



# GUJARAT TECHNOLOGICAL UNIVERSITY

**Program Name: Bachelor of Engineering**

**Level: UG**

**Branch: Electrical Engineering**

**Subject Code: BE05009041**

**Subject Name: Elements of Electrical Design**

W.E.F. Academic year	2024-25
Semester	5
Category of the Course	Professional Elective Course - 1

<b>Prerequisite:</b>	Basic Electrical Engineering, Electromagnetic Field Theory, Electrical Machines (Basic)
<b>Rationale:</b>	This course provides fundamental and contemporary knowledge for the design of electrical equipment and installations. The revised syllabus retains all time-tested classical design principles – magnetic circuit design, armature windings, transformer and choke coil design, starters, and residential/commercial wiring estimation – while integrating carefully selected modern topics: advanced magnetic materials (SMC, amorphous cores), FEM-based design, soft starters, high-frequency transformers, Application of standard CAD tools (AutoCAD Electrical, EPLAN etc..).

### Course Outcomes:

After completion of the course, the student will be able to:

CO No.	Course Outcome Statement	Marks % Weightage
1	Explain the fundamental principles of magnetic circuit design, including core material properties, FEM-based analysis, and insulation classification for electrical machines.	20%
2	Design small single-phase transformers, high-frequency transformers, choke coils, A.C./D.C. starters, field regulators and soft starters with supporting power circuit schematics.	20%
3	Develop armature winding diagrams for DC and AC Machines as per given specifications, and calculate the relevant winding performance parameters.	20%
4	Estimate the material, labour and total cost of electrical wiring for residential and commercial premises from prepared schematic diagrams.	20%
5	Design the electrical supply system, earthing arrangement and control panel for residential, commercial and industrial applications using CAD tools and current IS/CEA/IEC standards.	20%

### Teaching and Examination Scheme:

Teaching-Learning Scheme (in Hours per Semester)					Total Credits = TH/30	Assessment Pattern and Marks					Total Marks
L	T	P	PBL	TH		Theory		Tutorial / Practical			
						ESE (E)	PA (M)	PA (I)	PBL (I)	ESE (V)	
45	0	30	15	90	3	70	30	20	30	50	200



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Where: L = Lecture, T = Tutorial, P = Practical, TW/SL = Term-Work / Self-Learning, TH = Total Hours, ESE = End-Semester Examination, PA = Progressive Assessment

## Course Content:

*Note: Topics in **italics** represent newly added content relative to the previous syllabus (Subject Code: 3160918). All previous core topics are retained.*

Sr. No.	Unit No.	Content	No. of Hours	% of Weightage
1	I	<b>GENERAL DESIGN ASPECTS</b> Basic principles of magnetic circuits – use of B-H curves; Calculations of MMF for air gap and teeth; Real and apparent flux density; Field Form; Air gap flux distribution factor; Magnetizing current calculation; Leakage Reactance calculation for various slot types; Iron loss calculation concepts; Magnetic Materials, Insulating Materials & Classifications. Soft Magnetic Composites (SMC) and amorphous/nanocrystalline core materials; Application of FEM in calculation of force, torque, potential distribution and magnetic flux density; Introduction to digital twin concepts for electrical machines. IS 1271, IS 2026	10	20
2	II	<b>DESIGN OF STARTERS, FIELD REGULATORS AND SMALL TRANSFORMERS</b> Introduction and review of A.C. and D.C. starters; Schematic diagrams of control circuit and power circuit for starters with contactors and timers; Design of starters and Field regulators; Design of small single-phase transformers; Design of variable air gap single phase and three phase choke coil. Soft starters – design and selection criteria; Design of high-frequency transformers for SMPS applications.	10	20
3	III	<b>ARMATURE WINDINGS (DC AND AC MACHINES)</b> <b>DC Windings:</b> Simplex & Duplex windings; Lap & Wave windings; Applications; Basic terms related to armature windings; Dummy Coils; Equalizer connections; Split coils. <b>AC Windings:</b> Introduction; No. of phases; Phase spread; Concentric winding; Hemitropic winding; Whole coil winding; Mush winding; Double layer windings; Integral slot lap and wave winding; Fractional slot lap and wave windings; Performance analysis of various windings.	08	20



