# 203152 : Audit Course-III

**List of three audit course is provided. Students can choose any one from 203152(A) 203152(B) and 203152(C)**

## 203152 (A) : Solar Thermal System

| Teaching Scheme<br>Lectures: 2hrs/week | Credits<br>No credit | Examination Scheme [Marks]<br>Grade: PP/NP<br>Quiz and term paper |
|---|---|---|

**Description:** The course will introduce the basics of: solar energy, availability, applications, heat transfer as applied to solar thermal systems, various types of solar thermal systems, introduction to manufacturing of the systems, characterization, quality assurance, standards, certification and economics. The following topics may be broadly covered in the classroom. The field visits will be designed for first-hand experience and basic understanding of the system elements.

**Course Objective:**

- To understand basics and types of solar thermal systems.
- To get knowledge of various types of concentrators.
- To make students aware of different Standards and certification for Concentrator Solar Power.

**Course Outcome:** Student will be able to

**CO1**: Differentiate between types of solar Concentrators

**CO2**: Apply software tool for solar concentrators

**CO3**: Design different types of Solar collectors and balance of plant

**Course Contents:**

- Sun, Earth and seasons
- Solar Radiation
- Basics of heat transfer
- Absorption, reflection and transmission of radiation
- Types of Solar thermal systems
- Basic design of different types of systems
- Applications of solar thermal systems and their economics
- Need for solar concentration
- Various types of solar concentrators
- Movement of Sun and tracking
- Control systems for solar tracking
- Concentrating solar thermal (CSP)
- Concentrating solar PV (CPV)
- Balance of plant for CSP
- Critical points in concentrating solar system installation
- Operation and maintenance of CSP
- Typical financial analysis of CSP
- Software tools for concentrating solar power
- Environmental impact assessment
- Standards and certification for CSP
- Basics of solar thermal (STH) systems
- Elements of various STH systems
- Design, materials and manufacturing of
  - Flat plate solar collector
  - Evacuated tube solar collector
  - Parabolic trough collector
  - Dish type solar concentrators
  - Concentrating PV systems
  - Balance of plant
- Manufacturing standards
- Quality assurance and standards
- Certification
- Special purpose machines and Automation in manufacturing
- Site assembly and fabrication
- Typical shop layouts
- Inventory management
- Economics of manufacturing

**Assignment**

- Design of solar thermal system for residential/ commercial building.

**References:**


1. Trainers Textbook Solar Thermal Systems Module, Ministry of New and Renewable Energy, Government of India
2. Students Workbook for Solar Thermal Systems Module, Ministry of New and Renewable Energy, Government of India


# 203153: Audit Course-IV

**List of three audit course is provided. Students can choose any one from 203153(A) 203153(B) and 203153(C)**

## 203153(A): Solar Photovoltaic Systems

| Teaching Scheme<br>Lectures: 2hrs/week | Credits<br>No credit | Examination Scheme [Marks]<br>Grade: PP/NP<br>Quiz and term paper |
|---|---|---|

**Prerequisite:** Completion of FE or equivalent

**Description:** The course will introduce the basics of: solar energy, availability, semiconductors as photovoltaic convertors and solar cells, applications of photovoltaic, various types of solar photovoltaic systems, and introduction to manufacturing of the systems, characterization, quality assurance, standards, certification and economics. The following topics may be broadly covered in the classroom. The practical will be designed for basic understanding of the system elements.

**Course Objective:**

- To learn Solar PV system and its appliances
- To get knowledge of balance of PV system, batteries, inverters etc.
- To understand grid tied SPV solar plants

**Course Outcome:** Students will be able to

**CO1:** design of Solar PV system for small and large installations

**CO2:** handle software tools for Solar PV systems

**Course Contents:**

- Physics of photovoltaic (PV) electricity
- Photodiode and solar cell
- Solar radiation spectrum for PV •
- Types of solar cell and comparison
- Introduction to various types of solar module manufacturing
- Basic system design and economics
- Types of systems
- Common applications of solar PV
- Introduction to solar PV (SPV) systems
- SPV appliances
- Small capacity SPV power plants
- Grid tied SPV power plants
- Large scale SPV power plants
- Balance of system
- Solar inverters
- Batteries
- Financial modelling of SPV
- Operation and maintenance of SPV
- Software tools for SPV
- Environmental impact assessment
- Standards and certification for SPV
- Basics of SPV systems
- Elements of SPV appliances and power plants Procurement versus production
- Bought-outs, assemblies, sub-assemblies
- Manufacturing and assembly
- Manufacturing standards
- Quality assurance and standards
- Certification
- Special purpose machines and Automation in manufacturing
- Site assembly and fabrication

- Typical shop layouts
- Inventory management
- Economics of manufacturing

**Practical:**

- PV characterization
- Batteries and energy storage
- PV system design

**Assignment**

- Design of solar PV system for department / college.

