GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering
Level: Diploma
Branch: Electrical Engineering
Subject Code: DI04009021
Subject Name: Energy Efficiency & Audit

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

Prerequisite:	Basic knowledge of electrical engineering, machines, and electrical measurements.
Rationale:	This course provides practical knowledge and hands-on skills in energy efficiency and energy auditing. It focuses on improving the energy performance of motors, transformers, lighting, HVAC, and utility systems in industrial and building environments. The course also covers systematic energy audit procedures, cost-benefit analysis, and safety practices in accordance with BEE guidelines, preparing students for roles in energy auditing and industrial operations.

Course Outcomes:

After Completion of the Course, Student will be able to:

No	Course Outcomes	RBT Level*
01	Explain the fundamentals of energy audit and management	R, U
02	Understand energy efficiency standards, interpret star ratings of electrical appliances and energy saving.	U, A
03	Analyze reactive power and capacitor-based compensation of improved in system efficiency	A
04	Analyze performance and apply methods to improve efficiency in electrical equipment, lighting and distribution	U, A
05	Understand consumer tariff categories, tariff components, energy charges and calculate energy bill.	R, A

**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
L	T	PR	C	Theory		Tutorial / Practical		
				ESE (E)	PA / CA (M)	PA/CA (I)	ESE (V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	Unit 1: **Energy Management & Audit** • India's energy demand and per capital consumption (2024) • Terminology: Power, energy, energy audit, demand side management, PAT scheme, energy intensity • First and second law of thermodynamics • Scheme of BEE under energy conservation act (only names), Energy intensive industries, National mission for enhanced energy efficiency (NMEEE) • Energy Audit: Need of energy audit, preliminary, targeted and detailed energy audit, pre audit phase and post audit phase, classification of ENCON measures • Energy performance: Plant energy performance and production factor • Electrical measuring instruments: Non-contact infrared thermometer, stroboscope, lux meter, smart energy meter, thermography • Sankey diagram of three phase induction motor • Financial management: simple payback period, net present value and cash flow, return on investment and internal rate of return, case study of payback period	8	18%
2	Unit 2 : **Star Level & Energy Saving** • Technical Details of Standards & Label • Star label applicable to Mandatory appliance and voluntary appliance • Significance of star label 1, 2, 3, 4 and 5 of frost-free refrigerator, color TV, washing machine, Tubular Fluorescent lamps, Room Air conditioner, ceiling fan, Electronic / Magnetic ballast, Distribution transformer, Solid state inverter, Induction motor, Agricultural pump sets, Solid-state inverter & EV Charger • Case study of energy saving in case of energy efficient water pump and Distribution transformer considering star rating **Window & Split AC** • Operating principal of Air conditioner: Evaporation, Compression, Condensation and Expansion • Types of Room Air conditioner (RAC): Window AC & Split	10	22%

	AC • Terminology: Energy efficiency ratio (EER) and Indian seasonal energy efficiency ratio (ISEER) • Methods of evaluation of ISEER and significance • Variable Frequency drive compressors • Window & Split AC star rating • Improve RAC efficiency: Advanced heat exchangers, advanced compressor, electronic expansion valves and high efficiency motors, Dual barrier, Power plasma, Low GMP refrigerants • IoT based applications in RAC, super-efficient air conditioner		
3	Unit 3 : **Reactive Power Compensation** • Concept of reactive power, causes of low power factor, advantages of reactive power management by capacitor • Centralized compensation, individual and group compensation • Capacitor rating for power factor improvement by using standard table and formula • Effect of power factor on three phase line current, explain by case study • Effect of power factor on copper losses, explain by case study • Capacitor rating for star and delta connection • Effect of power factor on cable size and energy saving, case study	5	11%
4	Unit 4 : **Energy Efficiency in Electrical and Utility Systems** Major Energy-Consuming Loads – Motors, lighting, HVAC, transformers, compressors **Distribution transformer** • Energy efficient distribution transformer • Methods of reducing core loss and load loss • Compare amorphous and CRGO core material • Choice of liquid and dry transformer considering efficiency • Effect of loading on transformer rating • Reduction of load loss due to increase in power factor • Star level of distribution transformer • Total cost of ownership of transformer and case study **Energy efficient induction motor** • Energy efficient motors, international efficiency classes IE4, IE3, IE2 and IE1, • Effect of load and power factor on efficiency • Methods to minimize losses in motor	16	36%

