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Conditions of selection of the photovoltaic module for the microgeneration

Damian Głuchy
Poznań University of Technology
60-965 Poznań, ul. Piotrowo 3A, e-mail: damian.gluchy@put.poznan.pl

In the study the attention was paid to the problem of proper selection of photovoltaic modules. Normative definition of the term of photovoltaic microgeneration was given. Attention was paid to the criteria used for inverters at the stage of planning the investment with a selected value of rated power. Their application and usefulness for the microgeneration were described. A number of practical comments was given, the observance of which would allow to maximize the efficiency for the systems with smallest powers.

KEYWORDS: PV, renewable energy sources, photovoltaic microgeneration, potential induced degradation

1. Introduction

Energy security is one of the most significant problems with which our civilisation has been faced over the last several dozen years. Constantly growing demand for electrical energy is connected with its secure and rational energy generation. The events which were taking place over the last months are the best proof of the scale of the problem. Discussions which were held in connection with subsidies for mining and introduction of the Act on Renewable Energy Resources prove that there is the need for conscious investment in the electrical energy generation systems. The variable economic situation connected with fossil fuels depending on political and economic situation of the world inclines us to increase the potential of renewable and ecological sources.

Although the increase in the share of renewable energy sources in Poland is perceptible these are mainly systems with big rated powers. However, using the experiences of western European countries one should appreciate the potential of diversified microgenerations that generate electrical energy. One of the leading technologies of the renewable energy sources is the use of PV modules which are basic components of photovoltaic microgenerations.

2. Parameters of photovoltaic modules

The objective of the photovoltaic module is to convert the energy of solar radiation into direct current electrical energy. Hence before starting the investment one shall pay particular attention to the value of solar radiation for a given area. The selection of the type of PV modules, type of the system and its method of works depends mainly on its level. The availability of solar energy and the associated average annual temperature of the area depends – to a large degree – on the latitude. The solar exposure levels for Europe were presented in Figure 1 [8].

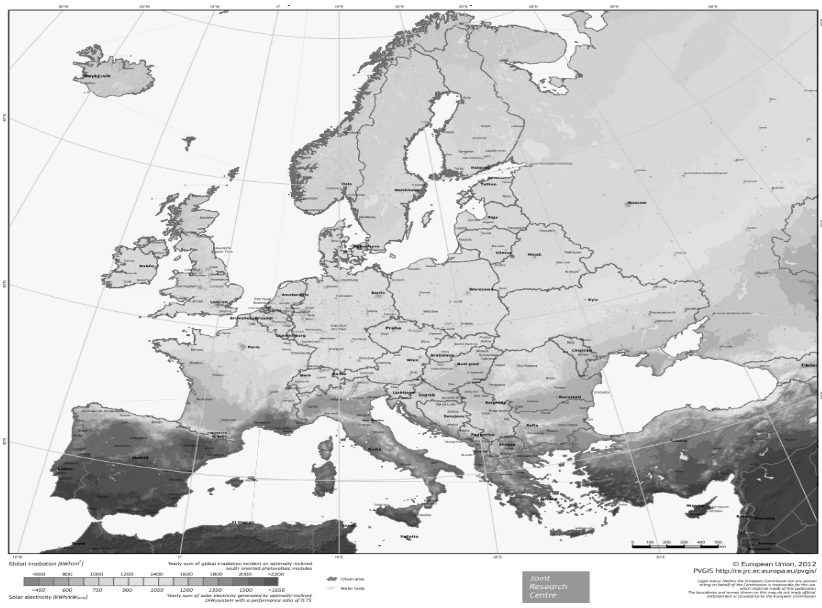

Fig. 1. Availability of solar energy in Europe [8]

However, geographical location is only the element of the location which – apart from availability of the solar radiation – also defines the optimum angle of placement of solar batteries. It also has a considerable impact on partial local shading by the objects located in the vicinity, such as trees or buildings.

The frequently ignored location and geographical parameter which has a significant impact in practice is albedo. It is responsible for the impact of reflected radiation from flat surfaces (water, snow, lawn) in front of PV panels and has a big significance for the final energy output from the system.

