GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering
Level: Diploma
Branch: Electrical Engineering
Subject Code: DI04009011
Subject Name: Substation Engineering

w. e. f. Academic Year:	2025-26
Semester:	4th
Category of the Course:	PCC

Prerequisite:	Basic knowledge of AC and DC circuits, electrical machines and electrical power generation.
Rationale:	The **Substation Engineering** course equips diploma-level electrical engineering students with essential competencies to operate and maintain electrical substations, aligning with India's power sector needs. It enables students to interpret and apply substation classification, layout, and site selection principles to ensure reliability, safety, and operational efficiency, adhering to Indian Standards (IS). The course fosters skills in analyzing and applying functional principles of critical substation equipment (e.g., transformers, isolators) per IS/IEC standards and Industry 4.0 practices like IoT-based monitoring. Students learn to implement operational, earthing, and reactive power compensation practices, ensuring compliance with safety regulations and leveraging smart technologies. Additionally, the course introduces operational principles of advanced GIS, HVDC, and digital substations, emphasizing smart grid integration, cybersecurity, and sustainable practices, preparing students for roles as junior technicians or operators in modern power utilities while addressing India's growing energy infrastructure demands.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
01	Interpret and apply the principles of substation classification, layout, and site selection to ensure reliability, safety, and operational efficiency in power system applications.	Apply
02	Identify, interpret, and apply the functional and monitoring principles of substation equipment in accordance with relevant IS/IEC standards and emerging Industry 4.0 practices.	Apply
03	Apply substation operational, earthing, and reactive power compensation practices in compliance with national and international safety standards and Industry 4.0 monitoring systems.	Apply

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04	Apply the operational principles and automation technologies of GIS, HVDC, and digital substations with awareness of smart grid, cybersecurity, and sustainable industry practices.	Apply

Revised Bloom's Taxonomy (RBT)

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	**T**	**PR**	**C**	**ESE(E)**	**PA(M)**	**PA(I)**	**ESE(V)**	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Introduction to Electrical Substations** Contents: 1. **Definition and Purpose of Substations:** • Overview of substations as critical nodes in power systems • Importance in India's power infrastructure 2. **Types of Substations:** • Classification based on function: Transmission, distribution, Switching substation • Classification based on voltage level: EHV, HV, MV, LV • Indoor vs. outdoor substations. 3. **Essential Features of Substations:** • Key characteristics: Reliability, safety, scalability, and maintainability. • Basic requirements for substation location (site selection) and accessibility. 4. **Typical Layout of Substations:** • Overview of substation layout components: Switchyard, control room, and auxiliary systems. • Introduction to single-line diagrams (SLDs) of 66 kV / 132 kV / 220 kV layout. • Examples of common layouts (e.g., single bus, double	06	15 %

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	bus).		
2.	**Substation Equipment** For all the equipment covered in this unit, Indian Standards (IS) are for references only and the questions of Unit 2 pertaining to Indian Standards (IS) should be avoided in theory exams, considering the scope of the syllabus of this subject" Contents: 1. **Transformers (Power Transformers: IS 2026 Part 1 to 4 and Interconnecting Transformers: IS 1180):** • Requirement of inter-connecting & power transformers • Operational and Maintenance checks of transformer • Condition monitoring (Parameters – Sensor/Methods – Alarm Threshold) 2. **Isolators (with and without Earthing switch) (IS 9921: Parts 1 to 5)** • Types and Voltage class: Horizontal and Vertical break / double / centre break, Manual / motorized, with/without earthing switch. • Pad-locking arrangement, mechanical and electrical safety interlocking between isolator and earth swich. 3. **Busbars (IS 8084, IS 5082):** • Types: strain, flexible, rigid type • Material: aluminium pipes, ACSR, AAC • Ratings: Rated voltage, current, ampacity, material (Copper, Aluminum), Short time withstand current, peak withstand current, temperature rise limits etc. • Functions: Switching, Power transfer /distribution within substation • Maintenance: Joint inspections, corrosion checks. 4. **Auto-Reclosers (IS 7567):** • Types: Single-phase, three-phase. • Functions: Automatic fault clearing, circuit restoration. • Contact checks, reclosing mechanism inspection. • IoT-enabled fault logging, remote configuration. 5. **Surge Arrestors (IS 3070 Parts 1-3):** • Types: Expulsion type, Thyrite type, Metal oxide (MO) conforming IEC 60099-4, • Application, Routine and periodic maintenance procedures	16	35 %

