GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: All (Except Electrical Engineering and Allied Branches)
Subject Code: BE05000431

Subject Name: Energy Audit and Management

w.e.f. Academic Year:	2024-25
Semester:	5
Category of the Course:	MOPEC-02

Prerequisite:	-
Rationale:	India is one of the world's largest energy consumers and has committed to ambitious targets under the National Action Plan on Climate Change (NAPCC) and COP-26. The Energy Conservation (Amendment) Act, 2022 introduces Carbon Credit Trading, Non-Fossil Consumption Obligations, and mandatory energy audits by BEE-accredited auditors for designated consumers. Gujarat, as a major industrial state with power-intensive sectors such as petrochemicals, textiles, ceramics, and SEZs, requires skilled energy professionals with strong expertise in electrical energy audit and management. This course integrates theory and practice to develop competencies in electrical energy auditing, power quality analysis, demand-side management, renewable integration, and compliance with IEEE, IEC, IS/BIS standards and regulatory frameworks. Thermal and mechanical aspects are covered contextually, while the primary emphasis remains on electrical systems, equipment efficiency, and electrical infrastructure management.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes
01	Describe India's energy scenario, legislative framework (EC Act 2001 and Amendment 2022), BEE programmes, and the qualifications and roles of BEE-certified Energy Managers and Energy Auditors.
02	Apply electrical energy audit procedures and instruments to measure and benchmark energy performance of industrial and commercial electrical installations.
03	Analyse power quality parameters — harmonics, power factor, voltage unbalance and flicker — and recommend corrective measures in conformance with IEEE 519, IEC 61000 and relevant IS standards.
04	Evaluate energy efficiency improvement opportunities in electrical equipment and systems including motors, variable frequency drives, pumps, lighting and distribution networks.
05	Prepare an electrical energy audit report with an energy management plan, PAT scheme compliance, renewable energy integration strategy, and financial viability analysis.

Teaching and Examination Scheme:

Teaching-Learning Scheme (inHours per Semester)					TotalCredits = TH/30	AssessmentPatternandMarks					Total Marks
						Theory		Tutorial/Practical			
L	T	P	PBL	Total		ESE (E)	PA/CA (M)	PA/ CA(I)	PBL (I)	ESE(V)	
45	0	0	15	60	2	70	30	00	30	0	130

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:

Unit No.	Content	No.of Hours	%of Weightage
1.	**Energy Scenario, Policy and Legislative Framework** Energy scenario in India and Gujarat: electrical energy consumption patterns; sector-wise analysis (industrial, commercial, residential). Energy Conservation Act (EC Act) 2001 — key provisions, designated consumers, penalties. Energy Conservation (Amendment) Act 2022: Carbon Credit Trading Scheme, Non-Fossil Consumption Obligations (RCO/RPO), sustainability building codes. Bureau of Energy Efficiency (BEE): structure and programmes — Perform Achieve and Trade (PAT) scheme, Energy Saving Certificates (ESCerts), Standards and Labelling, UJALA. National Mission for Enhanced Energy Efficiency (NMEEE). State-level energy policies: GUVNL, GEDA, Gujarat Solar and Wind policies, GERC tariff orders. Electricity Act 2003 — relevance to metering and distribution. India's COP-26 commitments and SDG 7.	08	18

