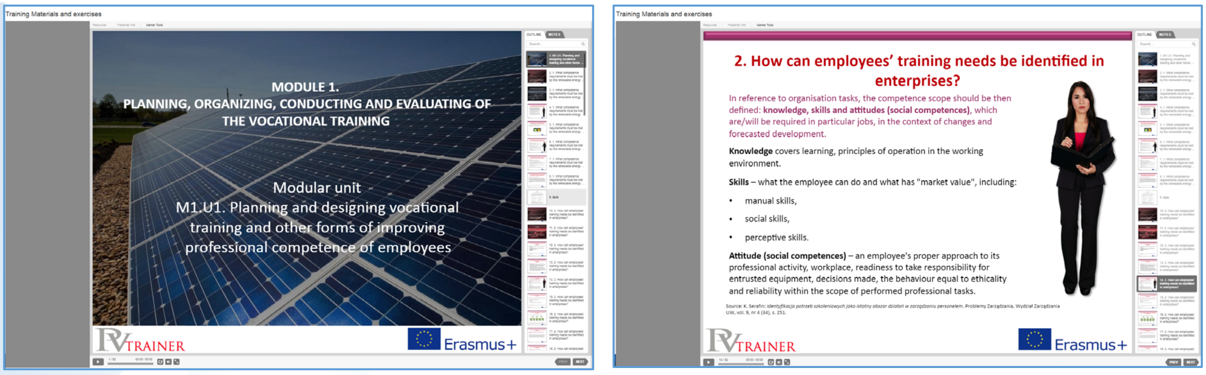

Fig. 15. Example of presentation from training materials under the modular unit M1.U1

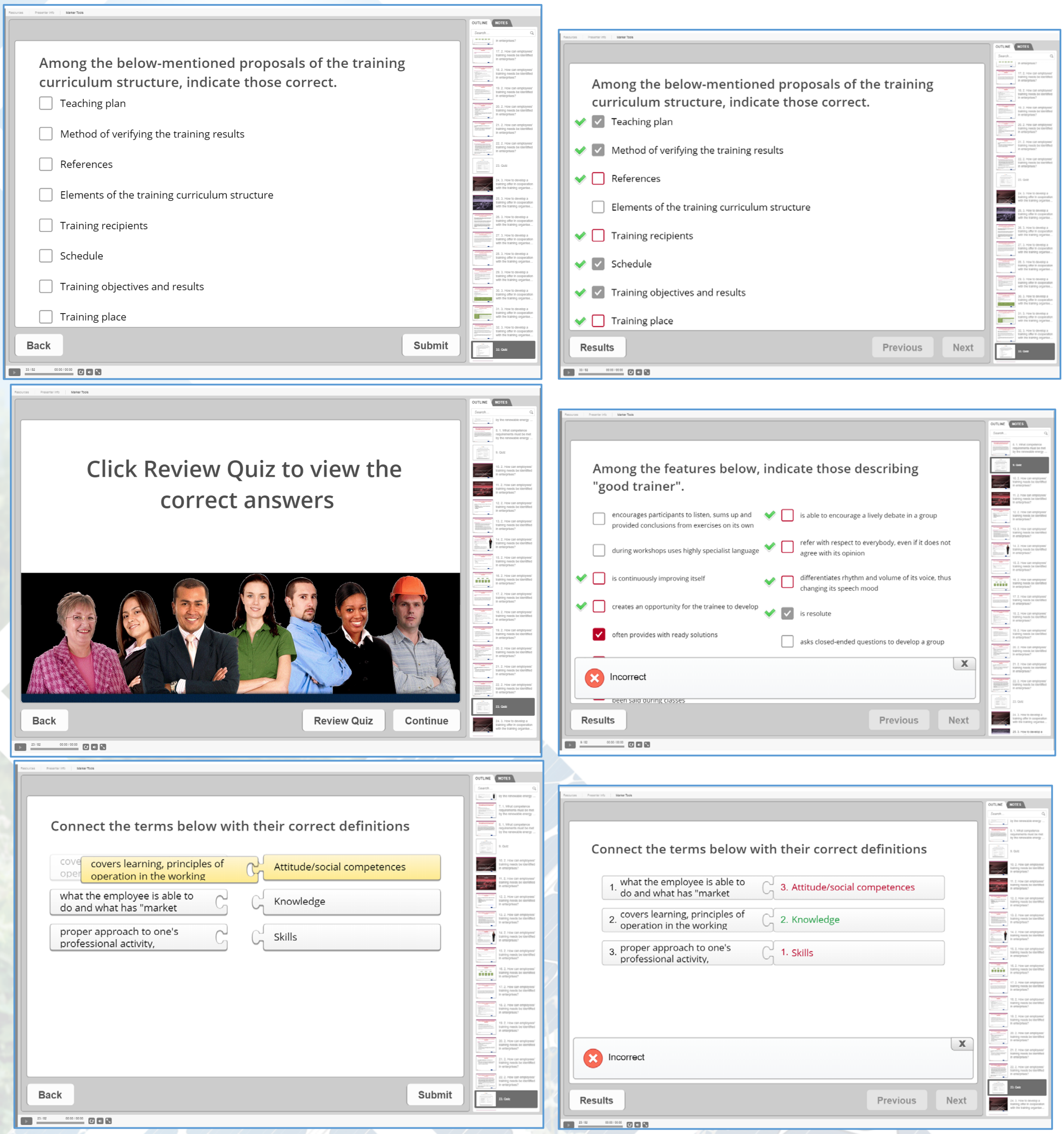

Fig. 16. Examples of exercises for the unit M1.U1

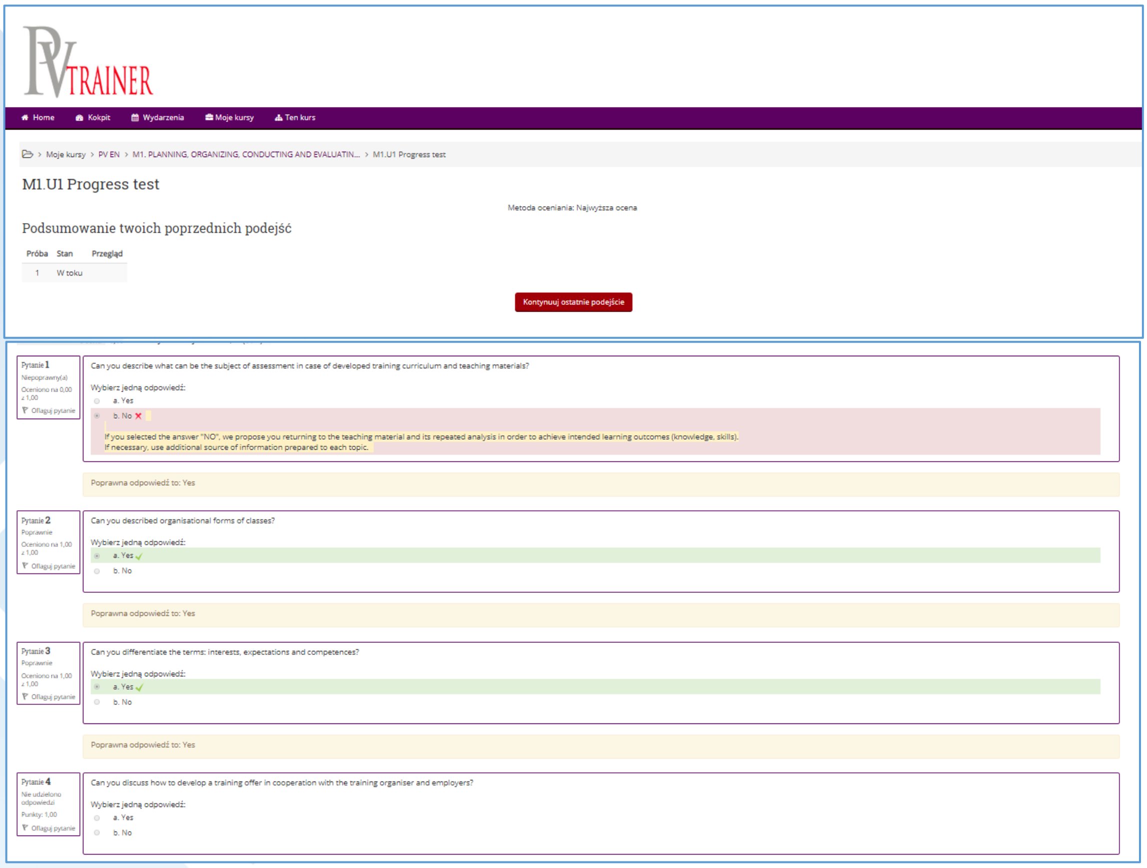

Fig. 17. Examples of progress test for the unit M1.U1

Fig. 18. Example of instructional video

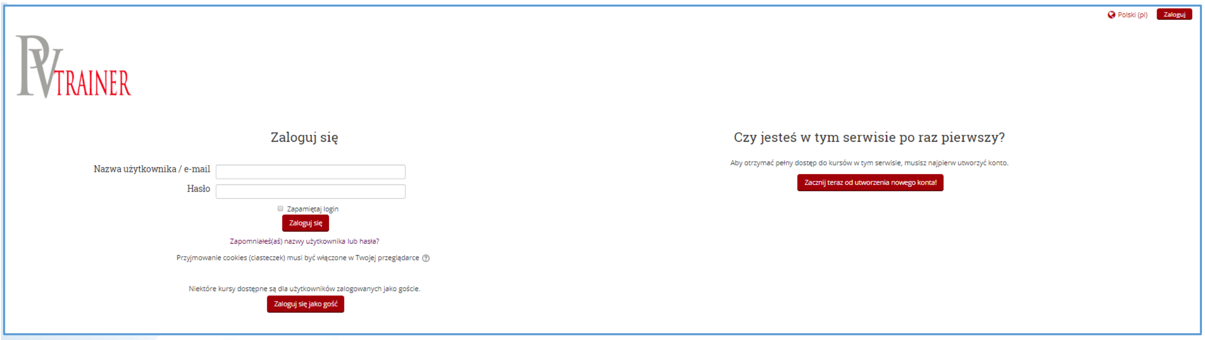

Fig. 19. Website to log on the course

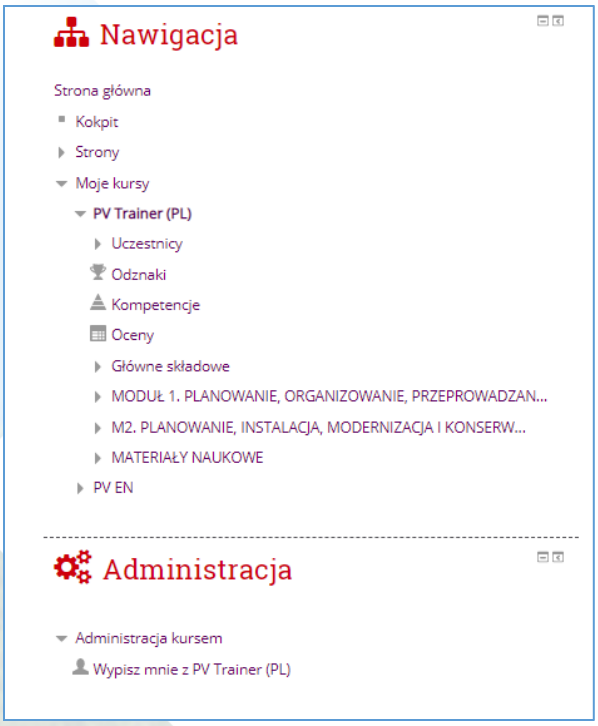

Fig. 20. Navigation menu

9. IO.6. Bank of tests in the form of IT tool to check the level of professional competences for the photovoltaic trainer

As part of the task, the following tasks were developed:

1) Common methodology for creating a test bank (in English).

   The following methodological assumptions covered:

   – bank of tests for checking the level of photovoltaics trainer's professional competences is a tool which was used to assess the level of acquired knowledge, skills and social competence of the tested persons in various areas resulting from the requirements of the standard of professional competences as the result of IO2;

   – the components of the tests bank are the following: a list of tests with their short descriptions, sets of tasks/questions (including the scale of assessment), method (algorithm) of calculation of the final assessment score, and table linking the test results with the relevant training modules and learning outcomes;

- the tests bank will comprise an element of ICT tool that supports the selection of appropriate training modules (individual learning path) at the stage of the candidates' recruitment for training, monitoring of trainees' professional competences
- development, as well as the process of confirming competences (acquired in non-formal and informal learning) and their documentation in the form of certificates;
- development of tests will be carried out in line with the preparation of training modules (as the results of IO 4), particularly during: determining the substantive scope of each test and the calculation method of the final grade which must be coherent with ECVET points.

To the development of the output, it was used the methodology of: desk research, the experts' panel. Several trainings were analysed for the tools used to verify the level of knowledge and skills of online training participants. External experts in the field of teaching and experience in the design of tools for verifying knowledge and skills, have established that:

- a set of questions verifying both knowledge and skills will be developed for each modular unit. According to Bloom's taxonomy, knowledge consists of information that is used to perform specific tasks and perform a specific function at a workplace. The skills consist of observable, measurable competences to perform specific activities. Therefore, it was assumed that knowledge will be verified through questions focusing on the ability to remember and recall concepts, facts, terminology, procedures, methods and models, or the ability to explain and interpret the meaning of concepts, compare and infer on the basis of remembered information. However, skills will relate to the use of information, their application to solve known problems, by choosing a solution, e.g. from a closed list. In the case of verification of skills in control questions, attention will be paid to the analysis process, which requires the ability to recognize components, as well as connections and relationships between elements of some structure, which leads to inference and problem solving by providing your own answer from the list.
- It has been assumed that for each modular unit, due to its complexity, 15 to 25 questions will be developed. In the process of verifying the participant's knowledge and skills at the entrance (before starting the modular unit) and after completing the modular unit, the participant will answer 10 randomly selected questions about

a given modular unit. Due to this approach, several participants simultaneously performing a test from a given modular unit will not be able to communicate with each other. This approach also means that by joining the test for the second time, the participant
receives different sets of control questions.

- The test uses single-choice and "true" and "false" questions.
- It has been assumed that each test will be preceded by instructions in which the training participant will be informed how to complete the test.
- After finishing of the test, 2 variants of feedback will be developed. The first, will inform about passing the test, while the second will inform about the lack of passing and encourage the participant to get acquainted with the given training unit (entrance test) or to re-review the training materials or materials from other sources.
- It is possible for the participant to complete the test several times. It will be recognized that the self-assessment of learning outcomes acquired in the learning process and the results of the test in conjunction with the responsibility associated with conducting teaching in the future in the field of assembly of PV installations should be a sufficient argument that the participant will not deceive himself, that he has acquired the necessary competences in in this respect.
- Obtaining 8 or more correct answers out of 10 questions, in the case of performing the test before starting the modular unit – passing the modular unit, and thus exemption from the obligation to learn. Aside from this, it was decided in the partnership that a message would also appear to encourage training within the given modular unit. After completing the education within a given training unit – 8 and more correct answers to 10 questions is the basis for passing it and allows you to continue learning in the frames of the next modular unit. Completing all tests for 6 modular units distinguished in the training program results in the issue of a PV trainer training completion certificate, which is a pass to be issued by the institution recommended under the project environmental certificate confirming the acquisition of PV trainer qualifications.

2) A set of tests verifying the level of professional competence of photovoltaic trainer in individual modular units (in English).
It is initially envisaged that the tests bank will contain approximately 6 tests consisting of about 15-24 questions/tasks each. The first version of the test will be developed in a paper version. The authors will be the same experts who are to develop individual

modules and modular units.

A set of tests in the paper version will be reviewed by two external experts who also will review the educational packages for the lecturer and trainee. One of the experts evaluated 3 sets of questions in the field of photovoltaic packages, and the other – 3 sets of questions in the field of pedagogical competence. Comments submitted by experts will be taken into account in the process of improving the developed tests and concerned, among others answer key (wrong answers have been inserted in 4 questions) and adding a few to verify learning outcomes omitted in the reviewed sets and included in the educational packages for individual modular units. Experts highly rated the quality of the developed sets of questions and found them quite difficult, which was also justified by the fact that the participants of the training are people who are to teach others how to perform PV installations.

3) On-line tool for testing enabling the selection of training units (in English).

   An ICT tool and the electronic version of the tests will be developed. The tests in the electronic form will be a part of the e-learning platform as one of the components of the distance learning course.

   The main objectives of the ICT tool are the following: to automate the selection process of training modules, to monitor the competences development (study of the effectiveness of training) and to support the certification process at the end of the training cycle.

   The target users of this tool will be mainly photovoltaic trainers (but also: job seekers, or persons planning to change jobs, HR staff intending to set and measure the professional development of the personnel) who want to improve their competences within the scope of conducting of theoretical and practical photovoltaic training. The ITC tool will be an open source. Due to this tool, any user may receive the results of the tests juxtaposed with the model results that define the required level of competences or with the results of previous tests taken. In the first case, the user obtains access to modules which are to be learnt in order to cover the identified competences gaps. In the second – a report documents the competences development (progress) in relation to the archived data, or it is the document which entitles to receive a certificate confirming professional competences.

4) An improved bank of tests – final version (In English and in national languages of the partner countries)

   The English language version of the tests will be the subject to assessment in the

Multiplier Events which will contribute to their improvement.

The final version of the tests will be translated into national languages of the partner countries. It will be a contribution to the professional development of VET and the development of an European area of skills and qualifications, validation of learning outcomes acquired in non-formal and informal learning, as well as comparability of learning outcomes (ECVET).

Translated tests were transformed into e-learning platform.

The study in the following chapters presents the language version of test sets for individual modular units along with an answer key and instructions.

Bank of tests in the form of IT tool to check the level of professional competences for the photovoltaic trainer cannot be published in the database with examples of good practice, as it contains tests verifying the level of competence of training participants before and after completing learning within a given modular unit together with an answer key.

Fig. 21. Cover and table of contents of the test bank

10. IO.7. Development of community certification model for the photovoltaic trainer with regard to the requirements of EN ISO 17024

Output 7 includes the following interim results:

1) **Methodology of research (in English)**

Development of a common methodology was one of the activities undertaken in the project to facilitate the recognition and certification of knowledge, skills and competences acquired through formal, non-formal and informal learning and also to increase transparency of qualifications and diplomas in the RES sector in EU.

Validation and certification were based on concrete competence requirements, which serve as clearly defined and agreed reference points (Cedefop, 2009) for building curricula for trainers and for assessing the competences gained at work. The requirements were stated in various documents: (a) occupational standards, describing the profile of a person providing training; (b) qualification standards, describing the learning outcomes (knowledge, skills and competences) that everyone with a trainer's qualification is expected to possess.

Within the EU-PV-Trainer project, the partnerships tried to develop the models/systems of validation and certification of PV trainers' competences in the photovoltaic sector.

The methodology focused on the procedures for community certification (by leading industry organizations) of the competences of personnel based on the requirements of the ISO/IEC 17024 standard which was designed to harmonize the personnel certification process worldwide.

2) **Research report on certification and validation systems of photovoltaic trainer competences in the partner countries (in English)**

The report presents the outcomes of comparative studies of national policies and practices on recognition, validation and certification of non-formal and informal learning, regarding the models of certification and validation systems/ models for VET trainers in the photovoltaic sector in all partners' countries. The opportunities created for PV trainers in the photovoltaic sector, including the possibilities of certification of the competences and qualifications' are presented.

3) **Community certification model for the photovoltaic trainer**

An objective of international research in the partner countries (Poland, Spain, Romania, Cyprus) was constituted by the analysis of intentionally selected documents describing, among others, validation and certification processes for competences of selected experts, conducted by institutions meeting the requirements of ISO/IEC 17024:2012 with regard to the capacity of their use for validation and certification of the PV trainer's competences.

On the basis of the national reports, a common certification and validation system(s)/ model(s) for PV trainers in the photovoltaic sector was developed within the partnership.

It was a reference point for the description of the validation and certification procedures according to the requirements for "Conformity assessment; general requirements for bodies operating certification of persons" ISO/IEC 17024:2012.

4) **Recommendations for national organisations/authorities responsible for the area of photovoltaics in the EU partner countries (in English and the national languages of the partner countries)**

   Under the direction of PV Poland, the partnership has developed common recommendations on community certification and validation of the photovoltaic trainer's competences. The recommendations were presented to European and national organizations working for the development of renewable energy sources, in particular relating to the institutions, employers and professionals in the area of photovoltaics. The aim of the action is to promote community certification of photovoltaic trainers as well as the results developed in the project (modular training programme, educational packages, tests, e-learning course). The recommendations may contribute to the harmonization of qualification requirements for the PV Trainer and improve the recognition and validation processes of competences, including those acquired through non-formal and informal learning.

Specific objectives

1. Analysis of the requirements of EN ISO 17024 Conformity assessment – General requirements for bodies operating certification of persons (ISO/IEC 17024:2012) with regard to the indication of elements that, according to the partnership, may be applied for the validation and certification processes for the PV trainer's competences.
2. Comparative analysis of exemplary certification processes for persons in accredited institutions meeting the requirements of ISO/IEC 17024:2012.
3. Establishment of a model (exemplary) validation and certification procedure for the PV trainer's competences based on the conducted comparative analysis.
4. Development of an exemplary documentation for the purposes of an institution interested in the PV trainers' certification management in the partner countries.
5. Development of recommendations for national organisations/authorities responsible for the area of photovoltaics in the EU partner countries (in English and the national languages of the partner countries).

Research methods, techniques and tools

1. The main research method was the analysis of documents describing validation and certification processes for competences of selected experts, conducted by institutions meeting the requirements of ISO/IEC 17024:2012.

2. A complementary method was constituted by an unstructured in-depth interview, aimed at the supplement and explanation of collected information. The interview was conducted mainly by phone with employees of certifying institutions and institutions having an implemented management system compliant with the requirements of ISO/IEC 17024:2012.

   During the interview, notes were taken, while data collected from the analysis of documents and the interview were applied to develop data for the table presented in section 2.
3. Also a focus group method was applied under the partnership, allowing to develop common solutions.

Research organisation and area

The research was conducted in the project's partner countries: Poland, Spain, Romania and Cyprus, in the first and second quarter of 2019, with participation of the partner institutions' experts.

Every partner prepared data for a comparative analysis and then provided them to the action leader – PV Poland.

Particular national data were analysed with regard to similarities and differences in validation and certification processes for the personnel competences, as well as they were applied to develop a common model of validation and certification of the PV trainer's competences.

Conclusions from the conducted comparative analysis:

1) Application of the standard EN ISO 17024 Conformity assessment – General requirements for bodies operating certification of persons (ISO/IEC 17024:2012) allowed for the development of a consolidated procedure of validation (examination) and certificate issuance, but it should consider specific requirements, in particular, of the partner countries.
2) The certification process complying with the requirements of EN ISO 17024 Conformity assessment – General requirements for bodies operating certification of persons (ISO/IEC 17024:2012) was described through the Programme for verification of personnel qualifications and certification, including references to specimens of documents applied in the certification process.
3) The personnel certification process covered two stages: examination, i.e. according to the terminology adopted in the European Qualifications Framework, validation of acquired competences and the certificate issuance procedure.

4) The examination process was usually conducted traditionally. It took place before the examination commission appointed specially for this purpose and is composed of two stages: theoretical part and practical verification of acquired competences. No other evidence confirming acquired competences of a person applying for the certificate was allowed, which did not correspond with modern trends of confirmation of competences acquired in various ways and based on various evidence.

Recommendations formed under the partnership based on the conducted comparative analysis

1) It is recommended to adopt the process approach complying with the standard requirements for development of a community certification model for photovoltaic trainer.
2) Within the framework of the PV trainer's certification model, it is recommended to develop an exemplary programme for verification of the PV trainer's qualifications and certification, together with exemplary appendices, e.g.:
   - Specimen of an application for verification of qualifications (validation)/certification;
   - Specimen of an application for certification and recertification;
   - Certificate specimen.
3) The validation process should consider other methods of confirmation of acquired competences, apart from the traditional examination system.


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Strategic Partnership for vocational education and training

"Training and certification model for photovoltaic trainers with the use of ECVET system (EU-PV-Trainer)"
No 2016-1-PL01-KA202-026279

Intellectual output O7.
Development of community certification model for the photovoltaic trainer with regard to the requirements of EN ISO 17024

Compilation of the team:
Instytut Technologii Eksploatacji – PIB (Poland)
Association of Polish Electricians Branch in Radom (Poland)
PV Poland (Poland)
Universitatea Dunarea de Jos Din Galati (Romania)
EDITC LTD (Cyprus)
Fundación Equipo Humano (Spain)

2019

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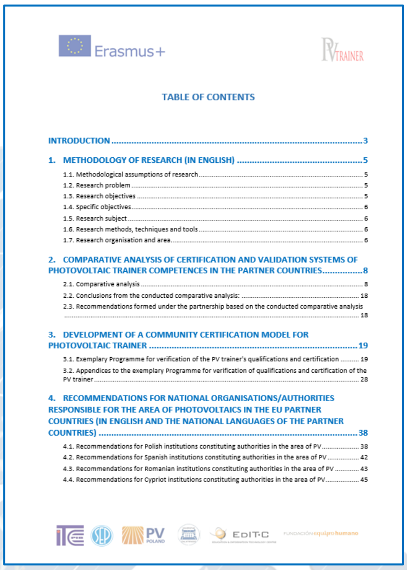
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Fig. 22. Cover and table of contents of the study concerning a model of certification for the PV trainer with consideration of requirements of the standard EN ISO 17024

Summary

The PV Trainer EU project supports the accomplishment of targets included, among others, in the Strategy Europe 2020, Education and Training 2020, Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, which imposes on the EU member states an obligation of reaching by 2020 the level of 20% renewable energy use. The need for the project completion has also been confirmed by results of the initial diagnosis conducted in countries – project partners, showing that a demand for highly qualified PV trainers will increase, while the level of preparation of current trainers is diverse. Additionally, it was recommended to develop the PV trainer certification model.

Aiming at the improved quality of education and training of future PV fitters through the alignment and improvement of quality of professional background of PV, tools recommended by the EU should be considered, in particular EQF, NQF, ECVET, EQAVET and specificity of partner countries.

We assess the project and products developed due to its completion as corresponding to the subject and targets of the Erasmus+ Programme – development of new innovative curricula/educational methods/development of training and improvement of recognition, transparency, certification and promotion of open and distance learning.

Six institutions (one university, one research institute, three institutions-associations for exercises, one training institution) from four EU countries will participate in the project. In our opinion, partnership selected in such a way is complementary and shall contribute to effective project completion and high quality of its outcomes.

Products developed in the project may contribute to the modernisation and improvement of education and training systems for PV trainers, and indirectly may contribute to:

– achievement of a higher quality of education, training and work of PV trainers;
– better adjustment of the education/professional improvement systems for PV trainers for the needs of the labour market;
– more effective assessment of skills of PV trainers, including knowledge of foreign languages;
– increase in synergy and improved transfer among various education and training systems at the national level, as well as dissemination and better use of European tools supporting the recognition of qualifications, certificates and transparency of competences and qualifications (ECVET, validation of non-formal and informal competences);
– popularisation of creating curricula based on the identified competence-related requirements for PV trainers through research in real working environment and

presentation of their results in the form of description/standard of professional competences;
- establishment and strengthening at the international and national level of cooperation for the benefit of improved quality of professional preparation of PV trainers among various types of partner institutions (from research institutes to training institutions);
- promotion of the use of ICT and open educational resources in professional improvement of specialists already functioning on the labour market.

In our opinion, potential long-term project benefits related, among others, to the internationalisation of the project outcomes shall contribute to the development and improvement of vocational education and training directly for PV trainers, thus also PV installation fitters. The project internationalisation shall also contribute to an increased mobility and employability of PV trainers.

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Emilia PECHEANU, Adina COCU, Ioan ȘUȘNEA, Luminița DUMITRIU
Department of Computing, University "Dunarea de Jos" of Galati (Romania)

Building professional competence standards for vocational training

Introduction

Professional competence standards are the cornerstones of any national or sectoral qualification system or framework. This paper aims to describe the various paradigms that can be adopted when creating a professional competence standard. The two most common existing methods in development of competence standards are investigate, as well their conceptual basis and rationale, advantages and drawbacks.

The Romanian solution for competence standards' structure and content is further presented, as an example of a mixed approach in strategy of building norms for a professional qualification system. The PV-Trainer project approaches' in development of a competence standard is pointed out with their possible impact in building effective qualification programs for vocational education.

1. Qualification systems and competence standards

A qualification system consists of descriptions of requirements to be met by a person carry out successfully the work related to a specific occupation, profession or job. The requirements may include the level of education, physical standards, security regulations, necessary

work-experience or licensure, as well as the skills, knowledge, abilities, a person needs to possess in order to exercise a certain profession. To be valid, requirements in a qualification system must be job related.

The core component of any qualification system is the collection of statements referring to the knowledge, skills and abilities an individual should possess in order to exercise a profession.

These components are called "competence standards" of the qualification system and they represent the substantive part of the qualification system.

The national qualification systems/frameworks can have common points but also can vary widely, depending on what agency or institution has authority to establish the qualification specifications and practice settings. The differences are usually noticeable in the regulations that refer to working context or conditions of a profession, while the common elements occur in descriptions of knowledge, skills and abilities necessary to perform a certain profession, therefore in the so-called "competence standards" that are part of these systems.

The competence standards from various qualification systems typically have the majority of their common points at elementary level, and sometimes differ in their overall structure or model.

In this sense, studies on different European countries' qualification systems and frameworks pointed out two major structural models. Many European countries possess so-called "competency-based standards", that include detailed statements of the knowledge, skills, competence and performance measures required for any job on the labour market. Other countries adopted a national qualification framework and a comprehensive system of sectoral "competence-based standards".

The area of focus of the competency-based standards is the definition the personal attributes (as knowledge, skills, mindsets, thought patterns) leading an individual to perform successfully at work.

Behaviours that lie behind a successful professional performance, such as the capacity to work in team, the leadership skills, the critical thinking or other soft skills can be taken into consideration in a competency model. Competency models are used in a variety of ways by companies: to build training, evaluation and assessment programs or in hiring people [25].

The competence-based standards are focusing the definition of "measurable, objective milestones describing what a person has to accomplish" in order to achieve a certain job-specific goals. Competence modelling is searching answers to questions as: "what does a person have to do when working in this job?" or "what a person has to do to meet the work goals specific to this job?"

Correct and complete answers to the questions lead to the "skills, knowledge, and key tasks and behaviours to support competence" in that job [25]. Thus, competence modelling is meant to draw "a framework that defines the process used to generate the required results in a job, and the related tasks, and best practices" to achieve the work goals of that job [25].

Both approaches in modelling competence standards are closely related to the meaning of the two terms involved, competency and competence. While the term competency is focusing on the personal attributes and behaviours of an individual to successfully perform in a job, competence refers to demonstrable, worthy performance at work, where "performance" is considered the most efficient way to accomplish that work's goals.

Table 1. Competency versus Competence models – after [25]

What is a competency model?	What is a competence model?
A list of statements describing knowledge, skills, critical behaviours and attributes a person needs to possess for working in a certain job.	**A definition of the processes, tasks, work-results, and goals to consistently achieve by a person having a specific role or a certain job in an organization.**
Knowledge, skills, behaviours and aptitudes are divided into categories and ranked in order of their importance: job-specific knowledge, interpersonal skills, management skills.	**Best practices, critical skills and knowledge are mapped to the results required to achieve the tasks in a job. Supports to competence levels as well as obstacles blocking competence are described.**
Can be easily linked to training programs and assessment processes.	*Links tools and resources to the definition of competence in a job that enable people to produce the required results*

Many authors consider that a competence modelling (the description of the job) should precede and support the design of a competency model, i.e. the framework that describes skills, knowledge, attributes, and behaviours one person should possess in order to perform in a job. Competency and competencies are individual qualities allowing effective performance in practicing a work. Thus, competency supports competence and without competency there is no competence [22].

2. Competency-based versus competence standards

A competency-based standard is a list of "competency statements" in which are described the personal attributes of an individual should possess (in term of knowledge, skills, critical behaviours and aptitudes) in order to practice successfully a certain job. A competency-based standard is usually a construction derived from competency-frameworks, which are unified descriptions of jobs requirements and methods to assess their fulfilment by individuals. Most of these standards are created by acquiring knowledge based on task analysis (TA), functional analysis (FA) or a combination of the two previous methods.

Task analysis (TA) is the traditional approach in skill development and in vocational education and training. It focuses on the activity itself and not the result or outcome of the activity.
The task-based analysis involves identifying in detail the components of work activity, – usually in order to time and monitor performance, and also to structure training programmes.
Although this approach is still widely used, task analysis fails to capture some essential and broader aspects of competence: it does not take into account the essential planning, problem solving and communication skills that are components of a competent performance [22].

Functional analysis (FA) is activity-based rather than task or job-based. Functional analysis is an analytical approach by which a certain activity in an economic sector is defined and described.
Several factors are taken into account in their definition: the technical, strategic, creative and managerial aspects, as well as underlying values such as professional ethics and respect for diversity and equal opportunities. Functional analysis focuses on the "why?" rather than the "how?", thus allowing to link different activities in the domain of work by their common purpose.
Through the process of functional analysis, the "key fields" or "units of competence" of the domain or sector are established within a "functional map", – a representation of the professional sector describing the results of activities from organizational to individual level.
The unit of competence is the basic component of a competency-based system, and it describes a full activity carried out by an individual that can be assessed. Each unit of competence can then be divided into a number of "elements of competence", each one containing performance criteria and the underpinning knowledge and understanding required for an adequate performance.
Individual units or elements of competence may also contain information about the professional context in which the performance must be demonstrated and the performance criteria [22].

One advantage of functional analysis is development of cultural or work environment independent competency-based systems, by making explicit the best practices underlying values and ethics in occupational sectors. Other advantage of a functional analysis is the possibility to combine sector specific with "transversal" competencies. The transversal competencies, known as "key skills or competencies" have taken on a high role in the European education scene. As a result, the EU has produced a well-known framework for key-competencies that comprise eight domains of key competences considered necessary for all in the modern knowledge society.

By the other hand, studies [22] on educational frameworks found that competency systems have specific features in different countries and contexts. Competency-based systems can also contain levels, accordingly to the degree of complexity of the activity or task and such factors as responsibility for the work. Many competency-based systems have been converted afterwards into standards for sectoral or national qualification systems. A competency system becomes a standard when it clearly states the outcomes a person in particular work role are expected to achieve and indicates how these are to be measured (formal assessment) [22].

The analysis of competency-based standards can highlight characteristics of the complementary category, the competence standards. Competence standards describe the requirements to practice a profession in a certain domain, expressed as statements of what an individual should know and understand, is able to do in the professional context (his/her skills) and/or in the organizational context (his/her social abilities).

While any description of a competency-based standard should start from its connection to jobs or tasks' specific activities, competence standards can be analyzed and studied starting from the concept of competence and its meanings in professional context. Competence is a concept with many facets which is employed in work outcomes-based approaches as a reference to demonstrable performances of individuals related to specific professional activities.[24].

Research studies [14] underline the three components of the competence concept: (a) knowledge, – meaning "to have information, or to have experience of some subject area"; (b) skills, meaning "ability to use knowledge effectively"; and(c) attitude, considered to be a "mental or emotional approach to something or to someone". The competence concept and its components can be represented through a Venn diagram borrowed from the Set Theory (Figure 1).

The concept of competence has been approached in many international projects on educational and professional qualification fields as DeSeCo [13], TRACE [22] and Tuning [29] projects.

The DeSeCo (Definition and Selection of Competences) project established three broad categories of competences (Figure 2): use tools interactively, interact in heterogeneous and act autonomously, concluding that "there is no single concept of competence" [13].