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	6. **Insulator, strings, Clamps and Connectors, Spacers ((IS 2544, IS 731, IS 5561, IS 10162/14763)** • Insulator Types: Porcelain type (Disc, long rod), Composite type, Silicon Rubber, Hollow bushing type, Bus post insulators • Clamps & Connectors: Aluminium alloy casting type A6, bi-metallic liner/strip, galvanised mild steel. • Non-magnetic spacers • Routine and periodic maintenance procedures 7. **Power Line Carrier Communication (PLCC) (IS 9149, 4119, 1947, 11538):** • Components of PLCC, Wave trap • Working of PLCC and applications 8. **Batteries and DC Systems** • Introduction to Lead Acid and NiCD batteries • Trouble shooting chart for Lead Acid Batteries (Troubles – Symptoms/Cause – Remedies) • Maintenance Checks for Lead Acid Batteries • Battery Charger -Float and Boost charging		
3.	**Substation Practices, Earthing Systems, and Compensation Equipment** Contents: 1. **Routine Substation Operations:** • Switching schemes for 765 KV, 400 KV, 220 KV and 132 KV substations • Power flow and voltage level monitoring • Documentation and reporting for operational logs • Preventive, Predictive and Proactive maintenance 2. **Earthing Systems (IS 3043):** • Purpose of earthing systems, Step & Touch potential, Transferred & Floating potential • Earthing systems in substation: Solidly grounded, Resistive (NER), Grid & Rods, Counterpoise • General recommendation of IS 3043:2018, IS 5613 (Part 2, Section 1), CEA 2010 Regulation (Rule 42) for earthing systems in substations. 3. **Compensation Equipment:** • Capacitor banks: Introduction, Maintenance, OUCB – Optimum Utilization of Capacitor Bank, Case studies	10	22 %

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	for optimal capacitor bank operation, Commercial benefits of OUCB **4. Safety Standards and Regulations (IS 5216 Part 1 and 2):** • General recommendations of IS 5216 Part 1 • General recommendations of IS 5216 Part 2 • Typical safety clearances based on voltage level (minimum and working safety clearances). • Basic safety practices: Personal protective equipment (PPE), lockout-tagout procedures		
4.	**Specialized Substations and Automation Basics** **Contents:** **1. Gas Insulated Substations (GIS) & Hybrid GIS Substations (HGIS:** • Overview: Purpose, use in urban/high-voltage areas, compactness. • Components: Circuit breakers for GIS, Disconnector switches, non-fault initiating earthing switches, High speed earthing switches, three position disconnect / Earthing switches, View ports, CT, PT, Pressure relief devices, Density monitors, Gas-tight, Gas pass-through type insulators, • Routine check list of GIS, HGIS substations **2. HVDC Substations:** • Overview: Purpose for long-distance/renewable integration. • Components: Converters, filters, DC transformers. • Ratings: DC voltage (e.g., ±500 kV), power capacity (MW). • Functions and Maintenance (Efficient power transmission, grid stability, Converter valve checks, filter inspections) • Digital monitoring of converter performance. **3. Substation Automation Basics:** • Introduction, Definition and Advantages of SCADA substation • SCADA Architecture and Implementation • HMI (Human Machine Interface), OWS (Operator Work Station), EWS (Engineer Work Station) • Modern Technologies (Concept of Digital Substation-	13	28 %

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	GOOSE, MMS, Cyber security)		
	4. Future of Substations: • Introduction to Smart Grids • Green substation practices		
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
25	25	50	-	-	-

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

Suggested Course Practical List:

Sr. No.	Title of Experiment	Approximate Hours	CO
1	Demonstrate basic substation layout, key components using simulation / design software.	04	1
2	1. Simulate the successive operations of auto-recloser and sectionaliser operations during different recloser shots. 2. To simulate the isolation of faulty section and restoring supply to the healthy sections remotely from the substation control station using sectionalisers. (www.vlab.co.in)	04	2
3	Control of GOS from workstation using Status table from workstation & mmonitoring feeder parameter from workstation (www.vlab.co.in)	02	2
4	Demonstrate & Explain fault scenario in feeder and transformer bus in the substation using Virtual Lab Simulation. (www.vlab.co.in)	02	3
5	To demonstrate the load transfer from one Feeder to other during Transformer Maintenance using virtual lab (www.vlab.co.in)	02	3
6	To demonstrate control of bus voltages through On-load Tap Changer. (www.vlab.co.in)	02	3

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7	To perform breakdown test of transformer oil (Laboratory performance or Virtual Lab Simulation)	02	2
8	Design and fabrication of earthing system (Mesh / Pipe / Plate)	06	3
9	A visit to a nearby electrical substation.	06	3
10	Demonstration of cut-sections of substation equipment.	02	2
11	Safety protocol drills – use of PPE, lockout, tagout.	02	1
12	Demonstrate basic PLC operation using PLC trainer or virtual lab. (www.vlab.co.in)	02	4

Subject In-charge can add performance experiment only.

References/Suggested Learning Resources:
(a) Books:

1. "Electrical Substation Engineering & Practice EHV-AC, HVDC and SF6-GIS", Rao, Sunil S., Khanna Publishers, 2nd edition, ISBN-10: 8174091394
2. "Electric Power Substations Engineering", McDonald, John D., CRC Press, 3rd edition, ISBN-10: 1439856389
3. "Electrical Substation Practices (Elective - II)", Jadhav, Nitin S., Techknowledge Publications, 2024th edition, ISBN-10: B0CSJZB7FM
4. "Sub-Station Engineering, Design, Concepts & Computer Application", Gupta, B.R., S.K. Kataria & Sons, 1st edition, ISBN-10: 9350148456
5. "Electrical System Designing Made Simple, With CD", Saini, Giridhar, Viva Books, 1st edition, ISBN-10: 8130913438
6. "Electric Power Substations Engineering", McDonald, John D., Taylor & Francis, 3rd edition, ISBN-10: 1138076434
7. "Substation Engineering and Automation", Dr. Muthuselvi, Dr. Shanmugasundaram, SKH Publishing House, latest edition, ISBN: 978-81-977917-2-7