2.	**Electrical Energy Audit: Methodology, Instruments and Procedures** Definition and need of energy audit; types — preliminary (walk-through), detailed (diagnostic), investment-grade audit. Energy audit team, scope and boundaries. Data collection, historical energy bills analysis, load profiling, electricity tariff structures (ToD, ToU, HT/LT tariffs). Energy performance indicators (EnPIs), benchmarking and Specific Energy Consumption (SEC). BEE-certified Energy Manager (EM) and Energy Auditor (EA): qualifications, eligibility, accreditation process, statutory duties and responsibilities under EC Act 2001. Measurement instruments: energy analysers (IEC 61557-12 and IS 15884), clamp meters, data loggers, IR thermographic cameras, lux meters, power quality analysers. Measurement of: kWh, kVAh, kVArh, power factor, load factor, demand factor. Sub-metering surveys and feeder loss estimation. Energy audit report structure as per BEE format. Numerical problems on energy consumption analysis and benchmarking.	09	20
3.	**Power Quality Assessment and Improvement** Power quality — definition, importance and financial cost of poor power quality. Voltage sags/swells: causes and classification (IEEE 1159). Harmonics: generation by non-linear loads (VFDs, UPS, rectifiers), Total Harmonic Distortion (THD), harmonic spectrum; limits as per IEEE 519-2022, IEC 61000-3-2, IEC 61000-3-12. Harmonic filters — passive, active, hybrid. Voltage unbalance: causes and effects on motors (IEC 60034-26). Flicker: PST, PLT; IEC 61000-4-15. Power factor improvement: effect on losses and tariff penalty; capacitor bank sizing and placement (IS 13925 / IEEE 18); Automatic Power Factor Controllers (APFC). Power quality measurement instruments: Class A analysers per IEC 61000-4-30.	08	18
4.	**Energy Efficiency of Electrical Equipment and Systems** Electric motors: efficiency classes IE1–IE4 (IS 12615 / IEC 60034-30-1); right-sizing; efficiency testing (IEEE 112); motor rewinding losses. Variable Frequency Drives (VFD): energy savings, selection criteria and harmonic impact. Pumps and fan systems: affinity laws, system curve, Best Efficiency Point (BEP); specific energy consumption; audit methodology (IS 9137). Distribution transformers: energy-efficient amorphous-core types (IS 1180); K-factor transformers for non-linear loads; loading optimization. (Note: transformer loss theory is not re-taught here; only audit-relevant assessment is covered.) Lighting systems: luminous efficacy (lm/W), BEE star rating for LED luminaires; lux-level audit; ECBC lighting power density requirements	09	20

	(IS 3646). HVAC systems: EER, COP and ISEER ratings; BEE star labels; chiller and split-AC energy audit (secondary reference for electrical audit context only).		
5.	**Demand-Side Management, Supply-Side Efficiency and Grid Technologies** Demand-Side Management (DSM): objectives and strategies — load levelling, valley-filling, load shifting, peak-load management; Time-of-Day (ToD) tariff and smart metering (IS 16444); prepaid metering. Smart grid: Advanced Metering Infrastructure (AMI), demand response, Volt/VAR optimization. Power distribution feeder audit: feeder-level loss calculation, capacitor placement optimization, reconductoring economics. Renewable energy integration — overview: rooftop solar PV energy yield estimation (CUF, performance ratio); net metering (Gujarat policy, IS 16221); Battery Energy Storage Systems (BESS) for peak-shaving (IEC 62933); financial analysis: LCOE, simple payback, NPV, IRR. Non-Fossil Consumption Obligation (RCO) for designated consumers (EC Amendment Act 2022).	07	16
6.	**Renewable Energy Integration and Energy Storage for Audit and Management** Rooftop and ground-mount Solar PV systems: components, MNRE/SECI guidelines; grid-connection as per CEA regulations and CEIG norms; IS 16221, IEC 61730, IEC 61215 (PV module testing); net metering, gross metering — Gujarat net metering policy. Wind energy: capacity factor, wind resource assessment; integration issues; IS 61400 series. Battery Energy Storage Systems (BESS): technology comparison (Li-ion, flow batteries, lead-acid); Non-Fossil Consumption Obligation (RCO) compliance for designated consumers under EC Amendment Act 2022. Green hydrogen (introductory) and its role in industrial energy management.	04	08
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks					
RLevel	**ULevel**	**ALevel**	**NLevel**	**ELevel**	**CLevel**

10	0	20	20	10	10

Where, R:Remember; U:Understanding; A:Application, N:Analyzeand E:Evaluate C:Create (as per Revised Bloom'sTaxonomy)

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 above table.

References/SuggestedLearningResources:

Books:

1. W.R. Murphy & G. McKay, Energy Management (1st ed.), Butterworth-Heinemann / Elsevier, 2007.
2. B.K. De, Energy Management, Audit and Conservation (2nd ed.), Vrinda Publications, 2010.
3. Bureau of Energy Efficiency (BEE), Guide Books for Energy Auditors (Vols. 1–4) — available free at beeindia.gov.in (standard reference for BEE EA/EM examinations).
4. S.C. Tripathy, Electric Energy Utilization and Conservation, Tata McGraw-Hill, New Delhi (latest edition).
5. G.G. Khaparde & V. John, Harmonics and Power Systems, Springer, 2007.
6. W.C. Turner & S. Doty, Energy Management Handbook (7th ed.), Fairmont Press, 2009.
7. Roger C. Dugan et al., Electrical Power Systems Quality (3rd ed.), McGraw-Hill, 2012.
8. L.C. Witte, P.S. Schmidt & D.R. Brown, Industrial Energy Management and Utilisation (1st ed.), Hemisphere Publication, 1988.
9. Patrick, Patrick & Fardo, Energy Conservation Guidebook (1st ed.), Prentice Hall, 1993.
10. J. Douglas Balph, Power Factor Correction Handbook, ON Semiconductor, 2014.
11. E.I. Levi, Polyphase Motors: A Direct Approach to their Design, Wiley, 1985 (motor efficiency reference).
12. IEA, Energy Efficiency 2023 Report, International Energy Agency, Paris, 2023.

Design based Problems (DP)/PBL/Open Ended Problem:

1. Design of a capacitor bank (fixed + automatic stages) for power factor correction of an industrial plant with mixed loads; include protection scheme and cost-benefit analysis.
2. Design and sizing of a rooftop solar PV + BESS system for a 500 kVA industrial facility in Ahmedabad for peak-shaving and net metering; compute LCOE, payback period, and NPV.
3. Prepare an Investment-Grade Energy Audit Report (ASHRAE Level II equivalent) for a selected industry (cement, textile, ceramic or pharma sector in Gujarat) with identification of at least five electrical ECOs and PAT compliance roadmap.
4. Propose a Volt/VAR Optimisation (VVO) scheme for a radial 11 kV distribution feeder; simulate using any power systems tool (PSCAD / ETAP / PowerWorld) and estimate annual energy loss reduction.
5. Evaluate harmonic mitigation strategies for a 100 kW VFD-driven pump station: compare passive filter, active filter and 18-pulse rectifier options on cost, performance and IEEE 519-2022 compliance.

Note: Problems may be solved using hand calculations, MATLAB, ETAP, Homer, PVsyst or similar licensed/open-source simulation tools.

List of Open-Source Software/learning website:

Open-source software:

1. MATLAB / Simulink (MathWorks) — https://www.mathworks.com
2. Homer Pro (Renewable energy system design) — https://www.homerenergy.com
3. PVsyst (Solar PV design and simulation) — https://www.pvsyst.com
4. OpenDSS (Distribution System Simulation) — https://sourceforge.net/projects/electricdss/
5. ETAP (Power systems analysis) — https://www.etap.com (educational licence)
6. GNU Octave — https://www.gnu.org/software/octave/

Web / Digital Resources

Government and Regulatory Portals

1. Bureau of Energy Efficiency — https://beeindia.gov.in (Energy Audit resources, PAT data, BEE tools)
2. Ministry of Power, India — https://powermin.gov.in (EC Act, DSS, national policies)
3. MNRE — https://mnre.gov.in (solar / wind grid integration guidelines)
4. GEDA Gujarat — https://geda.gujarat.gov.in (state-level renewable energy policy)
5. GERC — https://www.gercin.org (tariff orders, net metering regulations)
6. Central Electricity Authority — https://cea.nic.in (grid standards, load generation balance report)

NPTEL / SWAYAM Courses

1. NPTEL: Energy Efficiency, Acoustics and Daylighting in Buildings — https://nptel.ac.in
2. NPTEL: Power Electronics — (for understanding inverter-based power quality aspects)
3. NPTEL: Power System Analysis — (for distribution loss estimation context)
4. BEE e-learning portal: https://beeindia.gov.in/content/energy-auditors

Standards Bodies

1. IEEE Xplore Digital Library — https://ieeexplore.ieee.org
2. IEC Standards — https://www.iec.ch
3. Bureau of Indian Standards — https://www.bis.gov.in

