Features of Degradation of Silicon-based Solar Photovoltaic Cells

Linda Boudjemila¹ ², V V Davydov¹ ³, V G Malyshkin⁴ and V Y Rud⁴

¹ Peter the Great St. Petersburg Polytechnic University, St. Petersburg 195251, Russia
² Department of Mechanical Engineering, University of science and technology Houari Boumedien Bab Ezzouar 16111, Algiers, Algeria
³ All-Russian Research Institute of Phytopathology, Moscow Region 143050, Russia
⁴ Ioffe Institute, St. Petersburg, 195256, Russia

lariessai21@gmail.com

Abstract. This work intends to present a method for efficient analysis of the phenomenon of degradation in photovoltaic cells in Saint Petersburg (Russia) and Algiers (Algeria). The data used contain weather parameters (T°, wind, solar radiation) for 10 years. The rates of degradation of Si- photovoltaic cells were obtained from the data. It was noted from the results of comparing various data that the main factor in the formation of the degradation process is the technology of manufacturing photovoltaic cells.

1. Introduction
The development of the technology in the last two centuries required more and more the use of the electrical energy [1-10]. As it’s known the production of the electricity from fossils resources has caused many problems of pollution [10-20]. That’s why scientists are interested to the alternative energies such as solar energy [21-27]. Recently the solar cell of first generation has known a rapid development and a certain maturity which had led the price to get lower [28-34]. Unlucky these cells are very delicate and many factors such as the shadow, humidity, the hot weather, the wind can cause the degradation in a short time. One of the important elements of studies about the degradation is the modeling of the operation of a solar power plant, taking into account the climatic conditions of operation of photovoltaic converters, the processes of their degradation, etc.

2. Solar cells degradation data analysis
The data obtained from solar power station is a time series. The number of recorded parameters can vary from three (time, current and voltage) to dozens (include temperature, wind speed, humidity, etc.) this depends on power station data acquisition system. Obtained data is typically very noisy, thus their analysis is a non—trivial task. The algorithms of data analysis can be broadly divided on “sensor based” which use sensor-measured solar irradiation and “clear sky”, where irradiation and cells temperature is calculated from generated power using mathematical models [35]. One might think that the accuracy of “clear sky” approach will be inferior to the “sensor based”, however this is not actually the case, clear sky avoids problems due to drift or recalibration of ground-based sensors. With recent
versions of the RDTools software two methods are actually on par with each other. Once the data is collected – a model for data analysis should be build. Current models [35, 36] include the following three stages: 1. Normalization: do nominal power, and temperature normalization. 2. Filtering: remove the data collected during periods of poor or variable solar resource conditions as well as nonrepresentative or biasing data. 3. Analysis: There several approaches, the most commonly used is YOY (Year Over Year) that is typically more robust than SLS (Standard Least Squares) and quantile regression. The result is the distribution of degradation rates. This distribution can be quite noisy due to random and systematic errors. One of the key factors affection the results is the cleanless of solar cells. In [37] the devices which are regularly cleaned (control device) are compared with the devices left to naturally soil (soiled device); the Soiling Loss can contribute up to 10 % to solar station performance reduction. In current work we did not take soiling loss into account. Data noise in for generated power is clearly observed in Figure 1 and 2 below along with seasonal power dynamics.

3. Features of the degradation of solar photovoltaic cells

The data base used when simulating the operation of a solar power plant in Algiers and saint-Petersburg is the NASA data on climatic factors illumination of a horizontal surface in energy units per day, temperature and wind speed; these last two parameters are measured at 2 meters altitude.

The RdTools is used in this work as well. It evaluates PV production data logged over several years to obtain rates of performance degradation over time. RdTools can detect the frequency of data automatically and therefore, handle both high frequency (hourly or less) and lower frequency (daily or higher) PV production data. RdTools is an open source tool developed in Python language by NREL (National Renewable Energy Laboratory) in USA based on the improved YOY method [36]. An analysis of the climatic conditions between the two cities shows large differences in illumination and temperature and little difference in wind speed. The first two factors have a significant impact on the power generated by a solar power plant throughout the year. Wind speed has a different effect on the rate of degradation of photovoltaic converters (warm or cold wind and humidity are of great importance). In Saint-Petersburg the low temperatures, strong winds and humidity are a determining stressor in the mechanisms of corrosion and delamination. In Algiers, the degradation process is affected by the high temperatures and humidity which caused the discoloration, hot spots and bubbles. The type of PV cells chosen is mono-crystalline silicon in Saint Petersburg and Algiers. This type is very common within easy reach.

The preferred method of degradation estimation is the annual (YOY) approach [35]. The algorithm includes: Normalizing the measured PV power, by site irradiance and temperature. Filtering the data (the most common filter is a low irradiance cutoff of about 200 W/m²), and Data Analysis step. There are actually two major categories of degradation calculation methods: with an independent measurement of solar irradiation and without it. Advances in algorithm processing [35, 38] allows to obtain sufficiently accurate value of the degradation rate even without independent irradiation measurements. Data availability is one of the major issues. In Figures 1 and (a, b) show the results of calculations of the rate of distribution of the generated power by a solar power plant and the confidence interval for the degree of degradation of photovoltaic stations for Algeria (figure 1) and St. Petersburg (figure 2).

The obtained results of modeling the operation of a solar power plant show that degradation process are more actively occurring at the solar power plant located in the region of St. Petersburg. For the research, data was taken on the operation of SES, in which photovoltaic converters of one company are used.

To obtain a more accurate forecast of the influence of climatic factors on the degradation of solar cells, it is necessary to carry out these measurements at various points in the region. There should be more than 20 such points. This will allow calculating the error in assessing the degree of degradation and the confidence interval.
Figure 1. The results of research a functionality of solar power plants over the past 8 years in Algeria: (a) is calculations of the rate of distribution of the generated power by a solar power plant, (b) is confidence interval for the degree of degradation of photovoltaic stations.

Figure 2. The results of research a functionality of solar power plants over the past 8 years in Saint-Petersburg: (a) is calculations of the rate of distribution of the generated power by a solar power plant, (b) is confidence interval for the degree of degradation of photovoltaic stations.

4. Conclusion
The modeling done in this work showed that the rate of degradation in solar cells is not very high. Degradation occurs over years of use. In other words, the efficiency of the solar panel is not affected. Harsh climatic conditions (severe frosts and high temperatures), leads to increase the rate of degradations visible to the naked eye. The results obtained shows that the location of the solar power plan is very important. The rate of degradation in Saint Petersburg (with rainy, snowy and windy weather) is quite high because of the presence of humidity which is much higher than the city Algiers which also has a humid climate but the weather is warmer. Another factor may be responsible is the different defects in solar cells because during the transportation which can cause invisible cracks that accelerate the degradation.

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