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		Thermal analysis and winding insulation class selection for high-efficiency motors (IE3/IE4). IS 12615,		
4	IV	<b>ESTIMATION AND COSTING FOR RESIDENTIAL AND COMMERCIAL WIRING</b> Preparation of schematic diagrams and estimation of cost of wiring for Tenements, Row houses, Bungalows, Flats, Multi-Storied Buildings, Commercial Complexes like Offices, Hospitals, Hotels, Theatres. Smart wiring – estimation for home automation (KNX/DALI/IoT-based); Fire detection and alarm system wiring estimation. IS 732	10	20
5	V	<b>DESIGN CONSIDERATION OF ELECTRICAL INSTALLATIONS AND CAD TOOLS</b> <b>Core topics:</b> Types of load; Electrical Supply Systems; Wiring systems; Load Assessment; Permissible voltage drops & Conductor size calculations; Design of Control panel; Estimation and costing for service connections. Design of earthing systems (conventional and advanced – chemical, deep bore); Overview of CAD tools – AutoCAD Electrical, ETAP, EPLAN; Simulation of SLDs using MATLAB/Simulink and FEMM; Standards and compliance: IS 732, IS 3043, IEC 60364, BEE energy efficiency ratings (IE3/IE4/IE5). IS 3043 (Earthing); IS 8623 (Factory-built Switchgear Assemblies)	07	20
		<b>Total</b>	<b>45</b>	<b>100</b>

Note: (i) 10%–20% weightage should be given to examples and short/MCQ-type questions. (ii) Question paper should include 40–60% numerical/design problems.

## Suggested Specification Table with Marks (Theory):

### Distribution of Theory Marks

R Level	U Level	A Level	N Level	E Level	C Level
0	20	20	20	0	40

Where: R – Remember; U – Understanding; A – Application; N – Analyse; E – Evaluate; C – Create (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from the above table.



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## Suggested Course Practical / Assignment List:

Sr. No.	Practical / Assignment Title and Description	CO Mapped
1	Design and draw armature winding diagram for a DC lap winding (given P, S, C) and verify winding closure; identify equalizer connection positions.	CO-3
2	Design and draw armature winding diagram for a DC wave winding (given P, S, C); compare with lap winding and tabulate differences.	CO-3
3	Draw a single-layer integral slot AC winding for a 3-phase, 4-pole induction motor (given Q, m, p); calculate winding factor.	CO-3
4	Draw a double-layer fractional slot AC winding diagram; calculate coil pitch, chording angle and distribution factor.	CO-3
5	Design of a small single-phase transformer: determine core dimensions, number of turns, conductor size, and estimate regulation and efficiency.	CO-2
6	Design of a variable air-gap choke coil: determine inductance, core cross-section and number of turns for a given specification.	CO-2
7	Design of a DOL starter for a 3-phase induction motor: select contactor, overload relay, fuse and draw the control and power circuit schematic.	CO-2
8	Design of a soft starter for a given motor load: determine firing angle range, heat dissipation and bypass contactor rating.	CO-2
9	Estimation exercise – Residential wiring: prepare schematic, bill of materials and itemized cost estimate for a two-bedroom flat (given load schedule).	CO-4
10	Estimation exercise – Commercial wiring: prepare schematic and cost estimate for a small office complex including fire alarm and emergency lighting.	CO-4
11	Conductor sizing and voltage drop calculation for an industrial feeder; design the control panel (MCCB, busbar, cabling) for a given load schedule.	CO-5
12	Simulation using AutoCAD Electrical / ETAP / EPLAN: generate a single-line diagram (SLD) and load flow result for a given distribution network.	CO-5



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13	FEM simulation using FEMM or MATLAB/Simulink: determine flux density distribution and inductance of a simple magnetic circuit; compare with analytical result.	CO-1
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*Note: Each practical / assignment shall be documented in the student's practical journal. A minimum of 10 practicals (from the list above) shall be completed per semester. The remaining may be substituted by open-ended design problems or simulation tasks at the discretion of the faculty.*

