INTRODUCTION TO PROGRAMMING AND MODELING PHOTOVOLTAIC SYSTEMS WITH PYTHON

Teaching hours: 40
Area of knowledge: Applied Physics (in collaboration with the CIESOL research center)
Academic Coordinator 1: José Alfonso Romero Ramos
Academic Coordinator 2: Manuel Pérez García

INTRODUCTION

Photovoltaic solar energy, thanks to the maturity achieved by its technology and its low costs, currently has a thriving and dynamic project development framework. This renewable energy has the advantage of contributing both to the decarbonization of the global energy mix through large generation plants, and, on a different power scale, to the reduction of the electricity bill of families or of industries and companies through individual self-consumption projects. In this context, and as with any other energy engineering project, the optimal design of facilities requires in-depth knowledge of the functioning of all the elements that constitute them, as well as the physical-mathematical models that support them. Once this knowledge of the systems has been achieved, it is possible to simulate specific operating scenarios and establish the final specifications that best adapt to the fulfillment of pre-established techno-economic objectives for the different types of projects.

Among the different resources available to universities, technology centers or specialized companies for modelling photovoltaic systems, it is worth highlighting the recent emergence of open-source software tools that allow, on the one hand, to take advantage of the contributions of a large and highly involved community of developers around the world, as well as to free users from the servitude of costs and opacity typical of software owner. In this context, the Python programming language enjoys great popularity in the academic and industrial sector thanks to the simplicity of its syntax and the variety of disciplines in which it is used (data science, biology, education, agronomy, engineering, etc.). Python is developed under an open-source license, with a wide repertoire of libraries dedicated to specific sectors, among which is of course the photovoltaic solar energy, where the PVLIB libraries stand out, among others, sponsored by the American institution Sandia National Laboratories, recently admitted the NumFOCUS Mission initiative for the support of open science. The PVLIB libraries allow you to address calculations related to the evaluation of the solar resource, the effects of temperature on the efficiency of the modules, the calculation of the electrical production of the systems or the monitoring of the maximum power point of the generators and are an excellent starting point to enter the field of photovoltaic solar energy in an open and collaborative framework.

This course is designed as an introductory course to Python programming for the analysis and design of photovoltaic installations and has three main blocks of content, a first block on the fundamentals of programming the Python language, a second block on the basic concepts of solar photovoltaic technology necessary for the design of installations and, finally, a third block on the exploitation of PVLIB libraries for carrying out calculations in photovoltaic projects.

MAIN OBJECTIVES

- Know the fundamentals of Python programming and become familiar with a scientific computation environment.
- Know the fundamentals of solar photovoltaic technology and the elements and configuration of the different types of installations.
- To achieve calculation capabilities based on PVLIB libraries that allow the modelling of the elements of the installations, as well as their basic design and dimensioning.
- Develop introductory skills for solar energy research.

WHO IS IT FOR?

University students or recent graduates of engineering and science degrees with an interest in the development of practical skills and the acquisition of up-to-date knowledge in the renewable energy sector, with the aim of achieving a professional specialization or the continuation of their studies in a postgraduate program.

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WHY ALMERIA?

Taking the course at the University of Almeria is a unique opportunity. The fact that the province belongs to the region with the highest availability of solar radiation in Europe means that there are many operational examples of installations in its territory and that numerous investigations in this field have been carried out in the province over the last decades. In fact, the province is home to a world-renowned research infrastructure, the Almeria Solar Platform, which has an agreement with the University of Almeria that has allowed the creation of a mixed research centre, the CIESOL centre, to which more than 40 researchers belong and which supports, among other training activities, the UAL-CIESOL Master's Degree in Solar Energy.

CONTENTS

Module A. Python Programming

A.1. Programming fundamentals

A.1.1. Introduction and tools. Programming examples. Expressions and variables.
A.1.2. Conditional Instructions. Selection statements. Loops and Data Structures
A.1.3. Functions. Functions with parameters.
A.1.4. DataFrames. Read, process and write files.

A.2. Data analysis and visualisation

A.2.1. NumPy and Pandas Libraries. Functionality. Data Import and Export.
A.2.2. Data Cleaning and Processing. Basic statistics.
A.2.3. Data visualization with MatPlotLib and PlotLib.