Due to technology and construction of photovoltaic modules they can be divided into thin-film and classic modules constructed on the basis of crystalline silicon.

Irrespective of the execution technology, the photovoltaic modules can be characterised by four basic electrical parameters:

– short-circuit current I_{sc},
– current in maximum power point I_{MPP},

– open circuit voltage U_{oc},
– voltage in maximum power point V_{MPP}.

These are mainly taken into account by potential investors at the stage of designing the systems. The specification of parameters are presented in Table 1 and 2. Apart from the above-mentioned four main parameters and the price, due to effectiveness and efficiency of the PV systems the authors suggest to pay attention to [1, 4]:

– efficiency value,
– wide selection of suppliers,
– demand for big area needed for assembly due to small efficiency,

Table 1. Specification of parameters of thin-film photovoltaic modules which are significant from the investor's point of view [3, 5]

	Thin-film modules		
	Made of amorphous silicon a-Si	**Made of cadmium telluride CdTe**	**Made of CIGS mixture**
Price EUR/W (November 2014)	0.5		
Efficiency [%]	12	15-17	8
Demand for big area needed for assembly due to small efficiency	Yes	Yes	No
Big selection of suppliers*	No	No	Limited
Type of the selected inverter	Transformer	Transformer	Each
Colours	Violet, uniform	Black	Black
Big number of low quality products on the market	No	No	No
High temperature power ratio	No	No	No
Good efficiency under poor lighting conditions	No	No	Yes
Corrosion of TCO layer	yes	Yes	No
Big weight per m^2	Yes	Yes	Yes
Construction without the frame, hindering assembly and reducing mechanical strength	Yes	Yes	No
Additional comments	Big efficiency drop in the first months of operation	-	Power yield in the first hours of operation

* for the market in Poland

Table 2. Specification of parameters of photovoltaic modules made of crystalline silicon which are significant from the investor's point of view [3, 5]

	Modules made of crystalline silicon		
	Polycrystalline c-Si	**Monocrystalline c-Si**	**Quasi-monocrystalline c-Si**
Price EUR/W (November 2014)	0.56	0.66	0.57
Efficiency [%]	21	24	23
Demand for big area needed for assembly due to small efficiency	No	No	No
Big selection of suppliers*	Yes	Yes	No
Type of the selected inverter	Each	Each	Each
Colours	Blue spotty	Black	Blue, intensively spotty
Big number of low quality products on the market	Yes	Yes	No
High temperature power ratio	Yes	Yes	Yes
Good efficiency under poor lighting conditions	No	No	Yes
Corrosion of TCO layer	Not applicable	Not applicable	Not applicable
Big weight per m^2	No	No	No
Construction without the frame, hindering assembly and reducing mechanical strength	No	No	No
Additional comments	-	-	Low efficiency in the first hours of operation

* for the market in Poland

– type of the selected inverter,
– aesthetic values (colours),
– quality of a given type of products on the market,
– high temperature power ratio,
– corrosion of the TCO (Transparent Conductive Oxides) layer,
– big weight per 1 m^2 of the panel area,
– construction (structure without the frame hinders the assembly and reduces strength).

Certain characteristic elements of individual types of modules are also significant, for example:

– low efficiency in the first hours of operation of the modules made of Quasi-monocrystalline silicon,
– big drop in efficiency in the first months of operation of thin-film modules made of amorphous silicon,
– power yield in the first hours of operation of thin-film modules made of CIGS mixture (combination of copper, indium, gallium and selenium).

All the above-mentioned parameters and characteristics may be determined both for thin-film modules (Table 1) and for modules made of crystalline silicon (Table 2).

By analysing the above-mentioned specifications considering the target location of the system the investor can obtain a number of assumptions which should increase the profits of the installed system. However, it shall be mentioned that the said parameters may be insufficient for the specific target group such as microgenerations and it may be necessary to consider extra criteria [2, 3].