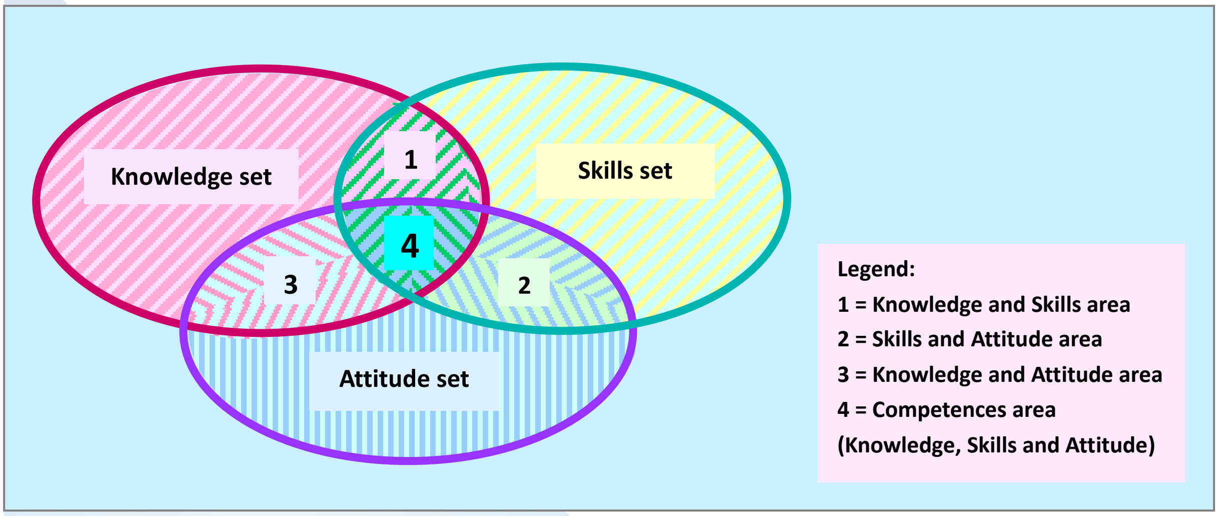

Fig. 1. Components of competences in a structured view [14]

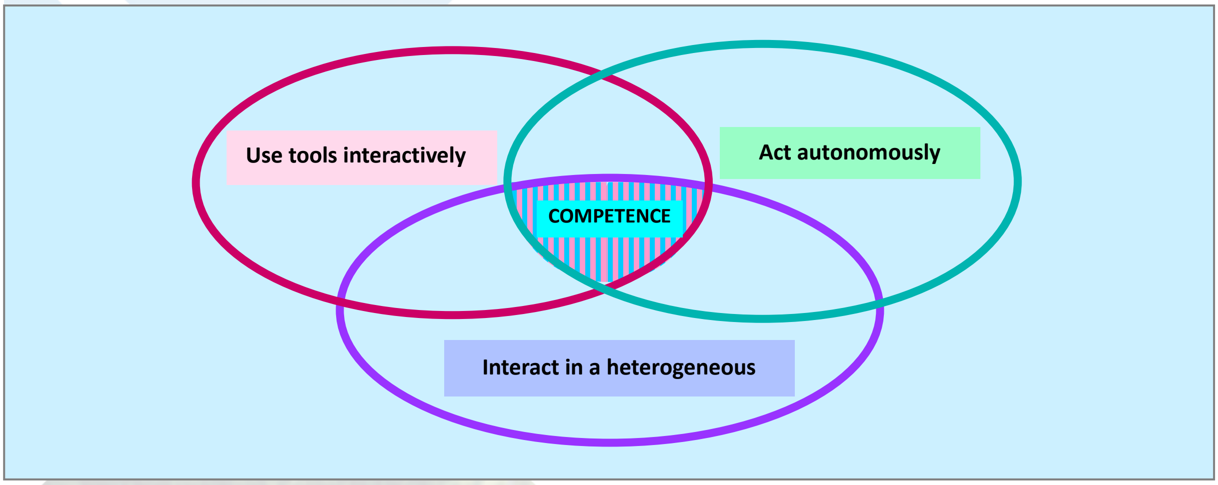

Fig. 2. Key competences established in the DeSeCo project

In TRACE project [22] gave a more holistic, integrative definition to the competence concept. It would include cognitive competence, (use of theory and informal tacit knowledge gained experientially), functional competence (skills or know-how), personal competence (knowing how to conduct oneself in a specific situation), and ethical competence (possession of certain personal and professional values). In TRACE project "competences are a job related descriptions of actions/behaviours/results that should be demonstrated by an individual in practicing that job.

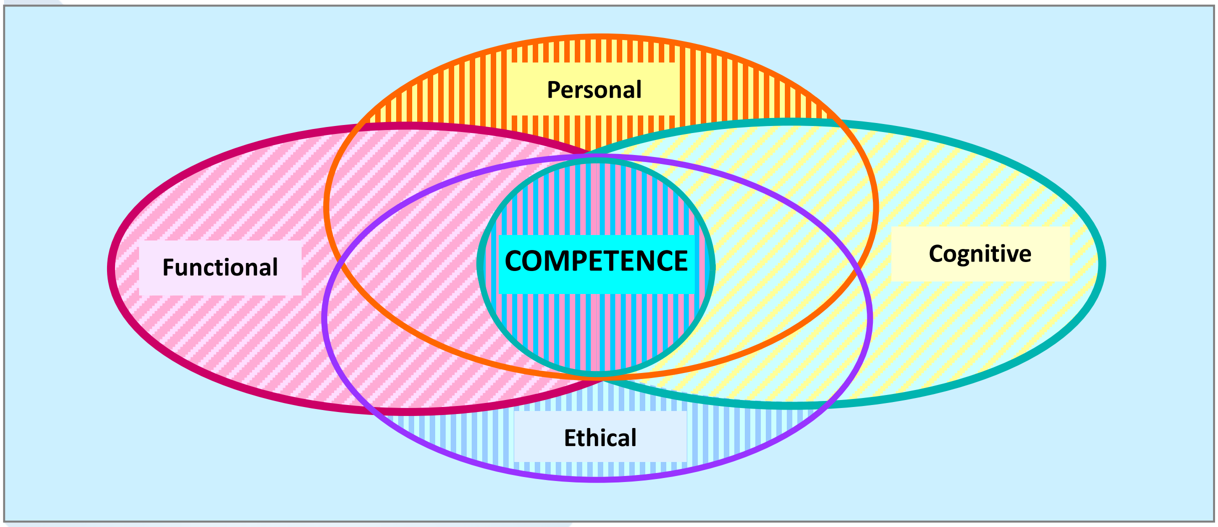

Fig. 3. The competences concept defined in the TRACE Project

In Tuning Project, competence is considered "a combination of attributes in terms of knowledge and its application, skills, responsibilities and attitudes".

The project made a distinction between generic and subject specific competences, describing three types of generic competences: instrumental competences (cognitive, methodological, technological and linguistic abilities), interpersonal competences (social interaction and co-operation), systemic competences (combinations of understanding, sensibility and knowledge). In the project view, a prior acquisition of instrumental and interpersonal competences is necessary to individuals, as a prerequisite condition to develop the systemic competences.

The concept of competence is also tightly connected to the principles of the European Qualification Framework (EQF), which is usually understood as a “framework for frameworks, meant to enable European national qualification systems, with their implicit levels or/and sectoral characteristics, to relate to each other”[1].

The EQF basic approaches rely on the principle of ***learning outcomes*** (LO).

A learning outcome is a statement specifying what a learner knows, understands and is able to do on completion of a learning process. In EQF methodology, learning outcomes are classified into three categories: knowledge, skills and social abilities (also named "soft skills", "social skills" or "social competences"). All the EU experts participating at the debates on EQF decided “to use the distinction between knowledge, skills and social abilities as basis of the EQF framework, because it is the most established way for categorizing learning outcomes”[1].

The EQF core concepts are described throughout the following definitions [1]:

- learning outcomes are statements of what a learner knows, understands and is able to do on completion of a learning process,
- knowledge means the outcome of the assimilation of information through learning; it is the body of facts, principles, theories and practices that is related to a field of work or study,
- skill means the ability to apply and use knowledge to complete tasks and solve problems,
- social abilities mean the proven capacity to use knowledge, skills, personal, methodological abilities in work or study situations and/or in professional or personal development,
- qualification means a formal result of a validation process, obtained from a competent body which can determine if an individual has achieved learning outcomes to given standards.

The EQF’s “learning outcomes” approaches represent a paradigm shift in thinking about education, which raises discussion on the input-based learning (described in terms of location, duration and/or teaching methods) versus outcomes-based learning, built on the principles of learner-centred education and professional oriented learning. From this EQF specific perspective, the concept of competence gains a holistic sense, encompassing skills, knowledge, understanding, attitudes of individuals related to a professional context and acquired through a formal or non-formal educational process. As a result, any model of competence standards based on these principles will be composed by statements describing the knowledge, skills and social abilities an individual should posses in order to perform successfully and safely in a professional environment.

3. Competence standards and outcomes-based qualifications

When taking into consideration the perspectives previously described, the competence standards naturally become foundational starting points in building of any VET or continuing education program for professional development. When the educational/training program is built around the approach of "learning-outcomes", the relationship between competence standards and professional education grows to be stronger and profound.

Learning outcomes are statements of what a learner knows, understands and is able to do on completion of a learning process. In a broader sense, learning outcomes describe knowledge, skills and social abilities a person can acquire by completing an education or training program.

The relationship between the competence standards and the learning-outcomes approach in developing educational programs can be expressed by pointing out the complementary roles of the two concepts. While learning outcomes are statements of "what a learner knows, understands and is able to do on completion of a learning process", in broader sense, competence means "the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in professional and personal development" [7]. As a result of this complementarities, competence standards are usually employed in many professional educational systems as "a basis of defining the outcomes of a learning module, program or training course" [2].

Despite the above considerations, there may be difficulties in putting into practice the idea to describe learning in terms of expected outcomes, in order to fulfil the requirements derived from the competence standard related to a profession or a job. Some forms of knowledge, skills and competence are difficult to be described as learning outcomes (for example tacit knowledge or highly contextualized knowledge, skills and competences) [2].

Other difficulties are generated by the different approaches in identifying and describing learning outcomes in the various national qualifications frameworks or systems. Many authors or EU-supported portals for the education in professional domains (as [20]) are presenting guidelines and rules for the description or the development of educational outcomes.

The holistic approach is based on the idea that in a professional context, work processes are not separately taking-place operations. Therefore, the educational outcomes describing the ability to carry out work processes should be determined accordingly to the whole model of the professional activity including those work processes. In this case, developing descriptors for learning outcomes and transferring them into the occupational profile should be based on the analysis of work processes composing that occupation.

Then, the development of the can follow several steps [20]:

1) identification of work and business processes that can be assigned to a certain profession,
2) partitioning of activity fields based on the work and business processes previously identified,
3) definition of learning outcomes related to each fields of activity,
4) transferring the fields of activity and learning outcomes into the occupational profile.

Other methodologies of writing learning outcomes propose a heuristic approach, based on common sets of recommendation rules [2]: “achievements” clearly identifiable, feasible for the learner, measurable and as a consequence, measurable should be taken into consideration when building an educational program based on learning-outcomes approaches.

Several European projects have been oriented on methodologies of development of learning outcomes for specific training domains. Here too, the directions have been different [5]:

- projects which expressed learning outcomes in terms of knowledge, skills and competence: AEROVET, OPIR, RECOMFOR, CREDCHEM, M.O.T.O, CAPE-SV, ECVET ASSET
  - ✓ the AEROVET project used common core occupational tasks, following a competence levels matrix in order to formulate the learning outcomes,
  - ✓ the M.O.T.O project developed an approach to learning outcomes starting from occupational tasks crossed with training contents as defined by training centres involved in the field of test, etc.,
- other projects, as SME MASTER Plus, VALOGReg looked for alternative ways of identifying learning outcomes; in these projects authors abstained from differentiating learning outcomes into knowledge, skills and competence, as division of the learning outcomes would have been contrary to the project claims to reflect professional capacities in a comprehensive and transparent manner [5].

In this last case, the competence-levels matrix indicates in the first row a list of core tasks, and then vertically the levels of proficiency in terms of ‘competence’ that can be achieved by mastering the tasks. It is considered that work processes do not allow learning outcomes to be split along the descriptors of knowledge, skills and competence. Consequently each task is described in expected competence levels, from novice to expert [5].

Anyway, all the above projects have a common feature: they take into consideration a set of related educational and professional standards in their attempt to develop or recommend how to design training activities in a specific professional domain.

4. Romanian qualification and competence standards for trainers

The Romanian Qualification Framework (RQF) for professional trainers has been developed by the Romanian National Qualification Agency (RNQA). The framework was created in order to comply with the national regulations on training activities: any person involved in a training program in the position of trainer, teacher, instructor, foremen-instructor, tutor should be authorized (certified) as a professional trainer. The Romanian qualification framework define the "job specific competences" for two categories of personnel that could be involved in training activities:

- The Trainer, defined as a specialist who designs, delivers, evaluates and revises theoretical or practical activities and/or programs meant to develop or enhance competences in a field of a professional domain/are,
- The Foremen-instructor, who deliver practical training in secondary vocational education establishments or conducts on-the-job tutoring at work place.

The RQF for trainers is currently used to develop and implement training programs for certification of the professional trainers. The certification offered by these programs is at Level 4 of ISCED (post-secondary non-tertiary level) or at Level 5 in EQF. The certification to be a foremen-instructor is at Level 3 of ISCED (upper secondary level) or at Level 4 in EQF.

After certification, a professional trainer could participate at training programs in his/her specific field of competence or domain of activity in which he/she is already authorized to train. The training programs could take place in non-formal or informal contexts and the instructional process could be undertaken in continuous vocational training (CVET) or initial vocational training (IVET).

The Romanian qualification system/framework for teaching in vocational or continuing education, i.e. the so called professional education context, is a competence-based framework built on the basis of functional analysis of the activity in the target domain, in this case the training of professional trainers. Its main component is an so-called occupational standard which plays, in broader sense, the role of a competence standard within the qualification framework.

In the Romanian specific approach, any occupational standard is composed of a set of descriptors of content and context of the professional activity it refers to. The descriptors take into account the requirements to practice a profession and are associated with a view connected to the labour market.

Any Romanian occupational standard is divided into ***groups (areas) of units of competence***. Each unit (area) of competence in a group has the typical meaning and structure of a unit of a functional map, as it follows:

- a unit of competence describes an activity that can be carried out by an individual, in order to generate a specific product or service,
- a unit of competence is divided into a number of elements of competence, and each element of competence encompass specific knowledge, skills and attitudes.

The occupational standard in RQF proposes three main groups of units of competence (Figure 4):

- ***Group of Key-competences Units***, comprising units of so-called "meta-competences": communication, mathematical, science and technology, digital, social competences, learning to learn, sense of initiative and entrepreneurship, cultural awareness and expression.
- ***Group of General-competences Units***, which includes units referring to domain specific regulations, work security and environmental regulations and quality assurance rules.
- ***Group of Job Specific competences Units***, which include the units:
  - ✓ preparation/organization of the training program/module,
  - ✓ preparation/organization of the practical part off the training module,
  - ✓ implementation of the training program,
  - ✓ evaluation of the trainees and evaluation of a training program.

Each unit of competence in the job specific group is comprising the following components :

- **elements of competence**, which is the description of a task, including at their turn,
- **context of achievement**, specifying the contexts of the ongoing tasks in that unit,
- **variables describing** the conditions and the sources/tools necessary to achieve the unit's,
- **knowledge requirements**, specifying the necessary to achieve the unit's work tasks,
- **level of responsibility**, which is the degree of autonomy and responsibility that a person should have in relationship with activities and tasks in that unit of competence.

Each element of competence in a unit also includes statements about:

- **achievement activities**, which are descriptions of the activities necessary to successfully and completely achieve the task specified by the element of competence,
- **achievement modalities**, which are descriptions of the necessary attitudes to support the achievement of the task specified by the element of competence.

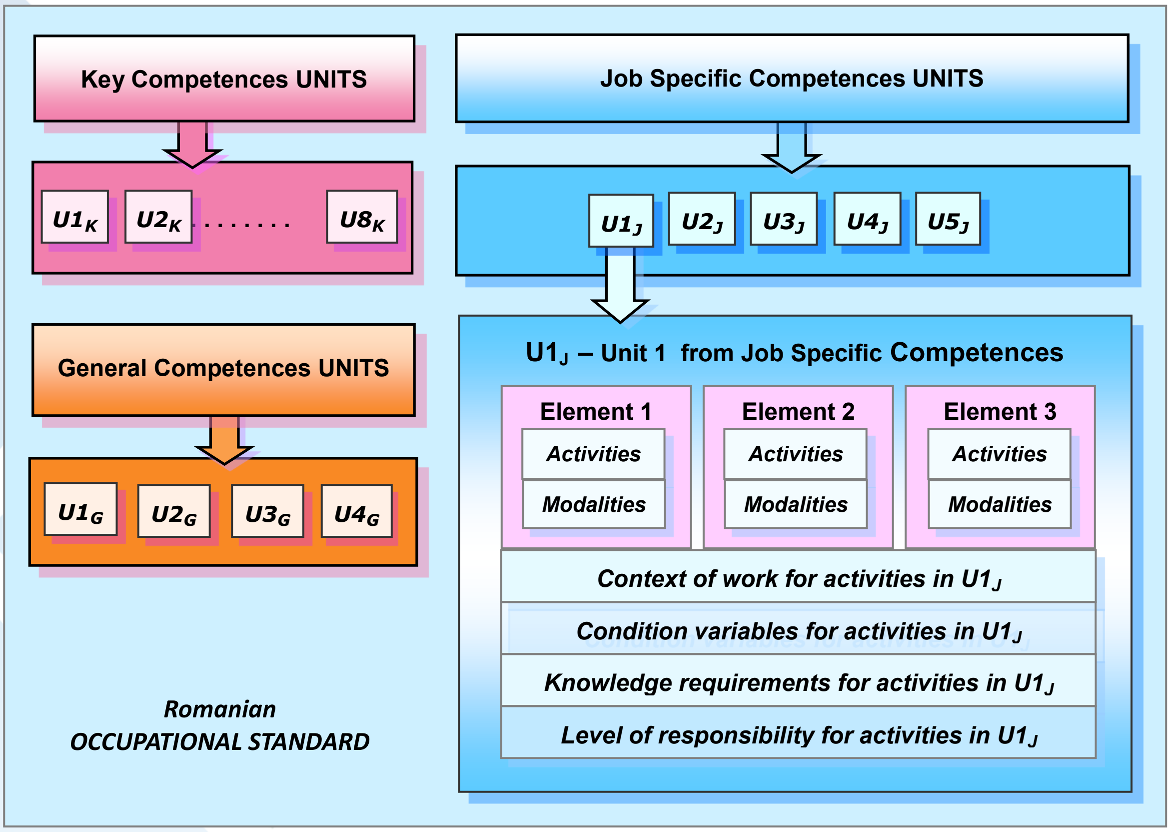

Fig. 4. Romanian occupational standard's structure

More in detail, the Romanian occupational standard for professional trainers proposes eleven main "competences":

- five competences correspond to the units in the Occupational standard,
- two competences are related to security and safety at work,
- four competences are derived from the category Key competences in the Occupational standard of the RQF (Figure 5).

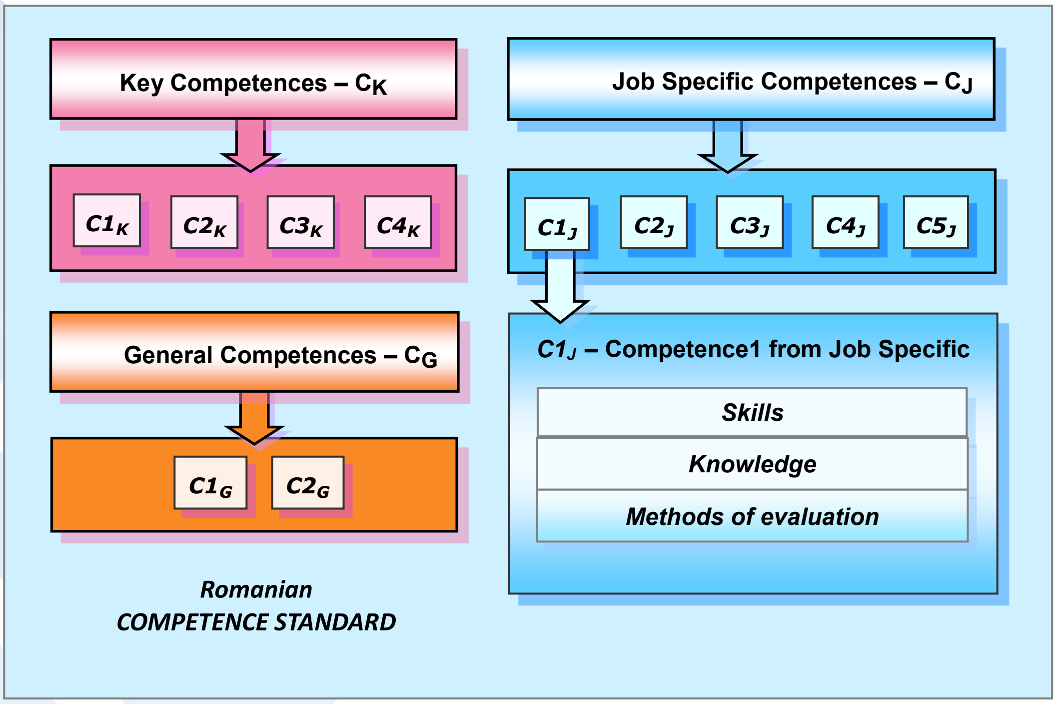

Fig. 5. Romanian occupational standard for the professional trainer qualification

Any attempt to translate of the Romanian occupational standard components as in Figure 5. into a competence standard comprising statements on knowledge, skills and social abilities specific to a professional qualification, need to be realized in several steps (Figure 6).

In this case, knowledge statements in should be extracted from the knowledge statements of the occupational standards, skills statements from elements of competence in the occupational standard, and the social abilities (competences) statements should be extracted from the specifications of "Level of responsibility" of the same occupational standard.

The translation (Figure 6) would permit a much easier development of any training program for trainers, based on labour market competence standards for professional trainers. The result would be a competence standard composed five units of competence including 3 to 5 tasks, and for each tasks, with the corresponding knowledge, skills and social abilities descriptors (Table 2).

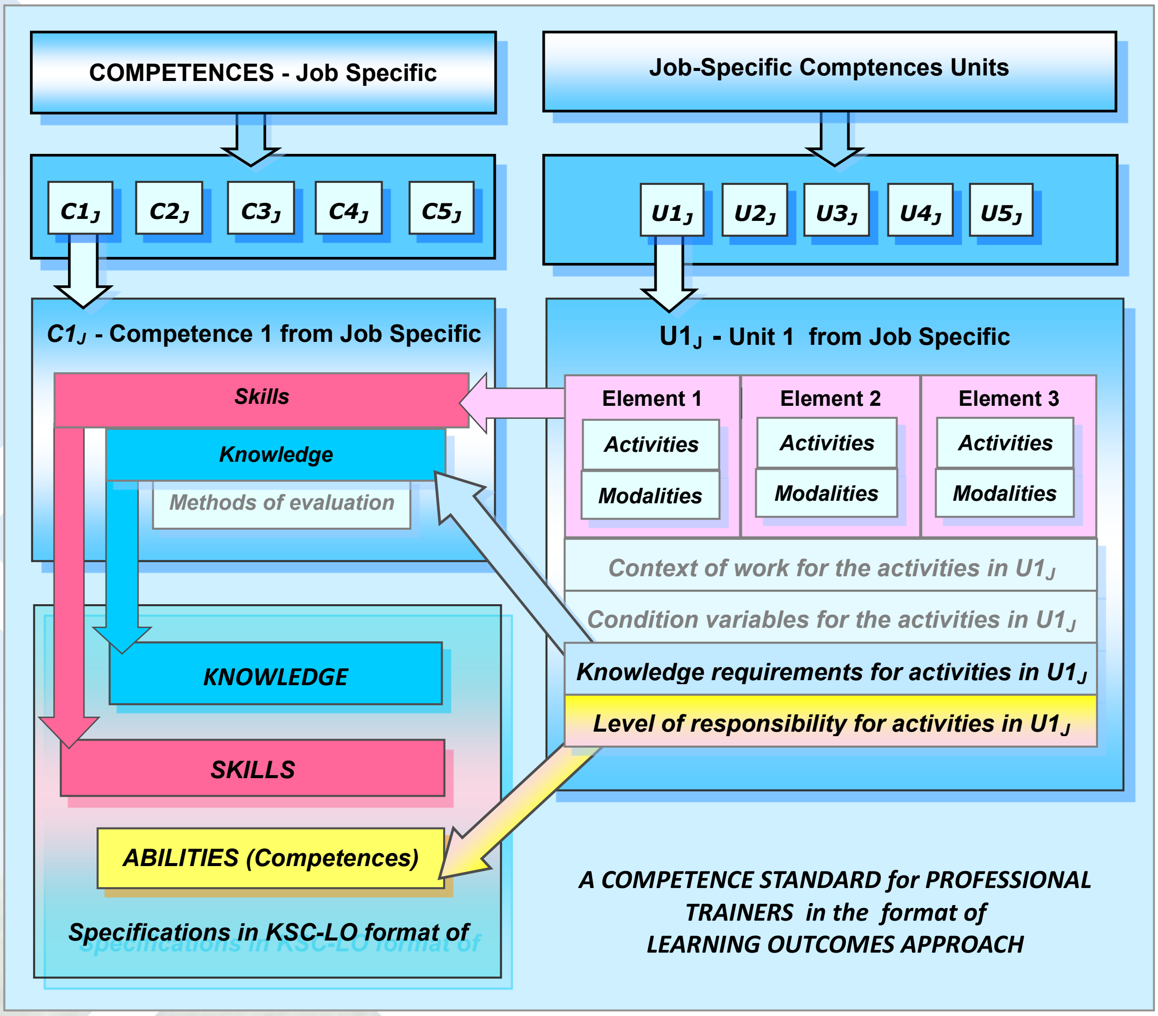

Fig. 6. Translation of a Romanian occupational standard into the learning-outcomes format

Table 2. Structure of a new Romanian competence standard for professional trainers

Units of Competence	Learning Outcomes		
	Knowledge	Skills	Competence
1. Preparation of the training course	**20** statements	**5** statements	**5** statements
2. Preparation of the practical part of the course	**12** statements	**3** statements	**3** statements
3. Implementation of teaching activity	**14** statements	**4** statements	**4** statements
4. Evaluation of the trainees	**10** statements	**4** statements	**4** statements
5. Evaluation of the training course	**12** statements	**3** statements	**3** statements

5. The professional competence standard in PV-Trainer project

The new competence standard for trainers in photovoltaic systems domain developed in the frame of PV-Trainer project is a relevant example about how to realize competence standards complying to the “learning outcomes” approach. In this new standard, each individual unit of competence contains descriptions of competences related to the profession of photovoltaics trainer as statements indicating specific knowledge (“he/she knows and understands”), skills (“he/she can do”) and social abilities (self-regulation and capacity to interact in a professional environment).

The collection of competence units in the new standard is organized in two main fields (or areas, or groups of units) of competence. The first field of competence in the standard is relating to the occupation of professional trainer, it is called "K1 – Planning, organizing, conducting and evaluating of the vocational training" and is comprising three units of competence:

- Planning and designing vocational training and other forms of improving professional competence of employees,
- Organisation and provision of teaching activities, consultation related to the training offer,
- Promotion and provision of the quality of training services and awarding the qualifications.

The second field of competence in the standard is referring competences in the sectoral domain of photovoltaic systems, it is called "K2 – Planning, installation, modernization and maintenance of photovoltaic installations" and is consisting of three units of competence:

- K2.1. Planning installation of photovoltaic systems,
- K2.2. Assembly of photovoltaic installations,
- K2.3. Modernization and maintenance of photovoltaic installations.

As it is organized in units of competence related to knowledge, skills and social abilities an individual should possess, the new standard’s statements can be easily translated into the learning outcomes of a modular qualification program for training the photovoltaics trainers. More than that, taking into consideration that the European ECTS and ECVET are learning-outcomes based credit systems linking the occupational/competence and the educational standards, the qualification programs organized on the basis of the new competence standard can provide credits.

These credits can be accumulated and transferred towards qualifications systems, thus facilitating a wide recognition of assessed learning outcomes gained by individuals through training programs.

They also allow for better understanding and readability of qualifications in different forms and contexts of learning throughout Europe, as the PV-Trainer aimed to do by developing a model of qualification through an e-learning system based on a competence standard.

The competence standard and the educational methods developed in the frame of the PV-Trainer project can help enabling European people to present in an understable way their qualifications acquired in non-formal or informal learning environments, and can make it easier for learners and workers to move across countries and occupations.

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Adina COCU, Emilia PECHEANU, Ioan ȘUȘNEA, Luminița DUMITRIU
Department of Computing, University "Dunarea de Jos" of Galati (Romania)

On-line systems for competences evaluation – methods and digital technologies

Introduction

The competences that a person possesses and uses for the purpose of obtaining, processing and communicating knowledge, constitute the main behaviour of the person, but also of the society or organization of which he is a part. Nowadays, there are many psycho-pedagogical methods and digital technologies for verifying and validating the competences held by a person in a particular learning field. Choosing a test method and its implementation technology is a decision that is based on a number of factors. Among them, we mention the number of people who will benefit from the evaluation of the competences that would justify the investment in an eLearning system, the specificity of the domain of competences focused on theory or practice, the age group of the users. Depending on the technology chosen, the instructors can benefit from various tools that allow them to assess competences, to analyse the results, to update the system performances. In addition, the methodology and technology chosen also influence the efficiency of the eLearning system. In the following article, we will explain what competence is, how it is formed and how it is measured.

1. What is a competence

Competence in a field is the ability to combine knowledge with skills and attitudes with the aim of solving a problem that has clearly defined goals and targets. In nowadays' globalized economy, competences are a tool used by companies to manage and develop the employee performance. In addition, competences' certification is used for recognition, flexibility and update of work performances of employees.

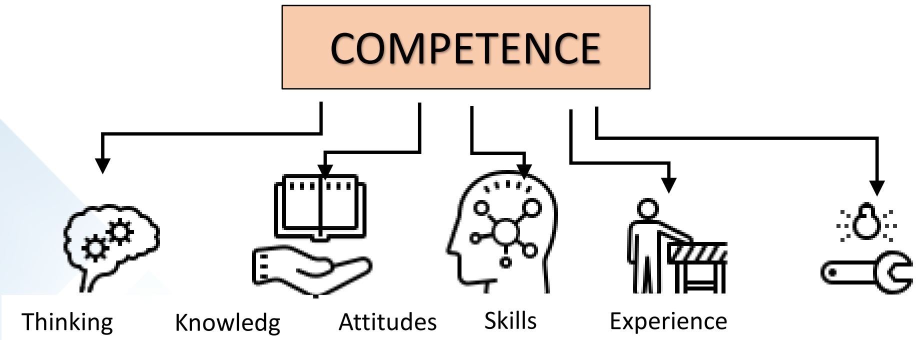

Fig. 1. What is competence

A person who have competence is able to solve new or complex problems in a given context, through processing and combining information (acquired by any method) according to objectives, thinking and choosing the right procedures, all of these with the aim to obtain a result in a specific, limited environment. Thus, competencies can be defined as generic skills that can be exercised by a person on knowledge and can be defined through the behaviours that define it. Behaviours can be described in terms of knowledge, skills and attitudes (K.S.A). Competencies involve reasoning over knowledge and concepts.

2. How to form competencies

Competencies are formed through the learning process, which have clearly expressed pedagogical objectives, well-defined content, well-proven pedagogical methods (exercises, case and situations studies), but also by assessment means that verify the achievement of the expected results (to perform a task, to understand and to accomplish a well-identified goal). The best results of an educational process are obtained by applying the method of individualized learning [2]. Such learning can be done one-on-one with a tutor or using a learning management system – LMS, that can be tailored to the user [1]. Such an educational system can be defined as a system used to create, supplement or maintain (through a learning process) skills specific to a clearly defined learning area.

In the field of education, the 70:20:10 rule is valid [3], means a person learns 70% through work experience, 20% through mentoring and coaching (informal learning) and 10% through formal learning and courses.

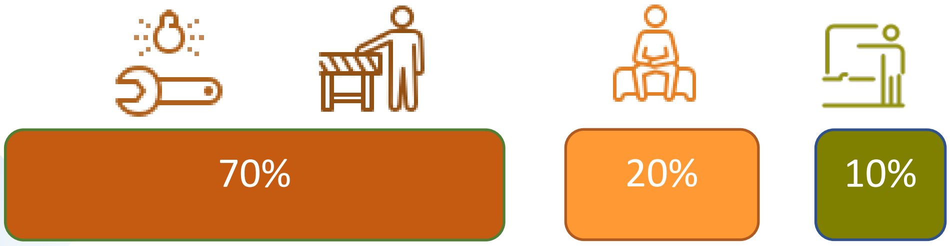

Fig. 2. Rule 70:20:10 for learning

Considering this rule, in order to increase the learning efficiency, an eLearning system should, in addition to presenting the course materials in the form of text, ensure asynchronous communication with the tutor or other participants in the learning process, to offer the possibility of completion tracking, to analyze the results obtained in tests and progress tests. All these features help student to see if the stages and the working methodology for solving a task or a practical exercise have been learned.

The most effective results are obtained when learning takes place combined, on-the-job and off-the-job.

In order for an educational system to be able to adapt to the student, then it should offer many student-related functionalities (for example, information about the student, the cognitive state in the learning area, the educational path, history of learning acquisitions through assessments charts). So, when choosing the technology for implementing an LMS, it must take into account the facilities offered for tracking and personalizing the educational path at the individual level [4].

According to Piaget [5], a theorist of pedagogy to learn appear when a person changes his mental schemes, when he reconstructs some of the cognitive references or when he changes his mental points of reference. Intellectual development involves three fundamental processes: assimilation, accommodation and strengthening. The assimilation consists in the incorporation of new knowledge into the pre-existing cognitive structures. The accommodation is used when the mental scheme does not accept new information because it disrupts the frame that was built. Therefore, the knowledge set must be reconsidered in order to reconstruct another vision on the subject studied. Strengthening means that the person achievements are for long term. All these processes are unique to each person and, therefore, the learning process has better results if it is carried out individually and not according to unique recipes for everyone. An LMS offers educational materials presented in various forms so that the user can assimilate knowledge. If the materials are well organized and structured as modules, then the accommodation process is easier. Offering practical exercises and continuous assessments during the learning period helps in the strengthening process.

3. How to measure competencies

Competency measurement consists in obtaining information about the behaviours that define that competence. Behaviour is expressed in terms of Knowledge, Skills and Attitudes (K.S.A). From this perspective, a behaviour can be divided into pieces of information related to the three aspects. Each piece of information can be monitored, observed and recorded by specific tools, easier to measure than the competence considered as a whole.

The measurement of competences can be done classically, by an evaluator who observes the associated behaviours and provides a grade or rating that reflects the quality and completeness of the observed behaviour (need development, novice, competent, highly competent, exceptional or expert). The evaluator's work can be supported by preparatory stages, carried out by the evaluator or by the evaluated himself. Proficiency measurement can also be done using digital applications, and the use of any of these steps greatly reduces time and cost. The evaluated person can train online through exercises, scenarios, preparatory tests, self-evaluation. The evaluator can use an online application or form to memorize the evolution and observability of the behaviours. The methods used in the preparatory stages are useful from financially point of view and also as human resources involved in the evaluation of competences. The methods applied by the evaluated person and the evaluator can be combined, classic and online. The classic evaluation methods, in which experienced evaluators are involved, are robust, quality, but expensive. In addition, there is a risk of not always having an evaluator ready for a specific domain. So when choosing the method used to measure skills, the question of choosing between quality and costs is raised.

Fig. 3. Competence assessment

The evaluators who are involved in the process of measuring competencies must be competent in the field of evaluation and be in situations where they can observe the behaviours associated with the competences to be evaluated. They can be managers, supervisors, teachers or tutors. Competence observation is usually done in controlled environments (laboratories) through simulation exercises or at the workplace, on-the-job situation. In order to grant a certification, it is necessary in addition to the educational process supported by online self-assessment and knowledge assessment methods, and an individual evaluation completed by one or more evaluators. And for a more robust assessment, evaluators will look at on-the-job skills and attitudes. The main disadvantages regarding classical evaluators are their availability and costs.

The competence performance can be measured through its behaviour manifestation and its responsibilities expression in the context in which competence is manifested. If you only want to evaluate and track employee competencies, then companies can choose to use a competency management system instead of management system. The efficiency of an LMS can be measured with the help of reporting and analytical facilities. These metrics help the developer to improve the structure and content of the course and to adapt it to the learning needs of the students and to the final beneficiary company.

Competency management tool pursues the selection, performance or development of competences. Such a system deals with the concentration of information on the strengths, weaknesses or deficiencies in the competences of the employees, moving from the individual level to the entire workforce. Tracking the level of individual competence helps persons in career management, in the recognition of the professional potential, in identifying the adaptation methods at the organization level. The ability to catalogue the collective competences of the organization is useful in making decisions regarding training, efficient allocation of resources, aligning personal development opportunities with the corporate purpose, adaptability of the corporation to changes.

For greater efficiency, the two management systems for learning and competencies, should be connected or the first one should encompass the second. These types of systems are capable to make available reports at the individual level and at the collective level that contain different information. In figure 4 can be observed the functionalities of a learning management systems and competence management systems.

Online competency assessment systems have a number of features: simple graphical interface, credential access, error feedback, and suggestions for study material to improve current skills, allow more evaluators to rate the same staff for different criteria, individual and group reports (allows to identify learning needs and group more people as needed to increase efficiency and reduce costs), archiving reports or analytics for different periods of time to track the evolution of the quality of staff training [6].

Competence assessment can be used to obtain a certification that demonstrates the ability to work in a certain position, to assess performance on a particular job in a company, or to prepare a professional path in a large company. This evaluation is also used to identify needs of a group or department into a company and to set up performance strategies. Competence assessment is generally done by human evaluators who are good professional specialists in the field and have experience, but can also have components that can be automated. Thus, the self-evaluation process can be streamlined through an on-line evaluation, and records and reports of the evaluator's observations can be made through an education system.

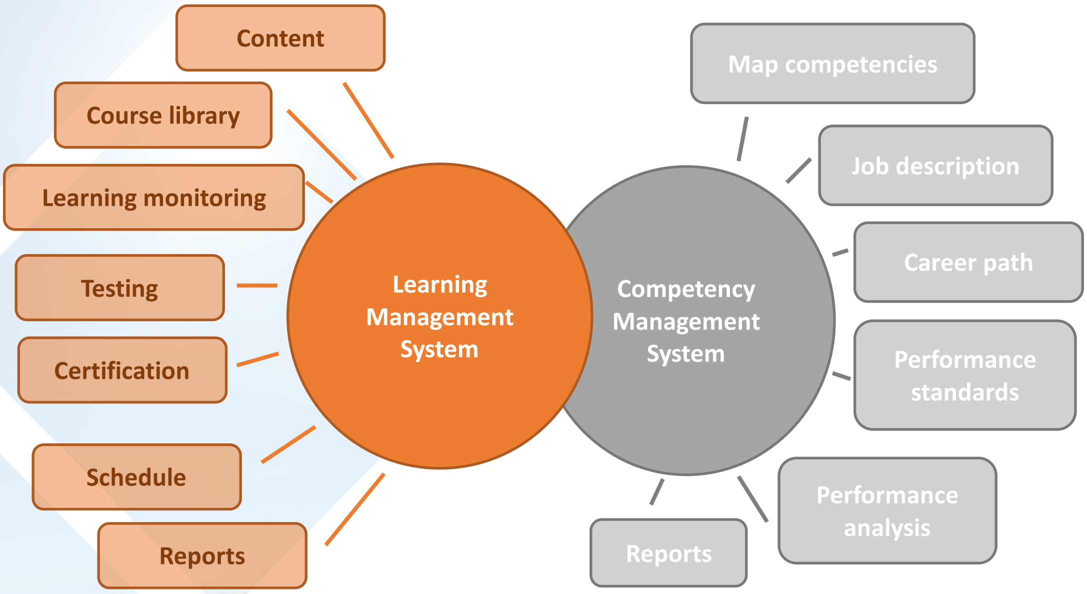

Fig. 4. Competence development and observation

4. How to increase ELearning efficiency

The efficiency of learning one-to-one is given by the ability of the teacher to adapt to the particular needs of the student. The LMS use a series of facilities through which students can customize their educational path, but also statistics dedicated to the course designers through which they find the areas where they can improve the educational process.