### Design Based Problems (DP)/PBL / Open-Ended Problems:

1. Design a 250 VA single-phase transformer for 230V/12V supply: determine core dimensions, turns ratio, conductor cross-sections, window area, and estimate full-load efficiency and regulation.
2. Design a DOL and star-delta starter for a 15 kW, 415 V, 3-phase induction motor: select all components (contactors, timers, overload relays, fuses), draw control and power circuit schematics, and justify the selections.
3. Prepare a complete wiring estimate (schematic, BOQ and cost) for a 3-BHK residential flat and compare with an equivalent smart-home (IoT/KNX) wiring solution; analyse the additional cost vs. energy saving benefit.
4. Using EPLAN, or AutoCAD Electrical, design the electrical installation (SLD, cable sizing, voltage drop, fault level and protection coordination) for a small industrial unit with a 100 kVA transformer, motor loads and lighting; generate the complete SLD and cable schedule.

*Note: Problems may be solved using hand calculations, MATLAB, EPLAN, AutoCAD Electrical or equivalent licensed/open-source tools. Students should clearly state assumptions and cite the applicable standard for each design step.*

### Major Equipment / Software Required:

1. Magnetic circuit demonstration kit with variable air-gap core and B-H curve measurement facility
2. Single-phase and three-phase transformer test rig with winding resistance, no-load and load loss measurement
3. D.C. motor/generator and 3-phase induction motor test rigs for winding inspection and starter testing
4. DOL, star-delta and soft starter demonstration panels (up to 5 kW)
5. Digital lux meter, clamp meter, power factor meter and portable energy logger
6. FEMM (free) and/or ANSYS Maxwell (student edition) for FEM simulation
7. AutoCAD Electrical / EPLAN / ETAP (educational licence) for CAD and load flow
8. MATLAB/Simulink with Simscape Electrical toolbox

### References / Suggested Learning Resources:

#### Books:

1. A. K. Sawhney, A Course in Electrical Machine Design, Dhanpat Rai & Co. (latest edition).
2. R. K. Agrawal, Electrical Machine Design, S. K. Kataria & Sons (latest edition).
3. V. N. Mittle & A. Mittle, Design of Electrical Machines, Standard Publishers (latest edition).
4. J. G. Jamnani, Elements of Electrical Design, GTU textbook.



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5. K. B. Raina & S. K. Bhattacharya, Electrical Design, Estimating and Costing, New Age International.
6. H. Joshi, Residential, Commercial and Industrial Systems, PHI Learning.
7. Matthew N. O. Sadiku & S. V. Kulkarni, Principles of Electromagnetics, 6th ed., Oxford University Press.
8. Sheppard J. Salon, Finite Element Analysis of Electrical Machines, Kluwer Academic (Chapter 6).
9. J. R. Hendershot & T. J. E. Miller, Design of Brushless Permanent-Magnet Machines, Motor Design Books.
10. M. H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson (for soft starter / drive topics).
11. National Electrical Code (IS 732: 2019), IS 3043 (Earthing), CEA Technical Standards 2010 & Regulations 2023 (latest edition).
12. BEE Publication: Energy Efficiency in Electrical Utilities, Bureau of Energy Efficiency, India (free download at [beeindia.gov.in](http://beeindia.gov.in)).

## Web / Digital Resources:

1. NPTEL: Electric Motors and Drives / Electrical Machine Design – <https://nptel.ac.in>
2. AutoCAD Electrical Tutorials – <https://www.autodesk.com/education>
3. ETAP Educational Resources – <https://etap.com/learn>
4. FEMM (Finite Element Method Magnetics) – <https://www.femm.info>
5. Bureau of Energy Efficiency (BEE) – <https://beeindia.gov.in>
6. Central Electricity Authority (CEA) – <https://cea.nic.in>
7. Bureau of Indian Standards (IS Standards) – <https://www.bis.gov.in>

## SDG Alignment

The following table maps the existing course units and topics to relevant UN Sustainable Development Goals (SDGs)