	• Calculate three phase unbalance voltage, effect of voltage unbalance on temperature rise, calculation of loading of motor • Performance of induction motor in Star and Delta connection during light load • Case study of payback period of energy efficient motor is replaced by three phase induction motor • Selection of proper capacitor bank for power factor improvement • Methods of load survey methodology – sampling, measurement, and analysis **Lighting system** • Relation between watt and lumens • Terminology: luminous flux, Illuminance, inverse square law, luminous efficacy, colour rendering index • Working of LED, energy flow diagram of LED, Advantages of electronic ballast over magnetic ballast • Lighting design: Light reflectance value, room index, utilization factor, number of light fittings, distance between two fixtures, Case study • Replacement of LED by Fluorescent tube light, energy saving and payback period, case study **Distribution System** • Methods to determine energy loss: Direct method and Indirect method • Causes of technical losses, Measures to reduce technical losses • Commercial losses, Calculation of AT & C losses, measures to reduces commercial losses **Demand Side Management (DSM)** • Meaning of DSM, DSM Methodology, meaning of load shape objective		
5	Unit 5 : **Tariff** • Category of consumers: RGP, RGP (rural), GLP, Non- RGP, LTMD, LTP, AG, HTP-I to IV, LT & HV Electric Vehicle • Terminology: Demand charge, contact demand, seasonal consumers, energy charge etc. • Energy bill components for tariff of RGP and RGP (rural), GLP, NON – RGP • Tariff for LTMD: Demand charge, energy charges, time of use	6	13%

	charges, reactive energy charges, billing demand, minimum bill, seasonal consumer • Tariff for LTP – Lift irrigation: Fixed charges and energy charge • Tariff for AG: HP based tariff, metered tariff • Tariff for HTP-I & HTP-II: Demand charges, energy charges, time of use charges, billing demand, minimum bill, power factor adjusting charges, rebate • Tariff for LT & HT Electric vehicle charging stations: Fixed charge & energy charge • Case study of electricity bill calculation for RGP, LTMD and HTP-1 considering all government charges		
	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**
10 %	35 %	55 %	00	00	00

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

References/Suggested Learning Resources:

(a) **Reference Books:**

1 Guidebook on Energy Efficiency – Bureau of Energy Efficiency (BEE)
2 Energy Engineering and Management – Amlan Chakrabarti
3 Energy Management and Conservation Handbook – Frank Kreith & D. Yogi Goswami
4 Energy Audit and Management – Abhishek Singh
5 Non-Conventional Energy Resources – G.D. Rai
6 Electrical Energy Utilization & Conservation – S.C. Tripathy, Tata McGraw-Hill.
7 Design of Electrical Systems for Energy Efficiency – S. Wadhwa, New Age International.
8 Handbook on Energy Efficiency – TERI (The Energy and Resources Institute).
9 Industrial Energy Management and Utilization – L.C. Witte, P.S. Schmidt, D.R. Brown, Hemisphere Publishing.
10 Guide to Energy Management – Barney L. Capehart, Wayne C. Turner, CRC Press.

11 ISO 50001: Energy Management Standard – International Organization for Standardization (official documentation).

12 Energy Management Handbook – Wayne C. Turner, CRC Press.

(b) Open-Source Software and Website:

Topic	Resource Type	Link
Energy Basics & Conversion Tools	Tutorial	https://energyeducation.ca/encyclopedia/Main_Page
Energy Data & Scenario	Data Portal	https://niti.gov.in/energy-dashboard
Sustainability & Climate	Educational	https://sdgs.un.org/goals
Carbon Footprint Calculator	Calculator	https://www.carbonfootprint.com/calculator.aspx
Motors, Transformers, Lighting	Manuals	https://beeindia.gov.in/energy-efficiency-manuals
DSM & Power Factor	Case Studies	https://www.opendss.com/
EV & Harmonics	Simulation Tool	https://www.epri.com/research/products/3002000700
Energy Audit Guides	Guidebook	https://beeindia.gov.in/energy-auditor-guidebooks
ROI & Financial Tools	Software	https://www.nrcan.gc.ca/maps-tools-publications/tools/retscreen/7465
Digital Audit Tools	Dashboard	https://openenergymonitor.org/
Smart Metering & IoT	DIY Kits	https://openenergymonitor.org/
Data Visualization	Dashboard Tool	https://grafana.com/
Policies & Standards	Official Document	https://www.indiacode.nic.in/bitstream/123456789/2003/1/A2001-52.pdf
Green Buildings	Guidelines	https://grihaindia.org/
Future Tech (EV, BESS, Smart Grids)	Resource Center	https://smartgrid.ieee.org/

RETScreen Expert: A free software tool for energy efficiency and renewable energy project analysis https://www.nrcan.gc.ca/maps-tools-publications/tools/retscreen/7465

Suggested Course Practical List: Each week includes one lab sessions (2 hours), designed such that they complement theory topics, means each experiment directly supports the classroom teaching.