Personalizing the learning process means proposing a training plan that is perfectly adapted to the level, needs, expectations, personal pace, way of learning of the student. It is necessary to personalize the learning process because the multitude of users of a system is heterogeneous.

Self-assessment is used as a form of reflection on the level of knowledge and skills that helps the student to actively participate in the assessment of his competencies. In the certification processes, self-evaluation is often used as part of the process in which the evaluated person is aware of his level of competence. But in a certification process the final result will be given by the evaluator. The results of the self-assessment are used in establishing the educational path plan, in identifying those modules that need to be resumed in order to improve the skills level. After such a stage of resumption of some parts of the educational material it is necessary to resume the self-evaluation. Because it is a cyclical, time-consuming process, it is useful to be implemented by the eLearning system.

During the evaluation process, those competences that are already mastered and the areas in which they need to be developed are identified. This information can be used when creating a ***study plan*** and choosing the right exercises. Using an educational system that presents the study materials structured on modules and which has implemented a completion tracking system is very easy to implement an educational roadmap.

Knowledge assessment is appropriate to be done through ***online tests***. Instead, the assessment of skills and attitudes is appropriate to be done by a human evaluator. In order to test attitudes and even skills, eLearning systems have implemented ***case simulations and multimedia tests*** (video, image sequences). But if the field in which the assessment requires a high degree of use of physical work, then the human evaluator must evaluate those skills.

The traditional pedagogical design methods are focused on the careful ***analysis of the competence*** training. Following the analysis, sequential development tasks are adopted, in stages, with loops of repeating actions to produce in a systematic and planned manner a finished product of training-education. Instructional design deals with aspects of analysis, conception, implementation and planning of the dissemination of educational systems. The specialists in instructional design integrate concepts, processes and principles from pedagogy, computer science and cognitive engineering in order to develop educational systems. They are trying to develop a theoretical framework (from a pedagogical or cognitive point of view) and methodological tools and software that integrate the theoretical elements in the LMS.

ELearning systems are recommended to be used by ***autonomous persons***. This feature shows whether the person is capable of organizing himself or herself to learn without having to be guided by a human trainer each time, if he can use the various available resources, if he can intensify his work effort to follow the deadlines, if it does not need to be motivated from the outside, if it does not need to be sanctioned or rewarded according to the learning assessment, if it can progress beyond the first satisfaction for a general understanding.

Evaluation, which is the mechanism to verify practical skills and theoretical knowledge acquired during the educational process and to correct then through self-evaluation. The LMS who offer different types of evaluations increase the effectiveness of learning acquisition. Evaluation attempts to determine what is known (information obtained correctly) and what the student does not know (information not acquired or obtained incorrectly). The evaluation process aims to achieve the pedagogical objectives and to track the effectiveness of the training. The verification of knowledge can also be regarded as a way of learning, by seeking new information and resources necessary to solve the problems proposed for evaluation or by raising awareness of the accumulated knowledge.

The evaluation system must be structured as the content it validates. In order to check the simple aspects, short questions can be used, but also can be used exercises, problem solving, case studies, confrontation with virtual situations. ***Assessment is a way of learning***, and therefore exercises that allow self-assessment increase learning efficiency. If the exercise offers the opportunity to search for information, to browse other resources, to understand how to solve them, then the evaluation becomes "formative" and is part of the learning process. This is also the way in which the student demonstrates his autonomy in the face of the problems to be solved.

Assessment is a way to raise awareness of what has been learned (pedagogues call meta-cognition), that is, awareness of the level before and after learning. This process is stimulated by classical trainers when they ask for a summary or resumes, or to recall what they have learned. In LMS, short questions can be used successfully, as they go through the different stages of a pedagogical sequence. LMS are able to implement summative-normative evaluation that verifies the fulfilment of the pedagogical objectives and has the purpose is to calculate scores. The score is evaluated by ***summative grades*** for a series of knowledge learned to determine the achievement of the initial objectives; by ***linguistic qualifications*** when the candidate's performance is express by labels located on a scale of values.

An effective educational system is capable to managing the actors and events involved in the educational process. It must ensure the ***planning and development of various activities*** specific to the learning process, to monitor the events, to direct the operations of information dissemination, to manage ***communications or social network, to organize groups and teams***, to distribute resources, to carry out the learning evaluation. Thus, the educational systems try to model the aspects related to learning, user modelling, collaboration between the people involved in the educational process, by acquiring, representing and processing the necessary knowledge in a software application.

Social learning – when the LMS system provides discussion forums between students. Applying the concept of social learning has a positive influence on the efficiency of learning: it encourages users to learn from each other leading to the development of the collaborative spirit, motivates them to work faster and better together, helps students determine if they have learned what they were supposed to learn, because to explain to a person what you know involves a thorough understanding of the subject.

5. A practical example of LMS used for trainers in PV Systems

The LMS Moodle environment in which the eLearning system was created is designed on a model based on resources and activities, from which were used the forum, the glossary, evaluations, the completion tracking, SCORM packages with exercises and content. By accessing reports related to grades and log (time, user, context, IP address), conclusions can be drawn about the efficiency of the educational material, the flexibility and adaptability of the learning environment. Thus, the course administrator can get to know the participants and their needs, by providing them tools to share their ideas, ask questions and receive answers from other participants or the tutor. Such an educational system provides flexibility in time and space, because participants can connect at any time, regardless of time zones and the location where they are. The communication tools used offer asynchronous connection, so the users work together, but at different times of time.

The educational material is divided into two modules each with three units. One module refers to the competences of Planning, organizing the development and evaluation of vocational training, and the second module deals with the Design, installation, modernization and maintenance of photovoltaic systems. For each unit was created an initial test, a progress test for self-assessment of the knowledge learned and a final test at which a score of 80% must be obtained in order to be considered passed. To these features there are added summaries in the form of interactive modules, exercises to verify the practical skills, with the aim of increasing the efficiency of the eLearning system.

The implemented LMS emphasize the short-term memory phase, presenting educational material in visual form to stimulate the student's sensory abilities. The most important part of the learning process, the long-term memorization phase uses the repeatability of presenting the educational material to reinforce the knowledge acquisition. An important role in the learning process is the presentation of the structured study material on modules. For this reason, the PV Trainer educational system considers the aspect of modularizing and structuring knowledge and representing the connections between the concepts. In addition, in practice students tend to repeat the same modules they have already understood, without taking into account the essential prerequisite knowledge. So, using pre-testing will help students to acknowledge what they know and thus to intensify the efficiency of learning process.

The main features of PV-Trainer online system are:

1) Course materials in modular organization
   – 2 modules,
   – 6 units,
2) Summaries of educational materials
   – ISpring,
3) Asynchronous communication with tutor and other colleagues
   – Forum,
   – Chat,
4) Completion tracking
   – Check the item.

6. Metrics used in PV Trainer eLearning system

Progress and completion rates for educational materials

Progress is expressed completion checks and is accompanied by the time spent to complete each activity in the course. In this way can be find out how often and how much a student is involved in a particular activity.

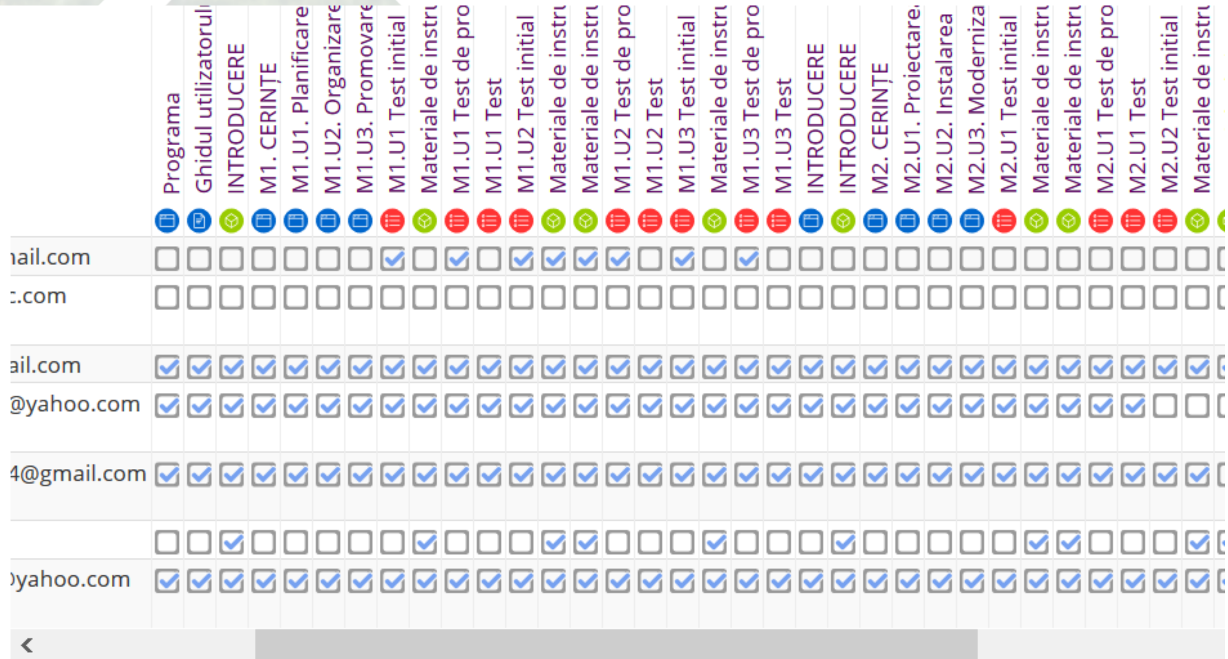

Fig. 5. Completion tracking for activities and resources

There are two scenarios that should be analysed: if the student stays too much for an activity without completing the assessment, if the student has completed the activity and have not obtained the exam passing score. In the first case, a survey can be implemented to discover the causes of lack of motivation. In the second case, the educational material may be too complex or the questions too heavy. In these cases, the material must be reorganized at the content level (breaking the content into smaller modules) or the delivery method (introducing interactive elements) or questions (simplifying the statements, replacing the questions with multiple answers with questions with only one the correct answer).

First name / Surname	Email address	Attempt	Started on	Last accessed on	Score
Panouri Solare	panourisolare04@gmail.com	1	Tuesday, 30 July 2019, 2:44 PM	Wednesday, 31 July 2019, 1:31 PM	77.55
Pv Install	pvinstall.ro@gmail.com	-	-	-	-
Sisteme Pv	sistemepv@gmail.com	1	Monday, 5 August 2019, 11:45 AM	Monday, 5 August 2019, 11:53 AM	92.81
Energie Verde	energie_verde@yahoo.com	1	Wednesday, 7 August 2019, 6:53 AM	Wednesday, 7 August 2019, 6:58 AM	100
Instalatii Solare	instalatii.solare@yahoo.com	1	Wednesday, 7 August 2019, 3:48 PM	Wednesday, 7 August 2019, 3:53 PM	93.34

Fig. 6. Time spend on an activity

Tracking evolution

The system has initial tests (before completing the educational material) and final tests (after completing the educational material). The LMS provides reports for tracking the evolution of learning, thus observing how much their students have improved their knowledge.

Score	M1U3_RO	Response 0	Result 0	Response 1	Result 1	Response 2	Result 2	Response 3	Result 3
77.55	77.55	1.y,0.z	correct	4.v,0.y,1.w,2.z,3.x		4.y,1.z,2.x,0.w,3.v		6,3,1,0,2,4,5	

Fig. 7. Response analysis

Custom reports

Many LMSs offer different types of information and reports that help identify the weaknesses of the education system. The implemented system offers:

- For Scorm activities the systems offer the time of accessed, number of attempts, score for resolving the included exercises, detailed responses and results for each exercise (Fig. 8);

Grade item	Calculated weight	Grade	Range	Percentage	Feedback	Contribution to course total
Materiale de instruire și exerciții	25.00 %	1.05	0–100	1.05 %		0.26 %
Materiale de instruire și exerciții - PARTEA A	25.00 %	0.65	0–100	0.65 %		0.16 %

Fig. 8. Reports on SCORM activities

- Activity report – how many users and how many times they accessed an activity and what was the last time they viewed it, how quickly they go through a module. In addition, a student-centred system personalizes the online experience by focusing on skills, allowing the student to repeat small parts only of the subject matter he or she does not yet master (Fig. 9),

Materiale de instruire și exerciții - PARTEA A	62 views by 8 users	-	Thursday, 8 August 2019, 9:18 AM (11 mins 59 secs)
M1.U3 Test	102 views by 6 users	-	Thursday, 8 August 2019, 7:45 AM (1 hour 44 mins)

Fig. 9. Activity report

- If a user does not obtain the minimum score for passing an exam, he can take it several times. Providing the correct answers can help the student fill in the knowledge gaps (Fig. 10),

☐		**Sisteme Pv** Review attempt	sistemepv@gmail.com	Finished	7 August 2019 8:41 PM	7 August 2019 8:46 PM	4 mins 25 secs	**5.65**
☐		**Sisteme Pv** Review attempt		Finished	8 August 2019 9:33 AM	8 August 2019 9:37 AM	3 mins 13 secs	**10.00**

Fig. 10. Reload a test

- Another situation is when a module is run by several users over a longer period of time, in which case the difficulty level must be taken into account.

- Analysis of answers – allows you to view the average score for each question. A large number of users who answered the same question incorrectly may show that the question is not clear or the subject has not been sufficiently explained in the educational material. If, on a question, the average score is very low or very high, then it must be redesign to decrease, respectively increase the degree of difficulty.

	✓ 0,56	✓ 0,56	✓ 0,56	✓ 0,56	✓ 0,28	✓ 0,56	✗ 0,00	✓ 0,56	✗ 0,00	✓ 0,56	✓ 0,56	✓ 0,56	✓ 0,56	✓ 0,56
	✗ 0,00	✓ 0,37	✓ 0,56	✗ 0,00	✓ 0,56	✗ 0,00	✓ 0,56	✗ 0,00	✓ 0,19	✗ 0,00	✗ 0,00	✓ 0,28	✓ 0,56	✓ 0,11
	✗ 0,00	✓ 0,56	✓ 0,56	✓ 0,56	✓ 0,56	✗ 0,00	✗ 0,00	✓ 0,56	✗ -	✓ 0,56	✓ 0,28	✓ 0,28	✗ 0,00	✓ 0,56
	✓ 0,56	✓ 0,56	✓ 0,56	✓ 0,56	✓ 0,28	✗ 0,00	✓ 0,56	✗ 0,00	✗ 0,00	✗ 0,00	✓ 0,56	✓ 0,14	✓ 0,56	✓ 0,22
	✗ 0,00	✗ 0,00	✗ 0,00	✗ 0,00	✗ 0,00	✗ 0,00	✓ 0,56	✗ 0,00	✗ 0,00	✓ 0,28	✓ 0,56	✗ 0,00	✗ 0,00	✗ 0,00
Overall average	0,44 (38)	0,34 (38)	0,44 (38)	0,33 (38)	0,38 (38)	0,35 (38)	0,35 (38)	0,34 (38)	0,17 (38)	0,16 (38)	0,37 (38)	0,33 (38)	0,43 (38)	0,27 (38)

Fig. 11. Analysis of answers

- History analysis – by implementing possibility to reload a test, the student can become aware about the subjects to be learned and if he has understood all.

	Sisteme Pv
Attempts	**1**, 2
Started on	Wednesday, 7 August 2019, 8:41 PM
State	Finished
Completed on	Wednesday, 7 August 2019, 8:46 PM
Time taken	4 mins 25 secs
Marks	13.00/23.00
Grade	**5.65** out of 10.00 (**57%**)

	Sisteme Pv
Attempts	1, **2**
Started on	Thursday, 8 August 2019, 9:33 AM
State	Finished
Completed on	Thursday, 8 August 2019, 9:37 AM
Time taken	3 mins 13 secs
Marks	23.00/23.00
Grade	**10.00** out of 10.00 (**100%**)

Fig. 12. History analysis

- Analysis of grades – the efficiency of a course can be demonstrated by the Gaussian distribution of the notes according to the total number of participants. The number of large and small notes (the extremes) should be small, and the number of medium notes should be large (Fig. 13).

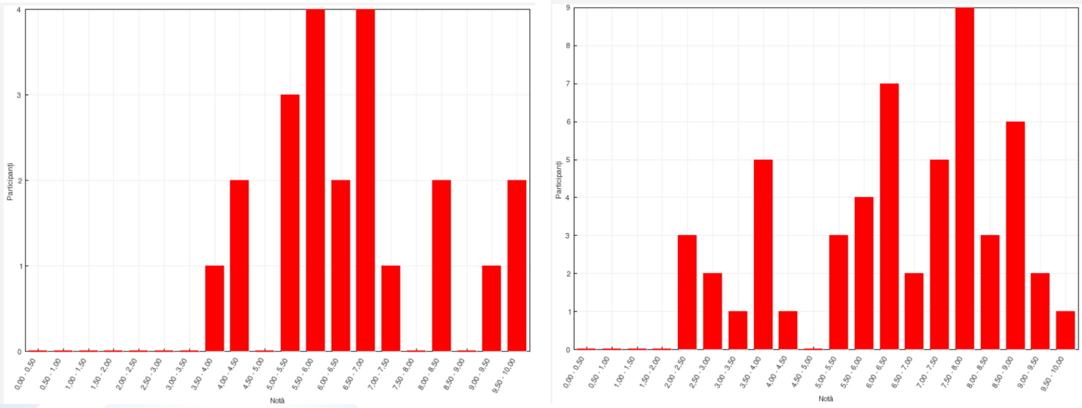

Fig. 13. Grade analysis

- How active a user is can be obtained through the number of interactions with the system.

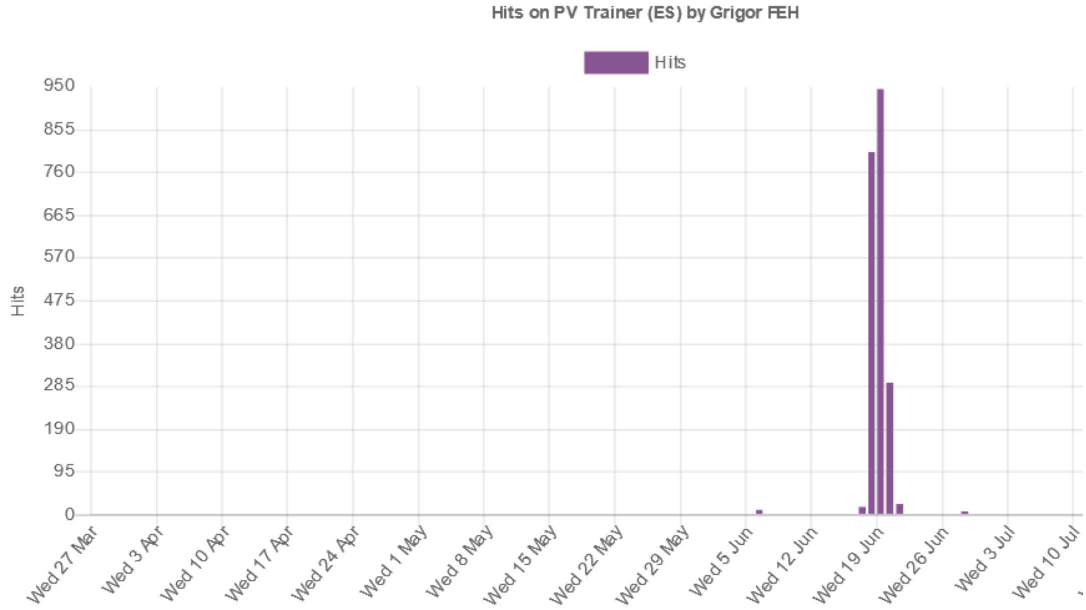

Fig. 14. Interactions with system

- Social learning – when the LMS system provides discussion forums between students. Applying the concept of social learning has a positive influence on the efficiency of learning: it encourages users to learn from each other leading to the development of the collaborative spirit, motivates them to work faster and better together, helps students determine if they have learned what they were supposed to learn, because to explain to a person what you know involves a thorough understanding of the subject.

Conclusions

The use of eLearning platforms reduces costs and increases the efficiency of learning. However, the use of LMS is justified when the number of users is large, when the users are autonomous, when the tutor is familiar with the development of materials and activities on a certain LMS platform or when the tutor collaborates closely with an eLearning systems designer. The use of analyses and reports offers an overview of the efficiency of the implemented educational strategy, helps to discover the weak points of the implemented pedagogical methodology, shows how the system can be improved so as to maximize the results and to minimize the costs. By using an LMS platform that offers many types of reports, the efficiency of the educational process is increased by systematizing many evaluation tasks.

Digital technologies have the advantage of availability anytime and anywhere, multi-sensory stimulation through multimedia tools, user and resource management, increased productivity and performance, personalization over tracking performances and progress, easily access to educational materials, improving collaboration through social learning, reducing costs and time, easily updating the materials.

The main advantages followed in PV Trainer platform were:

- Time and cost effective,
- Available 24/7,
- Avoid lack of human resources,
- Help to auto-reflection about own performances,
- Identify the gaps in learning outcomes,
- Help to build a career road map,
- Higher income per employee.

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Maria KNAIS
EDITC Ltd, Nicosia (Cyprus)

Learner's Engagement in Online Environments – The PV-Trainer E-learning environment

Introduction

Student engagement, in any setting of learning (e-learning or classroom-led training) is the most decisive factor for achieving the learning outcomes set out. Academics define engagement as a complex construct that consists of behavioural, cognitive, and emotional components, and claim that instructors should attend to each one of these components to effectively engage their learners [7]. According to Fredricks, Blumenfeld, and Paris [1] and Finn and Zimmer [2], sustained student engagement facilitates student learning, leads to meaningful outcomes and prevents students from dropping out of a course and prevents boredom.

Analysing the components of successful student engagement, the **behavioural component** is a blend of skills that are required in interpersonal relationships, effective communication, engaging attitudes and productive emotions that will allow students to perform well during the learning process. The **cognitive component** refers to attention, memory, auditory processing logic and reasoning which are important parts for the learning to succeed. The emotional component refers to the emotions that promote, drive, sustain and provide a sense of achievement – they are the driving force throughout the learning process, the motivation to start, maintain and successfully complete the learning, emotions that give happiness to the students. Research has shown that happiness has a positive effect on learning, memory and social behaviour. On the contrary, negative emotional states, such as anger and sadness, have been shown to have a negative impact on learning and motivation. Emotions can disrupt thinking and learning.

The behavioural component of student engagement in an online setting requires the learner to be physically oriented towards the instructor or materials [1, 3]. For example, to be positive in an online setting the students should feel connected with the instructor and the rest of the students, feel at ease that communication is feasible in various ways (skype, webinars or even phone), be satisfied with the online materials (level of interactivity, options for online or offline reading, quality and length).

The cognitive component of engagement involves cognitive processing of information by attending to learning tasks as well as responding to questions [1, 3].

Finally, the emotional component of engagement refers to student motivation to learn and their emotional responses to learning tasks [1, 3]. In addition, researchers examining student engagement support that student engagement can be "fragile" because it can be affected both by student characteristics as well as the quality of instruction.

Additional factors which affect student engagement is the diverse audience that may be attracted in online learning environments (age, cultural backgrounds, language, geographical location etc.). This diversity should be addressed. Whereas the flexibility of attending an online course is a blessing, the demographic diversity can also raise barriers in achieving student engagement.

Thoughtfully designed online instruction has proven to enhance learner's engagement [4]. Therefore, when designing an online course, one should consider the "Universal Design for Learning" (UDL), an instructional design framework offering flexibility and adaptability to meet the needs of increasingly diverse learners and maximizing engagement.

What is Universal Design for Learning?

UDL provides an intentional and systematic approach for building an environment that accommodates diversity and difference between and among the students. It is applicable in any learning context, online and instructor-led courses.

The UDL framework is nested in neuroscience with a particular focus on how the brain works and which parts of the brain are activated during the learning process [5]. The UDL guidelines fall under 3 principles:

a) Provide multiple means of Engagement,

b) Provide multiple means of Representation and

c) Provide multiple means of Action & Expression.

Regarding the Engagement principle UDL suggests that the learning environment provides options for recruiting interest such as optimizing individual choice and autonomy, optimizing relevance, value, and authenticity and minimizing threats and distractions. The learning environment should also offer options for Sustaining Effort & Persistence i.e. heighten salience of goals and objectives, vary demands and resources to optimize challenge, foster collaboration and community, and increase mastery-oriented feedback. Finally, the learning environment should provide options for Self-Regulation i.e. promote expectations and beliefs that optimize motivation, facilitate personal coping skills and strategies, and develop self-assessment and reflection [6].

The second principle of UDL, “Multiple means of representation” is also a key component for successful student engagement. Students may come from various cultural backgrounds, may speak different languages, may have learning disabilities (dyslexia, blindness etc.) or may have different ages. Taking these diversities into consideration the content should be appealing to all. But there **is not one means of representation that will be optimal for all learners**. Hence providing options for multiple representation is essential. UDL suggests providing various options for perception, for language and symbols and for comprehension.

To improve perception, a learning environment could offer ways of customizing the display of information, offer alternatives for auditory information and offer alternatives for visual information. One example would be to allow the student to change font size, or use contrast, or increase or decrease the volume of auditory aids.

Sound is a particularly effective way to convey the impact of information. However, information conveyed solely through sound is not equally accessible to all learners and is especially inaccessible for learners with hearing disabilities, for learners who need more time to process information, or for learners who have memory difficulties. Providing alternatives to learners with hearing disabilities such a visual diagrams, charts, notations of music or sound, provide written transcripts for videos or auditory clips could promote equal opportunities to these learners.

Images, graphics, animations, video, or text are often the optimal way to present information, especially when the information is about the relationships between objects, actions, numbers, or events. But such visual representations are not equally accessible to all learners, especially learners with visual disabilities or those who are not familiar with the type of graphic being used. Auditory information can cover the deficiencies of these learners. To ensure that all learners have equal access to information, it is essential to provide non-visual alternatives:

- provide descriptions (text or spoken) for all images, graphics, video, or animations,
- use touch equivalents (tactile graphics or objects of reference) for key visuals that represent concepts,
- provide physical objects and spatial models to convey perspective or interaction,
- provide auditory cues for key concepts and transitions in visual information.

Another method to provide multiple means of representation is by providing options for language and Symbols. For example, clarification of vocabulary and symbols can be helpful for participants. Many times, a word or phrase may be interpreted differently in various contexts so a glossary explaining the exact meaning in the context of the course could be very helpful. Moreover, if symbols are used in the training materials these should be explained especially when having participants from different cultural backgrounds and their understanding of symbols may be different.

When the syntax of a sentence or the structure of a graphical representation is not obvious or familiar to learners, comprehension suffers. To ensure that all learners have equal access to information, UDL suggests to provide alternative representations that clarify, or make more explicit, the syntactic or structural relationships between elements of meaning. For example, one could clarify unfamiliar syntax (in language for example) or underlying structure (in diagrams, graphs, illustrations) through alternatives that make relationships between elements explicit (e.g., highlighting the transition words in an essay, links between ideas in a concept map, etc.)

Another UDL guideline to promote multiple means of representation is through illustration via multiple media. Classroom materials are often dominated by information in text. But text is a weak format for presenting many concepts and for explicating most processes. Furthermore, text is a particularly weak form of presentation for learners who have text- or language-related disabilities. Providing alternatives – especially illustrations, simulations, images or interactive graphics – can make the information in text more comprehensible for any learner and accessible for some who would find it completely inaccessible in text:

- present key concepts in one form of symbolic representation (e.g., an expository text or a math equation) with an alternative form (e.g., an illustration, dance/movement, diagram, table, model, video, comic strip, storyboard, photograph, animation, physical or virtual manipulative),
- make explicit links between information provided in texts and any accompanying representation of that information in illustrations, equations, charts, or diagrams.

Another guideline to improve representation via multiple means is to offer the materials in various languages or in the case of monolingual learning environments, provide alternatives, especially for key information or vocabulary, an important aspect of accessibility. For example, make all key information in the dominant language (e.g., English) also available in first languages (e.g., Spanish) for learners with limited-English proficiency and in ASL for learners who are deaf or link key vocabulary words to definitions and pronunciations in both dominant and heritage languages.

Comprehension means to transform accessible information into useable knowledge. This process is not passive but an active process. **Constructing useable knowledge, knowledge that is accessible for future decision-making, depends not upon merely perceiving information, but upon active "information processing skills"** [6]. Examples that demonstrate "comprehension" of a topic could be integrating new information with prior knowledge, selecting the right information, strategic categorization, and active memorization. Individuals differ greatly in their skills in information processing and in their access to prior knowledge through which they can assimilate new information.

To improve comprehension UDL suggests providing various options to activate or supply background knowledge, to highlight patterns, critical features, big ideas, and relationships, to guide information processing and visualization, and to maximize transfer and generalization.

Barriers and inequities exist when some learners lack the background knowledge that is critical to assimilating or using new information. However, there are also barriers for learners who have the necessary background knowledge, but might not know it is relevant. Those barriers can be reduced when options are available that supply or activate relevant prior knowledge, or link to the pre-requisite information elsewhere:

- anchor instruction by linking to and activating relevant prior knowledge (e.g., using visual imagery, concept anchoring, or concept mastery routines),
- use advanced organizers (e.g., KWL methods, concept maps),
- pre-teach critical prerequisite concepts through demonstration or models,
- bridge concepts with relevant analogies and metaphors,
- make explicit cross-curricular connections (e.g., teaching literacy strategies in the social studies classroom).

The third principle according to the UDL framework is to provide multiple means of Action & Expression. It is a fact that **learners differ in the ways that they can navigate a learning environment and express what they know.** For example, individuals may be able to express themselves well in writing but not orally, and vice versa, or they may struggle with strategic and organizational abilities (executive function disorders), or have language barriers, and so forth approach learning tasks very differently. It should also be noted that action and expression require a great deal of strategy, practice, and organization, and this is another area in which learners can differ. In reality, **there is not one means of action and expression that will be optimal for all learners**; providing options for action and expression is essential.

To improve Action and Expression UDL suggests a number of guidelines such as providing

options for physical action, expression & communication and executive functions.
Various options for physical action could include different methods for response and navigation as well as optimization of access to tools and assistive technologies.
Learners differ widely in their capacity to navigate their physical environment. To reduce barriers to learning that would be introduced by the motor demands of a task one could provide alternative means for response, selection, and composition. For example, provide alternatives for physically responding or indicating selections (e.g., alternatives to marking with pen and pencil, alternatives to mouse control) or provide alternatives for physically interacting with materials by hand, voice, single switch, joystick, keyboard, or adapted keyboard

Moreover to improve expression and communication it is suggested to use multiple media for communication, multiple tools for construction and composition and build fluencies with graduated levels of support for practice and performance. It is important to provide alternative media for expression. Such alternatives reduce media-specific barriers to expression among learners with a variety of special needs, but also increases the opportunities for all learners to develop a wider range of expression in a media-rich world. For example, use social media and interactive web tools (e.g., discussion forums, chats, web design, annotation tools, storyboards, comic strips, animation presentations).

Finally to promote Action and Expression, UDL suggests multiple options for executive functions and specifically guide appropriate goal-setting, support planning and strategy development, facilitate managing information and resources and enhance capacity for monitoring progress. Examples for monitoring progress include a)ask questions to guide self-monitoring and reflection b) Show representations of progress c) Use of assessment checklists, scoring rubrics, and multiple examples of annotated student work/performance examples etc.

In PV-Trainer e-learning environment we took into consideration the UDL principles and have applied many of the guidelines to maximize student engagement, to improve representation for a diverse audience and promote action and expression:

- To optimize individual choice and autonomy in PV-E-learn we offer asynchronous learning through a series of small units which can be accessed by anyone at any time (UDL Engagement Principle – Optimizing Individual choice and autonomy).

- These units have been created as SCORM packages which can be opened in full screen mode enabling the user to go through and interact with the materials without any disruptions.
- PV-E-learn offers multiple means of presentation: all the content is available in multiple languages and the content can be downloaded as pdf for offline reading. The user can decide which units to read after reviewing the Detailed Learning Outcomes presented per unit.
- The user may also choose to do a self-assessment to measure the knowledge on a specific topic(unit) and decide which units she/he wishes to read.
- PV-e-LEARN uses diagrams where possible to provide information using both text and pictures/diagrams.
- PV-e-learn has embedded short tasks (multiple choice, matching exercises, put in the right order exercises etc.) in order to optimize challenge and increase mastery-oriented feedback.
- PV-e-learn forum fosters collaboration and community.
- To further promote collaboration, the PV-e-learn platform hosts the technology for synchronous learning to be utilized by the teacher if required.
- To facilitate Self-Regulation PV-E-learn includes a self-assessment at the end of each unit.
- PV-e-learn enhances capacity for monitoring progress by providing progress tests and final tests at the end of each unit.

Conclusion

Online learning environments may present barriers but a well-designed environment that uses the UDL framework may overcome these barriers and promote online learning with all the advantages that come with it.

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Jose Enrique Val MONTROS
Fundación Equipo Humano (FEH), Valencia (Spain)

How to implement a training plan in your Company, an holistic approach

About Fundación Equipo Humano

Fundación Equipo Humano is a private non-for-profit foundation constituted in 2010. The aim of the Foundation is social and labour integration of people. The Foundation was created by experienced professionals from the HR consultancy field. At present, 20 people from different backgrounds are working in our organization, including psychology, political sciences, labour sciences, labour relations, law, etc.

Particularly, FEH has specialised in the implementation of innovative techniques and strategies focused on Human Resources in areas such as, employee engagement, managing internal
processes and decision making, development and planning of organisational strategies and methods, relationships with clients and suppliers, work environment studies and outdoor trainings and experiential training on transversal skills such as leadership, creativity, entrepreneurship and time management, among others.

In that regard, FEH has experience in the development of e-learning contents (Erasmus+). FEH has experience in different EU projects that required the development of e-learning and training contents. This has provided them expertise in the development of learning materials, the know how to fit them in to platforms such as Chamilo, moodle, wordpress and others and how to address to different target groups.

Topics included in the training courses include:

1. Active search of employment
2. Social abilities
3. Motivation
4. Training for equality
5. Labour and family co-responsibility
6. Environmental awareness

7. Labour risk prevention

As part of the HR expertise of FEH, they have implemented several strategies that cover different stages and cycles of Human Resource Management (HRM).

- Incorporation and talent attraction processes: composed by selection processes based on search of talent.
- Acknowledgement: salaries studies, key performance indicators and compensation and benefits systems in companies.
- Age management: mentoring and training programs, age management programmes.
- Termination processes: relocation and outplacement programs.

Last but not least, FEH implement learning by doing training programs: tailored training actions with the focus on companies. These are mainly outdoor/indoor training activities where the participants' learning is booted through activities, tests and game dynamics transversal skills such as leadership, creativity, entrepreneurship, time managements, etc.

As part of these training programs, FEH also helps all kinds of companies to analyse their needs in terms of training. Due to this reason, the content of this paper focuses on good practices incorporated in the materials of the EUPV Trainer, some new tools and methodologies that have come up as useful for the photovoltaic sector, and useful practices and tools for the identification of needs. Last but not least, guidelines of how to set training plans for small and medium sized companies will be included. These last parts will take into account FEH's expertise.

Introduction

One of the most important parts of the EU-PV-Trainer, training has been a series of recommendations about how to set up a training program that meet the needs of a photovoltaic trainer or company related to the sector.
The project has developed a guide that constitutes a didactic development for a module focused on **Planning, organizing, conducting and evaluating of the vocational training, composed of three modular units**. These units are:

- Planning and designing vocational training and other forms of improving professional competence of employees.

- Organisation and provision of teaching activities and consultation related to the training offer.
- Promotion and provision of the quality of training services and awarding the qualifications establishing the didactic development for the modular curriculum for the course Photovoltaics Trainer.

In this article, Foundation Equipo Humano aims at acknowledging some of the practices and strategies included in the materials while highlighting some of the best practices regarding training programs within companies. The article tries to develop common strategies for photovoltaic companies for a training plan.

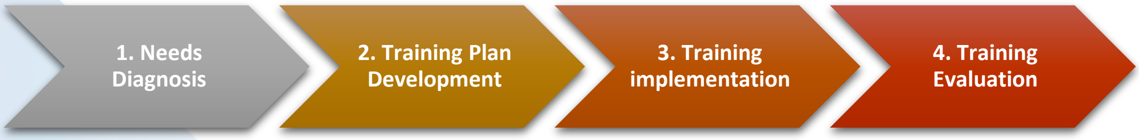
How to identify the training needs in your photovoltaic company

We may define training as the acquisition of knowledge, skills and aptitudes needed for a working position. Those responsible of a company or department, training should be interpreted as an investment in the future of their company since it will allow us to increase our employee's performance in the long term. It will also meet the objectives in mind as well as assume future challenges ahead.

