University of Science and Technology of Hanoi
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COURSE SYLLABUS

Subject: Photovoltaic Systems

Academic field: Energy/ Electrical Engineering

Lecturer: Dr. Nguyen Xuan Truong

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Academic year: 2019 - 2020

COURSE DESCRIPTION

Credit points	04	
Level	Undergraduate	
Teaching time Location	University of Science and Technology of Hanoi	
Time Commitment	Lecture	30 hrs
	Exercises (individual and/or group project)	10 hrs
	Practical	8 hrs
	Total	48 hrs
Prerequisites	Introduction to Renewable energies, Electric Circuits I, II. Material for Energy Conversion; Power Electronics	
Recommended background knowledge	Electrical circuit analysis	
Subject description:	This subject is about Renewable Energies and especially Photovoltaic Systems. We will deal with the conversion of solar energy into electricity. We will see the different technologies available to design the photovoltaic panels and the different installation methods based on electrical and environmental characteristics. One part will be devoted to the inverters, their operation and their installation. Finally we will discuss research and development.	
Course objectives	• Provide students a general knowledge on photovoltaic systems. • Provide students basic techniques to analyse and size a PV installation.	

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Course Learning Outcomes(LO)	Students should be able to: • Locate the sun position at any given location and time, interpret sun path diagrams, analyze solar insolation on a collecting surface, and measure solar radiation measurements. • Understand the inner workings of P-N junctions, determine a circuit model of a PV cell, PV module and PV array, measure and interpret I-V curves, understand the impact of temperature and solar insolation on I-V curves, have a broad knowledge on different types PV technologies and their limitations. • Determine the operating point of basic electrical loads connected directly to a PV module/ array. • Design a grid-connected PV system, including the PV array and balance of system (BOS), conduct an economic analysis, and be familiar with the impact of high PV penetration on the utility grid. • Have basic knowledge on different types of batteries and their electrical characteristics. • Design a stand-alone PV system by estimating the load, sizing and selecting the batteries, sizing and selecting the PV modules, charge controller and inverter. • Have basic knowledge on codes and standards associated with PV Systems	
Assessment/ Evaluation	Attendance/Attitude	10%
	Exercise (s)	10%
	Practicals and on-site visit	20%
	Mid-term test	20%
	Final exam (individual report and presentation)	40%
Prescribed Textbook/ textnote(s)	[1] Photovoltaics: System Design and Practice, Heinrich Häberlin, John Wiley & Sons, Ltd. DOI:10.1002/9781119976998 [2] Grid-connected-pv-system-installation-guidelines, www.seiapi.org [3] "Handbook for rooftop solar development in Asia", Anthony Jude - ADB report (2014)	

COMPUTER USAGE/ TOOL :

PVSYST, HOMER, MATLAB, SOLARGIS, EXCEL

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LECTURE NOTES : https://moodle.usth.edu.vn/course/view.php?id=349

EXPERIMENTAL COURSE CONTENTS

Laboratory 1: Electrical characteristics of PV module (Normal and Perturbed conditions, I-V curve depending on Temperature, solar irradiance)

Laboratory 2: Characteristic and working principle of solar power stand-alone system ((workbench of ERS 300) with load condition and different solar radiations

Laboratory 3: On-site visit, PV grid-connected system 15kWp (tracking system, with 15kWh Battery Storage system)

COURSE CONTENTS & SCHEDULE

Chapter	Contents	Hours			Assignment(s)
		Lect.	Exr.	Prc.	
1	**Renewable Energy Systems (Brief)** • Direct solar power conversion (PV), • Concentrating solar power, wind power, hydro power, biomass, geothermal power, ocean power				
2	**Solar Resource** • Solar spectrum, • Sun position, sun path diagrams, • Solar and clock times, • Clear sky insolation on a collecting surface, • Solar radiation measurements, resource of solar data				
3	**Photovoltaic Materials** • Semiconductor physics, photovoltaic materials, • Types of cells (Silicon, thin film, multi-junction, organic), cell materials and construction,				

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4	**PV Electrical Characteristics** • Equivalent circuit of a PV cell, modules and arrays, • I-V curves, impact of temperature, • Shading impacts				
5	**Grid-Connected PV Systems** • Interconecting with the power grid, • System sizing, and economicconsiderations				
6	**Stand-Alone PV Systems and Hybrid-PV systems** • Load estimation, batteries and their properties, • PV array and battery sizing				
7	**Solar PV Design Guidelines** • Introduction to PVSYST • Design a system with PVSYST				
8	**Other Related Topics** • IEEE Standard 1547, Code • Industry trends, microgrids, • Feasibility study of a PV project…				

Notes:

- Abbreviation: Lect. (lecture), Exr. (Exercise), Prc. (Practise).
- Exercises may include assignment, reports, student's presentation, homework, class exercises ...for each class sessions
- Practicals mostly refer to Lab- work or outside practice such as field trip.

REFERENCE LITERATURE:

[1]. Photovoltaic installations, Anne Labouret and Michel Villoz (Dunod)
[2]. Photovoltaic installations, Louis Paul Hayoun and Aurian Arrigoni (Eyrolles)
[3]. http://www.energies-renouvelables.org/sommaire.asp
[4]. http://www.leonics.com/support/article2_12j/articles2_12j_en.php

[5]. A guide to photovoltaic (pv) system design and installation - California Energy Commission Energy Technology Development Division 1516 Ninth Street Sacramento, California 95814 (Gray Davis)

[6]. Solar Electric System Design, Operation and Installation-An Overview for Builders in the Pacific Northwest, October 2009 (Carolyn Roos).