Fundamentals of Solar Power Plant Design

June 24–26, 2014
Madison, Wisconsin

An intensive, practical course focusing on...

- Photovoltaic fundamentals
- Solar energy and power generation basics
- Solar plant components and PV modules
- DC system and AC collector design
- Civil and geotechnical issues
- Interconnection to distribution and the bulk power grid

Grasp the fundamentals of solar photovoltaic energy conversion and gain insights into solar power plant design.
Fundamentals of Solar Power Plant Design
June 24–26, 2014 in Madison, Wisconsin

Practical Course Taught by Professionals
Attend this introductory course and learn the design fundamentals of photovoltaic projects. Gain knowledge and skills from engineers with real-life experience in solar energy and electrical delivery fields. After attending this course you will:

- Know the basics of photovoltaic energy
- Understand solar energy site assessment and planning
- Appreciate the fundamentals of power generation and delivery
- Identify what comprises a solar cell and solar panel
- Explain the components of a solar power plant including the collector
- Appreciate the function of the inverter for interconnection and power flow control
- Understand the role of the geotechnical testing and planning of the mounting system
- Navigate the complexities of interconnection requirements and issues
- Understand the impacts of PV energy on distribution feeders
- Appreciate the impacts of increasing PV energy on the bulk power system

Why You Should Attend
Tremendous changes are occurring in the energy field particularly with regards to solar energy. Within the last several years, photovoltaic installations have grown exponentially resulting in a cumulative capacity exceeding 10,000 MW. Both the installed cost and levelized cost of energy has dropped, creating a virtuous cycle for new growth. At the same time, the standards for interconnection of variable and distributed generation sources have been evolving rapidly.

Who Should Attend
People new to the field of solar energy and those desiring a refresher will benefit by attending this state-of-the-art course. This includes:

- Renewable energy developers
- Electric utility design engineers
- Electric utility planning engineers
- Power system dispatchers
- Consulting engineers
- Project managers
- Managers of design departments
- Engineering technicians

Your Faculty
Michael Arnold, PhD, is a professor in the Materials Science and Engineering department of the University of Wisconsin–Madison, focusing materials with unique and exceptional properties for next generation electronics, optoelectronics, and photovoltaics applications. He holds a PhD from Northwestern University.

Keith Beisner, PE, is the national head of field operations for Schletter Inc., a market leader in solar mounting solutions. He coordinates and supervises geotechnical investigations and foundation installations for commercial to utility-scale, ground-mounted solar projects throughout North America. He holds a MS in Geological Engineering from the University of Utah.

Mitch Bradt, PE, is an electrical engineer at the University of Wisconsin–Madison responsible for development and instruction of courses in the topic of alternative energy, electrical distribution, and power electronics. He has worked for a manufacturer of utility reactive compensation systems and has designed substations as a consulting engineer. He holds an MS–Power Electronics from UW–Madison.

Mahesh Morjaria, PhD, is the vice president of product management at First Solar where he leads the development of grid integration for utility scale PV projects. His career has included roles in solar and wind generation and grid integration, as well as product development. He holds a PhD from Cornell University.

Dave Mueller, PE, is the director of power system studies at EnerNex in Knoxville, Tennessee. He is an expert consultant on all types of power system studies, particularly on power quality problems on both sides of the meter. Mueller chairs the IEEE PES Power Quality Solutions working group. He holds an MS in Power Engineering from Rensselaer Polytechnic Institute.

Alex Panchula, PhD, is the director of prediction, performance and field reliability monitoring at First Solar, where he is responsible for technology performance models for predicting energy production of PV power plants. He has previously worked at OptiSolar, Samsung, and IBM’s Almaden Research Center. He holds a PhD in Applied Physics from Stanford University.

Nicholas Strevel is a technical sales manager at First Solar specializing in PV module technology and performance. He has worked in the thin-film PV technology space for seven years in module manufacturing, application engineering, and business development. Prior to joining First Solar, he held positions at United Solar Ovonic. He has a BSME from Michigan State University.

Giri Venkataramanan, PhD, is a professor in the Electrical and Computer Engineering department of the University of Wisconsin–Madison and is the associate director of the Wisconsin Electric Machines and Power Electronics Consortium (WEMPC). In this role he directs research focusing on utility applications of power electronics and renewable energy. He holds a PhD in Power Electronics from UW–Madison.
**Course Topics**

**Energy from the Sun**
- Solar irradiance principles
- Measure of merit for incident solar
- What makes a location good?
- Factors effecting incident energy
- Diurnal/seasonal pattern of incident energy

**Solar Power Assessment**
- Solar insolation mapping
- Standards
- Uncertainty and “bankability”
- Data collection and analysis
- Reports and graphs

**Electric Power Generation and Delivery Fundamentals**
- Power system fundamentals
- Conversion of DC to AC
- Power flow analysis example
- Real and reactive power
- Power system operation and control
- Power system protection

**Photovoltaic Basics**
- Semiconductors and the photovoltaic effect
- A brief history of the development of PV cells
- Cell materials
  - mono-crystalline silicon
  - poly-crystalline silicon
  - cadmium telluride
  - CIGS
- Makeup of solar panels from solar cells
- Conversion efficiency