In close liaison with what has been said above, we can talk about Learning Organisations like those that "seek to create their own future, which claims that training and learning is a continuous and creative process for all its members, and that develops, adapts and transforms in answer to the needs and aspirations both out and within the company itself (Navran, Associates Newsletter, 1993).

It follows from the above that "training" has many functions:
- Favour the adaptability and the evolution of professions and contents;
- Be a professional development instrument and a means of social promotion;
- Contribute to the improvement of competitiveness in companies;
- Contribute to the development of new economic activities.

The Training process has four different stages:



Needs Diagnosis

As some of the training materials argue, employees' training needs are identified to define the present and future demand of a given organisation with regard to broad staff competence, in the context of strategy of its development and by foreseen changes that may occur. Identification of training needs is an action striving for the establishment of the most optimal support within the scope of knowledge, skills and social competences for those employees who need it to act effectively.

It requires a thorough information analysis at the level of needs of:

- Organisation as whole, covering all departments;
- Employee groups (tasks);
- Individual.

The one that this section will mainly focus on is the individual scope. Further below there are different questions that can be delivered in order to identify needs of employees. This article is focused on the persona analysis of activities as a better way of accessing the training needs employees might need. On the other hand, others arise as possible, as indicated in some parts of the training materials:

- Assessment of the results of work, indicating the employee's strengths and weaknesses;
- Work observation;
- Interviews and questionnaires;
- Case studies;
- Assessment centres allowing for this process, which enables to collect information on knowledge, skills and attitudes (in this case) of employees;
- Role playing.

In turn, before choosing the approach and the tools you are going to use, it is important that you identify the needs that exist in terms of the number of people to be trained and in what areas to train them. Training needs can be foreseen through:

- The company's strategy for the future (new products, new markets, etc.);
- Technological trends (new work instruments, automation of certain tasks, etc.);
- Changes in the environment (economic, political, legislative, etc.);
- Customer satisfaction surveys;
- Analysis of the work environment.

An analysis of the external and internal factors that affect the company can also be carried out. Depending on whether they contribute to:

- The survival of the company and the improvement of its competitiveness;
- The implementation of a training plan;
- The analysis can be divided into two axes;
- Factors that condition the competitiveness of the company;
- Possibility of implementing a training plan.

Once the needs are defined, the training plan will be created, which is nothing more than a document in which the information is gathered to ensure the training of its staff in a given period.

Following the individual approach, the best way to know the need of each worker in a company, including the photovoltaic sector, is through questions. A specific group of questions aims to identify the needs of employees. It is important that some instructions or advice be followed when given them. Mainly, it is important to conduct the interview in a friendly and relaxed environment. This will always make it easier for attendees to develop their ideas and correctly express the answers to the questions they are asked.

Some questions that are advised to analyse these needs would be:

1. What are the most important problems you encounter in the performance of your work?
2. Of the above problems, which could be solved through training actions?
3. For the proper performance of your job do you need any specific training? (include them in order of importance).
4. What schedules do you think are most appropriate to implement the training actions we are commenting on?
5. Please provide any other comments.

If you are also responsible for a small group of people or a specific department, you can add other questions such as:

1. What style and characteristics do you think are most important for staff with command duties? This question can lead to possible training regarding leadership.
2. For the proper performance of employees you are responsible for, do you think any specific training is necessary?
3. Do you want to add any more comments?

Development of a training plan: implementation and evaluation

Plan Development

Once the needs of the company are clear and based on the same answers, different types of educational strategies can be proposed:

- **Focused on students or focused on teachers:** the one focused on teachers is the one that is determined, directed and controlled. On the contrary, in the student-centred one, he assumes responsibility for his own learning and how he prefers to achieve it, being the teaching facilitator.
- **Based on the resolution of problems or the transmission of information:** the resolution of problems has a clear effect on motivation and involvement of students in the learning of issues that they perceive near their professional practice and also allows them to participate actively. The information transmission strategy is based on the exposition of a topic by one or several people (teachers), who are the ones who direct and control the process; The most commonly used is the oral presentation or master class.
- **Integrated or subject-based:** the subject-based one usually reflects the particular interests of teachers, which include in the program the topics they consider most important according to their work areas or specialties. The result is usually a partial and disconnected teaching in which parts of a whole are added. The integrated involves an important coordination effort to agree on what is best for the interests of the students.
- **Multi-professional or Uni-professional:** whether or not to bring together different professionals in an educational activity depends largely on the tasks they must perform in their work in relation to the subject they are going to learn. If it is important that in your professional practice the tasks are carried out in a team, it is preferable that they share their learning, but if the professional tasks are very different, it is possible that trying to learn them together will hamper effective learning.

- **Individual or socialized:** socialized ones are focused on students working in groups. To develop them it is important to know the principles of the functioning of groups and how to energize them. Self-learning would be an example of individual learning.
- **Significant learning:** the strategy of meaningful learning is what allows us to build new knowledge based on the students' previous ideas**.**

We can only learn from what we already know and this prior knowledge is, in isolation, the variable that most influences learning. People learn from their previous experiences and cognitive models, reorganizing and modifying them to new information or experiences that, in this case, they will receive from the teaching-learning process. This process requires the use of strategies that involve the active participation of the student, and that allow us to promote student centred teaching, to facilitate the construction of meaningful learning.

The training plan is a set of training actions that a company develops to train its workers in order to improve their skills and thus the performance of companies. Specifically, training can be of skills (the most common) and attitudes. To know what kind of training to do, you can ask yourself a series of questions, such as:

- Do you know how to do the job? If the answer is No, the training will focus on Capabilities;
- Can you do the job? Qualities;
- Do you want or are you motivated to do the job? Attitudes.

With all this, the objectives pursued by training in capabilities, which is the most common in companies in the photovoltaic sector are:

- Offer workers more opportunities with learning new technologies and new activities;
- Contribute new knowledge and improve the quality of the job;
- Review the knowledge to keep them updated;
- Improve job performance;
- Increase staff satisfaction.

When drafting the training plan, the following aspects must be taken into account:

- Preparation of a budget so that there is no improvisation;
- Definition of general objectives of the training plan and specific to each job position;
- Definition of a duration and make a calendar to implement the plan;

- Description of the actions to be implemented, will be taught with internal resources (this is facilitated by the internal controls of the companies, usually improving internal communication and saving costs); or external (it is when traveling to external companies to train workers, it is usually more objective and innovative);
- Identification of the groups that will be formed;
- Assignment of one or more managers to coordinate and evaluate the training. In the case of small companies, it could simply be the Head or Head of the section or department.

Training Execution

Based on the training plan and the contents to be taught previously, the most appropriate type of training for the company and the same knowledge is selected.

The first features to consider would be:

- Training contents: What theoretical and practical knowledge should be imparted to overcome the needs identified and acquire the skills indicated?
- Target population: What company employees would be more interested in training?
- Number of people: How many people would be recipients?
- Schedule: What period of the year is the most convenient for the staff to attend training activities?
- Duration: What maximum duration should the courses have according to production needs, and to reconcile the professional and personal life of the workers?
- Conference: What schedule would be most appropriate?
- Place of teaching: Where would it be more convenient to give the training?

In that sense, the types of training can become:

- Standard: a more general and common formation for several companies;
- Tailored: the training is adapted to each company and / or to a specific agenda, it usually has a greater impact due to specificity;
- Face-to-face: these are the typical classes with a teacher;
- Online: is the training given through online devices;
- Mixed: the training is distributed by face-to-face and online mode;
- Workplace training: the training is aimed at learning specific skills in a job.

Below are some methods to conduct the training in a practical way:

- Training in learning: "learning by doing";
- Case studies;
- Simulation of exercises;
- Representations;
- Conferences, videos, films and audio-visuals;
- Training in awareness workshops.

Training evaluation.

At the end of the training, an evaluation is carried out to know if there are changes in the productive results and in the skills, knowledge and abilities of photovoltaic workers or installers. For this, managers can apply the Kirkpatrick Evaluation Model, which is used by analysing 4 evaluation levels:

- **Reaction:** measure the degree of satisfaction of the participants to the training through a questionnaire, knowing the positive and negative aspects of the training.
- **Learning:** the knowledge and skills acquired by those trained are measured through knowledge tests before and after training, interviews or skills tests or field work. It is recommended that you take tests or questions before and after training on the specific topic.
- **Behaviour:** evaluate if the knowledge acquired is being applied in the workplace and if there are changes in the results. This phase is later, since the results of the different positions must be compared. This phase can be evaluated through a Performance Evaluation (See corresponding section) and where we will evaluate the learning objectives obtained.
- **Impact:** evaluate the benefits produced by the training, such as customer satisfaction or corporate image. It can be applied through customer questionnaires.

Other aspects to evaluate can be:

- Transferability: it assesses the degree to which the trained person puts into practice, in the workplace, the knowledge acquired;
- Return on investment: measures the economic profitability of the training through the comparison between the amount invested in the training action and the increase in the company's profit as a result of said training.

In addition, Depending on when and for what knowledge, skills and attitudes are evaluated, we have the following types of learning assessment:

- **Initial diagnostic assessment:** is carried out at the beginning of the course when a previous assessment is necessary to provide information on the level of the attendees regarding the course contents and their expectations. It is used to adjust the objectives and methods, and for comparison with the final evaluation.
- **Formative or process evaluation:** is applied continuously to obtain information on what is happening, especially on those aspects that can be modified during the teaching-learning process: the impression that the course is causing students (motivation, confidence) or the achievement of partial objectives (questions, resolution of exercises).
- **Summative-final evaluation:** is carried out once the training process is completed and its purpose is to qualify the final learning levels achieved by the participants. The consequences of this evaluation may refer to the student body itself (for example certification or access to a job) or to the training program (decisions on its continuity, for example).

Once the types of evaluation are chosen, the techniques for the evaluation of the activities can be emphasized. These can be divided into:

Tests or exams: an evaluation instrument that allows collecting evidence about student learning. According to their nature they can be: written, oral and practical. These can be written, oral or practical, based on observation.

Below, you can find some written and closed evaluation forms that would be ideal for the types of capacity building, applied to this project.

Table 1. Simple evaluation chart

	Very little	Little	Enough	Quite
1. Do you think the course in general has been useful for your future performance?				
2. Have the course contents been adequate?				
3. The contents of the course have the level needed to perform job duties properly				
4. Theoretical activities have served to increase previous knowledge about the established contents				
5. Has the use of practical activities favoured the development of your business skills?				

	Very little	Little	Enough	Quite
6. Have the implemented course hours been sufficient?				
7. Have you missed more practical sessions?				
8. The trainers had enough knowledge to teach adequately				
9. The knowledge acquired and the practices carried out during the sessions have helped me to develop my skills.				
10. Have you met the expectations you had about the training course?				
11. Did you have a hard time understanding the trainers?				
12 Has it been difficult for you to carry out joint activities with the rest of your classmates?				
13. The schedules have been distributed appropriately				
14. The environmental conditions, such as the light and the location of the course, have been very good				

The evaluation of teaching and its contents is an important aspect at the same time for a trainer.

The quality of the effort made by the institution or organization, and the teaching staff responsible for the teaching activity, must also be evaluated. Its purpose is to improve the design and development of subsequent courses.

Usually a student satisfaction survey is carried out at the end of the course, so you have to reserve a specific and sufficient time. The aspects to include in this evaluation are those related to: the goals and objectives of the course; the teaching staff; the content; the methodology; the environment; Resources and materials.

It can be done through a questionnaire in which students, individually, give their opinion on these aspects. You can also use some group technique that provides qualitative information. The choice of technique will depend on the existing climate of confidence to express opinions freely, the time available and the experience of the person who evaluates them, as well as the requirements of the organizing institution. Efforts should be made to return the information obtained to the group, at least the general results.

Final conclusions

Training programs in companies are a complex scenario where several issues/axis need to be taken into consideration. As explained during the article, several are the techniques and approaches that can be implemented along the different techniques for its evaluation. During this report, several have been highlighted. The objective of it is for photovoltaic companies to find it suitable to implement in their own case. For further information, the bibliography can be consulted.

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dr Stanisław PIETRUSZKO, Kamil KULMA
Polskie Towarzystwo Fotowoltaiki, Warszawa (Poland)

Photovoltaic systems – history and present status

Introduction

One of the most important tasks at present is the development of strategies and systems to provide energy on an ecologically sound basis. From today's perspective, only renewable energy sources such as the sun and the wind satisfy all the conditions, which must be placed on the energy supplies for the future. Further, these energy sources are inexhaustible, whereas the exploitation of fossil fuel reserves can continue only for a limited period.
Liberalisation of the European energy market means that there will be more intense competition in the energy sector in the area of production, distribution and sales of electrical energy. New players shall appear due to an open access to energy networks on the market. They shall increase the current tendency of increasing the share of scattered energy generation. Photovoltaic systems may become a significant part of energy infrastructure in this process.

History of photovoltaics

Photovoltaics has a long history that started in 1839 from observations of Edmond Becquerel, son of Antoni Cesar Becquerel and father of Henri Becquerel, both famous physicists. Becquerel noticed that if two platinum electrodes were placed in the solution and exposed to the sunlight, current flowed. That effect was very small and had no practical meaning in that time, however it has not been forgotten.

The name of photovoltaics was formally used for the first time by A. Einstein in his paper from year 1905 published in the journal *Annalen der Physik* under the title of "*On a Heuristic Viewpoint Concerning the Production and Transformation of Light*". He explained the external photoelectric effect as the emission of electrons from the metal surface through its performance of the work function under the impact of particle radiation with proper wave length. Therefore, photovoltaics is the field of science and technology occupying with the research of direct conversion of solar radiation energy to electrical energy. The first solar cell was built in 1954 in Bell Laboratories in Murray Hill, USA, by researchers Chapin, Fuller and

Pearson. The solar cell achieved the efficiency of 6%, which was soon improved and increased to 10%. Back then, space technology constituted the most important application of solar cells. The beginning was in 1958, when first 108 cells were installed on the Vanguard satellite. Results went beyond expectations – cells provided the satellite with electrical energy for much longer than it was originally assumed. It allowed for the development of a limited market of photovoltaic cells, however characterised with high quality.

Due to its high costs, application of photovoltaics on Earth had been rejected for a long time as unrealistic. However, its benefits were fascinating scientists and public opinion, so research on it has never been fully abandoned. Step by step, solar cells found its way to autonomous applications in supply systems independent on the network. It started with calculators and watches, and then it was used in larger devices, such as parking meters. Emergence of the first fuel crisis in 1973 was accompanied by thinking about the use of solar cells on Earth, and shortly afterwards there were launched production plants of silicic cells and modules. At the beginning of 1980s, global trade in solar cells was at the level below 20 MWp/year. In 2008, an annual trade in solar cells achieved more than 7000 MWp. It constituted an increase by 400 times over only 27 years. In 2017, total power of installed PV systems came to 40 GW. A key role in development of photovoltaics was played by the solar energy market promotion, which began in 1990 from the program 1000 Roofs in Germany. That program was very successful and then it was implemented in many countries. A short time later, on the turn of 1998 and 1999, the program 100 Thousand Roofs was introduced, and in 2004 the Renewable Energy Act (EEG) came into effect. EEG appeared to be the most appropriate tool for promotion of photovoltaics. The market noted down a dynamic increase.

For many decades, efforts have been made to replace silicon with other materials. Materials of high light absorption are searched for in order to make cells thinner and cheaper. That searches result in thin layer cells that are 100-times thinner than those from crystalline silicon. The first solar cell was made from amorphous silicon already in 1976 by David Carlson and Chris Wronski. However, in 1980s high expectations concerning that material were not realized. Another thin layer material that is still at an early stage of market implementation is CIS (copper indium selenide), known also as CIGS, if it contains an addition of gallium. These cells are characterised with high stability and achieve, at least in laboratory, high efficiencies. Cadmium telluride is another thin layer material from which solar cells are produced. Socalled micromorth photovoltaic cells (structure from amorphous and microcrystalline silicon) are also present on the market.

Fields of application of PV systems independent on the network constitute usually autonomous systems in developing countries, leisure (camping, sailing, etc.), telecommunications systems, as well as PV/diesel fuel hybrid systems. The role played by photovoltaic cells in consumer products (watches, toys, etc.) should not be underestimated. In the past, photovoltaic systems were almost exclusively installed on existing roofs, so they were regarded as additional elements. However, for several years photovoltaic products are available, which can be applied directly as roof covering, so they constitute an integral part of roof. There are also PV components in the form of dormer windows. Moreover, all main glass producers offer photovoltaic elements that can be easily integrated with warm or ventilated facades.

In today's world, energy priorities are changing. New technologies, cleaner, more quickly installed and better adjusted to local needs attract interest of investors and local authorities, slowly competing with monopolised and centralised energy sector. While comparing various energy options, economic costs are gradually no longer a vital criterion – factors which economic value is difficult to be calculated directly, such as energy independence, diversification of energy sources or stability of supplies, are more and more important. It is particularly important against the possible appearance of another energy crises.
Throughout the year 2017, almost 100 GW of power was installed all over the world, which constitutes another record for global photovoltaics. Total installed PV power came to 400 GW at the end of year 2017, which means an increase by 25% as compared to 2016. In 2017, 9.2 MW of new PV installations was established in Europe.

The advantages of PV are manifold:

- Primary energy supply of the sun is larger than from all other energy sources.
- It is available in all regions of the world.
- Its modular design varies from miliwatt (mW) in consumer products to gigawatt (GW) in a utility-scale power plants.
- During operation, it produces electricity with no atmospheric emissions and no waste production.
- It requires virtually no maintenance.
- It is silent during operation.
- It requires no water to generate electricity.
- PV systems offer a carbon footprint that is 10 to 20 times lower than conventional energy generation technologies.

- The energy payback time of PV systems is between 0.5 and 1.5 years depending on technology and location.
- It has a proven technical lifetime of 30+ years.

Global solar PV market

In 2018, solar took a little break from the enormous growth rates seen in previous years. Although the solar market grew modestly by only 4%, it was enough to again outdo any other power generation technology last year. More solar PV was deployed than all fossil fuels and nuclear together. Solar also added more capacity than all renewables combined – including large hydro – and had twice as much installed than wind power (see Fig. 1).

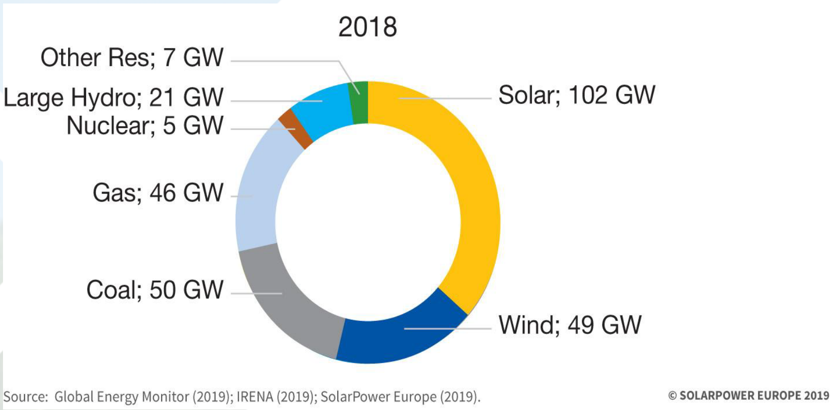

Fig. 1. Net power generating capacity added in 2018 by main technology
Source: Global Market Outlook For Solar Power / 2019 – 2023, http://www.solarpowereurope.org/wp-content/uploads/2019/05/SolarPower-Europe-Global-Market-Outlook-2019-2023.pdf

Relatively, solar's share reached 36% of all newly added power capacities in 2018, compared to 38% the year before. While impressive at first sight, the 'stagnation' in both solar and wind growth in 2018 meant that renewable capacities only contributed 63% to total power additions). When looking at the share of total installed power generation capacities, renewables contributed 33% in 2018, and 26% in terms of power output. All solar PV power plants together produced only 2.2% of the world's electricity output. This shows that despite solar's recent dominating role in annual power generation additions, there's huge untapped potential for both solar and its renewable peers.

The 2018 solar market not only exceeded the 100 GW level for the first time: as the year passed, it was also the first time the world had more than 0.5 TW of solar power capacity up and running. One year earlier, at the end of 2017, total global solar power capacity reached over 400 GW, after it surpassed the 300 GW level in 2016 and the 200 GW mark in 2015.

Total installed PV power capacity grew by 25% to 509.3 GW by the end of 2018, up from 407 GW in 2017 (Fig. 2). Since the beginning of the century, when the grid-connected solar era began with the launch of Germany's feed-in tariff scheme, total solar power has grown by nearly 320 times. When looking back just a decade, the world's cumulative PV capacity increased by over 3,200% – from 15.8 GW in 2008.

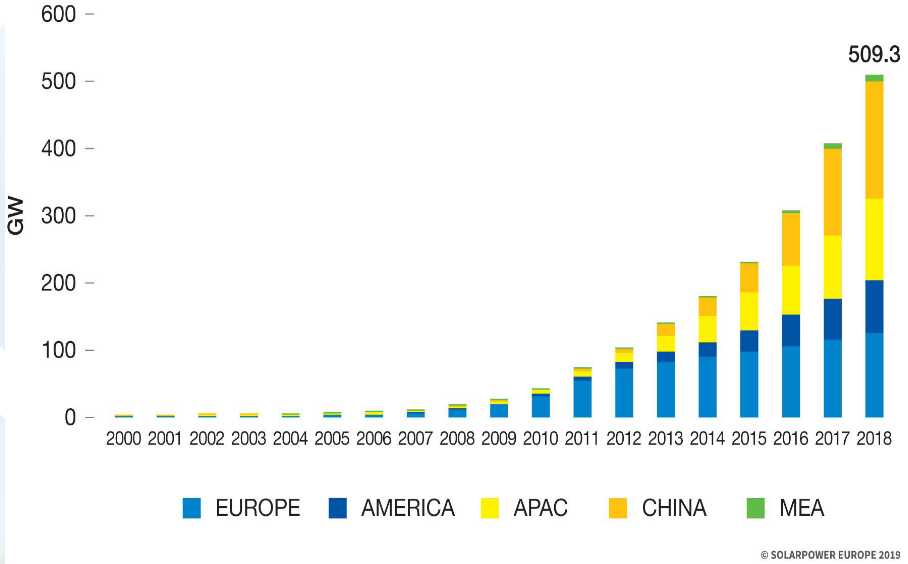

Fig. 2. Global total solar PV installed capacity 2000-2018
Source: Global Market Outlook For Solar Power / 2019 - 2023, http://www.solarpowereurope.org/wp-content/uploads/2019/05/SolarPower-Europe-Global-Market-Outlook-2019-2023.pdf

Although growth in the top 3 Asian markets slowed, the Asia-Pacific region further expanded its solar leadership in 2018, again representing more than half of the global power generation capacities (see Fig. 3; note that due to its large size, China is listed separately from the Asia-Pacific region). Additions of 71.3 GW in 2018 resulted in 295.7 GW of total installed capacity, equal to a 58% global market share – a 3% points year-on-year growth. The new growth phase of European solar pioneers couldn't stop the continent from losing market share, which dropped by 3% points to 25%. Still, Europe maintained its second position based on a cumulative PV capacity of 125.8 GW. The Americas was again the world's third largest solar region in 2018 – with a cumulative installed capacity of 78.2 GW and a 15% stake. Increasing activity in the Middle East and Africa (MEA) changed the region's solar development path last year. With a total solar capacity of 9.6 GW, it's world market share grew slightly in 2018, moving up to 1.9%, from 1.7% the year before.

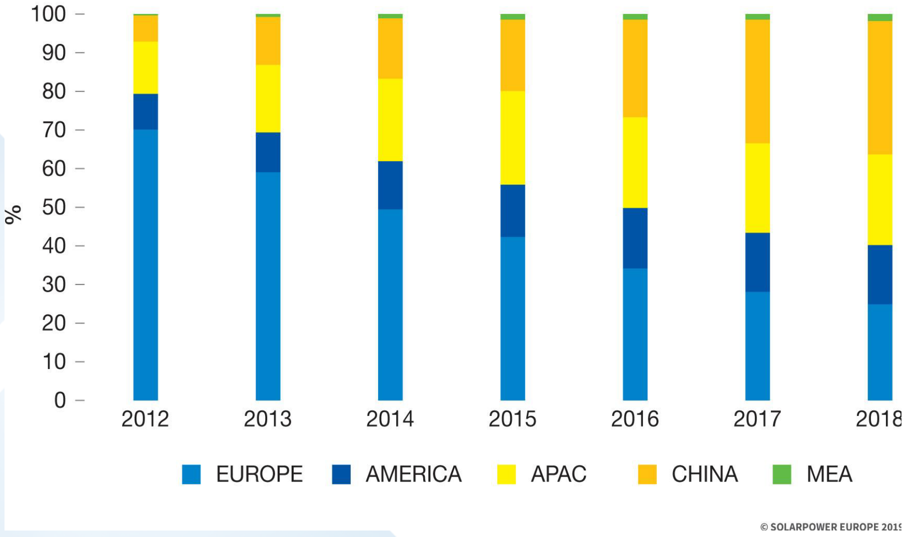

Fig. 3. Global total solar PV installed capacity shares 2012-2018
Source: Global Market Outlook For Solar Power / 2019 - 2023, http://www.solarpowereurope.org/wp-content/uploads/2019/05/SolarPower-Europe-Global-Market-Outlook-2019-2023.pdf

A look at individual countries clearly shows that China's market contraction in 2018 has not at all affected its solar dominance. Its operational solar power generation capacity reached 34.4%; this is 2% points higher than in 2017, when China's share was at 32.3% and already close to presenting one-third of global power generation capacities, which it now surpassed. Like in the previous years, China was followed by the United States, Japan and Germany. All three lost market shares in 2018, with Germany now down to single-digits. The US' cumulative installed PV capacity reached 62.1 GW, equal to a global share of 12.2%; Japan's 55.9 GW resulted in a 11.0% share, and Germany's 45.9 GW meant a 9.0% share, down from 10.6% in 2017. While India didn't have a good solar year in 2018, its market decline is not reflected in the total global power rankings – its 27.3 GW of total installed solar capacity was enough to stay ranked in fifth place and increase its share to 5.4%, from 4.7% in 2017.
All other solar markets significantly trail behind the top 5. In that group, there are only two notable changes to report: following Italy at 19.9 GW and UK at 13 GW, Australia now turned into a +10 GW solar power generation capacity market on grounds of its massive growth streak that led to a total installed capacity of 12.6 GW by the end of 2018. Moreover, South Korea, after reaching a total solar capacity of 7.7 GW, replaced Spain in this top 10 list.

The European solar market

2018 was a great year for solar in Europe. The continent added 11.3 GW in 2018, a 21% rise over the 9.3 GW installed the year before (see Fig. 4). In the European Union, demand even soared by 37% to 8.2 GW, up from 6.0 GW deployed in 2017. Europe's comparatively lower growth results primarily from the solar market contraction of Turkey, the continent's number one in 2017. On the other hand, the EU-28's switch from 'no growth' to two-digit growth, to a large extent, stems from the national binding 2020 renewables targets that many member states yet have to meet.

The growth of the European/EU solar market in 2018 was impressive, although a little below our expectations in last year's GMO (34% for Europe, 45% for EU). Turkey's sudden and strong market decline due to the financial crisis and lack of political support was neither awaited by us nor Turkish Solar Association GÜNDER. None of Spain's nearly 4 GW of solar tender-awarded projects or any of the huge merchant/PPA pipeline was grid-connected in 2018, and in France, market demand even shrank last year. On top of it all came a surprising shortage for high-efficiency modules in Europe combined with a price hike towards the end of the year, as Chinese demand was unexpectedly high in the fourth quarter.

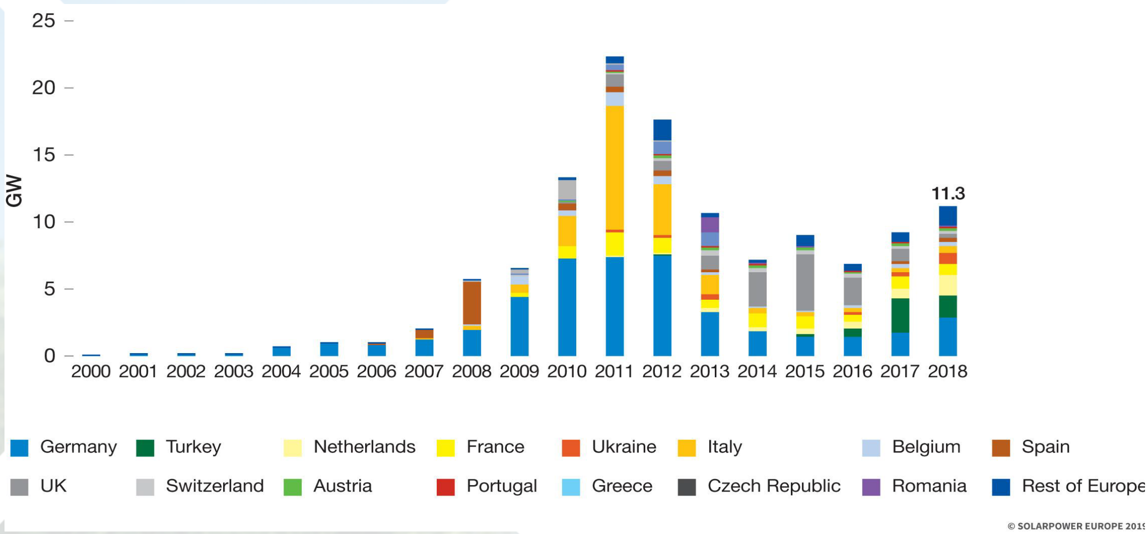

Fig. 4. European annual solar PV installed capacity 2000-2018
Source: Global Market Outlook For Solar Power / 2019 - 2023, http://www.solarpowereurope.org/wp-content/uploads/2019/05/SolarPower-Europe-Global-Market-Outlook-2019-2023.pdf

Top 5 European solar markets 2018

Germany was Europe's top solar PV Market in 2018. In 2018, four years after it lost the title to the United Kingdom in 2014, Germany took back the sceptre from previous market leader Turkey. At 2.95 GW, the German market grew 67% year-on-year, after it added 1.76 GW in 2017 and almost the same capacity in the two years before – 1.52 GW in 2016 and 1.45 GW in 2015. This is the first time Germany met its 2.5 GW target since 2013. The main driver for the country's 2018 solar boost were self-consumption/feed-in premiums for medium to large commercial systems ranging from 40 kW to 750 kW, which contributed to more than half of the new capacity, while residential systems up to 10 kW contributed around 400 MW.

Tender-based ground-mounted systems above 750 kW were responsible for around 550 MW. The Mieterstrommodel (on-site community solar) regulation, introduced in 2017 to enable collective self-consumption of PV installations on apartment buildings, continues to attract limited interest as participants are subject to full EEG levy payments.

The second largest solar market in Europe was Turkey, which fully disappointed last year. After a short and very high flight in 2017, when the market rose nearly 4.5 times to 2.6 GW, compared to 584 MW the previous year, Turkey was hit by a financial crisis in 2018. It installed only 1.64 GW, a year-on-year decrease of 37%. After around 1.2 GW was grid-connected in the first quarter, less than 500 MW was added in the following 9 months. Almost all new capacity was so-called 'unlicensed' solar systems up to 1 MW but often clustered to larger project sizes, while from the 600 MW of 'licenced' systems tendered in 2014/15 only nine systems totalling 82 MW were realised by the end of 2018, with 60 MW being installed between August and December of that year.

Solar needed to become cost-competitive with other technologies for the Netherlands to develop from a medium-size market to one of Europe's leaders. Last year was the first time the Dutch solar market reached the GW-scale, one of three European markets in that group. The Netherlands installed 1.5 GW in 2018, almost doubling from the 770 MW it added in 2017, when it had already grown by over 50% over the previous year. While The Netherland's solar 'baseload' are net-metering incentivised residential installations, which contributed around

40% in 2018, the bulk came from commercial and utility-scale systems awarded in technology-neutral tenders of the Dutch SDE+ scheme. In the 2018 SDE+ autumn round, solar scored 55% of the tendered volume, equal to over 4,400 projects and 2.9 GW; in the 2018 SDE+ spring round, solar won 1.7 GW of the of 2.3 GW total.

The French solar market disappointed again in 2018. It still did not reach the GW-scale, but much worse, unlike most of the other European solar markets, it even contracted slightly by 4% to 873 MW. A complicated incentive scheme requiring solar systems as small as 100 kW to participate in tenders hasn't worked as intended so far; even regulatory changes and plans to tender more capacities as of 2018 have had no positive effects so far. France missed its 10 GW cumulative solar target in 2018 by over 1 GW. However, several tenders were held and awarded in 2018, including a 200 MW technology-neutral solar/wind tender, where solar won the entire capacity.

A very generous feed-in tariff of 15 euro cents/kWh for large-scale PV systems has catapulted Ukraine into the top 5 European solar markets in 2018. A total of 803 MW was installed, 228% higher than the 245 MW connected to the grid in 2017. In addition to large-scale solar, a net metering scheme for PV installations up to 30 kW attracted considerable interest last year. In the first three quarters of 2018 alone, installed rooftop capacity had more than doubled to 121 MW, from 51 MW at the end of 2017.

In summary, solar in the European Union and Europe as a whole is on the upswing. From the 28 EU member states, 22 connected more solar to the grid than the year before; for the entire continent, less than a dozen countries experienced lower demand for solar power technology.

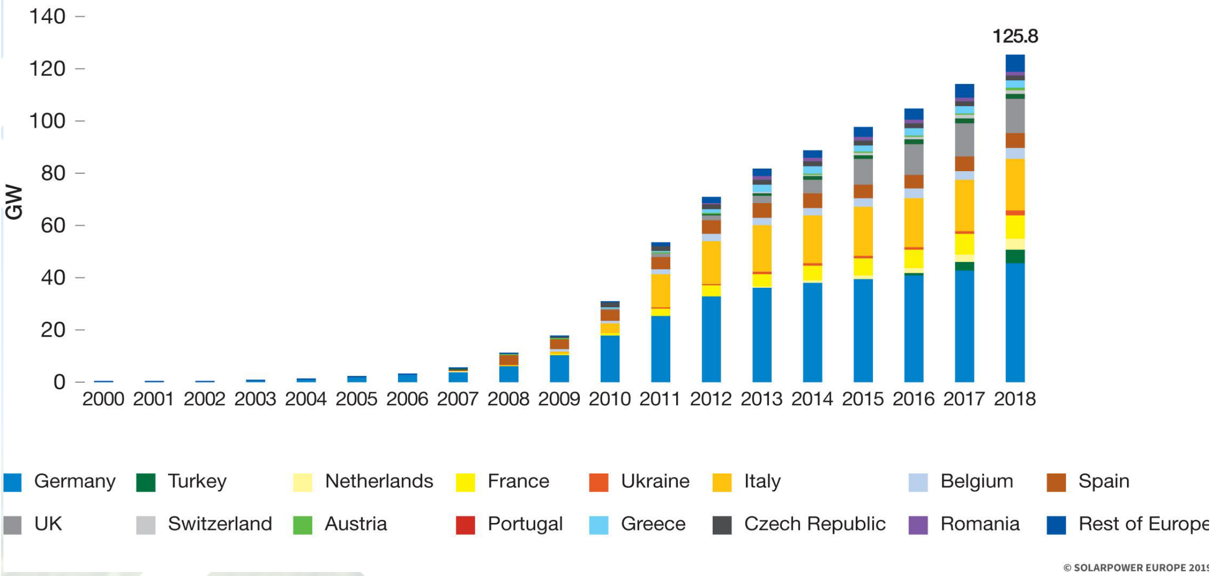

Fig. 5. European annual solar PV installed capacity 2000-2018
Source: Global Market Outlook For Solar Power / 2019 - 2023, http://www.solarpowereurope.org/wp-content/uploads/2019/05/SolarPower-Europe-Global-Market-Outlook-2019-2023.pdf

The picture of European total solar installed capacities in 2018 is very similar to 2017 (see Fig. 5). Germany remains Europe's largest solar power plant operator with 45.9 GW of total installed capacity, followed by Italy with 19.9 GW. Again, Germany (36.5%) and Italy (15.8%) were home to over half of Europe's solar power generation capacities. However, their share slightly decreased – 52.3% vs. 54.7% in the previous year. The only other European market having more than 10 GW installed was the UK, but as it installed only 286 MW, adding up to a 13 GW total, its share decreased by 1% point to 10.3%. Next to the three European 2-digit level solar markets, 12 countries had solar capacities in the 1-digit GW-level (France, Spain, Turkey, Netherlands, Belgium, Greece, Switzerland, Czech Republic, Ukraine, Austria, Romania, Bulgaria), while most countries on the continent operated less than 1 GW of total solar power.