Module B. Fundamentals of Photovoltaic Solar Energy

B.1. Solar resource and photovoltaic technology

B.1.1. Components of solar radiation.
B.1.2. Solar photovoltaic technology.
B.1.3. Types of solar photovoltaic installations.

B.2. Design and optimisation of photovoltaic installations

B.2.1. Pre-design of photovoltaic solar installations.
B.2.2. Design and optimisation of photovoltaic solar installations.

Module C. Introduction to PVLIB Libraries

C.1. Introduction to PVLIB. Overview.

C.1.1. Installation. Variables and symbols.

C.2. Modules and functions

C.2.1. Atmosphere, clear sky, irradiance and solar position modules.
C.2.2. Photovoltaic system. PVSystem to model photovoltaic output and performance.
C.2.3. Examples and applications.

METHODOLOGY

Laboratory ☒ Sessions Company Visits ☐ Academic Visits Lectures ☒ ☐ Classes Other ☐ ☒

The methodology to be applied includes theoretical classes, problem and practical classes and technical visits to facilities. The distribution of the classes and their format will be a master classes on theoretical content, problems and practices (75%, 30 hours) and technical visits to solar installations (25%, 10 hours).

ACADEMIC VISITS & NETWORKING

The purpose of the academic visits is to bring students closer to current research projects. During these visits, the operation of the solar installations, the different measuring instruments that exist and the control and data collection systems are described. Data is extracted for further processing and analysis with Python.

- VISIT 1: CIESOL CENTER – UAL https://ciesol.com
- VISIT 2: ALMERIA SOLAR PLATFORM https://www.psa.es

PREREQUISITES AND EVALUATION

The Python course applied to solar energy does not require prior knowledge in programming or solar energy. It is aimed at final year students and graduates of science and engineering degrees who want to get started in the field of modelling and design of photovoltaic solar energy installations. To follow this course, basic skills related to the use of computer systems and the performance of scientific calculations are established as prerequisites.

The evaluation will correspond to the teaching methodology and will consist of the following tests and percentage: Multiple-choice exam on theoretical content (30% of the grade) and practical exam on exercises and practices (70% of the grade).

TEACHERS

Professor José Alfonso Romero Ramos (Coordinator 1)

He has a degree in Physics from the University of Murcia and a Master's degree in Solar Energy from the University of Almeria. He has specific training in programming in Python language and has made scientific publications in the field of techno-economic and functional assessment of solar installations in thermal and photovoltaic applications and in the analysis of the potential application of solar systems for energy supply in isolated agri-food micro-industries.

Professor Manuel Pérez García (Coordinator 2)

PhD in Physics from the Complutense University of Madrid. Professor of Applied Physics at the University of Almeria. Researcher at the Modeling and Automatic Control Unit of CIESOL, Solar Energy Research Center. UAL-CIEMAT Joint Centre. He has more than 25 years of research and teaching experience in solar energy systems for applications in buildings and industries. In recent years he has coordinated the following specialized courses for CIESOL: "Dynamic simulation of solar thermal installations using TRNSYS", "Simulation and control of solar thermal installations of parabolic trough collectors in industrial applications and refrigeration" and "Training Course on Photovoltaic Solar Plants. UAL-UNISANTA Course (Brazil)".

Professor Rolando Lázaro Cabrera Dalés

He has a degree in Physics from the University of Havana and is a researcher in training at the Almeria Solar Platform. His field of work is the study, through simulation models and experimentation, of the adverse effects associated with fouling and degradation of the properties of modules on the operation of agrivoltaic plants. He has published scientific articles on the application of PVLIB libraries in the evaluation of solar resources and in the generation and evaluation of photovoltaic module operation curves.

TIMETABLE (indicative)

Monday 1 July	**Tuesday 2 July**	**Wednesday 3 July**	**Thursday 4 July**	**Friday 5 July**
A.1.1. A.1.2. A.1.3.	A.1.4. A.2.1. A.2.2.	A.2.3.	PRACTICE 1	VISIT 1 B.1.1 B.1.2.
Monday 8 July	**Tuesday 9 July**	**Wednesday 10 July**	**Thursday 11 July**	**Friday 12 July**
B.2.1.	C.1.1.	C.2.2.	PRACTICE 2	VISIT 2

B.2.2 B.1.3.	C.2.1.	C.2.3.		