3. Criteria of selecting the PV module for the microgeneration

The issue of selection of photovoltaic modules was raised many times by many authors in their publications. However, in the studies on this type, the problems of designing the microgenerations which – in certain aspects – differ from industrial electric power plants of bigger powers are treated marginally. This can be confirmed by the legislator who defines the microgeneration as "renewable energy source with total installed electrical power not greater than 40 kW, connected to the power supply network with the rated voltage lower than 110 kV or with total installed thermal power not greater than 120 kW" [6]. Hence it shall be considered that not every solution which is efficiently used on the photovoltaic farm may be successfully used for a few kilowatt systems mounted on the roofs of the buildings. Practical criteria for selection of PV modules for the microgeneration, based on the previously mentioned parameters from the catalogue notes, were included below.

a) Application of PID-resistant modules

The PID (English: Potential Induced Degradation) is nothing else than degradation using induced voltage, and simply speaking loss of power by the PV module caused by small leaking current with high voltage. This problem concerns all the modules, both these made of crystalline silicon and of thin-film silicon. The issue of the PID is connected with the voltage occurring between the extreme poles of module chains and the earthed frame. While connecting the chains of the PV modules to the inverter high voltage is generated between its poles "+" and "-", most frequently ranging from 300 to 600 V. Due to earthing securing against atmospheric discharges, the module frames have the potential of 0 V, which causes the occurrence of high voltage between the frame and the extreme modules in the chain. Such big difference of potentials results in the appearance of electrostatic field, the electrons of which freely migrate to the pane, further to the frame, and consequently – through the earthing – to the ground. The idea of the occurrence of the PID phenomenon is presented in Figure 2.

Therefore, due to the construction of the cells, this problem appears in the modules located closest to the negative end and is intensified by operation in high temperatures of the air and high humidity. Also, this phenomenon has double character: polarisation, which is fully reversible, and electrochemical, resulting from corrosion of the cells and connected with irreversible loss of power. Although initially manufacturers of photovoltaics were disregarding this subject, it very quickly turned out that in extreme cases the loss of power of the PV module may reach from 30 to 70% of its rated power.

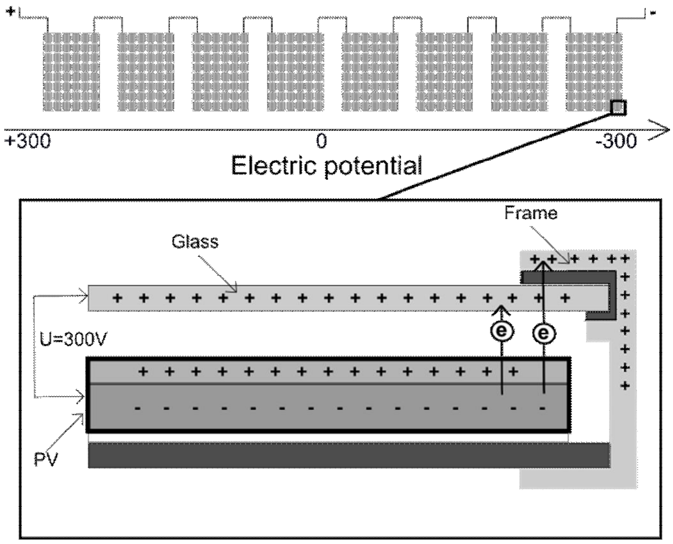

Fig. 2. Concept of the occurrence of PID phenomenon [5]

The problem of the PID – although first it only results in slight reduction of the modules' efficiency – in the long-term perspective leads to quicker degradation of cells and reduction of energy output. This constitutes the basis for selection of modules which are tested by the manufacturer with regard to resistance to potential induced degradation. Such type of information is always given in the catalogue note, while its lack clearly proves that such test has not been conducted [5].

b) Certified products

All the photovoltaic modules should meet standards which were adopted in a given country. In Poland the trustworthy systems comply with the following standards:

- PN-EN 61730-1:2007 Photovoltaic (PV) module safety qualification. Part 1: Requirements for construction.
- PN-EN 61730-2:2007 Photovoltaic (PV) module safety qualification. Part 2: Requirements for testing.
- PN-EN 61730-1:2007/A2:2013-11 English version. Photovoltaic (PV) module safety qualification.