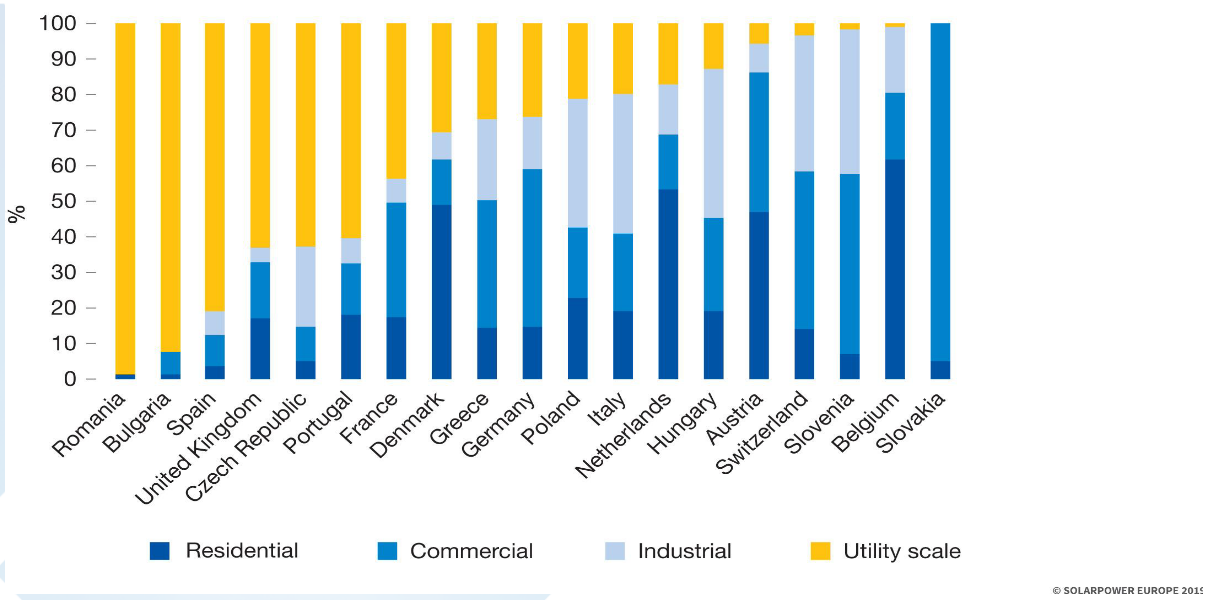

Fig. 6. European solar PV total capacity segments until 2018 for selected countries
Source: Global Market Outlook For Solar Power / 2019 - 2023, http://www.solarpowereurope.org/wp-content/uploads/2019/05/SolarPower-Europe-Global-Market-Outlook-2019-2023.pdf

In Europe, solar market segmentation today still mirrors, to a large extent, the evolution of the respective market (see Fig. 6).

Those countries that offered at some point, and usually for a short period of time, very attractive feed-in tariff programmes are still dominated by the utility-scale solar segment in Europe. However, hardly anything has been installed since the FIT schemes were terminated. This is the case for Eastern European countries Romania, Bulgaria, Czech Republic, as well as Spain, which was almost fully dormant for years, when it added only small amounts of distributed systems. However, while the recent termination of the solar tax will drive more self-consumption systems in Spain's new solar growth phase, the bulk will be tender-based ground-mount power plants and PPA-based utility-scale systems.

In other markets with continuously functioning solar demand, like Germany, the distribution is much more even. Here, the earlier uncapped large-scale FIT schemes were replaced by tenders with decent and limited volumes, while self-consumption/premium FIT distributed systems are still uncapped – and that's where today's demand mostly takes place. In several Central European markets, like Austria, Belgium, Switzerland or the Netherlands, utility-scale solar has not played a role in the past – they have been always focussing on rooftop solar. In the Netherlands that is now changing, as auctions have started to drive growth for large commercial and utility-scale systems.

By 2018, 19% of Europe's cumulative PV system capacity was installed on residential rooftops, about 30% on commercial roofs, while the industrial segment accounted for 17% and the utility market for 34%.

The development of the different solar segments in Europe will clearly depend on the boundary conditions and policy frameworks of the individual countries. However, utility-scale ground-mounted power plants and large rooftop systems will thrive in any country with regular tenders and attractive conditions for merchant/PPA systems, while distributed rooftop solar in particular needs environments without taxes on self-consumption.

Why solar in Europe is growing again

As forecasted in last year's GMO – Europe has returned to a growth path and is supposed to stay there for the coming years for several reasons:

- EU 2020 targets: The deadline for EU member states to meet their national binding 2020 renewable energy targets is quickly approaching. A recently published update from EU statistics office Eurostat revealed that only 11 out of 28 EU countries had already fulfilled their obligations by the end of 2017, the majority was still on its way, and several had quite some way to go. With solar being the most popular power generation source among EU citizens, the most flexible, easy to install and often the lowest cost means to expand renewables shares, governments increasingly take solar into their climate strategies. Hungary, for example, which was the fifth largest solar market in the EU in 2018 with over 400 MW, now has a clear focus on solar when it comes to renewables.
- Tenders: Only a few years ago, many in the European solar industry – that were used to uncapped attractive feed-in tariffs – feared that tenders were only a means to control and limit growth. In the meantime, many European countries have embraced solar tender tools, which have played a key role in bringing down solar power prices and prove to politicians, businesses and the public how quickly its cost continues to decrease. Solar has also shown in several European countries, including Denmark, Germany, the Netherlands and Spain, that it can win technology-neutral tenders against any other renewable technology if the boundary conditions are properly set. The next stop will be 'intelligent' tenders, which strive to support system and grid services. Germany will launch such a tender, which will also enable combined solar/wind solutions, in September.
- Self-consumption, digital & storage: Solar power is much cheaper than retail electricity in most European markets and will continue to reduce in cost, which is increasingly a major driver for people and companies to invest in on-site power generation. The quickly falling cost of battery energy storage combined with the benefits of digital and

smart energy products supports the sales case for solar, as many consumers prefer to have better control over their energy bill. However, in order to empower prosumers, it is key that solar is not inappropriately taxed and that market design is adapted to the needs of the new energy world.

- Emerging & reawakening markets: The low cost of solar is attracting European countries that haven't been very active in the field in the past. For European solar shooting star, Ukraine, energy security was one important aspect for its incentive programmes for large-scale and residential solar. There are also European solar pioneers that have turned to low-cost solar again, such as Spain, which might even turn into Europe's largest PV market in 2019.
- Corporate sourcing: Sourcing renewable power has become a crucial part of the energy and sustainability strategy of many leading corporates – and with costs for renewables continuing to decrease, the appetite for cost-competitive solar and wind power is now growing quickly. Started in the US, today's leading market for corporate renewable sourcing, this trend is now quickly embraced in Europe as well. So far, corporates have chosen primarily wind over solar for renewable PPAs. Primarily, it has been easier to access large renewable power volumes from big wind farms; smaller, commercial solar has rather been directly installed on-site. With the advent of large-scale solar in Europe, low-cost solar is going to play a much bigger role in corporate sourcing.
- Merchant solar / PPAs: We are now starting to see direct bilateral PPAs with solar increasingly competing with wholesale power markets in a number of European countries. This development will be seen primarily in those European countries with the widest spreads between solar and wholesale power prices, and where access to ancillary service markets is granted. There had been talk about pure PPA based projects, in particular in Spain, for some time, and a huge pipeline of over 30 GW had accumulated. But it took until 2018, before the first of these systems was being built; a 175 MW system from BayWa was sold before final grid-connection to the asset manager of Munich RE/Ergo at the end of 2018, and in early 2019 the world's largest PPA was signed for a 708 MW solar project portfolio in Spain and Portugal. Also, in Germany, where wholesale power prices are lower than in Spain, development for a 'subsidy-free' 175 MW system started last year.

- Clean Energy Package: The outcome of Europe's 'Clean Energy for All Europeans' legislation is very positive for solar and energy storage. It has set a higher-than-expected 32% renewables target by 2030, ensures the rights for self-consumption, and maintains priority dispatch for small-scale solar installations, among many other pro-solar provisions. Finally, it has addressed many needs for a flexible, renewable energy system by creating a new electricity market design framework and implementing new tools. An important milestone has been reached, now it is about implementing the directives in the member states.

2019 will be an exceptionally good year for solar power in Europe. The Medium Scenario of our European annual solar PV markets scenarios 2019 – 2023 expects very strong growth for the continent until 2020. This year, we see demand surging by 81% to 20.4 GW, for 2020, we expect an 18% growth to 24.1 GW, which would be a new installation record, beating the 22.5 GW added in 2011. The main drivers for the higher-demand assumptions are the same – the EU-28 countries have until 2020 to meet their binding national renewables targets, then, there is the volume that needs to be installed from various tenders. None of the PV systems from the large Spanish PPA pipeline were grid-connected in 2018. Another factor is a quicker-than-anticipated price decrease. The Chinese market restructuring has freed capacities and led to unexpected price reductions for cells and modules, which has triggered demand for solar around the world. After 2020, EU member states would take their time before they invested heavily again in renewables, as the next targets only need to be met in 2030. We still see a flattening of the growth curve in 2021, but that's only very short-term; rather taking a breath to prepare for the next growth phase, the momentum won't stop. Utilities, corporates, and big funds in Europe are putting renewables high on their agenda – and solar, as both the lowest cost and most versatile energy generation source, will be their favourite means for clean power sourcing and investing.

Photovoltaics in Poland

The photovoltaics market (PV) in Poland is at an early stage of development, but its growth is very dynamic. At the end of 2018, installed capacity did not exceed 500 MW. On the one hand, it is a significant improvement, especially in comparison to several MW by the end of 2013. On the other hand, it is still little, as the potential of such a country as Poland should come to at least ten times more.

According to the Polish Society of Photovoltaics (PTPV), the target announced already in 2009 is the accomplishment of 1% of consumed electricity from photovoltaics in 2020, i.e. 1.4 GW of installed power. It is highly probable that this target will be reached by the end of 2020. An increase in installed power will result from the development of a large number of prosumer systems and the construction of large photovoltaic power plants under the auction system after 2022.

The prosumer sector is supported by the discount mechanism. The distribution system operator (DSO) must collect energy from microinstallations. Support consists in the so-called discounts. Prosumers may receive 0.8 kWh (in the case of systems with capacity below 10 kW) and 0.7 kWh (in the case of systems with capacity of 10-50 kW) for every 1 kWh delivered to the grid. This support mechanism seems to have a relatively low capacity for growth. Significant subsidies from European and national programmes, as well as no taxation support the RES growth more. It is estimated that every year several dozen photovoltaic installations shall be developed.

More than 50% of the installed capacity is located in the south-eastern and southern part of Poland. It results from the highest scale of support system and the highest intensity of solar radiation. The Lublin Voivodship has the largest installed capacity of 32.480 MW. The largest number of systems appeared in the Silesian Voivodeship – 153 with total capacity of 9.331 MW; Amendment of the Act on Renewable Energy Sources, from 1 July an average system capacity comes to 61 kW.

Poland may not ignore trends present on the European and global energy market. These trends mean that the role of photovoltaics in Poland as a technology producing clean electrical energy in large photovoltaic power plants and small rooftop systems shall increase. Falling costs of energy from renewable sources, limited impact of energy technology on human health, changing role of carbon, emerging new business models in the energy sector, including micro-sources and distributed energy systems are only some of trends to form power engineering in Poland. It contributed to an increase in environmental awareness of Polish society and knowledge about renewable energy technologies, increase in public participation in making decisions concerning new investments in infrastructure and willingness to participate in satisfaction of its energy needs through the development of national sources.

Summary

The above presented information confirms that the market of photovoltaic services is dynamically developing all over the world. Therefore, the demand for qualified fitters of photovoltaic installations shall also increase, thus for highly qualified trainers preparing fitters for work.

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Radosław FIGURA
Uniwersytet Technologiczno-Humanistyczny im. Kazimierza Pułaskiego, Stowarzyszenie Elektryków Polskich oddział Radom (Poland)

Analysis of photovoltaic module working parameters

Introduction

The prices of conventional fuels increase continuous, the depletion of their resources and the tightening of environmental protection regulations force the search for alternative, low-emission energy sources such as solar energy. Solar energy is free of any pollution, which is its additional advantage compared to other energy sources.

An energy stream of approximately $178x10^{15}$ W reaches the Earth's atmosphere from the Sun, and this is a small part of the total solar radiation. Nevertheless, this stream is 30,000 times greater than the total power of all devices installed on Earth. The quantity that characterizes the energy reaching the Earth's atmosphere is a solar constant of 1.395 kW / m^2 [6]. It is estimated that the value of solar radiation energy in Poland is in the range of 0-5.5 kWh/m^2/day and the average solar radiation is 1000 kWh / m^2 / year [3,10].

Radiation reaching the earth's surface is dispersed and reflected. Therefore, three types of radiation can be distinguished..

Direct radiation is radiation that reaches the Earth's surface without any obstacles and can be absorbed by a solar cell. The greatest effect of solar radiation conversion into electricity is obtained at the radiation angle on the cell surface of 90º.

Dispersed radiation arises due to the dispersion of the photon stream, e.g. in the cloud. Scattered radiation reaches the Earth's surface, but photons have less energy and the direction of their incidence on a flat surface is random. The share of scattered radiation in the total radiation reaching Poland ranges from 47% in summer to 70% in winter.

Reflected radiation arises as a result of reflection from objects on the ground, e.g. buildings [4]. The impact of reflected radiation on electricity production is negligible.

1. Construction and operation principle of photovoltaic cells

1.1. Photovoltaic effect phenomenon

The conversion of solar radiation into electricity in photovoltaic cells occurs as a result of the photovoltaic effect [5, 8].

The mechanism of the phenomenon is the creation of an electromotive force as a result of physical phenomena in a heterogeneous medium as a result of its lighting. This medium can be, for example, a joint of two semiconductors, an electrolyte and a semiconductor or a semiconductor and metal [11]. The photovoltaic effect occurs in all semiconductors. In each of them it runs with different intensity and occurs at different wavelengths of incident light. Semiconductors are those elements whose barrier potential is less than 5 eV [5].

Visible light waves cause electrons to be knocked out of the semiconductor crystal lattice from the valence band to the level of conductivity. This results in the creation of holes (+) in the places of electrons struck (-). This hole is replaced by an electron from a neighbouring crystal lattice node, and a new hole is created in the place of this electron. When there is a predominance of electrons in a semiconductor, it is called an n-type semiconductor. If there is a predominance of holes, it is called a p-type semiconductor [2]. The n-type and p-type
semiconductor boards pushed together form a p-n junction. At the junction of these two types of semiconductors, an internal electric field called a potential barrier is created [10]. When the semiconductor remains unlit, the holes move to the left and a small diffusion current (I_d) flows in the semiconductor. However, if the p-n junction is illuminated, then photons cause the electron-hole pairs ((-) and (+)) to burst. The potential barrier then shifts negative charges to the n-type area, and positive charges to the p-type area. The result of this movement of charges is the creation of a constant DC voltage on the connector. Because the separated charges in the junction have an unlimited lifetime (as long as the junction is exposed), the p-n junction acts as a DC voltage source (Fig. 1 – c) [2].

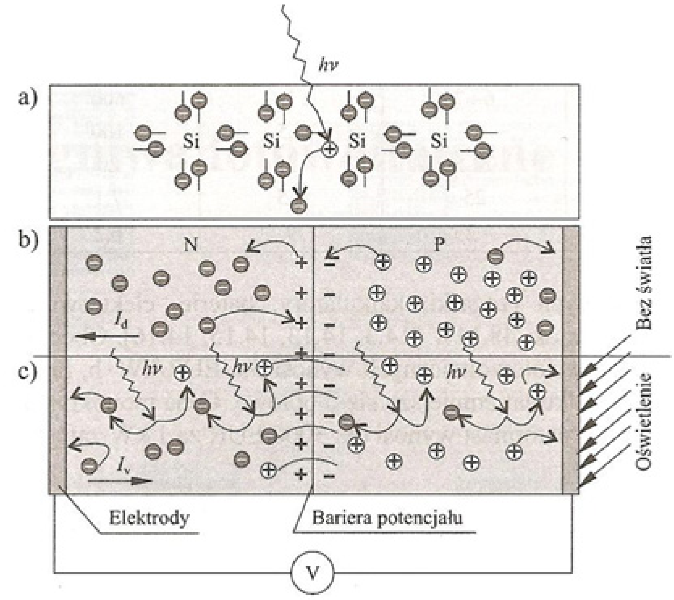

Fig. 1. Photovoltaic mechanism; a) hole formation mechanism, b) diffusion reverse current, c) current flow (illuminated connector) [2], where: elektrody – electrodes, bariera potencjału – potential barrier, oświetlnienie – lighting, bez światła – without light.

1.2. Construction and division of photovoltaics

Since the creation of the first selenium photovoltaic cells with 0.5% efficiency, many new material and construction solutions have been created. The last several years have caused the photovoltaic cell industry to develop in a very dynamic way. This results in a significant decrease in the prices of solar modules and an increase in their energy efficiency.

Silicon is the dominant material used for the production of solar cells. The share of silicon photovoltaic cells is estimated at over 80% of world production [4].

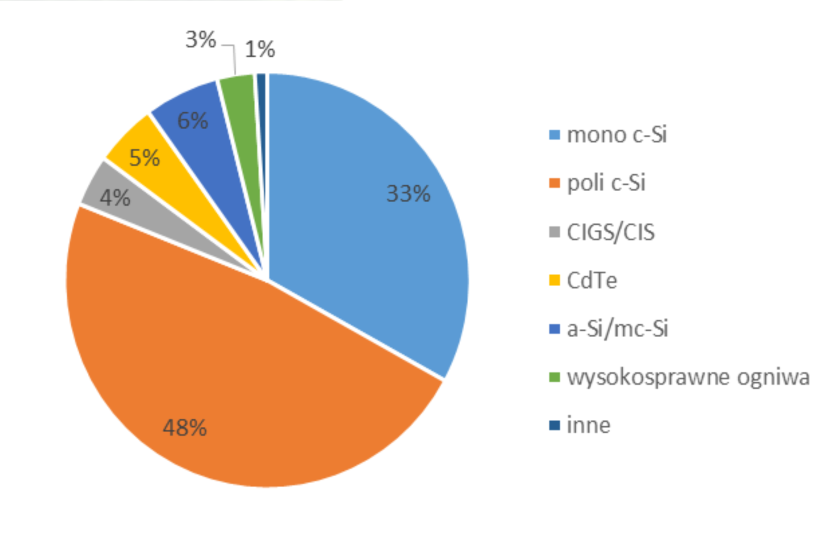

Fig. 2. Share of individual technologies in the photovoltaic module production market in 2012 [13], where: wysokosprawne ogniwa – high-efficiency cells, inne – other.

1.3. Operation principle of photovoltaic cells

The extraordinary popularity of silicon cells results from the wide availability of SiO_2 quartz sand and from the satisfactory efficiency of the main material used for their production – silicon. The content of this element in the outer layers of the Earth is about 27% and it is available in almost every region of the world.

Monocrystalline cells

The quartz sand melts at 1800°C and then cleans. The purity of the finished silicon is 99.9999%. Silicon monocrystalline with a small amount of boron is obtained under vacuum from this purified and molten raw material. A single crystal is a formed cylinder with a diameter of 5÷30 cm and a length of 1-2 m. It is the starting material for the production of monocrystalline cells [5,7].

Monocrystalline cells are manufactured by laser cutting the monocrystalline into p-type plates with a thickness of about 0.30 mm. On the surface of the second plate, an n + type region is generated by phosphorus diffusion. Due to the fact that the light beam is reflected from the surface of the photocell 40%, it is covered with an active silicon surface, transparent anti-reflective material (ARC). Before applying the ARC layer, the surface is textured. This treatment causes beneficial changes in the colour of reflected and diffused light and the refractive index. Selective layers are also applied that filter the light spectrum, passing the desired wavelengths. All these processes reduce losses in the form of reflected radiation energy to about 5%. Metallized electrodes are glued on the upper and lower sides of the cell. The upper electrode has an area ten times smaller than the lower one. The lower electrode is completely covered with a metallized layer, whose task is to create a mirror reflecting photons in silicon, and thus increase their absorption in silicon. Additionally, in the lower part of the p-type semiconductor, a p + area is diffused by diffusing the Group III admixture. The p-p + junction formed in this way on the border of these areas is associated with the formation of a back electric field (BSF). The BSF electric field returns electrons from the bottom electrode, and increases the likelihood of charge carrier separation [10, 11].

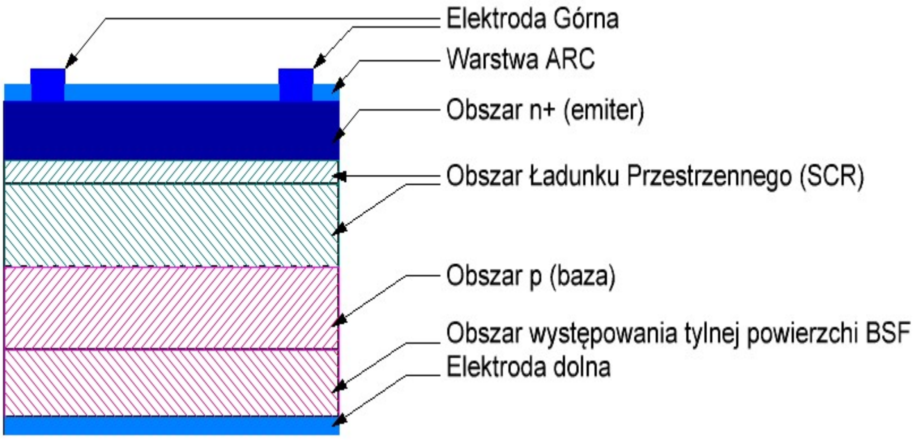

Fig. 3. Construction of silicon photovoltaic cell [11], where: Elektroda Górna – Upper electrode, Warstwa ARC – ARC layer, Obszar n+ (emitter) – n + emitter area (base), Obszar występowania tylnej powierzchni BSF – BSF posterior area, Elektroda dolna – Lower electrode.

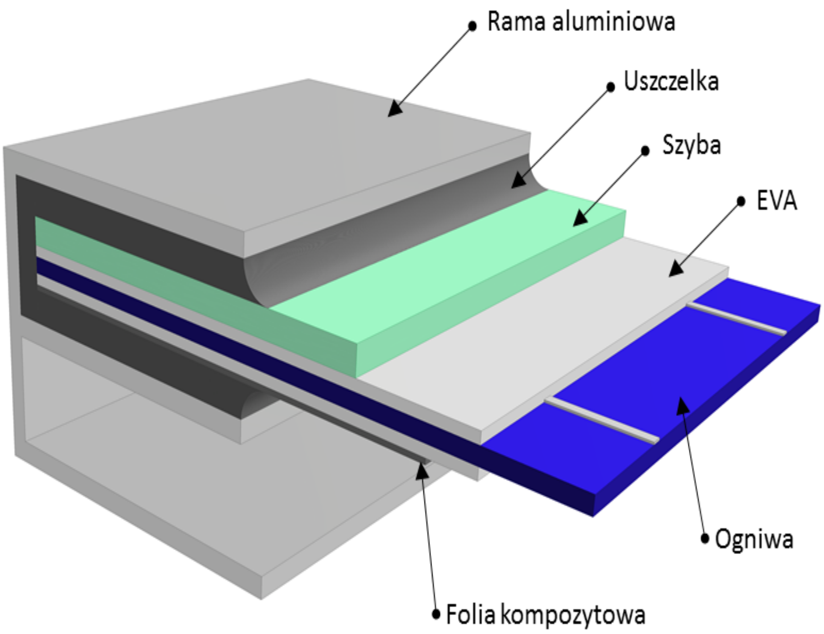

Fig. 4. Construction of a photovoltaic module [14], where: Rama aluminiowa – Aluminium frame, Uszczelka – Gasket, Szyba – Glass, Ogniwa – Cells, Folia kompozytowa – Composite film.

A typical value of the voltage generated by crystal cells is 0.5÷0.6 V. In order for the photovoltaic cell to reach 24 V, 48 cells are mounted in it. 36 photovoltaic cells connected by aluminium tape give the module. The modules are connected in series or in series-parallel manner, thus creating a PV module.

The share of monocrystalline solar cells for 2014 was 33%. These are the most expensive links, and also achieve the highest efficiency in commercial production (22%). The structure of a typical photovoltaic cell is shown in figure 3, while the structure of the entire photovoltaic module is shown in figure 4.

Polycrystalline cells

An alternative to monocrystalline silicon cells are cheaper polycrystalline cells. The basis for the production of polycrystalline photovoltaic cells is a silicon block. This block is usually obtained by two methods, the Brigman method or the block casting method. Then the block is cut into smaller blocks – cuboid with a base of 15.6 x 15.6 mm. Silicon wafers up to 0.2 mm thick are cut from the block obtained. Cutting takes place with simultaneous grinding of the surface of the resulting tiles.

Further processing of polycrystalline wafers involves:

- grinding,
- doping with e.g. phosphorus,
- application of metallized electrodes,
- anti-reflection coating.

Polycrystalline cells have a characteristic blue colour with a clearly visible crystal structure. The efficiency of a polycrystalline cell is less than that of a monocrystalline cell. and within 14÷19%. The reduced efficiency is compensated by lower production costs.

All polycrystalline silicon cells are covered with tempered glass with increased light transmission. The modules of the described cells can work individually or combined in batteries with a voltage not exceeding 1000 V [5, 10].

Thin film cells

It is assumed that monocrystalline and polycrystalline cells belong to generation I. Whereas thin-film cells (including those made of amorphous silicon) belong to generation II of photovoltaic cells. During the study of the photovoltaic effect, it was found that the conversion of light energy into electricity occurs only in the boundary layer between the electrodes, whose thickness is about 0.001 [mm]. This resulted in the development of photovoltaic cell technology whose construction focused on a thin boundary layer. Thin film cells are created by applying negligible semiconductor layers to cheap base substrates.

In addition to amorphous silicon, these semiconductors are:

- cadmium sulfide *CdS,*
- cadmium telluride *CdTe,*
- indium copper diseoxide $CuInSe_2$ or *CIS,*
- gallium arsenide *GaAs,*
- copper indium gallium diseoxide $CuInGaSe_2$ *(CIGS).*

Due to the fact that the thin-film cell production process is not as energy-consuming as mono and polycrystalline cells, their cost is lower. In addition, material losses are limited (no cutting and grinding of crystals). Another advantage is the ability to create large panel surfaces, and the use of this type of links on building facades [7]. The efficiency of thin-film photovoltaic cells ranges from 5÷9% for a-Si, 20% CIS, to 26% for GaAs [7, 10].

Amorphous silicon photovoltaic cells

In addition to silicon with a crystalline structure, amorphous (amorphous) silicon is increasingly used to build solar cells. Amorphous silicon cells contain 8 to 12% hydrogen in them. They also have numerous defects in their structural structure. In amorphous photocells, as a result of the sun's rays, the efficiency coefficient relative to its initial value is reduced (Staebler-Wroński effect). This effect is based on the fact that long-term exposure to amorphous silicon causes a significant increase in its conductivity. It is a reversible process, but it requires regeneration by heating the cells in the dark. This effect causes an output power loss of up to 20% before the material stabilizes. Hence the efficiency of amorphous cells at the level of 5÷9% [5, 10].

The process of producing amorphous photovoltaic modules involves applying thin layers of silicon on a material such as glass, plastic or stainless steel. The individual modules are not visible on the resulting module. This production is simple and easy to automate, and material and energy consumption is relatively low, which affects their price. The value of amorphous cell efficiency was increased by the introduction of multi-joint structures. It consists in laying the materials of the connectors on top of each other by absorbing different wavelengths of light.

Today thin-film photovoltaic cells made of amorphous silicon are made as single or multi-junction. These are p-and-n connectors. The upper layer of the cell is usually covered with a double layer of conductive indium and tin oxide (ITO). The absorber in two-connection cells is a-Si: H and a-SiGe: H, and three-connection is additionally a-SiC:H [5, 10, 11].

Figure 5 shows the construction of the three-junction cell.

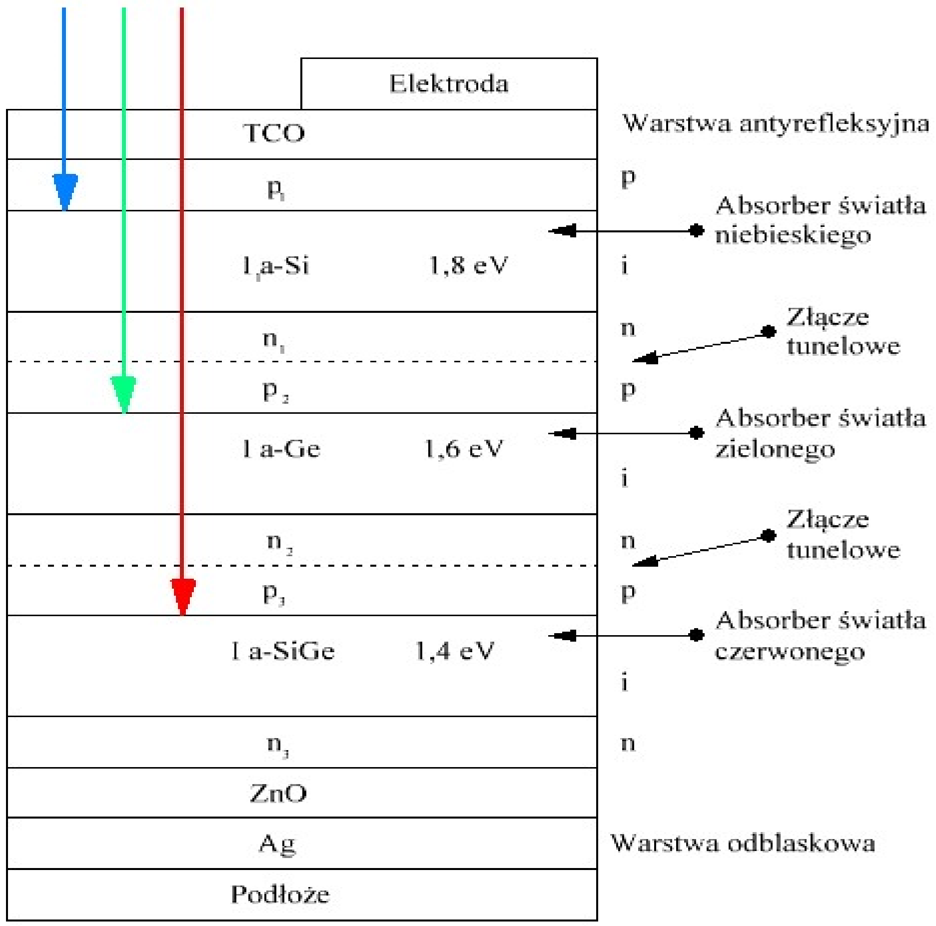

Fig. 5. Construction of the three-junction cell [9], where: Elektroda – Electrode, Warstwa antyrefleksyjna – Anti-reflection layer, Absorber światła niebieskiego – Blue light absorber, Złącze tunelowe – Tunnel connector, Absorber światła zielonego – Green light absorber, Absorber światła czerwonego – Absorber red light, Warstwa odblaskowa – reflective layer, Podłoże – substrate.

Gallium arsenide cells

Photovoltaic cells made of gallium arsenide (GaAs) are cells that can appear as crystalline or thin-film. Panels built from these cells achieve high efficiency compared to other solar cells. The efficiency of this type of photovoltaic cells in mass production is 26%, and in laboratory conditions they reach 30%. The great advantage of gallium arsenide is that the cells produced are characterized by a relatively small influence of temperature on their electrical parameters. The parameters are maintained even at 400°C. This advantage causes that these cells are used in supply systems using solar concentrators and in space technology [5].

In addition to the advantages described above, gallium arsenide also has disadvantages. The price of the cells is very high because gallium is an element rarely found and available in small quantities. The disposal of this type of solar module is also a serious problem. Another problem is arsenic – the ingredient of junction, which is highly toxic [5,7].

Third generation cells

In recent years, many photovoltaic cells have been created, which are included in the 3rd generation cells. Polymer cells belong to this group. Polymers behave like typical semiconductors. They can be created on the basis of materials with the properties of rubber, linoleum or rigid coatings. The advantage of polymer cells is that they can be shaped and adapted to any surface. The disadvantage of polymer cells is their low efficiency (6÷8%) compared to other types of solar cells. The intensity of research on polymer cells is evidenced by the fact that not so long ago this efficiency was 4%.

Third generation cells also include dye cells also called photoelectrochemicals. They are made of two glass tiles. In the gap between the plates, which is 40 μm, titanium dioxide with a photosensitive dye in the solution containing iodine ions is introduced. Dye cells have very low efficiency, but do not change their properties over time. They have another great advantage – they are inexpensive [7].

2. Simulation of photovoltaic cell operation

The growing use of photovoltaic cells requires detailed analyses related to the operation of photovoltaic systems. One of the applications being developed for photovoltaic systems is the possibility of charging electric bus batteries. The capacity of bus energy storage and the desire to quickly charge them necessitates the use of high-power electrical connections. Chargers equipped with photovoltaic installations and energy storage are becoming an alternative, they are loading slowly and giving energy to the bus depot in a short time.

This article presents a solar cell model and analyses the energy production characteristics of a solar module using a simple mathematical model of a solar cell.

2.1. Photovoltaic substitute scheme

The values that characterize the cell and determine its quality include:

- R_{SZ} series resistance – it consists of connection resistances, base resistance and other cell layer resistances. For silicon cells, the R_{SZ} series resistance (Fig. 6) is from 0.05 Ω to 0.1 Ω;
- R_B shunt resistance – is a representation of the possibility of leakage of the I_{ph} photocurrent along the cell edge or along the grain boundaries. For silicon cells, the value of the parallel resistance R_B (Fig. 6) is in the range of 200-300 Ω,

– R_L load resistance – external resistance connected to the electrodes of the cell. The selection of load resistance should be dynamic in order to adjust the cell operating point ensuring work around the maximum power point as the operating conditions change [4].

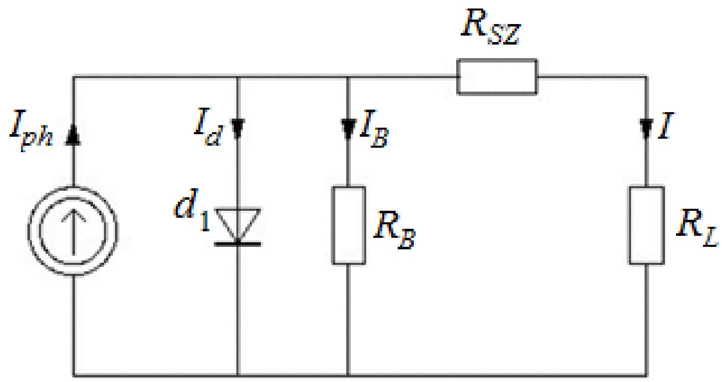

Fig. 6. Photovoltaic substitute scheme

The ideal cell is characterized by the resistance values $R_B = \infty$ and $R_{SZ} = 0$, so at the design stage of photovoltaic cells one should strive to obtain the highest possible shunt resistance R_B and the lowest series resistance R_{SZ}. Too high R_{SZ} resistance value can cause a decrease in the I_{ph} photocurrent value, however its influence on cell parameters is more visible at higher solar radiation intensity and at higher operating temperatures. Shunt resistance affects the value of photovoltage, and its effect on the parameters of photovoltaic cells can be seen at low values of radiation intensity and low operating temperatures [4, 5].
As a result of the photovoltaic phenomenon, the current source generates the I_{ph} current, which is directly proportional to the intensity of solar radiation. This current can be described by equation [5]:

$$I_{ph} = I_{SC}\left(\frac{G_0}{1000}\right) + J_0(T_C - T_{odn}) \tag{1}$$

Where: I_{SC} – short circuit current [A],

T_{odn} – STC temperature [K], i.e. at solar power density G0 = 1000 W/m^2; module temperature T_{odn} = 298 K; AM-1.5 spectrum distribution;

G_0 – solar power density [W/m^2],

T_C – cell operating temperature [K],

J_0 – temperature coefficient [A/K].

Diode current I_D [A] can be described by equation [5, 11]:

$$I_d = I_0\left[exp\left(\frac{q(U+R_{SZ}I)}{\alpha\, k_B T_c}\right)-1\right] \qquad (2)$$

Where:

$$I_0 = I_{d0}\left(\frac{T_C}{T_{odn}}\right)^3 exp\left[\frac{qE_q}{\alpha k_b}\left(\frac{1}{T_{odn}}-\frac{1}{T_C}\right)\right] \qquad (3)$$

R_{SZ} – series resistance [Ω],

U – voltage drop over load [V],

I_d – diode current[A],

I – load current [A],

I_{d0} – „dark" current of diode [A],

q=1,602·10^{-19} – elementary charge [C],

E_q – energy barrier of potential [V],

k_B – Boltzmann constant k_B=1,38·10^{-23}[J/K],

T_C – photovoltaic cell operating temperature [K],

α – diode quality factor (for perfect cell α=1, for real cell 1< α < 2).

The current flowing through the shunt resistance is described by the equation [5]:

$$I_B = \frac{U+R_{SZ}I}{R_B} \qquad (4)$$

Where: I_B – current on the shunt resistance [A],

R_B – shunt resistance [Ω].

Using the current Kirchhoff's law for the substitute cell diagram (Fig. 6) the following relationship was obtained:

$$I = I_{ph} - I_d - I_B \qquad (5)$$

Substituting the equation (5) from (1) to (4), a non-linear equation describing the current-voltage characteristics of the photovoltaic cell was obtained [4, 5, 12].

$$I = I_{SC}\left(\frac{G_0}{1000}\right) + J_0(T_C - T_{odn}) - I_0\left[exp\left(\frac{q(U + R_{SZ}I)}{\alpha\, k_B T_c}\right) - 1\right] - \frac{U + R_{SZ}I}{R_B} \quad (6)$$

Assuming that U=0 V and ignoring the I_0 component, which is much smaller than the I_{ph} current, a mathematical description of the approximate short-circuit current value of the photovoltaic cell was obtained [11]:

$$I_{SC} \approx \frac{I_{PH}}{1 + \frac{R_{SZ}}{R_B}} \quad (7)$$

Therefore, for good quality solar cells, the R_{SZ} / R_B << 1 ratio can be considered $I_{SC} \approx I_{ph}$. Assuming that I=0 A and U=U_{OC}, i.e. when the photocell electrodes are not connected by the load resistance R_L, based on the dependence (6), an open circuit voltage is also obtained, also referred to as the idling voltage of the cell [5,11]:

$$U_{OC} = \frac{k_B T_C}{q} ln\left(1 + \frac{I_{SC}}{I_0}\right) \quad (8)$$

Simulation of a photovoltaic module work

One of the three sections of the photovoltaic generator built in 2013 at the Kazimierz Pulaski University of Technology and Humanities in Radom was presented in the simulation. This generator is part of the island network of the UTH Photovoltaic Laboratory. The solar installation consists of three photovoltaic chains, each of which contains seven Green Tech GT-180MCY solar modules connected in series. Each of the three photovoltaic chains is connected by overcurrent protection with separate SUNNY BOY 1200 solar inverters (Fig. 7). The total maximum power of one branch of the photovoltaic installation in question is 3x1260 W, and the voltage level of the generator for standard test conditions is 264 V. The SB1200 inverters are supplied by the over-current protection of the island installation of the Photovoltaic Laboratory [1].