(b) Open-source software and website:

1. https://matpower.org (Open Source Software)
2. https://sourceforge.net/projects/electricdss (Open Source Software)
3. https://github.com/LLNL/GridDyn (Open Source Software)
4. https://www.gridlabd.org (Open Source Software)

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5. https://www.getcogujarat.com/getco_newsite/index.php
6. https://cea.nic.in/
7. https://www.getcogujarat.com/getco_newsite/index.php
8. https://grid-india.in/en/
9. https://www.electrical4u.com
10. https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-061-introduction-to-electric-power-systems-fall-2011
11. https://www.pdhonline.com/courses/e163/e163_new.htm
12. https://www.khanacademy.org/science/electrical-engineering
13. https://phet.colorado.edu/
14. https://ndl.iitkgp.ac.in
15. www.vlab.co.in

List of Laboratory/Learning Resources Required:

1. Digital Multimeter - 600V, 10A, 20MΩ
2. Hand-Driven Megger Insulation Tester - 500V/1000V, 0–1000MΩ
3. Earth Resistance Tester - 0–10Ω, 1000V
4. Digital Capacitance Meter - 0.1pF–20mF
5. Low-Voltage Transformer Demonstration Model - 1kVA, single-phase, 220V
6. Basic Isolator Switch Model Kit - 220V, manual
7. Aluminum Busbar Sample Kit - 10m, 100A, 600V
8. Copper Rods and Wires for Earthing Mesh - 6mm², 10m, 4 rods (15mm dia, 30cm)
9. PPE Kit - Safety gloves (1000V), helmet, lockout-tagout set
10. Capacitor Bank Components - 5x 10μF, 400V
11. Sandbox/Tray for Earthing Simulation - 1x1m
12. Basic PLC Trainer Kit - 8 inputs/8 outputs, 24V DC or emulator

Suggested Project List:

1. Simple SLD Drawing for 66 kV Substation
   - Description: Students work in groups to draw a single-line diagram (SLD) for a 66 kV substation, using a template to place switchyard and control room parts, and check safety features visually.
2. Model of Substation Types
   - Description: Build a small physical model (using cardboard/LEDs) to show differences between transmission and distribution substations, labeling voltage levels (e.g., HV, MV).
3. Safety Gear and Lockout Practice

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- Description: Students practice using PPE (gloves, helmets) and lockout-tagout on a mock circuit, acting as "safety inspectors" to spot errors in a setup.
4. Transformer Bushing and Cooling Check
    - Description: Inspect a transformer model's bushings and cooling system (e.g., radiator), measuring insulation resistance (IR) with a simple tester in a "maintenance shift" scenario.
5. Isolator Locking and Testing Model
    - Description: Build a small isolator model with pad-locking, test continuity, and check interlocking safety in groups, simulating a "maintenance prep" task.
6. Busbar Joint Inspection Setup
    - Description: Assemble a simple aluminum busbar model, inspect joints for corrosion, and measure resistance, acting as "site technicians" to ensure power flow.
7. Earthing Mesh Build and Test
    - Description: Design and build a small mesh earthing grid (1x1m) in a sandbox, measure resistance (<1 ohm) with a tester, and compare with standards in a group "safety audit."
8. Capacitor Bank for Power Factor Fix
    - Description: Assemble a small capacitor bank, measure capacitance, and simulate power

Suggested Activities for Students:

1. SLD sketch Task
    - Sketch 66 kV/132 kV SLDs to identify components and ensure safety compliance using Tinker-cad Circuits / card boards / wooden or acrylic panel.
2. Substation Type Sorting
    - Categorize transmission/distribution substations by voltage and function in a group quiz using Virtual Labs.
3. Safety Drill Simulation
    - Practice PPE and lockout-tagout on a circuit model, spotting safety errors in a timed scenario.
4. Maintenance schedule chart of Transformer Accessories (Bushings, Radiators etc.)
5. Prepare charts on various tests on Transformer Oil
6. Equipment Inspection Game
    - Inspect transformer bushings and isolators on a model, listing defects per IS/IEC standards.
7. Earthing Resistance Test
    - Measure resistance of a mesh earthing model with a megger, comparing to <1 ohm standard.
8. Power Factor Correction Lab
    - Assemble and test a capacitor bank, simulating voltage regulation with MATLAB Online.

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9. GIS Maintenance Check
    - Simulate SF6 gas leakage detection on a GIS model using ETAP student version.
10. HVDC Operation Demo
    - Test virtual HVDC converter efficiency with MATLAB Online, analyzing power flow.
11. SCADA Monitoring Setup
    - Configure a basic SCADA interface for substation monitoring using LogixPro in groups.
12. Smart Grid Poster
    - Create a visual poster on smart grid and cybersecurity features in substations with minimal text.

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