Advanced Solar PV Engineering: Off-Grid, Hybrid and Grid-Tied Systems

Target Audience

This course is designed for electrical engineers, renewable energy professionals, project engineers, EPC professionals, consultants, solar PV designers, technicians, and engineering professionals seeking advanced practical expertise in designing and analyzing off-grid, hybrid, and grid-connected solar photovoltaic (PV) systems. It is particularly suitable for participants with foundational knowledge of solar PV technology who want to develop advanced competency in system sizing, energy storage integration, electrical protection, grounding, solar water pumping, PV simulation, performance analysis, and optimization of complete solar PV systems.

Course Outcomes

Upon successful completion of this course, participants will be able to:

- Analyze complex solar PV system requirements for residential and commercial applications.
- Design and size complete off-grid solar PV systems.
- Design hybrid PV systems incorporating battery storage and load management.
- Design grid-connected PV systems and evaluate expected energy yield.
- Size PV arrays, battery banks, charge controllers, and inverters for practical applications.
- Design electrical protection systems for DC and AC PV circuits.
- Apply cable sizing, isolation, overcurrent protection, and surge protection principles.
- Develop grounding, earthing, and lightning protection designs.
- Design solar water pumping systems based on water demand and PV requirements.
- Configure and simulate PV systems using PVSyst.
- Analyze system energy yield, losses, shading, and overall performance.
- Optimize PV system designs based on simulation and performance results.

Course Objectives

By the end of this course, learners will:

- Develop advanced competency in complete solar PV system engineering.

- Apply structured design methodologies to off-grid, hybrid, and grid-connected systems.
- Perform detailed PV array and battery sizing calculations.
- Select and integrate appropriate system components based on technical requirements.
- Develop practical electrical protection and grounding strategies.
- Understand system architecture and load management for hybrid PV applications.
- Apply solar PV engineering principles to water pumping applications.
- Develop professional SLDs and supporting engineering documentation.
- Use PVSyst to simulate, analyze, and optimize PV system performance.
- Interpret energy yield, system losses, shading, and financial evaluation results.
- Apply engineering practices to real-world solar PV design and performance evaluation.

Course Outline

The course comprises **32-hours** of theory and labs and is divided into 8 different chapters. Each chapter will be followed by hands-on lab exercises to reinforce learning and gauge understanding of the topics covered.

Table of Contents

Chapter 1: Advanced Solar PV System Architecture and Design Requirements

- Off-Grid Systems
- On-Grid Systems
- Hybrid Systems
- Grid-Tied with Battery Backup
- Comparison of PV System Configurations
- Applications of Different System Types
- Hybrid System Architecture
- Load Management
- Battery Integration
- PV System Design Requirements
- System Component Selection
- Residential PV System Applications

- Commercial PV System Applications
- System Performance Considerations

Chapter 2: Advanced Battery Energy Storage and System Sizing

- Battery Fundamentals
- Battery Voltage Selection
- Battery Capacity Calculations
- Battery C-Rate
- State of Charge (SOC)
- Depth of Discharge (DOD)
- Cycle Life
- Calendar Life
- Self-Discharge
- Lead-Acid Batteries
- Lithium-Ion Batteries
- Nickel-Based Batteries
- Flow Batteries
- Battery Connections
- Battery Charging Methods
- Reading Battery Datasheets
- Battery Bank Sizing
- Battery Integration in Hybrid Systems
- Battery Selection Criteria
- Energy Storage Design Considerations

Chapter 3: PV Array, Inverter and Charge Controller Engineering

- PV Array Design
- PV Array Sizing
- PV Module Selection
- Series and Parallel Connections
- Charge Controller Selection

- PWM Charge Controllers
- MPPT Charge Controllers
- Controller Working Principles
- Controller Sizing
- Selection Criteria
- Installation Considerations
- Introduction to Solar Inverters
- Types of Inverters
- Grid-Tied Inverters
- Off-Grid Inverters
- Hybrid Inverters
- Inverter Specifications
- Reading Inverter Datasheets
- Inverter Selection Criteria
- Component Compatibility
- Design Example – Residential System
- Design Example – Commercial System

Chapter 4: PV Electrical Protection, Cable Sizing and Grounding

- Electrical Protection Requirements
- Overcurrent Protection
- DC and AC Isolators
- String Protection
- Fuse Selection
- Circuit Breakers
- Surge Protection Devices (SPD)
- PV Combiner Boxes
- Cable Sizing
- Solar Cables and Connectors
- Importance of Earthing

- Equipment Grounding
- System Grounding
- Lightning Protection
- Earthing Design
- Safety Standards
- Best Practices
- Protection Design Examples

Chapter 5: Off-Grid and Hybrid PV System Design

- Load Assessment
- Daily Energy Consumption Calculation
- Battery Bank Sizing
- PV Array Sizing
- Charge Controller Selection
- Inverter Selection
- Cable Selection
- Design Example – Residential System
- Design Example – Commercial System
- Hybrid System Architecture
- Load Management
- Battery Integration
- PV Array Design
- Component Selection
- Hybrid Design Example
- Performance Analysis
- Off-Grid System Performance Evaluation
- Hybrid System Performance Evaluation

Chapter 6: Grid-Connected PV Systems and Solar Water Pumping

- Grid-Tied System Fundamentals
- Energy Yield Estimation

- PV Array Design
- Inverter Selection
- Grid Connection Requirements
- Net Metering Concepts
- System Performance Evaluation
- Introduction to Solar Water Pumps
- Types of Solar Pumps
- Pump Selection
- Water Demand Calculation
- PV Sizing for Pumps
- System Design Example
- Installation Considerations
- Solar Pumping System Component Selection
- PV-Based Water Pumping Applications

Chapter 7: PVSyst Simulation and Performance Analysis

- Introduction to PVSyst
- Software Interface
- Creating a New Project
- Meteorological Data
- Component Selection
- Off-Grid Simulation
- Result Interpretation
- 3D Shading Analysis
- Performance Reports
- Creating Grid-Connected Projects
- Weather Data Import
- PV Array Configuration
- Inverter Configuration
- System Simulation

- Energy Yield Analysis
- Loss Analysis
- Financial Evaluation
- Report Generation
- Performance Optimization

Chapter 8: Advanced PV Engineering Documentation and Optimization

- Introduction to SLD
- Electrical Symbols
- PV System Representation
- AC and DC Circuits
- Protection Devices in SLD
- Preparing Professional SLDs
- Documentation Standards
- AutoCAD Interface
- Basic Drawing Tools
- PV Layout Preparation
- Roof Layout Design
- Electrical Layout Drawing
- Single Line Diagram Drafting
- Plotting and Exporting Drawings
- PVSyst Performance Reports
- Energy Yield Analysis
- Loss Analysis
- Performance Evaluation
- Financial Evaluation
- Performance Optimization
- Engineering Design Documentation
- Professional PV System Reporting