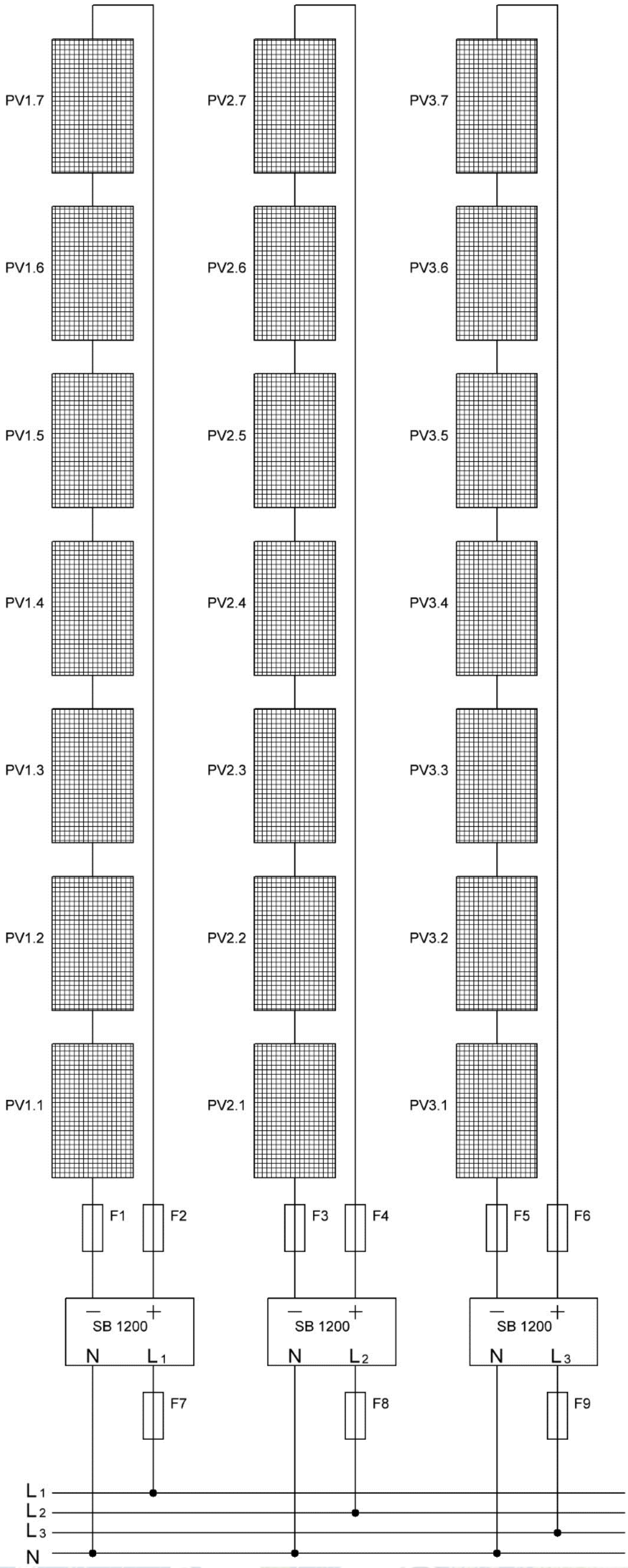

Fig. 7. Connection diagram of a solar installation [1]

Tab. 1. Electrical properties of the used PV modules

Electrical properties		
Maximum power (P_M)	[W]	180
Toleration	[Wp]	+5
Voltage in max. power point (U_M)	[V]	36,50
Current in max. power point (I_M)	[A]	5,10
Open circuit voltage (U_{OC})	[V]	41,35
Short circuit current (I_{SC})	[A]	5,4
Maximum system voltage (U_{SYS})	[V]	600/1000
Diodes (By-pass)	szt.	3
Maximum fuse in series	[A]	10
Efficiency η	[%]	14,10
Fill factor (*FF*)	[%]	>73

3.1. Impact of temperature on solar module parameters

The temperature of the photovoltaic module depends on the ambient temperature, the intensity of solar radiation, the structure of the module itself and the speed of blowing wind, which is a natural coolant of the module.

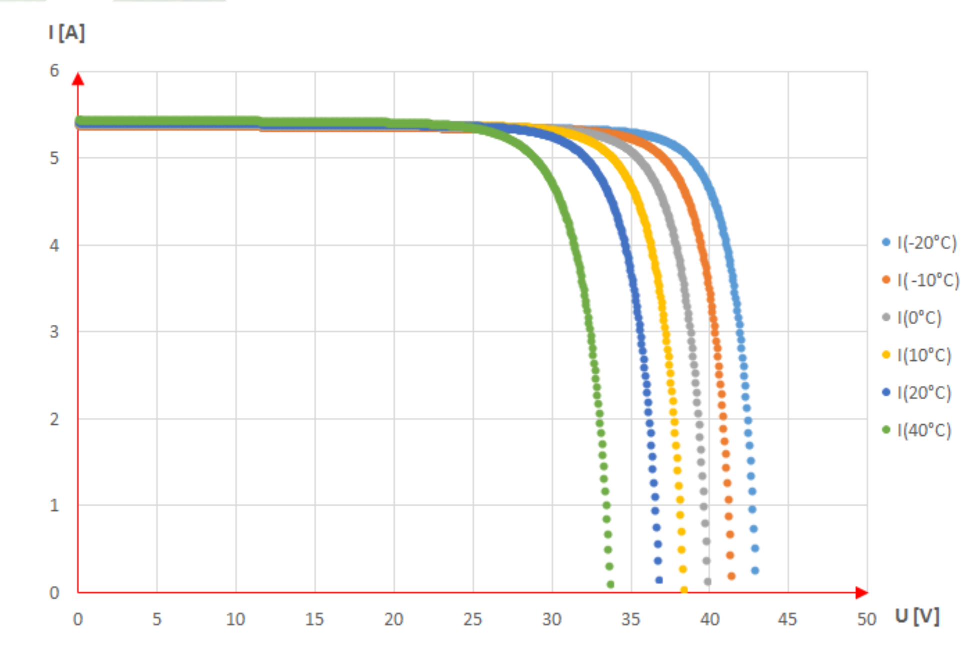

Fig. 8. Impact of ambient temperature T_{ot} on the course of the current-voltage characteristics of the photovoltaic module at constant radiation intensity G_0=1000 W/m^2

Figure 8 shows the effect of ambient temperature T_{ot} on the characteristic *I=f(U)* of the photovoltaic module at constant solar irradiance G_0=1000 W/m^2. As the temperature rises, the open circuit voltage U_{OC} decreases. From the changes in the U_{OC} voltage value, the percentage temperature coefficient *β* of the open circuit can be calculated, which in the case of the module under consideration is:

$$\boldsymbol{\beta} = \frac{\boldsymbol{dU_{OC}}}{\boldsymbol{dt}} \rightarrow -149\,\frac{\mathrm{mV}}{^\circ\mathrm{C}} \rightarrow\ -0{,}359\ \%/^\circ\mathrm{C}$$

The change of open circuit voltage as a function of ambient temperature T_{ot} is presented in figure 9.

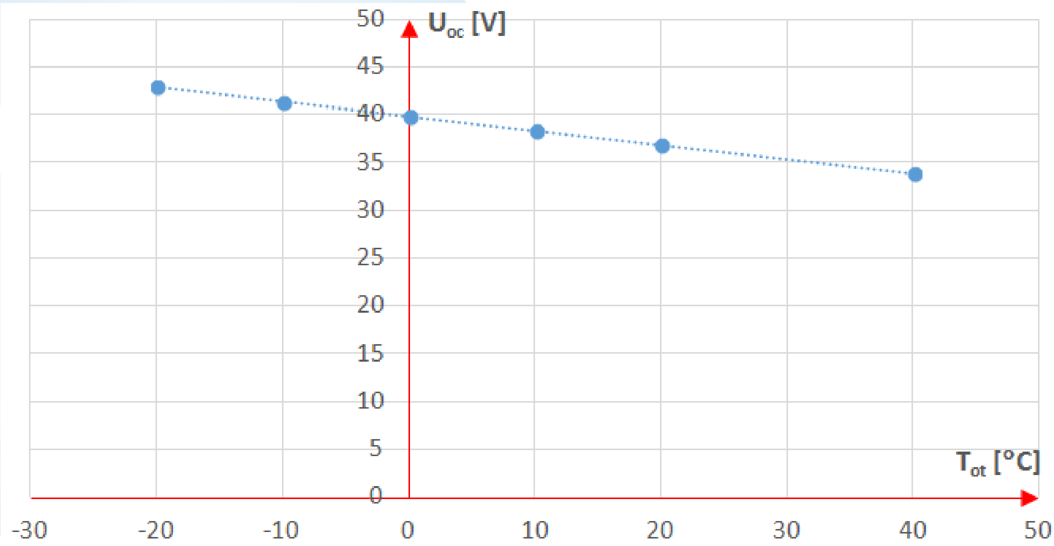

Fig. 9. Change of open circuit voltage as a function of ambient temperature T_{ot}

A change in the cell temperature also affects its current efficiency (Fig. 10). Changes in the short circuit current I_{SC} of the solar cell are directly proportional to the temperature rise. The current temperature coefficient *α* is determined by equation:

$$\alpha = \frac{\boldsymbol{dI_{SC}}}{\boldsymbol{dt}} \rightarrow 1{,}0\left[\frac{\mathrm{mA}}{^\circ\mathrm{C}}\right] \rightarrow\ 0{,}019\ \left[\frac{\%}{^\circ\mathrm{C}}\right]$$

The effect of ambient temperature T_{ot} on the I_{SC} current is shown in figure 10.

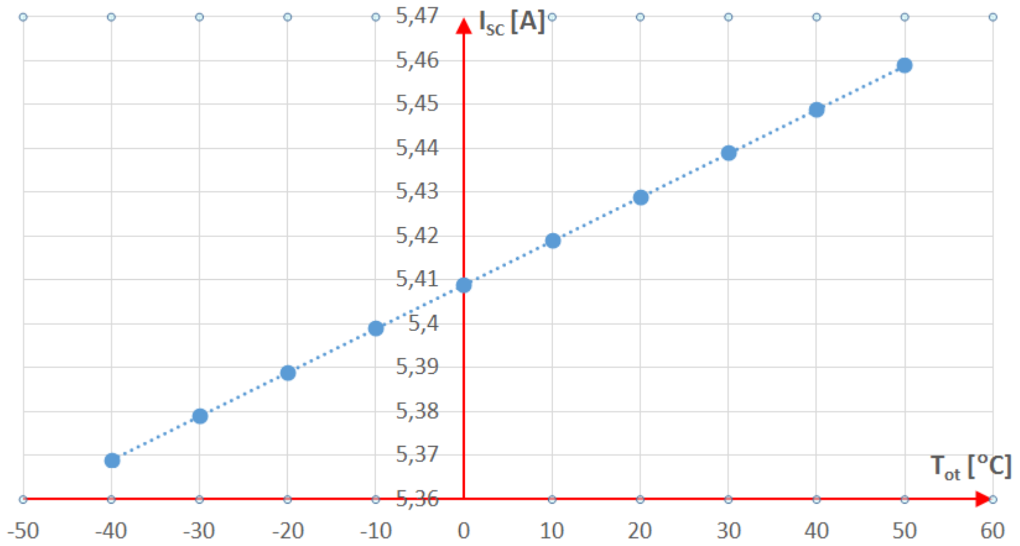

Fig. 10. Change of short-circuit current as a function of ambient temperature t_{ot}

The open circuit voltage drop is mainly caused by the exponential nature of the I_0 saturation current, which is strongly dependent on the operating temperature of the photovoltaic module (Fig. 11). At temperatures above 25°C, a sharp increase in cell saturation current can be seen.

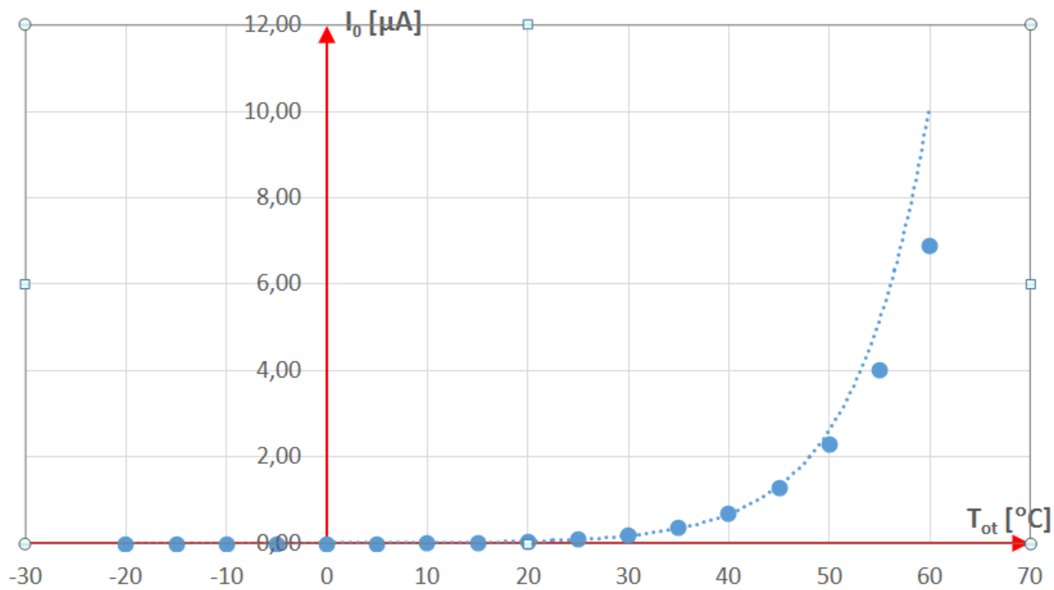

Fig. 11. Influence of ambient temperature t_{ot} on saturation current I_0

Decreasing the value of the open circuit voltage with increasing temperature is a decisive reason for reducing the power of the solar module (Fig. 12-13).

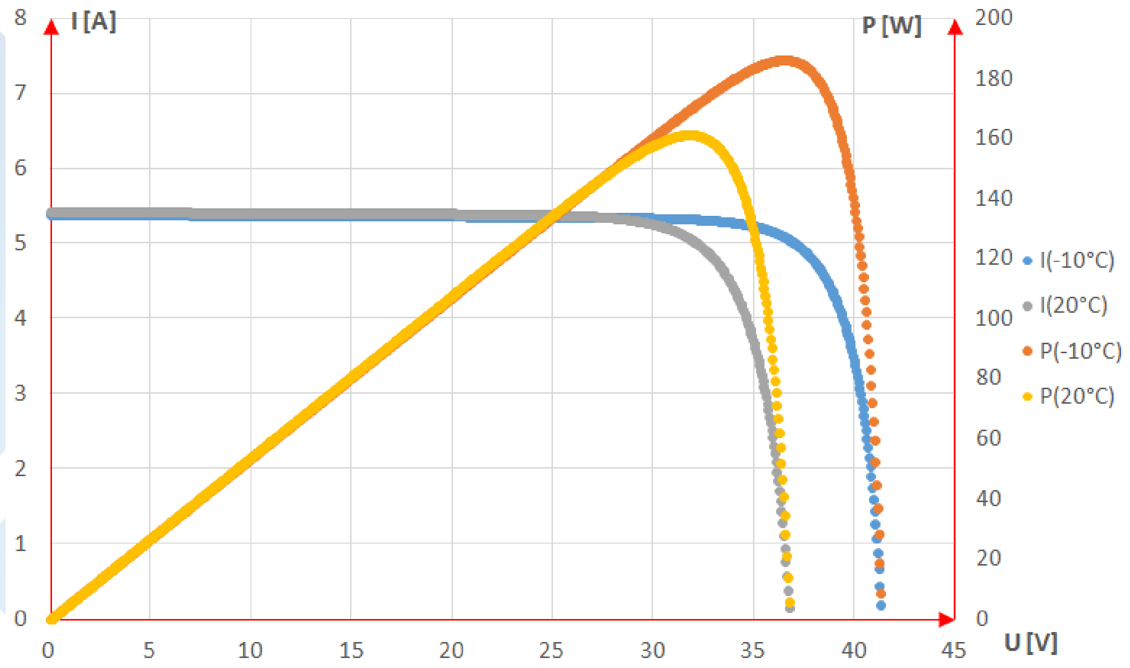

Fig. 12. Impact of temperature on characteristics I=f(U) and P=f(U)

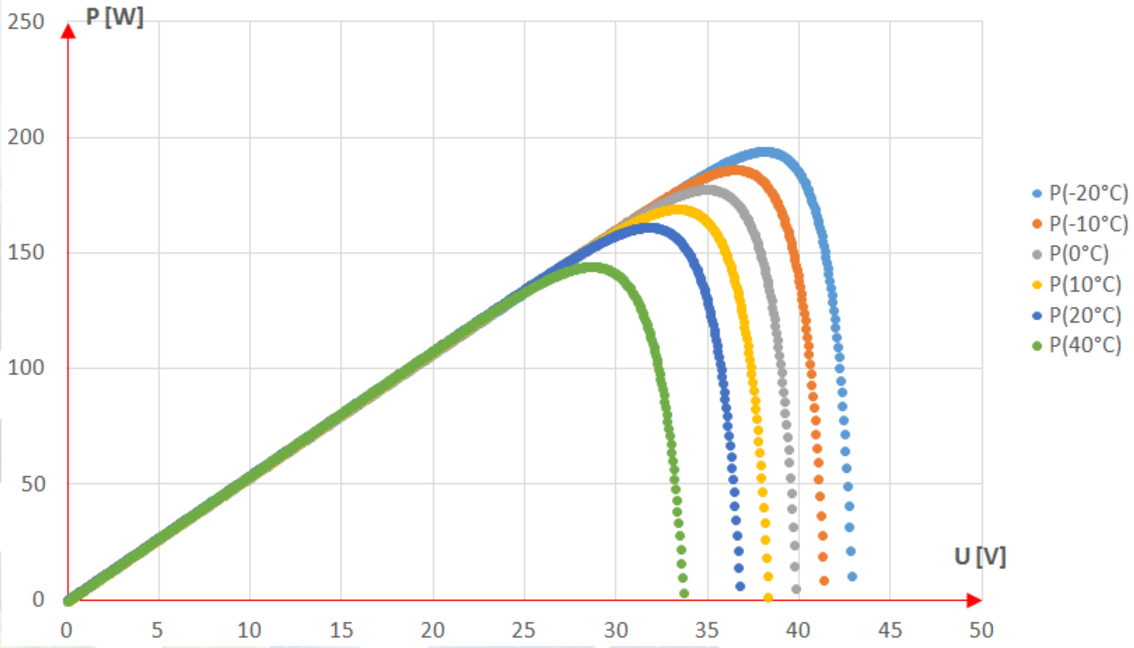

Fig. 13. Change of solar module power as a function of ambient temperature t_{ot}

The decrease in the ambient temperature t_{ot} causes an increase in the power generated by the photovoltaic module. At t_{ot} < 0°C, the photovoltaic module's power exceeds the nominal values. An increase in temperature causes the maximum power point (MPP) on the characteristic to shift toward less than nominal values. The change in the position of MPP in relation to temperature is illustrated in figure 14.

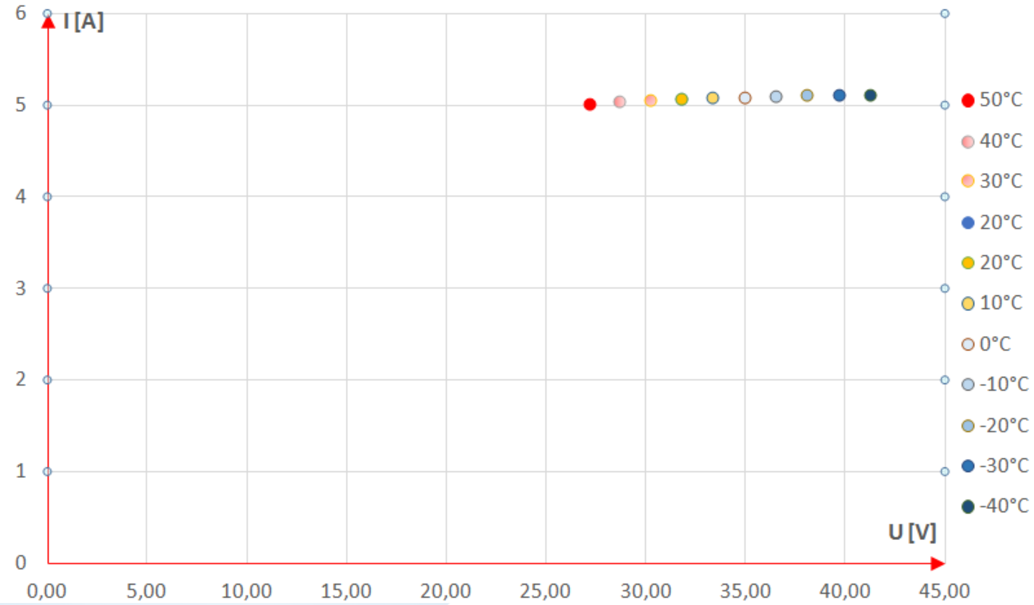

Fig. 14. Changing the position of MPP points on the characteristics I=f(U)

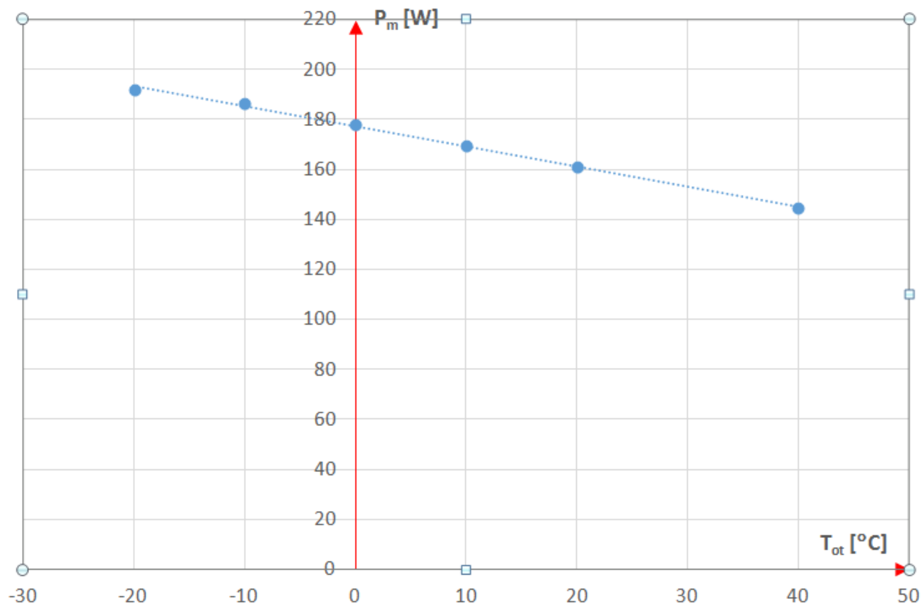

Fig. 15. The impact of temperature on the maximum power of the solar module

For the tested module, the power drop with the temperature increase was 0.597 W/°C, so the temperature maximum power factor is -0.332%/°C. A decrease in the module power results in a reduction of the efficiency η and the value of the *FF* fill factor of the solar module (Fig. 16-17). The decrease in the efficiency factor η of the photovoltaic module as a function of ambient temperature tot is linear. The value of changes is 0.066% for each degree of temperature increase t_{ot}. The conversion efficiency of the tested module within the temperature range from -40°C to + 50°C decreased by 5.86%. The decrease in the fill factor is also a linear relationship as a function of temperature. In the analysed temperature range it varied from *FF* = 0.85 for an ambient temperature tot close to -30ºC to *FF* = 0.78 for an ambient temperature tot close to 50ºC.

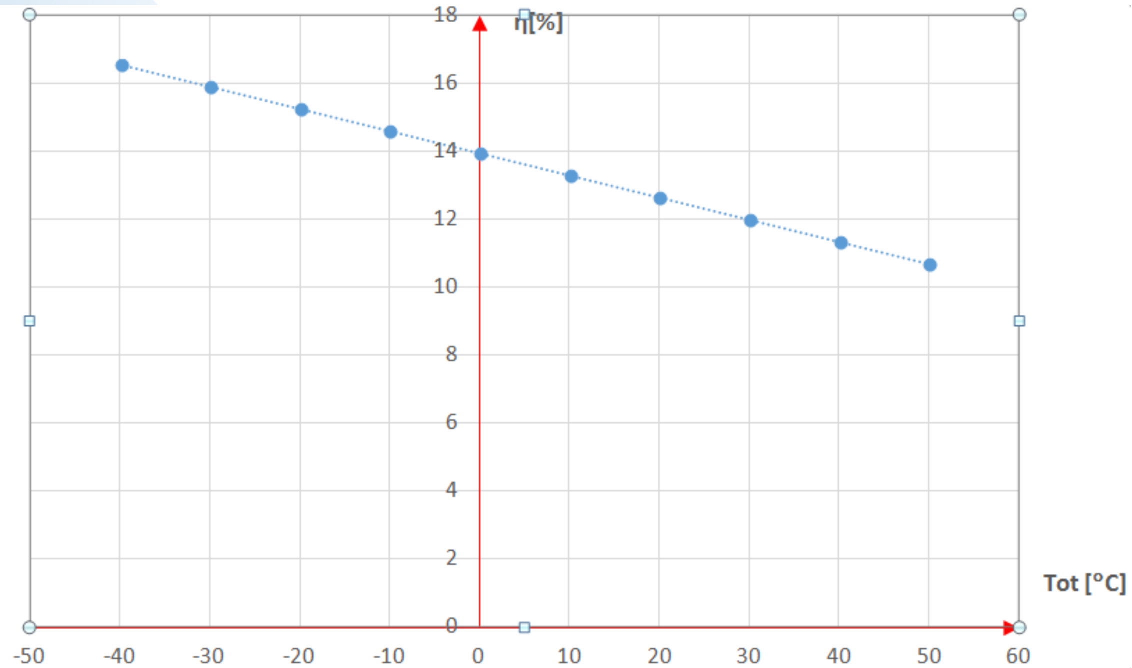

Fig. 16. Change of efficiency η of the solar module as a function of ambient temperature t_{ot}

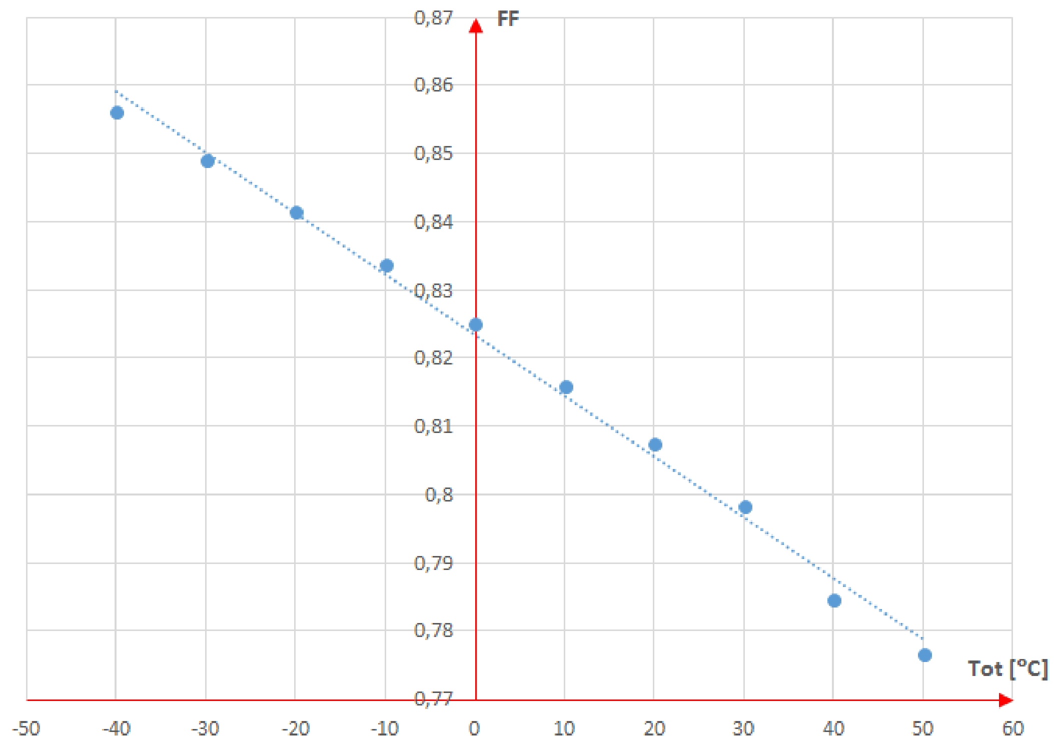

Fig. 17. Impact of ambient temperature t_{ot} on fill factor

3.2. Impact of solar radiation intensity changes on the solar module operation

Based on the mathematical model of the photovoltaic module, a simulation of the photovoltaic module was performed at the changing intensity of solar radiation G_0. The constant temperature value T_{ot} = 20°C was assumed in the calculations. The impact of changes in G_0 solar irradiance on the *I = f (U)* characteristic is shown in figure 18.

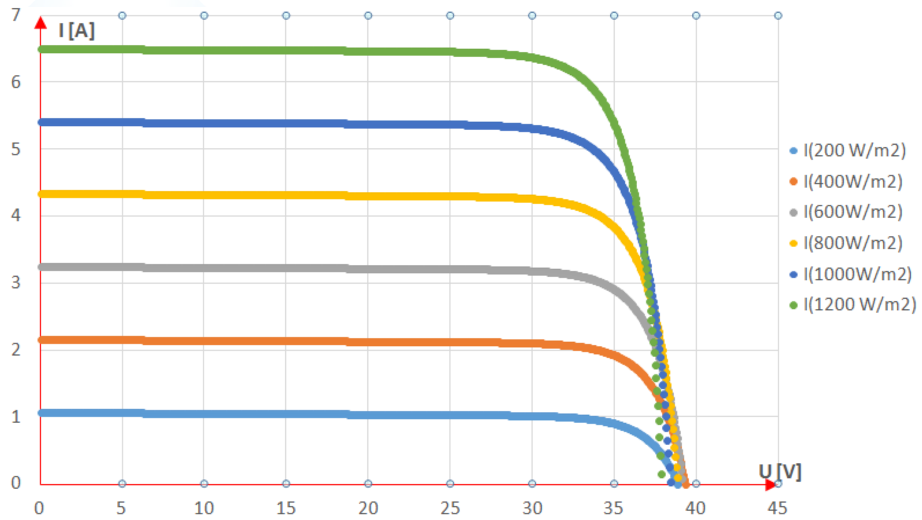

Fig. 18. Change in the characteristic I = f (U) for some G_0 values at T_{ot}=20 °C

The increase in G_0 solar irradiance causes an increase in the current and photovoltaic module. Changing the value of the G_0 solar radiation intensity causes small changes in the voltage *U* generated by the module. The increase of current and photovoltaic module with small changes in voltage *U* of the photovoltaic module increases the power *P* generated by the photovoltaic module (Fig. 19).

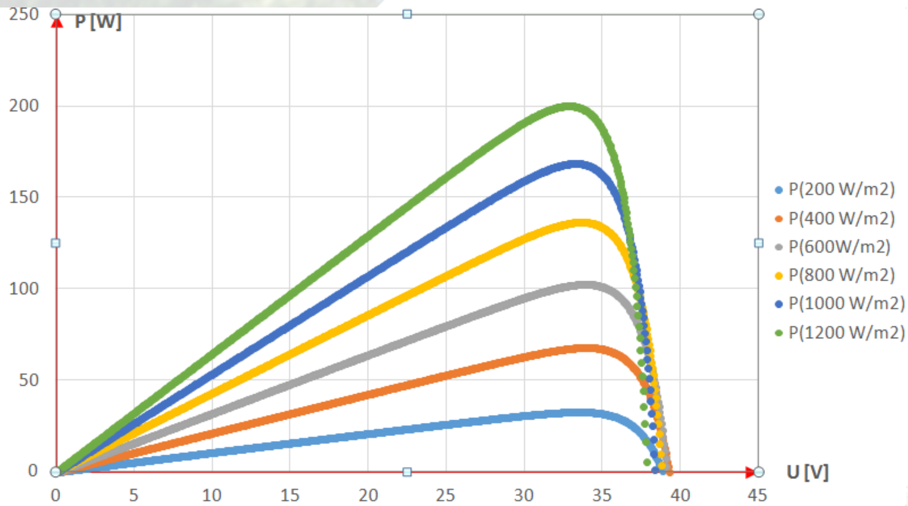

Fig. 19. Change of modul power P=f(G_0) at T_{ot}=20°C

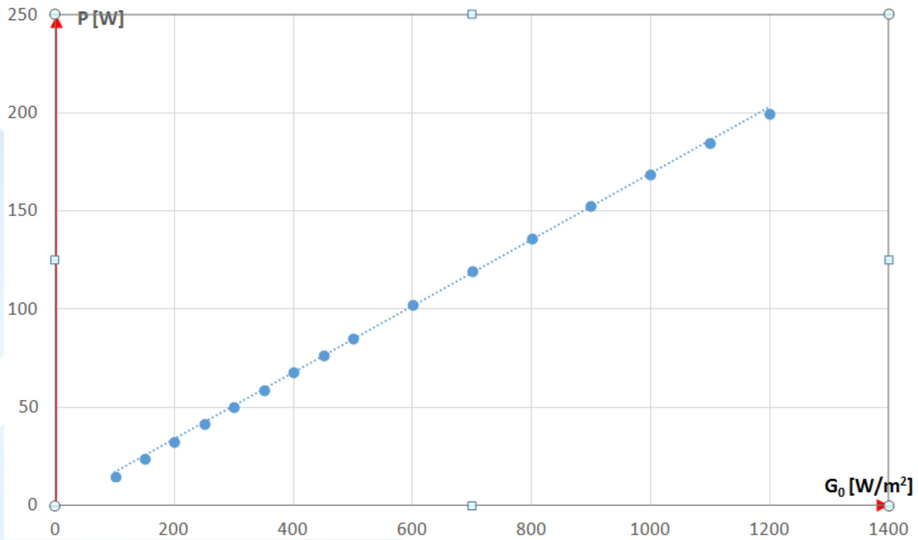

Fig. 20. Maximum power value P_m for selected values of solar radiation G_0 at T_{ot}=20°C

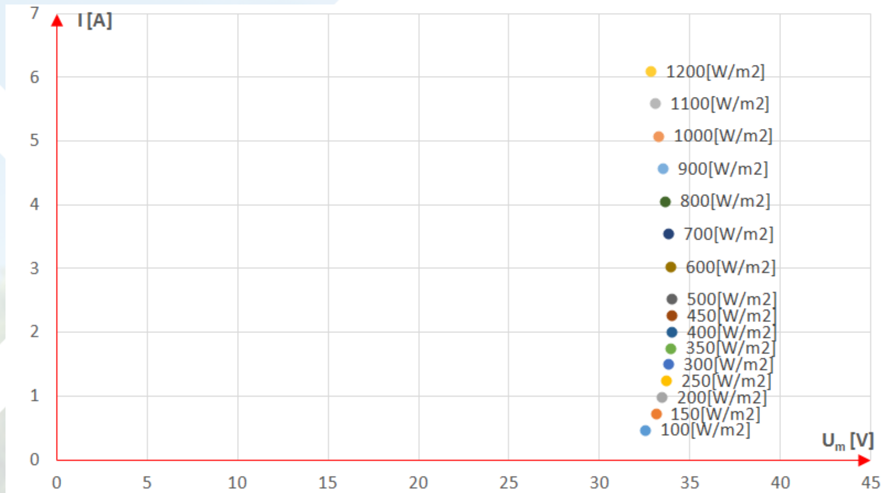

Fig. 21. Change of MPP position on the I-V characteristics for selected values of solar radiationG_0

Figure 20 illustrates the dependence of the maximum power points depending on the intensity of solar radiation. The power increase in depends linearly on the value of solar radiation intensity G_0. The maximum power point changes is illustrated on the current-voltage characteristics in Figure 21. As the solar radiation increases, the MPP take on increasing values.

The impact of G_0 solar irradiance changes on the open circuit voltage U_{OC} is shown in Figure 22. The open circuit voltage U_{OC} initially increases to 39.26 V at G_0 = 350 W/m^2, and then decreases to 37.8 V at G_0 = 1200 W/m^2. With varying solar irradiance, a decrease in U_{OC} does not have a significant impact on the module's power compared to changes in ambient temperature.