SDGs Relevant to Energy Audit & Management

SDG	Goal Title	Connection to Energy Audit & Management Syllabus
SDG 3	Good Health & Well-Being	Safe handling of electrical equipment; lab safety protocols during energy audits
SDG 4	Quality Education	BEE mock exams, NPTEL/BEE e-learning, simulation-based practicals, self-learning activities
SDG 7	Affordable & Clean Energy	Entire course — energy auditing, RE integration, demand-side management, energy efficiency
SDG 8	Decent Work & Economic Growth	BEE-certified Energy Auditor/Manager careers; PAT scheme compliance in industry
SDG 9	Industry, Innovation & Infrastructure	Motor efficiency (IE4), smart metering (AMI), FACTS devices, grid modernisation
SDG 11	Sustainable Cities & Communities	ECBC building energy codes, smart grid/DSM for urban feeders, lux-level audits in buildings
SDG 12	Responsible Consumption & Production	SEC benchmarking, load profiling, VFD adoption, transformer optimisation, AT&C loss reduction
SDG 13	Climate Action	EC Act 2022 carbon credits, COP-26 commitments, RE integration, NMEEE, green hydrogen
SDG 17	Partnerships for the Goals	Industry–institution linkage via BEE, GEDA, GERC; international standards (IEC/IEEE/ISO)

Activities Suggested for Self-Learning:

Sl. No.	PBL Activity	Activity	Hours	Evaluation Criteria
1	Industry / Research Laboratory Visit	Industry Visit: Conduct a walk-through energy audit of a nearby industrial unit (textile, pharma, ceramics, engineering) or electricity distribution substation. Document electrical load inventory, meter readings, and preliminary energy conservation opportunities (ECOs).	Visit=5h, Report=5h, Total=10h	Quality of one-line diagram sketched, completeness of load inventory, clarity of ECO identification, adherence to BEE audit format.
2	Survey & Mirco Project	Power Quality Measurement Campaign: Use portable PQ analyser (or simulated data) to conduct a 24-hour power quality survey of the institute's electrical installation; prepare report with IEEE 519-2022 compliance assessment and	Measurement=5h, Report=5h, Total=10h	Accuracy of captured parameters, correct application of IEEE 519 limits, quality of mitigation

		recommendations.		recommendations.
3	Assignment/ Technical Writing / Research Writing	Numerical Assignments: Minimum 5 assignments covering — tariff analysis, power factor correction sizing, motor energy savings calculation (VFD vs. DOL), transformer all-day efficiency, harmonic filter design, solar PV yield estimation, NPV/IRR of ECO.	5 × 2h = 10h	Correctness of methodology, application of appropriate standards, logical presentation.
4	Complex Problem-Solving targeting relevant SDGs. / Mini Project	Simulation Task: Model and simulate a power distribution feeder with capacitor placement in OpenDSS or ETAP; compare losses before and after VAR compensation. Alternatively, simulate harmonic spectrum and passive filter design in MATLAB/Simulink.	5 × 2h = 10h	Simulation accuracy, proper interpretation of results, correct use of software tools, documentation quality.
5	MOOC Course	Online Certification: Complete at least 10 hours of an online course related to energy audit, power quality, renewable energy or smart grid (NPTEL, Coursera, edX, BEE e-learning platform).	10h	Certificate of completion + quiz/viva on course content.
6	Seminar / Poster Presentation	Technical Seminar / Poster Presentation: Prepare and present a 10-minute seminar or technical poster on a current topic — examples: 'Impact of EV Charging on Grid Power Quality', 'Rooftop Solar + BESS for SMEs in Gujarat', 'Carbon Credit Trading under EC Act 2022', 'IE4/IE5 Motor Adoption Roadmap in India'.	Research=5h, Preparation=5h, Total=10h	Technical accuracy, use of standards and data, communication clarity, response to questions.
7	BEE Mock Examination	BEE EA / EM Mock Examination: Attempt one full-length mock examination of BEE Energy Auditor (Paper I or Paper II) under examination conditions; review answers with faculty.	5h	Score and quality of review noting error patterns, identification of weak areas for improvement.
8	Patent Search / Literature Review	Patent / Literature Review: Search 5–8 recent patents or IEEE/Scopus papers on a chosen topic (e.g., smart energy metering, demand response algorithms, AI-based energy forecasting, advanced APFC controllers); prepare a one-page annotated bibliography.	10h	Relevance of papers selected, quality of critical analysis, identification of research gaps.

Note:
Notes: (i) All activities must be directly related to electrical energy audit and management. (ii) Suggestive hours may be redistributed by faculty, but total hours are fixed. (iii) Evaluation rubrics shall be prepared and displayed by the concerned 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. (vi) In alignment with Outcome-Based Education (OBE) and NBA accreditation requirements, the subject Energy Audit and Management 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 in practical applications of Energy Audit and Management. 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. (vii) The hours allocated to specific activities should be proportionate to the total no. of PBL hours and marks.

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