Moreover, the following standards are applicable for the modules made of crystalline silicon:

- PN-EN 61215:2002 Crystalline silicon terrestrial photovoltaic (PV) modules: design qualification and type approval.
- PN-EN 61215:2005 Crystalline silicon terrestrial photovoltaic (PV) modules: design qualification and type approval.

The thin-film modules should meet the following standards:

- PN-EN 61646:2002 Thin-film terrestrial photovoltaic (PV) modules - design qualification and type approval.
- PN-EN 61646:2008 Thin-film terrestrial photovoltaic (PV) modules - design qualification and type approval [7].

c) Modules with ARC film

The ARC film is a thin anti-reflexive layer with the thickness of a few dozen nanometres used to improve the efficiency of solar cells. By placing it on the module's pane it is possible to increase the efficiency from 3.5 to even 5% in relation to modules covered with classical hardened glass. Also, the systems with anti-reflexive coating are not significantly more expensive than those without this layer.

d) Assembly structures

In order to reduce installation costs, the investors frequently use the modules without the frame. Such solutions are very well known in case of thin-film modules. This encouraged the manufacturers to produce the modules without the frame made of crystalline silicon. However, such types of systems are much more difficult to install, and hence are less resistant to mechanical damage.

e) Guarantee conditions

One of the marketing tricks used by PV distributors is offering a 25-year guarantee for power. However, you should be aware that there is practically no company in the market which has been offering photovoltaic sub-assemblies for such a long time. Hence you cannot be sure whether the potential guarantee will be possible to be execued. As shown by the example from the year 2013 (decline of Chinese company – Suntech), even the biggest companies with current multi-million orders cannot be sure about their future. In practice you can notice problems with basic guarantee for hidden defects of the PV, which amounts to about 10 years, and which is difficult to implement, particularly if the manufacturer does not have a factory or branch in Europe. Bearing in mind that none of the 10 biggest PV manufacturers produces their modules, there are considerable threats as to the reliability of the guarantee.

f) Selection of high-voltage and low-voltage modules

One of the biggest problems in case of microgenerations is proper current-voltage configuration of the system. The effective operation of the inverter is made possible only in case of proper voltage at the input, which comes from the modules' chains. In case of the most popular modules on the market, connected in series, with rated power from 250 to 260 W, you can often encounter too low voltage value. This is particularly visible in case of the smallest systems.

While selecting the inverter for the photovoltaic system, you should pay special attention to a few various values of voltages, characteristic for specific states of its operation. The inverter's scope of operation in the function of power with regard to voltage was presented in Figure 3.

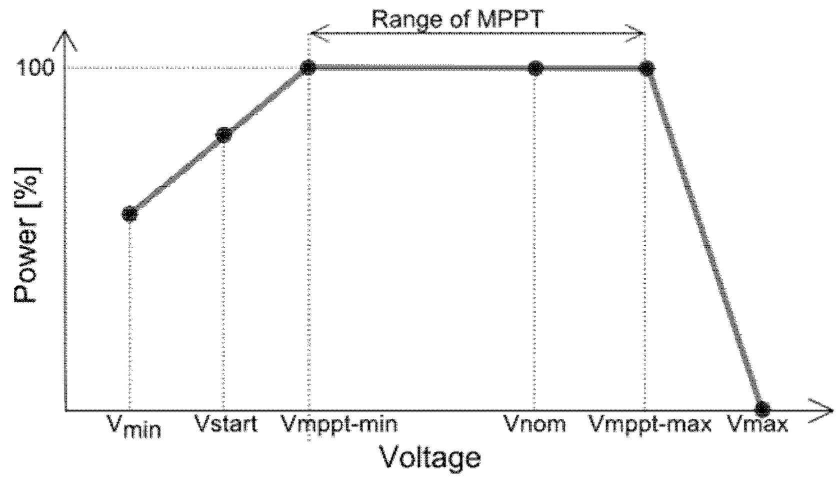

Fig. 3. Scope of the inverter's operation in the function of power with regard to voltage [5]