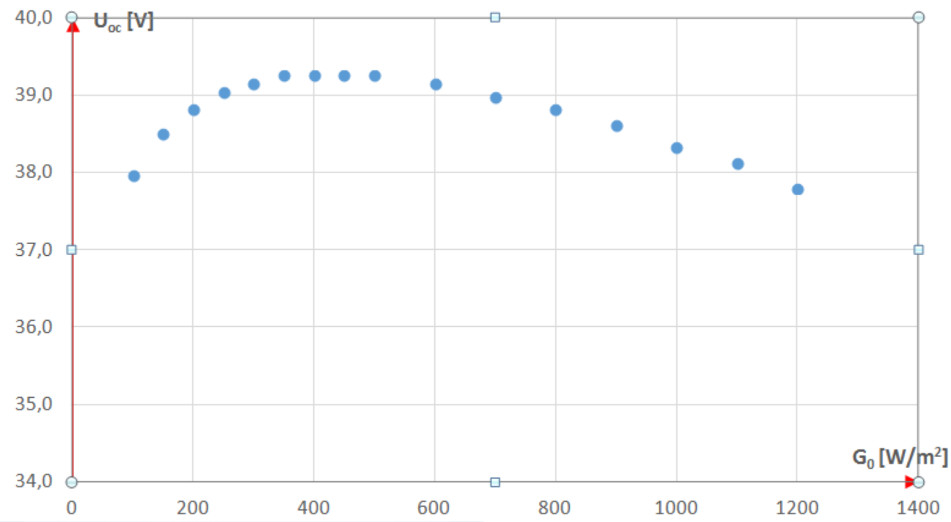

Fig. 22. Impact of G_0 solar irradiance to U_{OC} open circuit voltage

The cell efficiency depend of solar radiation. This is non-linear depending (Fig. 23).

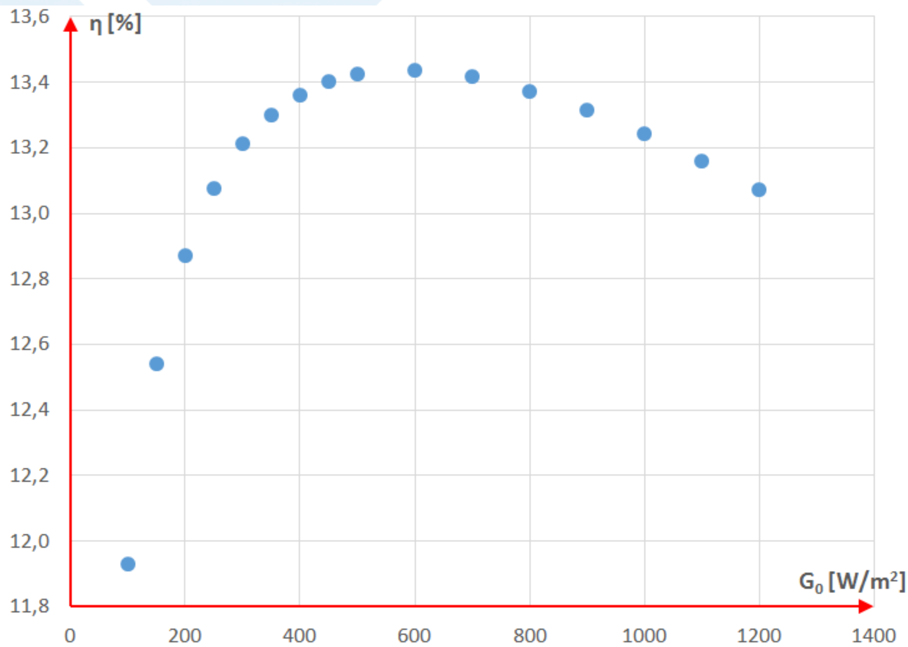

Fig. 23. The cell efficiency η as a function of solar radiation G_0

3.3. Impact of wind speed on solar module operation

On the basis of a photovoltaic cell mathematical model, a simulation of the photovoltaic module was performed at the changing wind speed ω [m/s]. A constant ambient temperature T_{ot} = 20°C was assumed, and the photovoltaic cell operating temperature was based on a two-component model of the cell operating temperature, developed by Sandia National Laboratory (USA) [15].

The two-component model also takes into account the speed of blowing wind, which is the cooling factor of the photovoltaic module according to the relationship:

$$T_C = G_0 e^{(a+b\omega)} + T_{ot} \qquad (9)$$

Where: T_C – solar cell operating temperature [K],

G_0 – solar radiation [W/m^2],

T_{ot} – ambient temperature [K],

a, b – coefficients represented the technology and mounting execution,

ω – wind speed [m/s].

Wind increases the intensity of receiving heat from the PV module. The increase in wind speed ω [m/s] reduces the T_C temperature of the cells contained in the photovoltaic modules, which causes an increase in the voltage U of the photovoltaic module and a simultaneous increase in the generated maximum power (Fig. 24).

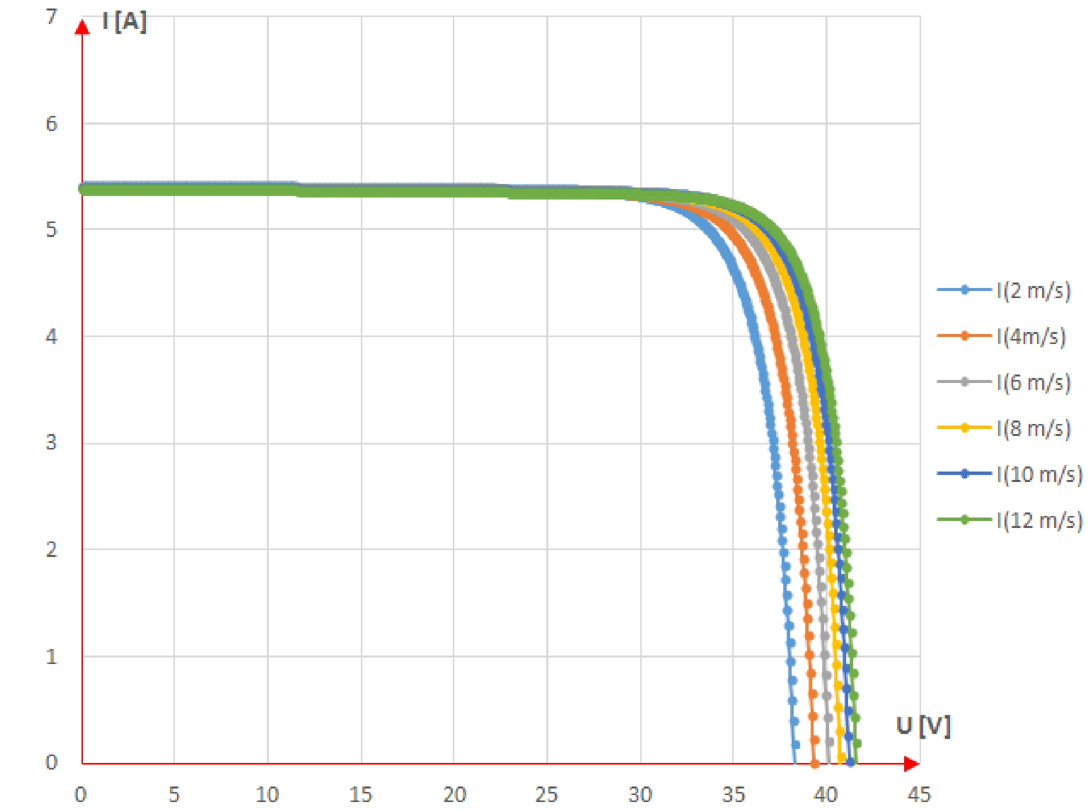

Fig. 24. Impact of wind speed ω on the change the PV module characteristics

The photovoltaic module MPP change for selected wind speeds ω is illustrated at Figure 25. It should be noted that the value of the maximum PV module current I_m with changes in wind speed remains unchanged.

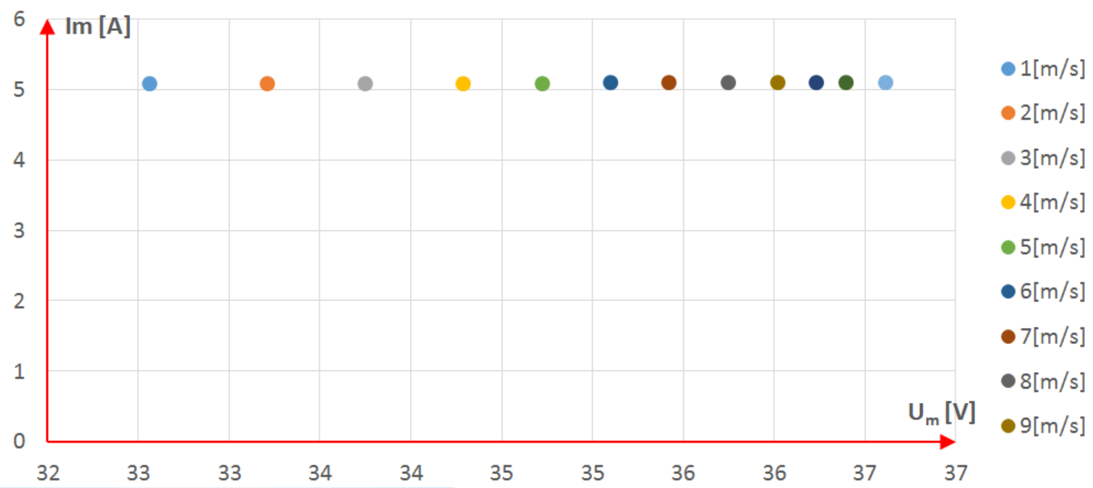

Fig. 25. The photovoltaic module MPP change for selected wind speeds ω

An increase in wind speed ω causes a non-linear PV module power increase (Fig. 26). This is the effect of increasing voltage (Fig. 28) when the T_C temperature of the solar cell is lowered (Fig. 27).

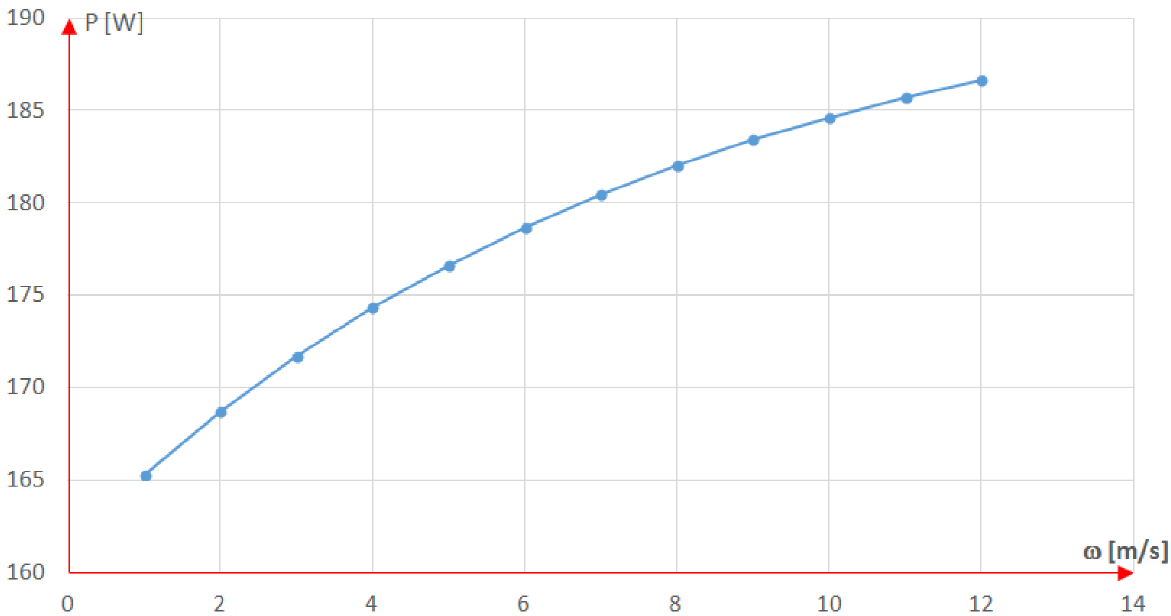

Fig. 26. Impact of wind speed ω on the maximum power of the solar module

The cell's U_{OC} voltage increases non-linearly with increasing wind speed ω. The non-linear change in U_{OC} voltage as a function of wind speed ω is caused by the non-linear ability to lower the T_C temperature of the solar cell at higher wind speed ω (Fig. 28).

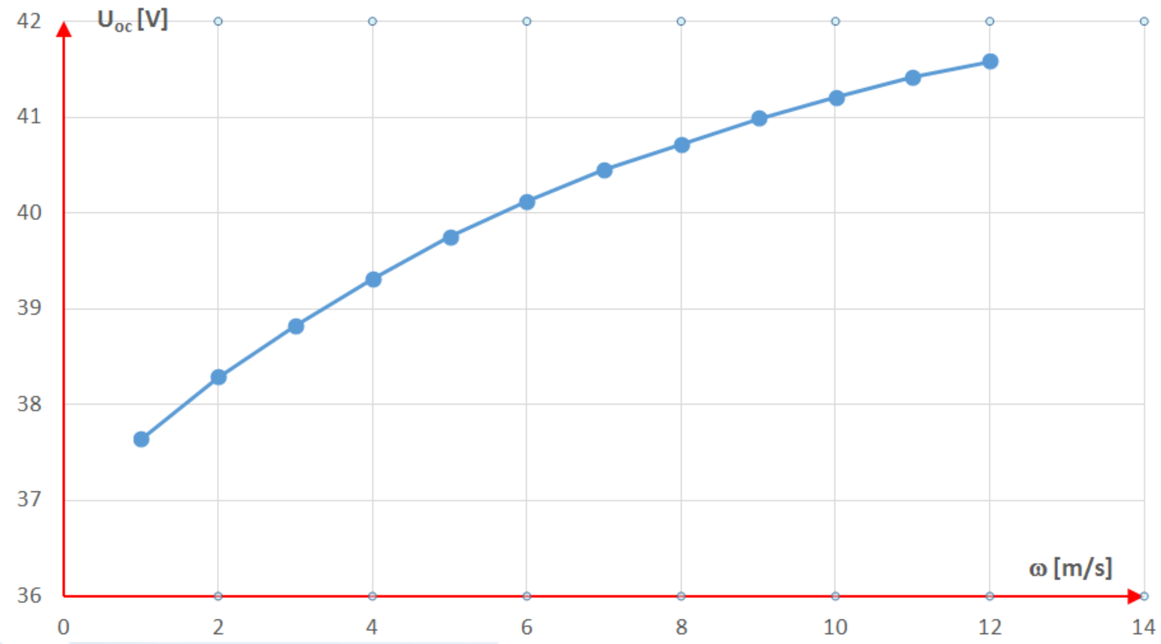

Fig. 27. Wind speed impact ω for U_{OC} voltage changing

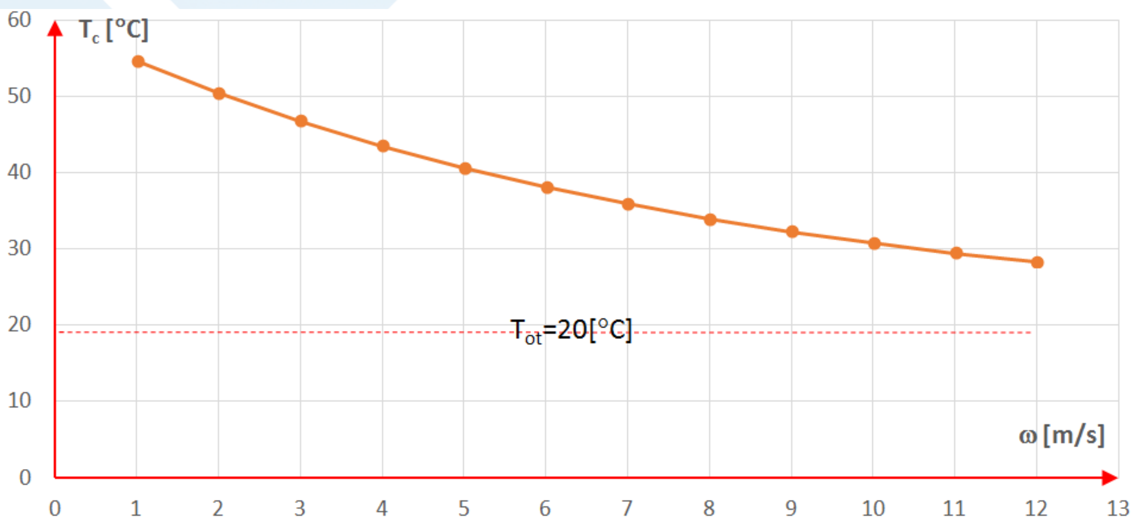

Fig. 28. Reduction of the photovoltaic panel operating temperature due to the increase in wind speed.

The cell temperature T_C decreasing caused by wind causes increasing efficiency factor η of the photovoltaic module (Fig. 29).

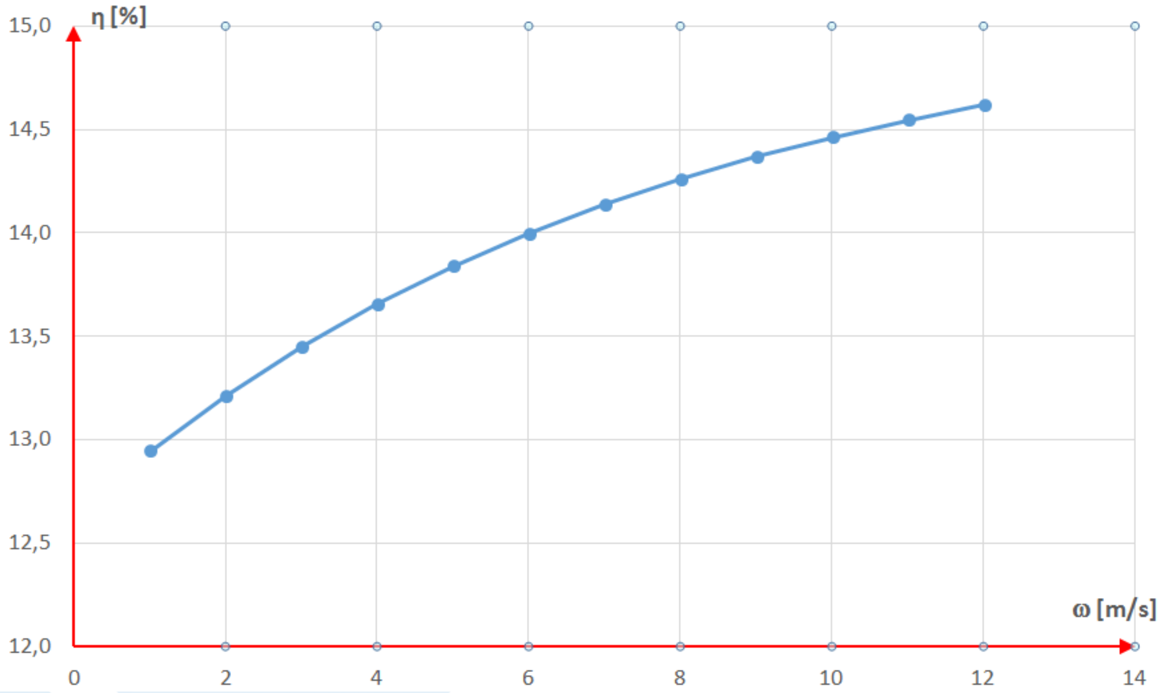

Fig. 29. *PV module efficiency η in wind speed function.*

Summary

The article presents basic types of photovoltaic cells, including their structure and materials used for their production. The results of the mathematical model analysis of the polycrystalline technology are presented. The cell model took into account the impact of solar radiation, ambient temperature and wind speed. The impact of these factors on the electrical parameters of the photovoltaic module was analysed.

The article shows the dependence of the photovoltaic module output power and atmospheric factors. It has been shown that the increase in ambient temperature has a negative effect on the power and efficiency factor of photovoltaic cells. The influence of wind, which naturally lowers the operating temperature of the photovoltaic module and improves the adverse effect of the increase in ambient temperature on its operating parameters is of significant importance. The higher the wind speed, the higher the efficiency factor of the solar cell. The analysis contained in the article shows that the impact of ambient temperature and cooling of the module by wind have very little effect on the currents flowing in the photovoltaic module. It can be stated that these factors do not affect either the module short-circuit current or the current at the maximum power point.

The solar radiation change has a decisive influence on the module current values. The short-circuit current change is directly proportional to the change of the solar radiation

intensity. The solar irradiance increasing causes the module power increasing. But it also causes a linear increase in the temperature of the photovoltaic module.

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Radosław FIGURA
Uniwersytet Technologiczno-Humanistyczny im. Kazimierza Pułaskiego, Stowarzyszenie Elektryków Polskich oddział Radom (Poland)

Hybrid inverter and lithium-iron energy storage cooperation

Introduction

Hybrid system is a next step when speaking of the development of photovoltaic systems used for production of electrical energy. These systems are intended for those who want to consume the whole energy generated by photovoltaic installations for their own purposes and to ensure operation of electrical equipment in case of power grid failure. So far installations of this kind required use of few devices [1]. One of the crucial drawbacks was battery life time, which depending on the applied technology guaranteed operation no longer than 3 – 7 years. Another problematic issue was worsening battery capacity and the necessity to maintain battery state at a respective level. Solutions offered today lack the above described faults and enable storing of surplus amounts of power produced by photovoltaic installation. Accumulated surplus power is used during the period of increased need of energy and when there is no sun energy [2]. Should power grid failure occur, home grid is supplied with power from an autonomic power source using battery-accumulated electrical energy. Despite greater investment costs of hybrid installation when compared to On-Grid installation, the cost reimburse may take less time due to use of the whole produced energy for one's own purposes. Use of hybrid photovoltaic installation makes the user independent from energy supplier and guarantees that even in case of power grid failure the electrical equipment remains powered [3, 8].

PHOTOVOLTAIC HYBRID INVERTER

Photovoltaic hybrid inverter may power electrical equipment with power obtained from a photovoltaic generator, power grid or energy storage, i.e. the battery. If there is enough of output power, then it is possible to supply the equipment, charge the storage and sent the excess of power to the power grid simultaneously. At sun energy lack, hybrid inverter powers the energy load from the energy storage or the power grid [5,8]. Hybrid inverter parameters for cooperation with the grid and the energy storage can be configured. It is possible to set priority regarding use of power supply sources, energy storage charge/discharge, possibility to give the excess of energy to the power system (SEE). Exemplary configuration of hybrid installation is presented in figure 1 [5, 7].

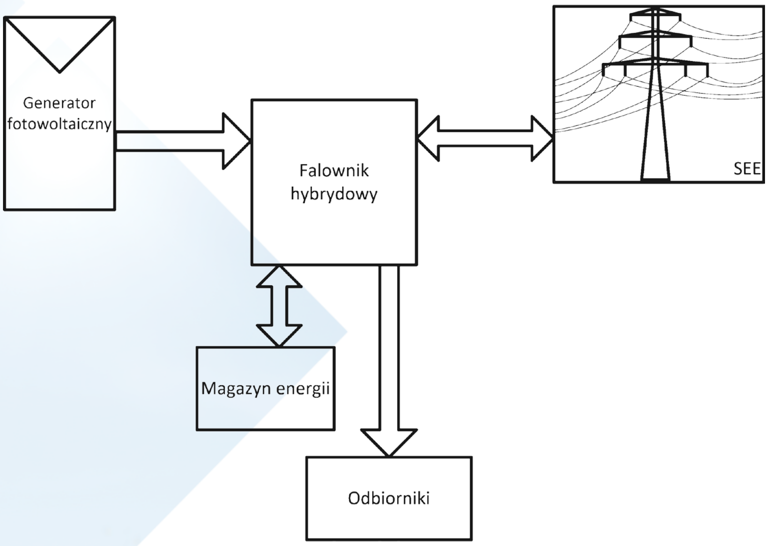

Fig. 1. Block diagram of hybrid installation, where: Generator fotowoltaiczny – Photovoltaic generator, Falownik hybrydowy – Hybrid inverter, Magazyn energii – Energy storage, Odbiorniki – Receivers.

Hybrid inverters ensure possibility of bidirectional flow of energy between the inverter and the power grid or energy storage. Connection with the photovoltaic module and energy load is onedirectional (fig. 1) [5].

LitHIUM-IRON ENERGY STORAGE

Use of energy storage in photovoltaic systems allows to store surplus amounts occurring during electric energy production. The stored energy can be used when there is no sun due to unfavourable atmospheric conditions or at night [7, 8]. Use of energy storage technology in hybrid systems means powering of the electronic equipment when there is a failure in supply of energy from the power system. Energy storage technology includes lithium-iron Energy storage of lifetime up to 20 years and charge/discharge cycle of up to 7000 [4].

Lithium energy storage requires precise control of parameters such as cell temperature, charge and discharge voltage. Due to this each energy storage made using lithium technology is equipped with an integrated or external management system, so called BMS (*Battery Managment System*) [4]. BMS, should any failure be detected, disconnects particular cells or the whole energy storage. The energy storage gets disconnected when:

– permissible cell temperature gets exceeded,
– maximum cell voltage gets exceeded,
– minimum cell voltage gets exceeded.

The above mentioned failure types may result with cell sealing damage. Released outside lithium may react with oxygen and cause ignition of the lithium cell.

Experimental laboratory workstation intended for tests of hybrid systems have been equipped with lithium-iron energy storage (fig. 2) of the following parameters [4]:

– nominal cell capacity: 50Ah,
– nominal voltage: 50,4 V,
– buffer operation voltage: 55,6 V,
– operation voltage: 40,6-57,4 V,
– nominal storage capacity: 2,5 kWh,
– maximum continuous current: 45 A,
– maximum continuous discharge power: 2,25 kW,
– maximum continuous charge power: 2,25 kW,
– permissible operation temperature range at discharge: -20 – 60˚C,
– permissible operation temperature range at charge: 0 – 60˚C,
– max. discharge cycle quantity (25°C and 80%): 7000,
– assumed lifetime: 20 years,
– mass: 25 kg.

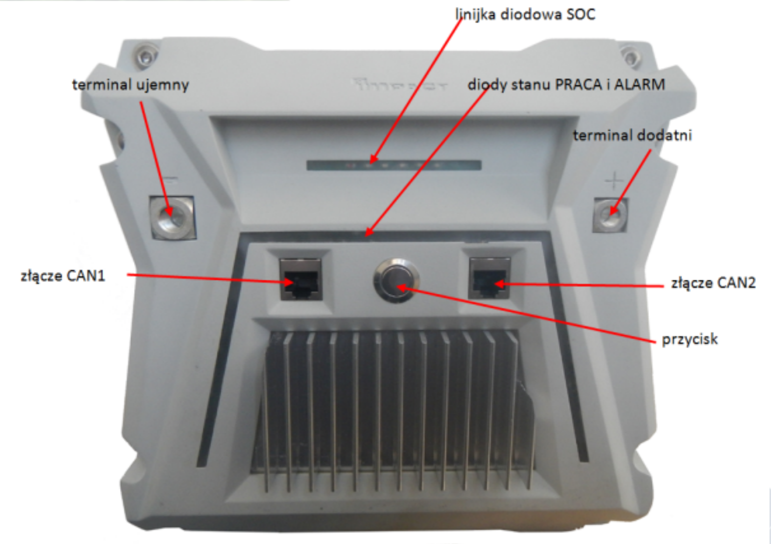

Fig. 2. Front panel of lithium-iron energy storage [4], where: złącze CAN1 – CAN1 connector, Terminal ujemny – Negative terminal, linijka diodowa SOC – SOC diode line, Diody stanu pracy PRACA i ALARM – OPERATION and ALARM status diodes, terminal dodatki – terminal accessories, złącze CAN2 –connector CAN2, przycisk – button.

Experimental tests

The aim of the tests was analysis of electrical parameters of hybrid inverter cooperating with a power system during charge and discharge of the energy storage. The storage was charged using the inverter with power form power grid. The discharge process was carried out via the inverter too, the energy was delivered to the power grid. The test started for charged energy storage (fig. 3). The measurements were performed via grid parameter analyzer PQM-701Z [6].

Figure 3 shows inverter activation and charged energy storage. From minute 21:00 to minute 22:30, of the recorded waveforms, the inverter charges the energy storage with current of about 1 A, in minute 22:30 the inverter switches to a status in which it maintains the charged energy storage, current supplied from the grid is maintained at the level of about 0.25 A. Such process occurs for a charged storage energy.

According to the energy storage manufacturer, charge current decrease below 0.5 A means a necessity to stop charging or to change inverter operation status to discharge. The discharge process starts with slight, 1-second current impulse (22:50 min), next for a few seconds it drops until again stable operation begins. At the same time, insignificant voltage increase is observed, it lasts until minute 55:30.

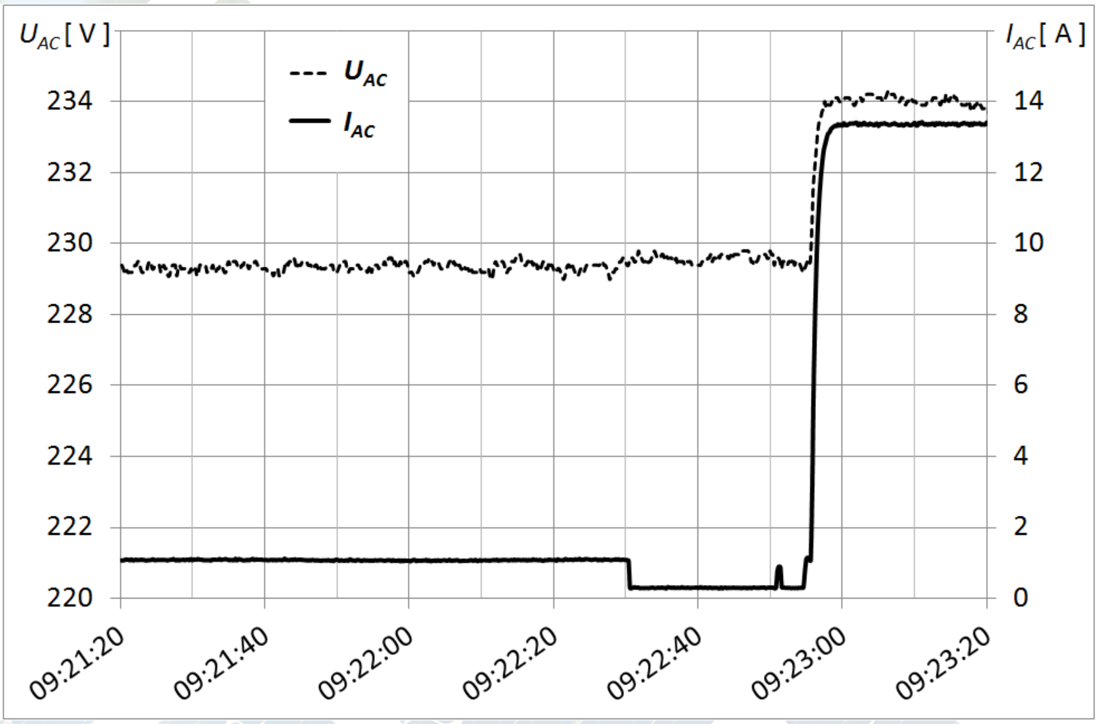

Fig. 3. Switching the inwerter on, storage discharge start

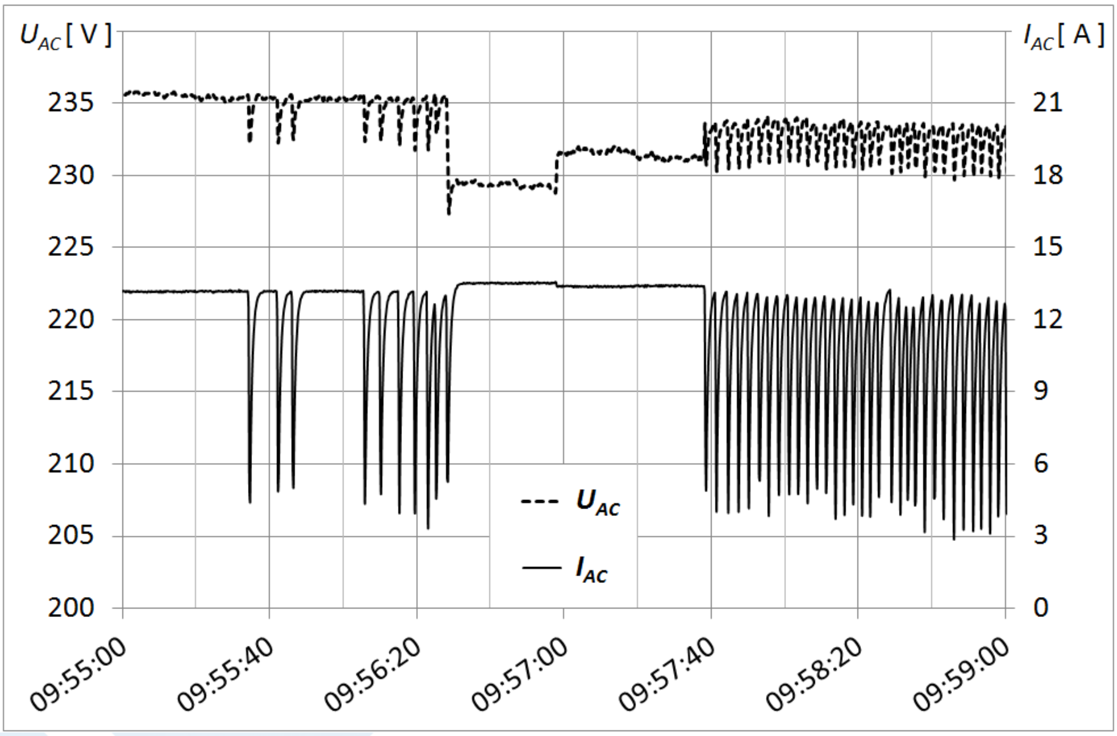

Fig. 4. Energy storage discharge process

Discharge process start is accompanied by increase of U_{AC} voltage on AC input of inverter's power grid. U_{AC} voltage increases to about 5 V. Energy is supplied to the grid with P_{AC} power of about 3 kW. I_{AC} current value at the connection hybrid inverter and the power grid increased to 13.31 A. Like U_{AC} voltage, also I_{AC} current remains constant until minute 55:30 (fig. 4). From this moment, I_{AC} current drastically drops by about 9 A and increases to the value of 13.31 A. During these I_{AC} current fluctuations, at a certain time the value of 13.26 A is

obtained, it remains so for few minutes. Simultaneously U_{AC} voltage decreases. Within the first stage of discharge the I_{AC} current was 13.31 A, whereas in ¼ and ¾ of the discharge interval, the I_{AC} current changed by about 13 A.

At the energy storage discharge process end, drops of I_{AC} current values are observed. The drops stabilise and after a moment destabilise again. U_{AC} voltage respectively decreased when I_{AC} current increased, and it increased when the I_{AC} current remained at the lower level (fig. 5).

In figure 5, I_{AC} current fluctuations are observed within the period of 27 minutes (from 9:56 to 10:23). The fluctuations result with total drop of I_{AC} current value, this causes storage discharge to target minimum voltage, U_{DCmin}. Till the end of discharge process, U_{AC} voltage oscillates from about 226 to 236V (fig. 5).

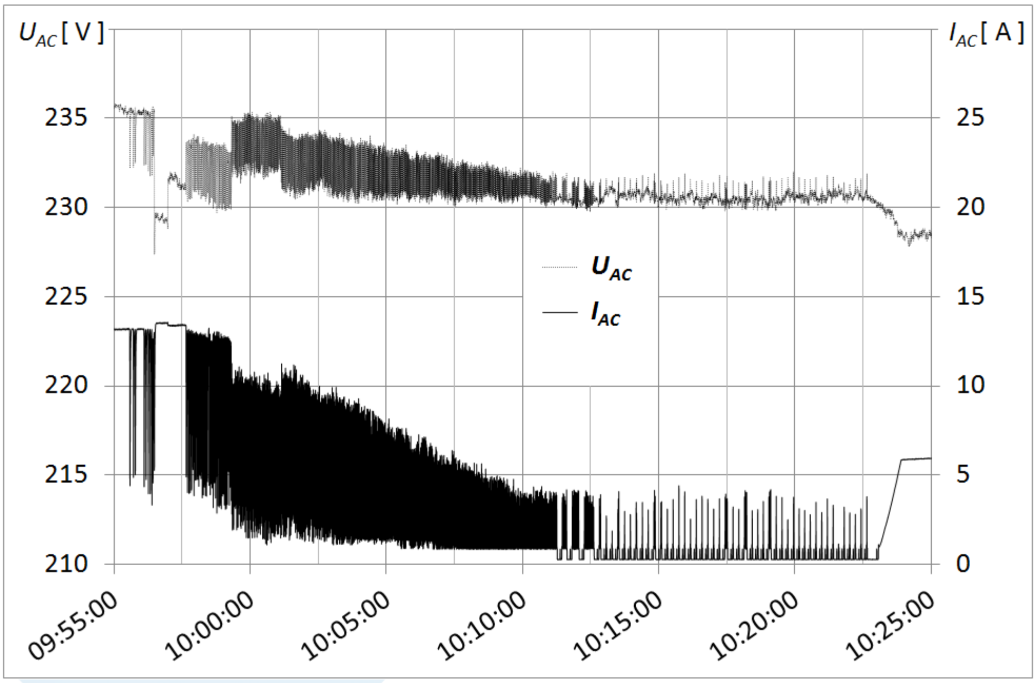

Fig. 5. Energy storage discharge process end

The Energy storage was not discharged in 100% because the inverter for low U_{DC} voltage, on energy storage terminals (46.2 V) switched from discharge to charge, next upon a while it switched to discharge mode again although the target minimum voltage, $U_{AC\text{min}}$, of energy storage discharge by the inverter was set to the value of 40.6 V.