Unit	Existing Topic	Relevant SDG	How It Connects
I	Amorphous/nanocrystalline core materials; Iron loss calculation	SDG 7 (Affordable & Clean Energy); SDG 12 (Responsible Consumption)	Low-loss core materials reduce transformer energy waste; energy-efficient insulation extends machine life.
I	FEM-based design; Digital twin concepts	SDG 9 (Industry, Innovation & Infrastructure)	Modern simulation tools support innovative and resilient industrial infrastructure design.
II	Soft starters; High-frequency transformers for SMPS	SDG 7 (Clean Energy); SDG 12 (Responsible Consumption)	Soft starters cut inrush current and reduce energy use during motor startup; SMPS transformers enable compact, efficient power conversion.
III	IE3/IE4 motor efficiency; Thermal analysis and insulation class selection	SDG 7 (Clean Energy); SDG 13 (Climate Action)	High-efficiency motors directly reduce electricity consumption and carbon emissions; IS 12615 mandates IE3/IE4 levels in India.



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<b>IV</b>	Smart wiring (KNX/DALI/IoT); Fire detection & alarm system wiring	SDG 11 (Sustainable Cities & Communities)	Smart building wiring reduces energy consumption and improves occupant safety, directly supporting sustainable urban development.
<b>V</b>	Earthing systems; Conductor sizing; Control panel design	SDG 9 (Infrastructure); SDG 11 (Sustainable Cities)	Proper earthing and panel design ensure safe, reliable electrical infrastructure; BIS compliance is mandatory for all installations in India.

• **Activities Suggested for Problem Based Learning/ Self Learning (PBL: 15 Hours):**

Sl. No.	Activity	Hours	Evaluation Criteria	CO Mapped
1	Industry / Site Visit: Visit a local electrical panel fabrication unit or transformer manufacturer. Document the equipment design parameters, materials used and fabrication steps. Prepare a one-page visit report with photographs.	Visit = 5h Report = 5h Total = 10h	Relevance of observations, quality of report, ability to link field observations to course topics.	O-4 / CO-5
2	<b>Mini Project:</b> CAD Tool Practice: Use AutoCAD Electrical, ETAP (student version). Submit the drawing file and a brief interpretation report.	10h	Accuracy of drawing, correct use of symbols (IS/IEC), quality of documentation.	CO-5
3	<b>Micro Project:</b> Simulation Task: Use FEMM or MATLAB/Simulink to simulate the magnetic flux distribution in a transformer core or an induction motor cross-section. Vary one design parameter and study its effect on flux density.	5 h	Simulation accuracy, correct interpretation of results, comparison with analytical values.	CO-1
4	Online Certification / NPTEL: Complete a minimum of 10 hours from an NPTEL/SWAYAM course on Electrical Machine Design, Submit certificate and a one-page learning summary.	10h	Certificate of completion + short quiz/viva on course content.	All COs
5	Technical Seminar / Poster Presentation: Prepare and present a 10-minute seminar or A1-size technical poster on a current topic – e.g., 'IE4/IE5 Motor Adoption in India', 'Design of High frequency transformers'	Research = 5h Preparation = 5h Total = 10h	Technical accuracy, use of standards and data, communication clarity, response to questions.	CO-2 to CO-5



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## **Notes:**

(i) All self-learning activities must be directly related to the course. (ii) Suggestive hours may be redistributed by faculty, but total hours are fixed at 15. (iii) Evaluation rubrics shall be prepared and displayed by the faculty. (iv) All records must be maintained at institute level and produced on demand. (v) Digital submission via Microsoft Teams, Moodle or institute LMS is encouraged. In alignment with Outcome-Based Education (OBE) and NBA accreditation requirements, the subject Elements of Electrical Design incorporates;

- Mini Project – 10 Marks
- Micro Project and – 5 Marks

These activities are incorporated as integral Project-Based Learning (PBL) components. These activities are designed to foster experiential learning, encourage innovation, and strengthen problem-solving skills by engaging students. The inclusion of PBL ensures that learners develop higher-order cognitive abilities mapped to Bloom's taxonomy, while simultaneously enhancing teamwork, communication, and research competencies essential for professional engineering practice.

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