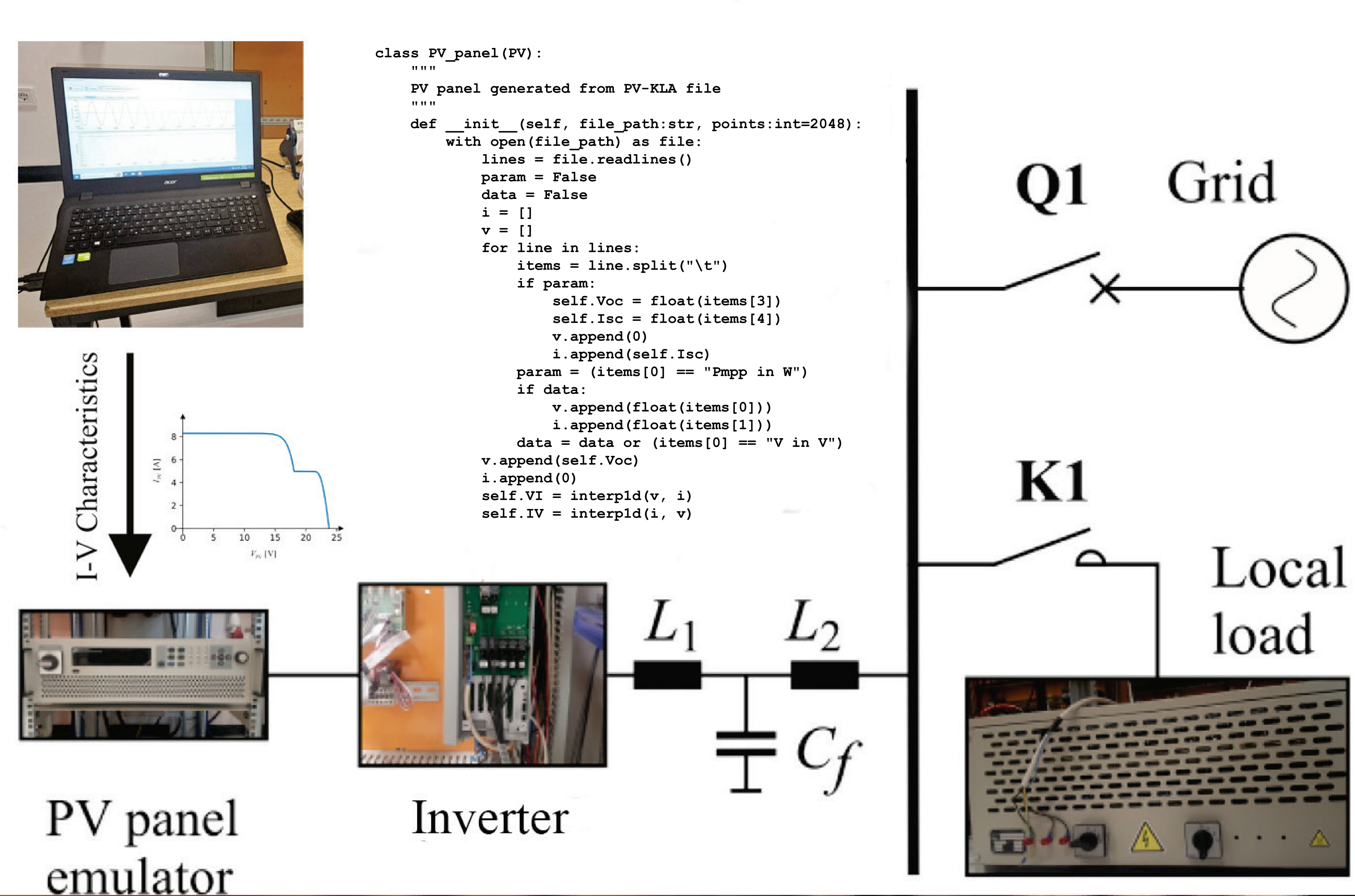
Emulation of Photovoltaic Arrays Under Nonuniform Environmental Conditions

Marko A. Dimitrijević and Milutin Petronijević
Faculty of Electronic Engineering, University of Niš, Aleksandra Medvedeva 14, 18000 Niš, Serbia