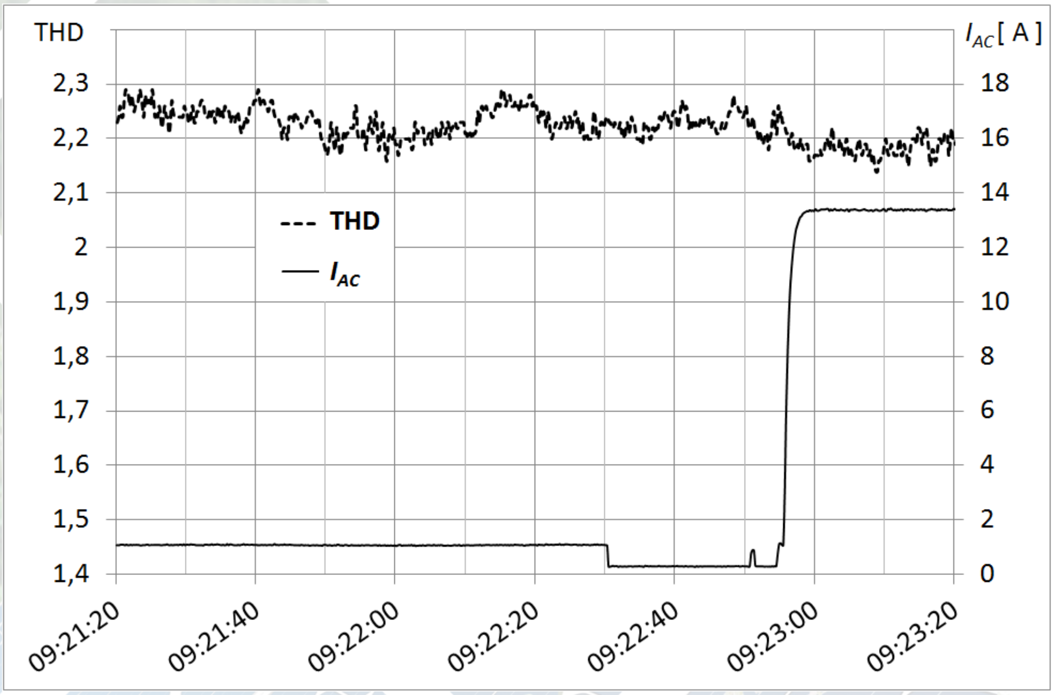

Fig. 6. Change of THD coefficient and I_{AC} current

Unstable inverter operation took few minutes. No U_{DC} voltage change was noted on Energy storage terminals, and I_{AC} current value oscillated between 0.27 A and 3.78 A. This was observed for 38% charged energy storage. The experimentally obtained energy storage discharge rate was only 62%. The discharge process ended at this stage.

Figure 6 presents change of THD coefficient value during the switch of the inverter to the energy storage discharge state. At the beginning the wave reflects energy storage charge to the maximum. I_{AC} current value dropped to the minimum. THD coefficient stayed at the level of 2.2 – 2.3. Increase of the current caused insignificant drop of the THD coefficient (to value not greater than 2.2).

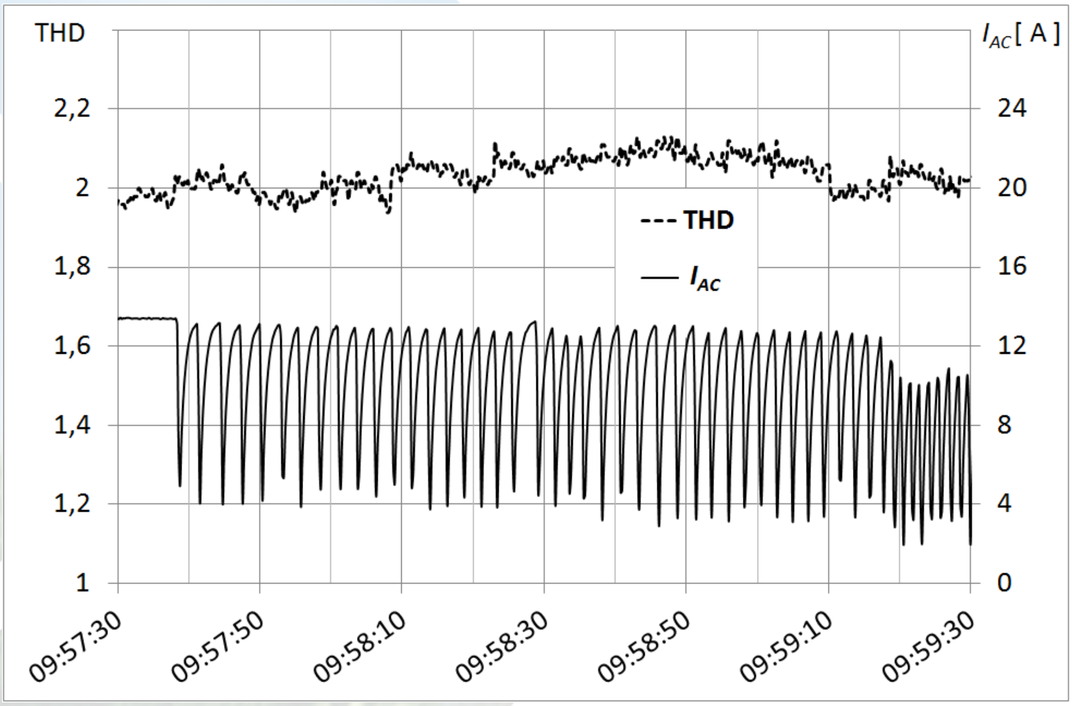

Fig. 7. Change of THD coefficient at unstable inverter operation

In the course of unstable inverter operation, at oscillation of I_{AC} current within the range of 4 – 13 A (fig. 7) the THD coefficient remained stable and did not exceed the value of 2.2. oscillations of I_{AC} current in figure 7 are a cause of drop of U_{DC} voltage of the energy storage. Consumption of energy from the storage causes drop of voltage on the energy storage terminals. When the U_{DC} voltage on the terminals drops below the minimum value of U_{DCmin}, pre-set in the inverter program, then the inverter stops loading the energy storage. Voltage of the unloaded energy storage slightly increases. The inverter reads U_{DC} value that in comparison to U_{DCmin} is greater, and discharge starts. This is a moment when the inverter loads the energy storage in an unstable way (Fig. 7).

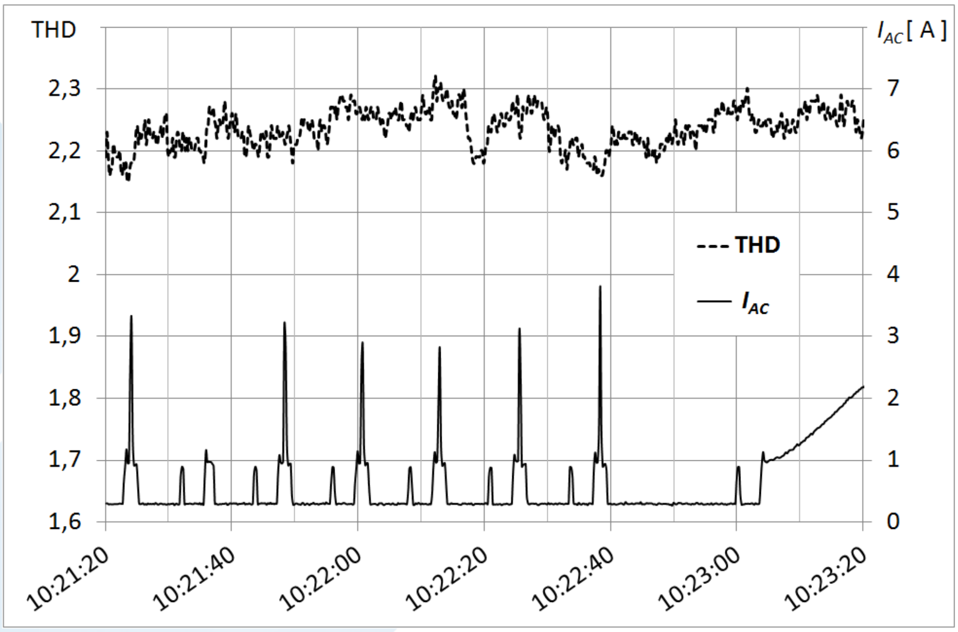

Fig. 8. Change of THD coefficient at a discharged storage

When the storage is completely discharged, the inverter starts charging. For an empty energy storage and at charge start, the THD coefficient remains stable at the level of 2.2 – 2.3. Upon analysis of figure 9, during stable storage discharge insignificant overtones may be observed. The first overtone is a signal of frequency equal to the frequency of analysed periodical signal, the remaining ones are multiplications of the first frequency. In the tested case, the first overtone equals the current value of the grid frequency, each next is its total multiplication (fig. 9). The first overtone is of the greatest value. It is possible to observe overtone 3, 5 and 7. Their values are much lower, they generate insignificant disturbances to the power grid. The following overtones of the I_{AC} current (fig. 9) are close to zero.

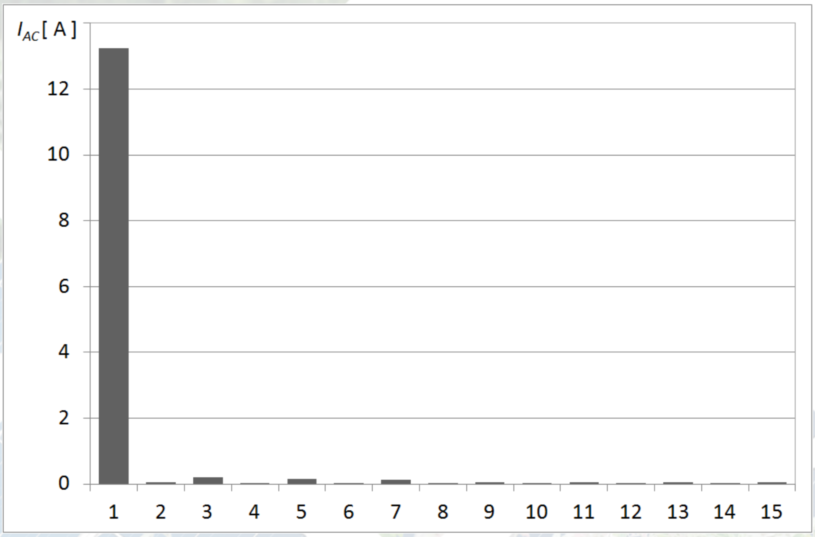

Fig. 9. Overtones of I_{AC} current during stable energy storage discharge

The greatest current overtones occur when the energy storage charge level gets lower, which results with unstable inverter operation. I_{AC} current waveforms and first overtone waveform do not cover (fig. 10).

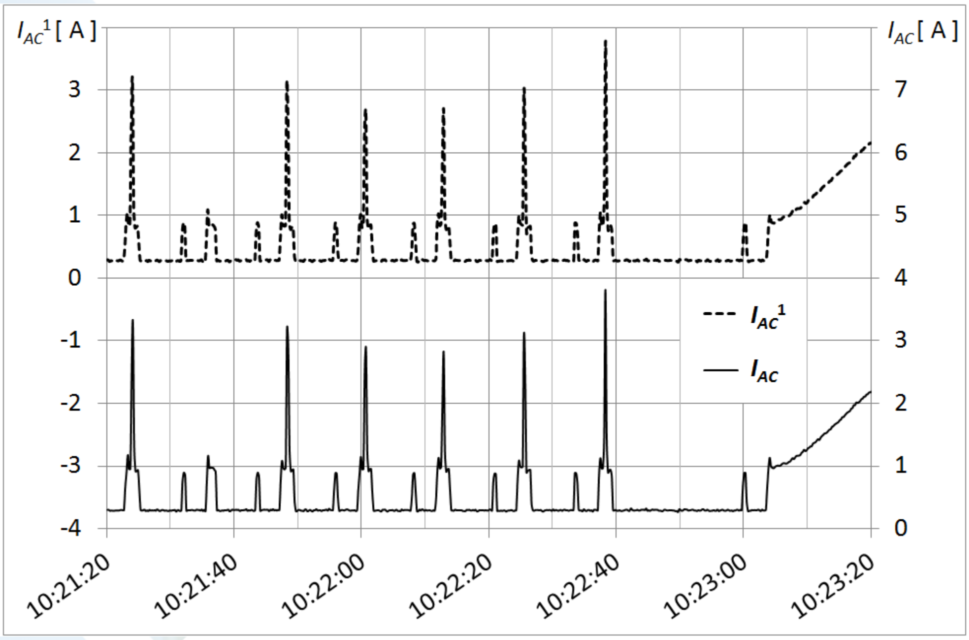

Fig. 10. Change of I_{AC} current and its first harmonic

It is worth paying attention to the behaviour of the power factor cos*φ* during the process of discharging energy storage into the power grid. When discharge mode of the energy storage turns on, the cos*φ* power factor value drops to a negative value. When the I_{AC} current begins to increase, the cos*φ* value drops to -1. This is the effect of giving away electricity to the power grid. While the inverter changes its operating mode to charge energy storage and the I_{AC} current increases to 6A, the power factor cos*φ* reaches 1.

The inverter powers were the next analysed parameters during the tests. One of them is the deformation power *D*, which is the result of the occurrence of phase shifts between harmonics of U_{AC} voltage and I_{AC} current and a different order of these harmonics. The second is *Q* reactive power, which in AC circuits is a quantity that describes the pulsation of electricity between circuit elements. The presence of this power causes an increase in the I_{AC} current, which increases the loss of electricity in devices generating and transmitting AC electricity.

When the energy storage discharge process is started, the share of components in the total power generated by the inverter changes. *P* Active power and *Q* reactive power have a negative value - energy is transferred to the network, while the *D* deformation power is positive and amounts to about 20 W (Fig. 11).

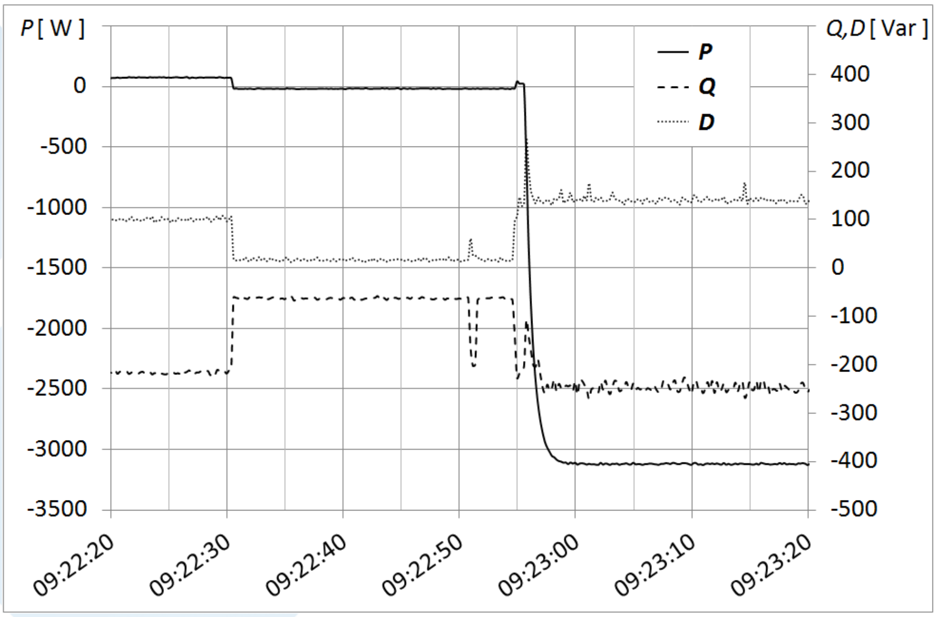

Fig. 11. Change of the active power P and reactive power Q at the discharge of energy storage process

When the discharge current I_{AC} reaches 13.31 A, powers *P* and *Q* maintain a constant value. This situation persists until the I_{AC} current begins to decrease. Then, each time the I_{AC} current drops, both powers increase. However, the *D* deformation power increases its value many times (Fig. 12). When the I_{AC} current sometimes returns to its maximum value, the powers return to previous levels. Such phenomena begin to occur when the maximum energy storage discharge level is reached.

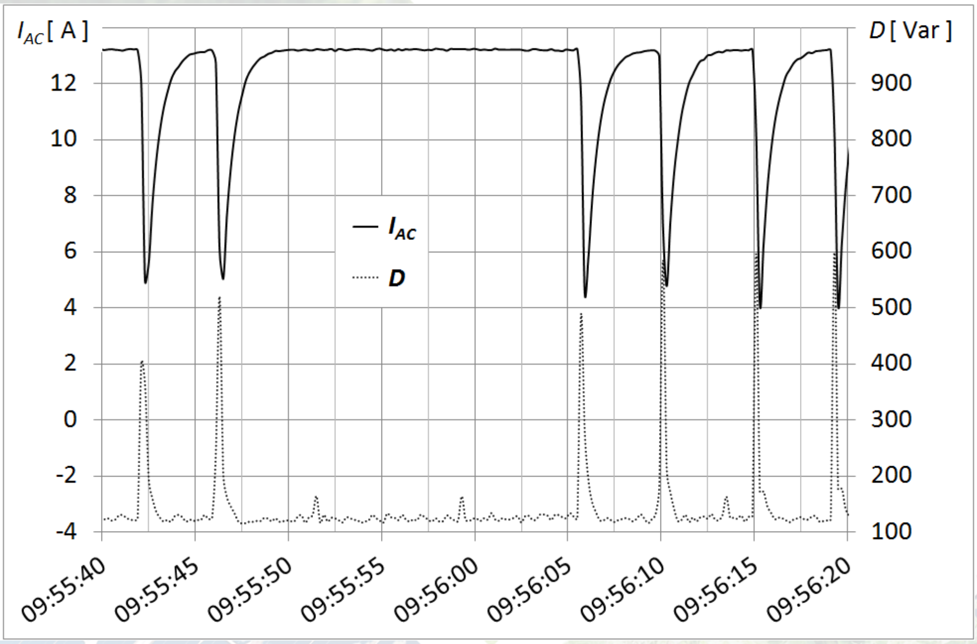

Fig. 12. Deformation power D and I_{AC} current with unstable operation of the inverter

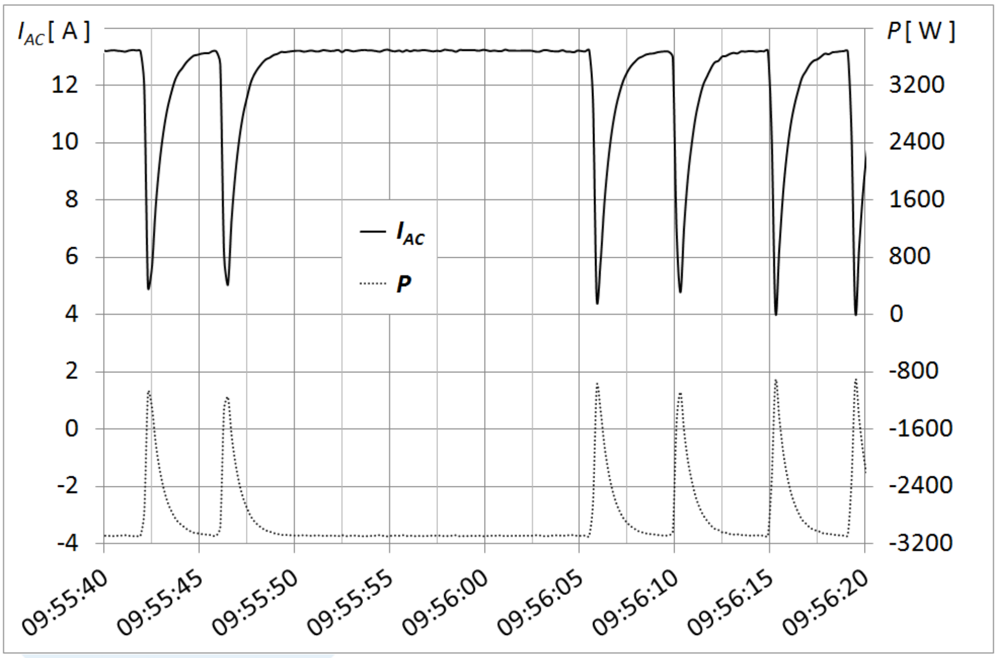

Fig.13. Change of the deformation power D and I_{AC} current during unstable operation of the inverter

The instantaneous increase in deformation power *D* of up to about 500 Var was noted with instantaneous increases in the value of current and the low energy level in the energy storage (Fig. 12). The value of active power *P* reaches the value of -3200 Var (Fig. 13).
Short current peaks appear when the energy storage is discharged to the set minimum level (Fig. 14).

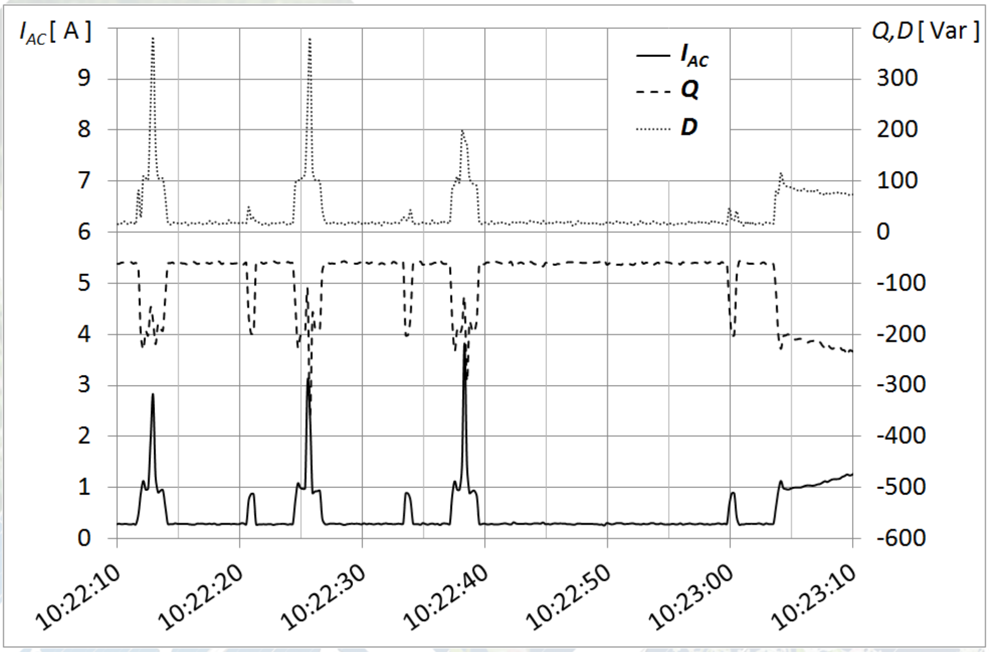

Fig. 14. Power and current waveform with discharged energy storage

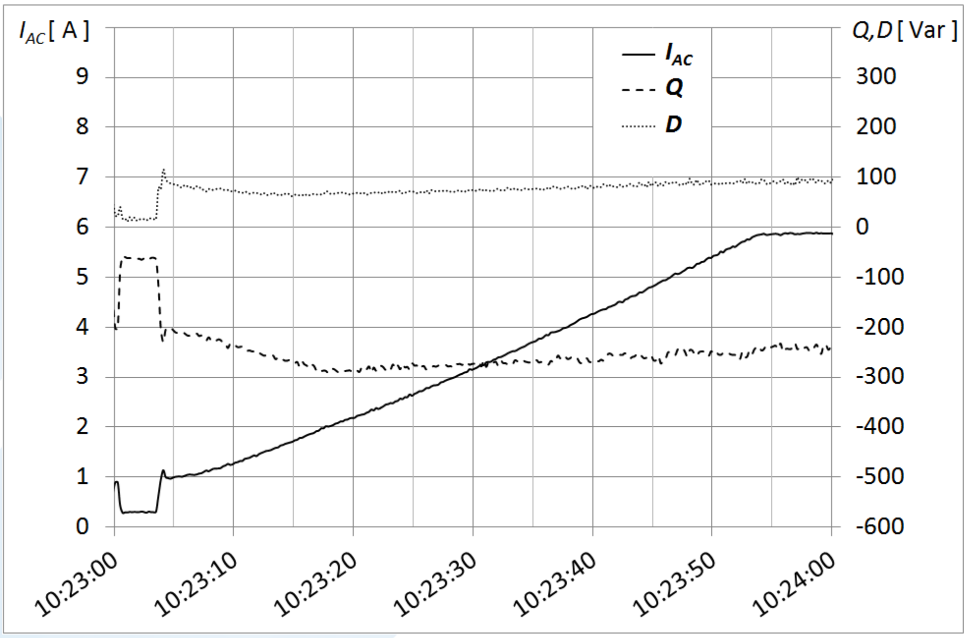

Fig. 15. Chart D and Q power when changing a current I_{AC}

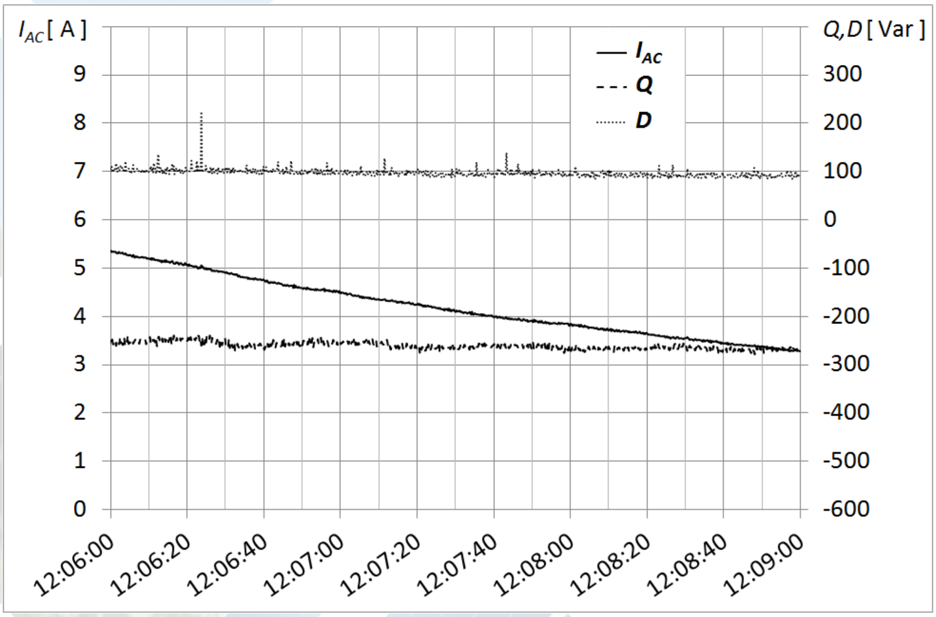

Fig. 16. Q and D Power graph when the energy store is charging

The *Q* and *D* power values maintain a similar level despite the increase in I_{AC} current when the energy storage is charging from the power grid (Fig. 15). Instantaneous peaks of I_{AC} current cause *D* and *Q* power peaks.

As the I_{AC} current increases (Fig. 15), the power values fall to a certain level. When the I_{AC} charging current reaches a constant value, the reactive power level remains within 90-100 Var for deformation power *D* 230 - 250 Var, respectively. I_{AC} current increases from 5.8A to 6,8A during charging the energy storage.

When the charge level of the energy store is getting higher, the I_{AC} current begins to decrease and the deformation power D and reactive power Q decrease slightly. When the I_{AC} current is 5A, the deformation power D falls below 100Var, and reactive power Q reaches below –250Var. Power wave fluctuations are ± 15Var (Fig. 16).

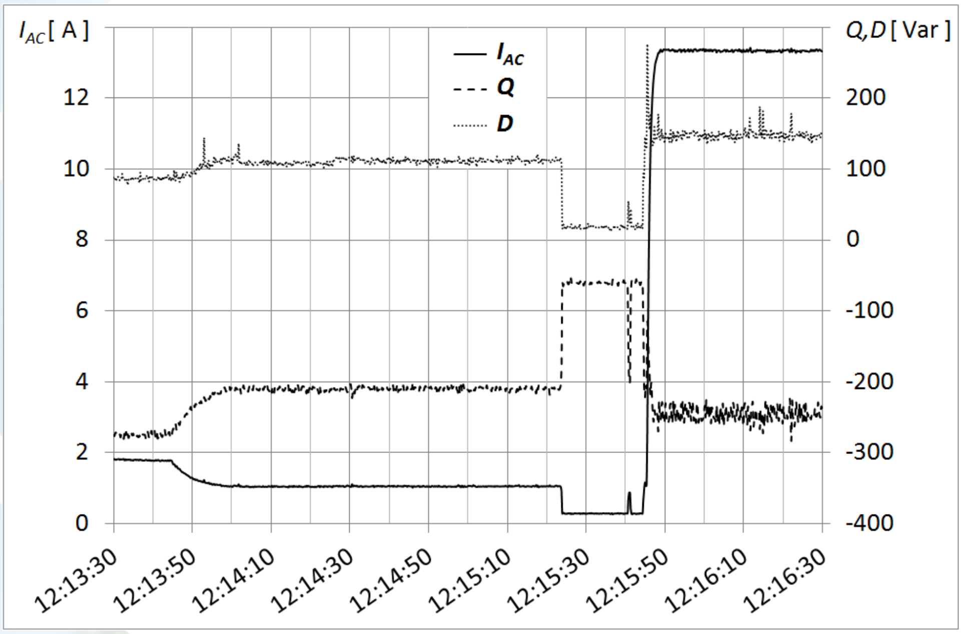

Fig. 17. End of energy storage charging process

The I_{AC} charging current drops below 0.5A after charging the energy storage to 100% (Fig. 17). The inverter stops charging the energy storage to avoid overcharging.

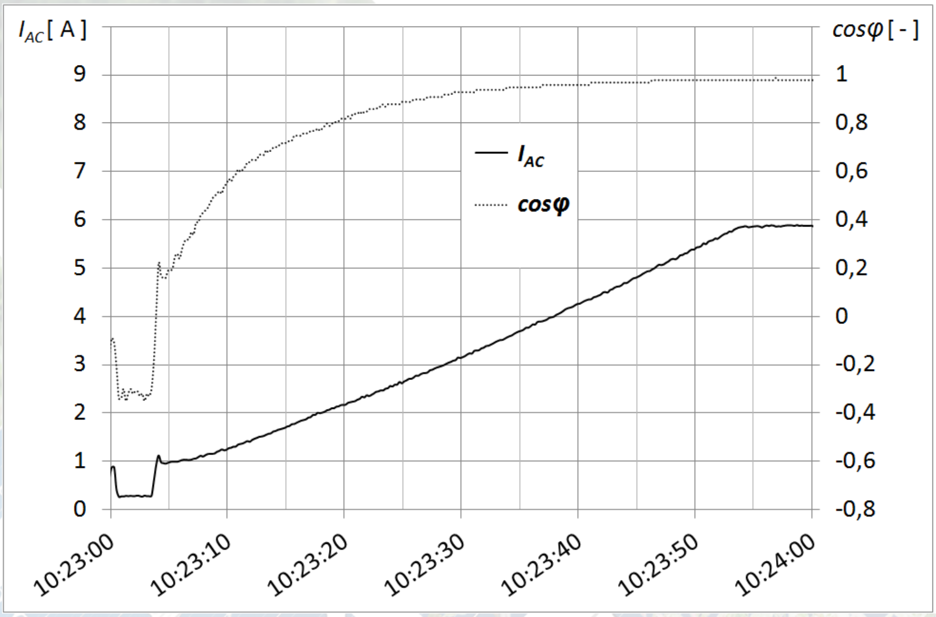

Fig. 18. Change of the power factor cos ϕ when loading energy storage

The change the deformation power D and reactive power Q can be observed when the I_{AC} charging current is reduced. The reactive power Q value changes to -60 Var, and the deformation power value is 20 Var when the I_{AC} charging current drops below 0.5 A

The power factor cosϕ increases as the value of the I_{AC} current increases (Fig. 18). The power factor $\cos\varphi$ reaches values close to 1 when the I_{AC} current stabilizes at around 6A.

The power factor cosϕ stays at 1 until the IAC charging current begins to decrease. During the last 10 minutes of charging the energy storage, the cosϕ dropped to 1/3 before restarting the discharge process (Fig. 19).

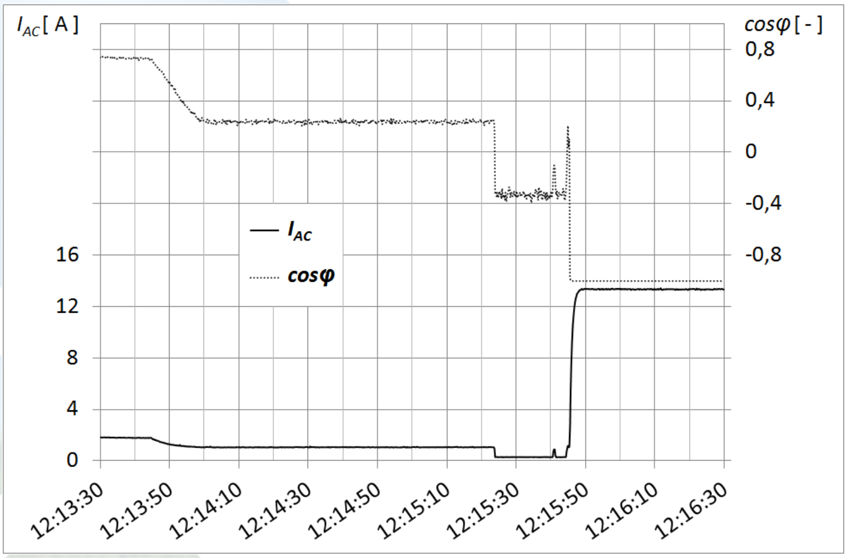

Fig. 19. Chart I_{AC} charging current and power factor of energy storage at charging

The first harmonic of the I_{AC1} current superimposes the I_{AC} current waveform for almost all the time the energy storage is charging. This continues until charging is complete (Fig. 20).

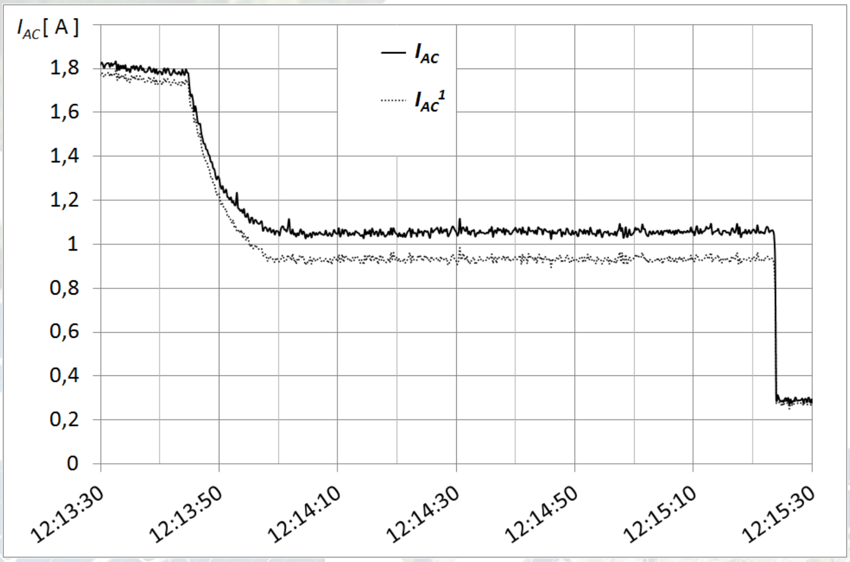

Fig. 20. Change of IAC current value and first harmonic value of IAC1 current

During the energy storage charging process, the IAC charging current flowed in accordance with the storage charging characteristics, and the interference introduced into the power grid by the inverter was within the range allowed by the standard. Both tests: charging and discharging energy storage allowed observation of phenomena accompanying these processes. Undoubtedly, the unstable operation of the inverter is noteworthy both in terms of maintaining a charged energy storage and when the storage is completely discharged.

Summary

Lithium-iron energy storage is a tool more often used to store energy produced from renewable energy sources. They make the exchange of the energy with the power system stable. They provide energy when there is a gap in supply of power from the grid or when there is a lack of energy coming from the renewable source. Taking advantage of the lithium-iron energy storage requires precise programming of the associated facility connecting with the energy storage. This is because exciding of the critical operation parameter values results with storage damage, which in turn leads to fire caused by leaking of lithium from the energy storage inside (lithium battery inside). Depending on the hybrid inverter it may be expected that interference will be introduced into the power grid. The interference is mainly a distortion of the generated current fed into the SEE. This article presents test results and analysis of some selected electric parameters being a result of cooperation between the hybrid inverter and the power grid during the charge and discharge process of lithium-iron energy storage.

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Partner Contacts

The organisations contributing to the development of PV Trainer are listed below. Please feel able to contact them for more information and support.

POLAND
Sieć Badawcza Łukasiewicz – Instytut Technologii Eksploatacji
Pulaskiego 6/10
26-600 Radom
katarzyna.slawinska@itee.radom.pl, miroslaw.zurek@itee.radom.pl
www.itee.radom.pl

POLAND
Stowarzyszenie Elektryków Polskich Oddział Radomski
prof. W. Krukowskiego 1
26-600 Radom
ckf@sep.radom.pl, r.figura@sep.radom.pl
www.sep.radom.pl

POLAND
Polskie Towarzystwo Fotowoltaiki
Pralatowska 5 lok. 50
03-510 Warsaw
pietruszko@pv-polska.pl
www.pv-polska.pl

ROMANIA
Universitatea Dunarea de Jos Din Galati
Strada DOMNEASCA nr. 47
800008 GALATI
emilia.pecheanu@ugal.ro, adina.cocu@ugal.ro
www.ugal.ro

CYPRUS
EDITC LTD
16 Imvrou Street
1055 Nicosia
maria@editc.com
http://www.editc.eu/

SPAIN
Fundación Equipo Humano
Passeig da la Petxina 12, bajo izuquierda
46008, Valencia
je.val@fundacionequipohumano.es, alfonso.cadenas@fundacionequipohumano.es
https://www.fundacionequipohumano.es/es/

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