SCHEME :K

Name :________________________________
Roll No.:__________ Year : 20 ___ 20 __
Exam Seat No. :_______________________

LABORATORY MANUAL FOR

ENERGY CONSERVATION AND AUDIT (316327)

ELECTRICAL ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
(Autonomous)(ISO21001:2018)(ISO/IEC27001:2013)

VISION:

To ensure that the Diploma Level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION:

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

QUALITY POLICY:

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programs.

CORE VALUES:

MSBTE believes in the following:

- Education industry produces live products.
- Market requirements do not wait for curriculum changes.
- Question paper is the reflector of academic standards of education organization.
- Well designed curriculum needs effective implementation too.
- Competency based curriculum is the backbone of need based program.
- Technical skills do need support of life skills.
- Best teachers are the national assets.
- Effective teaching learning process is impossible without learning resources.

A Laboratory Manual

For

ENERGY CONSERVATION AND AUDIT

(316327)

SEMESER - VI

"K-SCHEME"

(EE/EP)

Maharashtra State
Board of Technical Education, Mumbai.

(Autonomous) (ISO: 21001:2018) (ISO/IEC 27001:2013)

Maharashtra State Board of Technical Education, Mumbai
(Autonomous) (ISO21001:2018) (ISO/IEC 27001:2013)
4th Floor, Government Polytechnic Building, 49, Kherwadi,
Bandra (East), Mumbai – 400051,

Maharashtra State
Board of Technical Education, Mumbai.

Certificate

This is to certify that Mr. / Ms. ……………………………………………

Roll No……………, of Sixth semester of Diploma in ……………………………………………………………………….... of Institute……………………………………………………………..…………… ……………………………… (Code :……….) has completed the term work satisfactorily in course **Energy Conservation and Audit (316327)** for the academic year 20…… to 20…… as prescribed in the curriculum**.**

Place: ……………

Enrollment No: ………………..

Date: …………….

Exam. Seat No: …………………

Course teacher

Head of the Department

Principal

Seal of Institution

PREFACE

The primary focus of any engineering laboratory/ field work in the technical education system is to develop the much-needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programs with outcome-based education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher, instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome- based curriculum, every practical has been designed to serve as a ‘vehicle’ to develop this industry identified competency in every student. The practical skills are difficult to develop through ‘chalk and duster’ activity in the classroom situation. Accordingly, the 'K' scheme laboratory manual development team designed the practical to focus on the outcomes, rather than the traditional age-old practice of conducting practical to ‘verify the theory’ (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the relevant theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

The subject Energy Conservation and Audit plays a vital role in shaping an electrical diploma engineer into an efficient industry professional. In modern industries, reducing energy wastage, improving system efficiency, and ensuring economical operation are essential responsibilities. This subject equips students with the skills required to assess energy usage, identify losses, carry out electrical load surveys, analyze equipment efficiency, and recommend practical conservation measures. Through hands-on laboratory work and audits, students learn to apply energy-efficient practices, interpret performance data, and implement corrective actions that support sustainable and cost-effective industrial operation.

Although best possible care has been taken to check for errors (if any) in this laboratory manual, perfection may elude us as this is the first edition of this manual. Any errors and suggestions for improvement are solicited and highly welcome.

Programme Outcome (POs) to be achieved through Practical

PO 1. Basic & Discipline specific knowledge: Apply knowledge of basic mathematics, sciences and engineering fundamentals and engineering specialization to solve the engineering problems.

PO 2. Problem Analysis: Identify and analyze well defined engineering problems using codified standard methods.

PO 3. Design /Development Solutions: Design solutions for well-defined technical problems and assist with the design of systems components or processes to meet specified needs.

PO 4. **Engineering tools experimentation and testing:** Apply modern engineering tools and appropriate technique to conduct standard tests and measurements.

PO 5. Engineering practices for society sustainability and environment: Apply appropriate technology in context of society, sustainability, environment and ethical practices.

PO 6. **Project Management:** Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

PO 7. Lifelong learning: Ability to analyze individual needs and engage in updating in context of technological changes.

List of Relevant expected psychomotor domain Skills

This Lab manual intends to develop expected psychomotor domain skills of students. The skills mentioned below will be developed through the experiments performed in this Laboratory.