While analysing the above-mentioned diagram you can observe that when the voltage on the DC side of the inverter exceeds the value of V_{start} the system will switch to the operation mode of searching the maximum power point. If this point has the value of over V_{min} the inverter will start to feed the energy to the output. Obviously if this value is lower than $V_{mppt-min,}$ the inverter's operation will take place with the power lower than the rated power. The scope of adjustment of the system's load will take place with specific time interval (characteristic for each inverter) if the voltage is within the range from $V_{mppt-min}$ to $V_{mppt-max}$, with particular emphasis on characteristic point V_{nom} in which the highest efficiency of DC/AC conversion is achieved. Most of the inverters enable the operation over the value of $V_{mppt-max}$, but their power is quickly and linearly reduced in order to protect the power transistor.

The above-mentioned voltage ranges are given by each manufacturer in the catalogue notes, while on their basis you can start to configure module chains. It should be conducted in a way allowing to ensure the voltage of specific chain at the level maximally close to nominal voltage V_{nom}. This is equivalent to the inverter's operation closer to the top limit of V_{mppt}. Also, the variability of voltages in extreme temperature conditions shall be considered (drop of voltage during hot days and increase of voltage during frost time) and even in extreme cases the voltage should not exceed the MPPT range. Accurate selection of the voltage values is especially difficult with the use of industrial 60-cell modules with the power of 250-260 W.

In order to increase the effectiveness of work one shall select the modules based on smaller 5" of the cell instead of the previously mentioned 6" of the cell used in popular industrial systems. The alternative solution may be thin-film modules mainly based on the CIGS, which – as the modules made of crystalline silicon – are easy to install and operate.

g) Panels with low temperature power factor

This parameter was referred to in the earlier part of the study. It should be mentioned that low temperature power factor means small drop in efficiency during hot days, which is especially significant in case of roof systems which are usually not optimally ventilated. Therefore, the photovoltaic microgenerations installed on the roofs should be based on thin-film panels, optimally CIGS, instead of CdTe or on amorphous silicon. In particular, the first one of the above-mentioned technologies should be discussed. This results from Light Soaking Effect phenomenon, which is demonstrated by increase of initial power of CIGS modules by 1-3% compared to the nominal value. This is due to saturation with photons of the outside layer building p-n joint. Such phenomenon results in limitation of the barrier for movement of electrons from the semi-conductor area to the top electrode, and thus in the rise of current and voltage in the maximum power point of the module.

h) Avoiding modules made of amorphous silicon

The modules made of amorphous silicon have mainly one advantage, that is low price. The price is the primary factor that encourages the investors to use them. Other properties of these elements are frequently disregarded, which is a big mistake. Main weakness of the modules made of amorphous silicon is their low efficiency, which clearly translates into high installation costs as well as the need to earmark big installation area for the project. Another disadvantage is very low operation current. In practice this problem is solved by execution of numerous parallel connections, but this is related to the need of proper protection of each chain of the modules with locking diodes or fuses [5]. You can also add the frequent problem of corrosion of the TCO layer, which requires the use of expensive transformer inverters. Also, the modules made of amorphous silicon have low efficiency, and consequently the output from installed power is much lower than from analogical systems based on CIGS modules or crystalline silicon. All the above-mentioned features determine the fact that photovoltaics of such type is not a good selection in the microgeneration.

8. Conclusions

While selecting the type of photovoltaic module, the potential investor should base his decision not only on basic parameters of photovoltaic modules, but also on thorough analysis of all the other properties defined in the catalogue notes. Also, considering practical comments concerning proper selection of PV modules the risk connected with the project will be reduced to minimum. Thorough analysis of the market, with the consideration of the comments included herein, allows to narrow down the selection of panels for microgenerations to the mono- or polycrystalline systems with powers that are slightly lower from industrial systems, that is ranging from 190 to 220 Wp (60-cell 5") or CIGS modules with powers of 130 Wp or bigger, with the efficiency over 12%.

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