**References:**

[1] A.S.Kapur -A Practical Guide for Total Engineering of MW capacity Solar PV Power Project
[2] Solanki C.S- Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and Engineers- PHI
[3] Solanki C.S- SolarPhotovoltaics - Fundamentals, Technologies and Applications- PHI
[4] S. Sukhatme -Solar Energy : Principles of Thermal Collection and Storage- McGraw Hill

## 403143B: Power Quality Management

| Teaching Scheme | | | Credits | | Examination Scheme | |
|---|---|---|---|---|---|---|
| Theory | 03 | Hrs/Week | Theory | 03 | ISE | 30 |
| Practical | 02 | Hrs/Week/Batch | Practical | 01 | ESE | 70 |
| | | | | | Oral | 25 |

**Prerequisite:**

Fundamentals of Power Systems and Power Electronics

**Course Objectives:**

This course aims to:

1. Develop understanding of power quality attributes.
2. Make students describe problems associated with poor power quality.
3. Make students describe mitigation techniques for improving power quality.
4. Learn various equipment of monitoring and assessment.

**Course Outcomes:**

Student will be able to

CO1: Understand power quality and attribute of power quality

CO2: Describe voltage flicker and mitigation of it

CO3: Analyze the effect of power system events on voltage sag and its characteristics.

CO4: Identify the sources of harmonics and harmonics produced

CO5: Select proper method for harmonic mitigation along with methods of power quality monitoring.

CO6: Carry out power quality monitoring using power quality analyzers.

| Unit 01 | Basics of Power Quality | 07 hrs |
|---|---|---|

Importance of power quality, terms and definitions of power quality as per IEEE std. 1159-2019 such as transients, short and long duration voltage variations, interruptions, short and long voltage fluctuations, imbalance, flickers and transients. Symptoms of poor power quality. Definitions and terminology of grounding. Purpose of groundings. Good grounding practices and problems due to poor grounding, grounding and power quality, recommended grounding practices for noise and power quality control.

| Unit 02 | RMS Voltage variations, Flickers and Transient Over-Voltages | 07 hrs |
|---|---|---|

RMS voltage variations in power system and voltage regulation per unit system, complex power. Principles of voltage regulation. Basic power flow and voltage drop. Various devices used for voltage regulation and impact of reactive power management. Various causes of voltage flicker and their effects. Short term and long term flickers. Ferro-resonance Various means to reduce flickers. Flicker meter and monitoring. Transient over voltages, sources, impulsive transients, switching transients, Effect of surge impedance and line termination, control of transient voltages.

| Unit 03 | Voltage Sag, Swell and Interruption | 07 hrs |
|---|---|---|

Definitions of voltage sag and interruptions. Voltage sags versus interruptions. Economic impact of voltage sag. Major causes and consequences of voltage sags. Voltage sag characteristics. Voltage sag assessment. Influence of type of fault, fault location and fault level on voltage sag. Phase angle jumps. Types of sags ( Type 1 to type 7). Areas of vulnerability. Assessment of equipment sensitivity to voltage sags. Voltage sag limits for computer equipment, CBEMA, ITIC, SEMI F 42 curves. Measurement of voltage sag half cycle RMS, one cycle rms methods. Representation of the results of voltage sags analysis. Voltage sag indices. Mitigation measures for voltage sags, such as UPS, DVR, SMEs, CVT etc., utility solutions and end user solutions.

| Unit 04 | Harmonics-I | 07 hrs |
|---|---|---|

Definition of harmonics, inter-harmonics, sub-harmonics. Causes and effects of harmonics. Voltage versus current distortion. Overview of Fourier analysis. Harmonic indices and other indices for assessing impacts of harmonics. A.C. quantities under non-sinusoidal conditions. Triplen harmonics characteristics and non characteristics harmonics. Power assessment under waveform distortion conditions. Harmonic sources and harmonic generation from lighting loads, Computer and allied load including SMPS, household equipment, Office automation devices, Utility equipment like transformer, synchronous machines and FACTS devices. Industrial equipment – induction machines, AC and Dc drives, Arc Furnaces.

| Unit 05 | Harmonics-II | 7 hrs |
|---|---|---|

Harmonics resonances - series and parallel resonances. Consequences of harmonic resonance. Principles for controlling harmonics. Reducing harmonic currents in loads. K-rated transformer. Harmonic study procedure. Computer tools for harmonic analysis. Locating sources of harmonics. Modifying the system frequency response. Harmonic filtering, IEEE 1531 standard for key design criteria for filters. Passive filters, Notch filter, Tuned filters, Broadband filters and active filters. IEEE Standard 519-2014 for Harmonic control.