1. Ability to make correct electrical connections and use measuring instruments.
2. Ability to measure and compare electrical and illumination parameters.
3. Ability to select and operate capacitor banks for power factor improvement.
4. Ability to conduct basic energy audit tests and identify energy losses.
5. Ability to record, tabulate, and analyze results for efficiency and energy savings.

Guidelines to teachers

1. Teacher should provide the guideline with demonstration of each practical to the students along with all features involved.
2. Teacher shall explain the relevant prior concepts before starting each practical to ensure conceptual clarity.
3. Involvement of students during the execution of every practical is essential for better understanding.
4. Teacher should ensure that the intended skills and competencies are actually developed in students after completing the practical exercise.
5. Teachers should give students opportunities for hands-on practice after the demonstration to build confidence.
6. It is expected that the teacher explains the skills and competencies to be developed before starting the practical.
7. Additional industry-relevant knowledge and skills may be provided even if they are not explicitly mentioned in the manual.
8. Finally, a practical assignment should be given, and student performance should be assessed to verify whether the outcome matches the instructions given.

Instructions to Students

1. Organize your work in groups effectively and maintain records of all performed tasks and programs.
2. Students shall strive to develop maintenance-related skills as expected by industries.
3. Attempt to develop relevant hands-on skills during the practical sessions to gain technical confidence.
4. Cultivate the habit of generating new ideas, innovations, and related skills that extend beyond the scope of the manual.
5. Refer to technical magazines and literature to stay updated with current advancements in the field.
6. Submit your practical work on or before the scheduled date and time without fail.
7. Be well-prepared and thorough when submitting the write-up of any exercise.
8. Attach or paste extra sheets wherever required to explain diagrams, calculations, or observations clearly.

Practical Course Outcome matrix

Course Outcomes (COs)

- CO1 - Interpret energy conservation policies in India.
- CO2 - Implement energy conservation techniques in electrical machines.
- CO3 - Apply energy conservation techniques in electrical installations.
- CO4 - Use Co-generation and relevant tariff for reducing losses in facilities.
- CO5 – Carryout energy audit for electrical system.

Pr. No.	Title of the Practical	Mapped Course Outcome				
		CO 01	CO 02	CO 03	CO 04	CO 05
01	*Identification of star labelled electrical appliances/equipment and compare data sheets of various star labelled ratings.	√	--	--	--	--
02	Comparison of energy consumption in a green building with a conventional building using energy conservation instruments.	√	--	--	--	--
03	*Determination of reduction in power consumption in star mode operation of 3 phase Induction motor compared to delta mode.	--	√	--	--	--
04	*Performance of load test on three phase induction motor for different loading conditions and plot the curve.	--	√	--	--	--
05	Comparison of energy conserved in two identical transformers where one is a single phase transformer and the other one comprises of two single phase transformers in parallel operation. (For the same load).	--	√	--	--	--
06	Power factor improvement using APFC.	--	√	√	--	--
07	Power factor improvement using static capacitor.	--	√	√	--	--
08	Power factor improvement using IPFC.	--	√	√	--	--
09	*Comparison of power consumption of different types of Tube Light with choke, electronic ballast and LED lamps by direct measurement.	--	--	√	--	--
10	*Comparison of reduction in power by replacement of lamps in a classroom / laboratory by energy efficient lamps.	--	--	√	--	--
11	Tariff for industrial consumer for reducing the electricity bill.	--	--	--	√	--
12	Tariff for commercial consumer for reducing the electricity bill.	--	--	--	√	--

13	*Tariff for residential consumer for reducing the electricity bill.	--	--	--	√	--
14	Estimation of Energy saved by improving power factor and load factor for given case.	--	--	√	√	--
15	Preparation of Energy audit questionnaire for the given facility.	--	--	--	--	√
16	*Preparation of Energy audit report of electrical department.	--	--	--	--	√
17	Comparison of energy consumption using DOL, star delta and soft starter in a three-phase induction motor.	--	√	--	--	--
18	Energy audit using energy audit software such as SafetyCulture (formally iAuditor), EnergyCAP or any other equivalent software.	--	--	--	--	√

Content page

List of Practical's and Formative Assessment sheet.