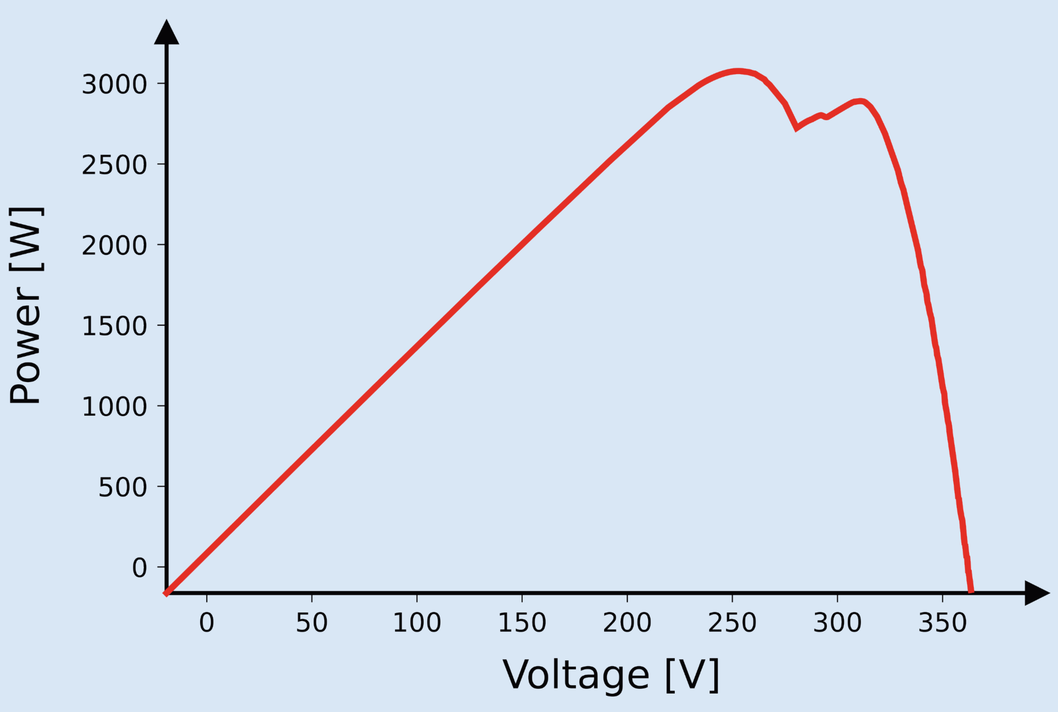
Introduction

In practical situations, a group of photovoltaic (PV) modules connected in a single array can be affected by factors such as dirt, shade, or varying heat levels. These environmental influences impact the characteristics of the panels, leading to variations in their I-V and P-V curves. For an array composed of multiple modules connected in series or parallel, the equivalent P-V curve will exhibit multiple local maxima. Although the maximum power point tracking (MPPT) algorithm typically locks onto the maximum closest to the open-circuit voltage V_{OC}, this may not always be the global maximum. Therefore, when assessing the performance of the MPPT algorithm and the PV inverter in general, it is crucial to consider these instances of non-uniform environmental conditions.



PV Module Modeling

There are several software tools for simulating PV modules, arrays, and complete power plants that can evaluate the impact of environmental conditions, such as different insolation, shading, soiling, or temperature. One of the most used software tools is *pvlib*, a tool for simulating the behavior of photovoltaic modules [1]. However, it cannot generate the equivalent series/parallel connection characteristics of panels that are shaded, soiled or heated differently, which is necessary for evaluating PV inverters under realistic environment conditions.



P-V characteristic of photovoltaic array with non-uniform shading

The PV System Emulation

Assessing the performance of PV systems [2] where the modules are under different environmental conditions experimentally is a very difficult undertaking. Therefore, a software tool written in Python and a set of methods were developed for the evaluation of PV systems under real environmental conditions, which combine the simulation of equivalent characteristics and the emulation of arrays using a programmable DC source.

Single-stage PV inverters are fed by programmable DC source *Itech IT6000C* (PV Panel Emulator). The equivalent characteristic is programmed into the DC source, which emulates the array.

The current-voltage characteristics of the PV arrays were obtained by using the aforementioned software, which generates an equivalent characteristic based on the characteristics of individual panels and information on their connection. The individual panel characteristics can be obtained by direct measurement under certain climatic conditions or by simulation, using already available tools.

Conclusion

Testing the operation of PV inverters in real environmental conditions is a complex undertaking due to the impossibility of setting those conditions during the experiment. Therefore, it is necessary to develop a series of methods that combine measurement and simulation of characteristics with panel emulation. This manuscript presents the methods for efficient testing, as well as the software tool necessary to realize the characteristics of the entire photovoltaic installation.

References

1. PV Performance Modeling Collaborative | PV_LIB Toolbox n.d. https://pvpmc.sandia.gov/applications/pv_lib-toolbox/ (accessed July 4, 2024).
2. Petronijević, M., Radonjić, I., Dimitrijević, M., Pantić, L., Ćelesan, M.: Performance Evaluation of Single-Stage Photovoltaic Inverters Under Soiling Conditions, Ain Shams Engineering Journal, Elsevier BV, June, 2023, pp. 1-18, ISSN 2090-4479, doi:10.1016/j.asej.2023.102353.

IGTE '24 on-site and online

21st International IGTE Symposium 2024
on Computational Methods in Electromagnetics and Multiphysics
September, 15 - 18, 2024 | Graz, Austria