| Unit 06 | Power Quality Monitoring & Assessment | 07 hrs |
|---|---|---|

Need of power quality monitoring and approaches followed in power quality monitoring. Power quality monitoring objectives and requirements. Initial site survey. Power quality instrumentation. Power quality analyser specification requirement as per EN50160 Standard. Selection of power quality equipment for cost effective power quality monitoring, Selection of power quality monitors, selection of monitoring location and period. Selection of transducers. Harmonic monitoring, Transient monitoring, event recording and flicker monitoring. Power Quality assessment, Power quality indices and standards for assessment disturbances, waveform distortion.

Text Books:


| | |
|---|---|
| [T1] | R. C. Dugan, Mark F. McGranaghan, Surya Santoso, and H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw-Hill Publication. |
| [T2] | C.Sankaran, "Power Quality", CRC Press. |
| [T3] | M. H. J. Bollen, "Understanding Power Quality Problems, Voltage Sag and Interruptions", New York: IEEE Press, 2000, Series on Power Engineering. |
| [T4] | Arrillaga, M. R. Watson, and S. Chan, "Power System Quality Assessment," John Wiley and Sons. |


Reference Books:

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|---|---|
| [R1] | Enriques Acha, Manuel Madrigal, "Power System Harmonics: Computer Modeling and Analysis," John Wiley and Sons Ltd. |
| [R2] | Ewald F. Fuchs, Mohammad A. S. Masoum, "Power Quality in Power Systems and Electrical Machines," Elsevier Publication. |
| [R3] | Arrillaga, M. R. Watson, "Power System Harmonics", John Wiley and Sons. |
| [R4] | G. J. Heydt, "Electric Power Quality", Stars in Circle Publications. |
| [R5] | EN50160 and IEEE 1100, 1346, 519, and 1159 standards. |

Mapping:

| Unit | Text Books | Reference Books |
|---|---|---|
| 01 | T1,T2, T3,T4 | R1,R2,R4, R5 |
| 02 | T1,T2 | R2, R4, R5 |
| 03 | T1,T2, T3 | R2, R4, R5 |
| 04 | T1,T2 | R1, R2, R3, R4, R5 |
| 05 | T1,T2 | R1, R2, R3, R4, R5 |
| 06 | T1,T2,T5 | R1, R2, R3, R4, R5 |

## List of Experiments:

***A minimum of 9 experiments are to be performed from the following list:***

***Compulsory experiments:***

1. Study of the power quality analyzer and measurement of various power quality parameters.
2. Measurement of harmonic distortion of various non linear loads.
3. Harmonic analysis of SMPS based Equipment such as UPS /AC/DC drive.
4. Harmonic compliance of institute as per IEEE 519-2014 standard and sizing of hybrid ( Active + detuned filter).
5. Power quality audit of institute or department.

***Any 4 experiments from following list:***

1. Harmonic analysis of transformer for various conditions (no load, inrush, full load etc.)
2. Harmonic analysis of UPS/ DC Drive/AC Drive.
3. Analysis of performance of induction motor/transformer operated with sinusoidal supply and under distorted supply conditions supplied by 3 phase inverter.
4. Measurement of voltage sag magnitude and duration by using digital storage oscilloscope/ power quality analyzer.
5. Design of 7% detuned Passive Filter.
6. Simulation study of transient and/or flicker measurement.
7. Simulation studies of harmonic generation sources such as VFD, SVC, STATCOM and FACTS devices and harmonic measurement (THD) by using professional software like MATLAB.
8. Harmonic load flow analysis by using professional software such as ETAP, PSCAD, ATP.

## Guidelines for the Instructor's Manual:

The Instructor's Manual shall have

- Brief relevant theory.

- Equipment with specifications.
- Connection diagram/methodology.
- Format of observation table and sample results.

## Guidelines for Students' Lab Manual:

The Student's Lab Journal should contain the following related to every experiment –

- Theory related to the experiment.
- Apparatus with their detailed specifications.
- Connection diagram or circuit diagram.
- Observation table/simulation waveforms.
- Sample calculations for one or two readings.
- Result table.
- Graph and conclusions
- Few short questions related to the experiment.

## Guidelines for Laboratory Conduction:

- Read and understand the power quality analyzer manual completely.
- Make sure that connections of the power analyzer are done as per manual.
- Follow safety protocols while doing a power quality audit.


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