Pr. No	Title of the Practical	Page No.	Date of performance	Date of Submission	Assessment marks	Dated sign of teacher	Remarks (if any)
12	Tariff for commercial consumer for reducing the electricity bill.	70					
13	*Tariff for residential consumer for reducing the electricity bill.	77					
14	Estimation of Energy saved by improving power factor and load factor for given case.	84					
15	Preparation of Energy audit questionnaire for the given facility.	91					
16	*Preparation of Energy audit report of electrical department.	98					
17	Comparison of energy consumption using DOL, star delta and soft starter in a three-phase induction motor.	105					
18	Energy audit using energy audit software such as SafetyCulture (formally iAuditor), EnergyCAP or any other equivalent software.	114					
Total marks :							

Note : Out of above suggestive LLOs

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

Practical No.1: Identification of star labelled electrical appliances/equipment and compare data sheets of various star labelled ratings.

I. Practical Significance-

Every diploma electrical engineer must have knowledge of energy consumption of the appliances they use. Identifying suitable star-labelled appliances helps in comparing energy efficiency and running costs while purchasing new equipment. Using energy-efficient appliances reduces carbon emissions, conserves energy resources, and contributes to environmental protection.

II. Industry or Employer Expected Outcome-

Student can identify energy-efficient appliances, interpret BEE labels, compare models, estimate energy cost, and recommend suitable equipment for procurement.

III. Course Level Learning Outcome-

Interpret energy conservation policies in India.

IV. Laboratory Learning Outcome-

LLO 1.1 Identify star labelled appliances and compare them for various star ratings.

LLO 1.2 Compare the data sheet of various star rating appliances.

V. Relevant Affective domain related Outcome

Adopt energy-efficient practices and promote energy conservation.

VI. Relevant Theoretical Background

The Bureau of Energy Efficiency (BEE) provides star ratings to electrical appliances based on their energy efficiency. Appliances with higher star ratings consume less power for the same performance, resulting in lower electricity bills and reduced environmental impact. The star label includes details like rated power, annual energy consumption, and efficiency parameters, helping consumers compare models before purchase. By analyzing data sheets of various star-rated appliances, one can estimate energy savings, operational cost, and select the most energy-efficient option suitable for domestic or industrial use.

VII. Actual Diagram with equipment specification

Paste photos or sketches of any one appliance showing the BEE label and its location; mention make/model, rated voltage, power, and capacity (L/tonnes/kg).

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	Catalogues by different manufacturers of Refrigerators	Three, Four and Five Star	01 each	
2	Catalogues by different manufacturers of Televisions	Three, Four and Five Star	01 each	
3	Catalogues by different manufacturers of Air conditioners	Three, Four and Five Star	01 each	
4	Calculator/Spreadsheet	MS Excel/Google Sheets	1	For computations

IX. Precautions to be followed

1. Ensure appliances are disconnected from supply before noting label details.
2. Do not open or tamper with any appliance to access the label.
3. While comparing two models, ensure they are manufactured in the same year and have the same size or capacity.

X. Procedure

1. Collect three catalogues of the appliance from different manufacturers with the same size/capacity and year of manufacturing.
2. Observe the star label on each appliance and note down the annual energy consumption (kWh/year).
3. Record the purchase cost of each appliance.
4. Calculate the annual running cost using:
$$\text{Annual Running Cost (₹)} = \text{Energy Consumption (kWh/year)} \times \text{Tariff (₹ per kWh)}$$
5. Calculate the annual interest on the purchase cost using:
$$\text{Annual Interest (₹)} = \text{Purchase Cost (₹)} \times \frac{\text{Rate of Interest (\%)}}{100}$$
6. Add annual interest to annual running cost to get total yearly expenses:
$$\text{Total Yearly Expenses (₹)} = \text{Annual Running Cost} + \text{Annual Interest}$$
7. Assume a reasonable life span for the appliance (years).
8. Multiply total yearly expenses by the life span to get life term expenses:
$$\text{Life Term Expenses (₹)} = \text{Total Yearly Expenses} \times \text{Life Span (years)}$$
9. Add purchase price to life term expenses to get life term cost:
$$\text{Life Term Cost (₹)} = \text{Life Term Expenses} + \text{Purchase Price}$$
10. Compare appliances and identify the most cost-effective option.
11. Repeat the above steps for other electrical appliances.