**Solar Plant Components and Overview**
- Plant design and optimization
- Solar panels and racks
- DC electrical connections
- Inverter block with step-up transformer
- AC collection
- Power plant controls and grid integration features

**Solar Cells and Modules**
- Current-irradiance relationship
- Voltage-temperature relationship
- Power-current relationship and maximum power point
- Incidence angle
- Electrical effect of shading
- Hot spots and by-pass diodes
- Reliability, testing, spectral response

**DC System Design**
- Panel sizing for site conditions
- Connecting panels as a string
- String planning and layout
- String DC combination levels
- DC cabling to inverter
- DC system protection
- Losses within strings

**Inverter and Power Control**
- The inverter as the heart of the power block
- Inverter equipment and modules
- DC connections from re-combiner
- Typical inverter controls
- Maximizing energy harvest through DC voltage control
- AC Current regulation for real and reactive power

**AC Collector System**
- Collector system overview and single-line
- Collector layout and installation
- Load flow modeling and sizing of conductors
- Inverters and step-up transformers
- System grounding considerations
- Reactive power and harmonic filters

**Civil and Geotechnical Issues**
- Geotechnical investigations
  - site preparation and earthworks
  - foundation considerations
- Ground-mount foundation solutions
  - rammed posts, helicals, or ground screws
  - ballast systems
- Design loads
  - dead loads
  - wind, snow, and seismic zones
  - adfreeze considerations
- Racking assembly
- Panel installation, connections, and wiring
- Measurement of soil thermal resistivity

**Interconnection of Renewable Energy Plants with the Electric Grid**
- Interconnection agreements and studies
- Grid codes
- Disturbance ride-through
- Post-fault recovery
- Solar plant modeling in power system analyses
- Cloud transients, ramp rates, and the case for energy storage

**Connection of Distributed PV Solar Units**
- Market drivers of rooftop PV units
- Impacts of rooftop PV units on a distribution feeder
  - voltage considerations
  - harmonics
  - feeder ampacity limits
- Distribution feeder PV “hosting” limits

**Bulk Power System Considerations**
- IEEE 1547 and “Smart Inverters”
  - initial philosophy of “trip at the first sign of trouble”
- Emerging needs for low voltage ride through
  - emerging needs for voltage / power factor control
- status and changes in the standard
- Changing load curves due to solar variability

---

**Daily Schedule**

**Registration and course will be held at**
The Pyle Center
702 Langdon Street
Madison, WI

**Day 1**
8:00 a.m. to 8:30 a.m. Registration
8:30 a.m. to 5:00 p.m. Class

**Day 2**
8:00 a.m. to 5:00 p.m. Class

**Day 3**
8:00 a.m. to 3:30 p.m. Class

Refreshments prior to the start of the course, mid-morning and mid-afternoon refreshment breaks, and lunch will be provided all three days.

---

**Related Courses**

All courses held in Madison, Wisconsin.

**Introduction to Electric Machines and Drives**
June 3–5, 2014
Course #P312

**Electrical Grounding and Bonding**
June 11–12, 2014
Course #P423

**Underground Electrical Distribution Systems**
September 9–11, 2014
Course #P458

**Electrical Systems Design for the Non-Electrical Engineer**
September 22–26, 2014
Course #P923

**Designing Electrical Overhead Distribution Lines**
October 21–23, 2014
Course #P459

**Fundamentals of Substation Equipment and Control Systems**
October 22–24, 2014
Course #P924

**National Electrical Code®**
November 11–13, 2014
Course #P439
Earn Continuing Education Credit

By participating in this course, you will earn 20 Professional Development Hours (PDH) or 2.0 Continuing Education Units (CEU).

Bring UW–Madison Expertise to Your Organization!

On-site training can equip your employees in skill areas critical to your success. We can:
- Assess training needs and design learning programs tailored to your situation
- Deliver course content, customized for your needs, in person or online
- Empower your employees to quickly translate practical knowledge into productive work

UW–Madison can help you meet your training goals! Contact Corporate Education Director Carl Vieth (608-263-7424 or vieth@wisc.edu) to discuss your opportunities. Or see epd.engr.wisc.edu/onsite

Need to Know More?

Call toll free 800-462-0876 and ask for:
Program Director: Mitch Bradt, PE 
bradt@wisc.edu 
608-263-1085
Program Associate: Maren Muñoz 
munoz@epd.engr.wisc.edu 
608-262-3748
Or e-mail custserv@epd.engr.wisc.edu

General Information

Fee Covers Notebook, break refreshments, lunches, certificate, continuing education credits (CEU/PDH), and rosters.

Cancellation If you cannot attend, please notify us at least seven days prior to the course start, and we will refund your fee. Cancellations received after that date and no-shows are subject to a $150 administrative fee per course. You may enroll a substitute at any time before the course starts.

Location This course will be held at The Pyle Center, 702 Langdon Street, Madison, WI. Phone messages: 608-262-2211.

Accommodations We have reserved a block of guest rooms (rates starting at $89, including parking and Madison Taxi’s silver cab from the airport) at Campus Inn, 601 Langdon Street, Madison, WI. Reserve a room online at epd.engr.wisc.edu/lodgingP425 or call 800-589-6285 or 608-257-4391 and indicate that you will be attending this course under group code 144068. Room requests after June 6 will be subject to availability. Other fees and restrictions may apply.