Sr. No.	Practical Outcome/Title of experiment	Unit/ CO	Approx. Hours
1	Estimate energy saving calculation by performing switching operation on LED lamp of 2 Star and 5 Star. (Case study is applicable for 1000 LEDs, energy saving calculation on yearly basis and calculate payback period, assume 10 hours per day operation of LEDs)	2	2
2	Estimate energy saving calculation by performing switching operation onMagnetic ballast and Energy saving electronic ballast. (Case study is applicable for 1000 LEDs, energy saving calculation on yearly basis and calculate payback period, assume 10 hours per day operation of LEDs)	2	2
3	Perform power factor improvement by capacitor connection in single phase circuit, calculate reactive power before and after and interpret result	3	2
4	Perform power factor improvement by capacitor in the star and delta connection in three phase circuit, calculate reactive power before and after and interpret result	3	4
5	Measurement of no load and full load reactive power of three phase induction motor and interpret result	3	2
6	Perform testing on single-phase transformer at no load test, estimate energy loss (kWh) yearly due to core loss.	4	2
7	Perform testing on single phase transformer at 50% and 75% and 100% load, estimate energy loss (kWh) yearly due to change in loading of transformer.	4	4
8	Estimate saving in copper loss due to increase in load power factor by performing test on single phase / three phase transformer	4	2
9	Perform testing on same rating of amorphous core and CRGO core single-phase transformer at no load and estimate energy saving (kWh) yearly due to core loss.	4	4
10	Perform the test on three phase induction motor with winding connection in star as well as delta during light load. (Estimate amount of energy saving in kWh per annum considering 12/18/24 hours operation per day)	4	4

11	Compare performance analysis in the tabular form of energy efficient motor IE1, IE2 and IE3 (https://new.abb.com/service/service/motion/energy-efficiency-and-circularity/energy-savings-calculator)	4	2
12	Measurement of illuminance by applying inverse square law	4	2
13	Interpret and explain each component of the three-phase energy meter bill of small industry	5	2

Subject In-charge can add performance experiment only

List of Laboratory/Learning Resources Required:

Category	Equipment / Tool	Specifications / Notes
A. Measuring Instruments	Clamp-on Digital Power Meter	AC/DC, true RMS
	Power Analyzer	Harmonics measurement, THD analysis
	Digital Wattmeter & Multimeter	Standard lab usage
	Lux Meter	For lighting audit
	Infrared Thermometer	Measures surface temperature
	Thermal Imaging Camera	Optional – shared use
	Data Loggers	Portable, USB/SD card-based
	Smart Energy Meters	With communication port (MODBUS/Wi-Fi)
B. Electrical Machines & Systems	Distribution Transformer	CRGO core, ~1 kVA lab unit
	Energy-Efficient Transformer	Amorphous core – demo model / simulation
	Induction Motors	Single-phase & three-phase, 0.5–5 HP range
	Capacitor Bank / APFC Panel	Lab-scale, 3–5 kVAR
	Lighting Setup	CFL, Tube light, LED, Sensor-based lighting
	HVAC Lab Setup	Room AC, Cooler, or Split AC with smart plug for monitoring
	Pump/Fan/Blower with VFD	Lab demo unit ~0.5–1 HP
C. Software / Digital Tools	Audit & Simulation Software	RETScreen (free), HOMER (trial), Open Source Energy Audit Spreadsheets
	Basic Data Analysis	Excel / MATLAB (if available)
	IoT Dashboard Platforms	ThingSpeak, Grafana, Blynk

Suggested Activities for Students:

To enhance the learning outcomes of the "Energy Efficiency and Audit" course, students are encouraged to participate in co-curricular activities that provide practical exposure to energy conservation, auditing techniques, and efficiency improvement measures.

- Measure electrical energy consumption in classrooms, laboratories, or small workshops using energy meters.
- Record and analyze load patterns, peak demand, and energy consumption trends.
- Identify areas of energy loss and suggest practical energy-saving measures.
- Calculate efficiency of motors, lighting systems, and other electrical equipment using standard formulas and instruments.
- Study real-life case reports on industrial or commercial energy-saving initiatives

Suggested Project List: Suggested Project List as given below:

Individual Level - Fundamental Activities

- Prepare a monthly energy consumption profile of your home/hostel from electricity bills.
- Develop an energy use pie-chart (lighting, fans, AC, appliances) for a single room.
- Case study: Compare star-rated vs. non-star-rated appliance (e.g., refrigerator, fan).
- Prepare a report on peak load demand vs. average demand from actual load data.

Group Level - Hands-on Projects / Circuit Implementation and Testing

- Transformer efficiency measurement at different loads.
- Testing of induction motor efficiency with power analyzer.
- IoT-based smart plug for monitoring AC/fan power use.
- Lighting audit project – measure lux levels in labs/hostels and propose LED retrofits.
- HVAC energy audit using smart wattmeter and thermostat sensors.
- Smart meter data logging project – analyze load profile of a lab/classroom.
- Build a simple Arduino-based IoT energy monitoring system with voltage/current sensors.

Advanced Activities (Skill-Based Activities)

- Develop an IoT-based wireless multi-load energy monitoring dashboard.
- Mini-project: Digital energy audit report for a college block using open-source software (RETScreen , Excel-based Models).
- Study of EV charging station load management and its impact on distribution transformer.
- Develop a low-cost daylight harvesting system using LDR sensors for classrooms.

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