XI. Observation Table

Sr. No.	Appliance / Equipment	Manufacturer	Star Rating	Annual Energy Consumption (kWh)	Purchase Cost (₹)	Annual Running Cost (₹)	Annual Interest (₹)

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. Explain the significance of the BEE star rating on electrical appliances.
2. List and describe the factors to consider when comparing star-rated products.
3. Identify the appliances for which energy labeling is mandatory.
4. Define the term EER mentioned on the star label of an air conditioner and explain its importance.

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	BEE Star Label Guide	Official guidance on star ratings and label fields.

2	Manufacturer Product Data Sheet	Model-specific performance and energy data.
3	Local Electricity Tariff Document	₹/kWh rate used for annual cost calculation.

XVII. Suggested Assessment Scheme

Performance Indicators		Weightage (%)
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%
Product related: 10 Marks		**40%**
1	Interpretation of result	10%
2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			Dated Sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.2: Comparison of energy consumption in a green building with a conventional building using energy conservation instruments.

I. Practical Significance-

Every diploma electrical engineer must understand the difference in energy performance between green and conventional buildings. Measuring and comparing energy consumption using conservation instruments helps in identifying efficient systems and practices. Such knowledge promotes the adoption of sustainable designs, reduces operational energy costs, and supports environmental conservation.

II. Industry or Employer Expected Outcome-

Student can measure, compare, and analyze energy performance of buildings to recommend energy-efficient and sustainable solutions.

III. Course Level Learning Outcome-

Interpret energy conservation policies in India.

IV. Laboratory Learning Outcome-

LLO 2.1 Compare energy consumed by a green building with that of a conventional building.

LLO 2.2 Use energy conservation instruments to measure the various electrical parameters.

V. Relevant Affective domain related Outcome

Develop awareness of sustainable building practices and encourage efficient use of energy resources.

VI. Relevant Theoretical Background

A green building is designed to use resources efficiently by incorporating energy-saving technologies such as LED lighting, efficient HVAC systems, natural ventilation, and renewable energy sources. In contrast, a conventional building typically relies on higher energy-consuming systems. Measuring parameters like lighting load, temperature, and power factor using energy audit instruments helps compare total energy consumption. This comparison highlights how design, materials, and equipment selection influence overall energy efficiency and sustainability.

VII. Actual Diagram with equipment specification

Attach simplified floor layout of both buildings/areas showing measurement points (lighting, HVAC, plug loads). Include instrument specs (range/accuracy).

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	Portable Energy Meter / Power Analyzer	Single-phase, digital display	1	
2	Clamp-on Ammeter	True RMS, 0–100 A	1	
3	Voltmeter / Multimeter	0–600 V	1	
4	LED lamps and Fluorescent lamps	10 W and 40 W	As required	
5	Fan and Air Conditioner (optional)	—	As available	
6	Stopwatch / Timer	Digital	1	
7	Lux Meter	0–200,000 lx	1	

IX. Precautions to be followed

1. Ensure all connections are tight and properly insulated.
2. Use only calibrated measuring instruments.
3. Avoid touching live parts during measurement.
4. Record readings at equal intervals of time.
5. Maintain identical load and time period for both conditions.

X. Procedure

1. Select a conventional classroom or laboratory for the experiment.
2. Connect the load circuit (lighting, fan, and plug loads) through a portable energy meter or power analyzer.
3. Step A – Conventional Condition:
   - Switch ON fluorescent lamps and fans as normally used.
   - Close windows or blinds to limit natural light.
   - Keep all plug loads in use.
   - Record voltage, current, power, and energy readings for a fixed duration (e.g., 30 minutes).
4. Step B – Simulated Green Building Condition:
   - Replace fluorescent lamps with LED lamps.
   - Increase natural illumination by opening windows or reducing artificial lighting.
   - Reduce unnecessary plug loads.
   - Adjust fan or AC thermostat for moderate comfort (e.g., 26°C).
   - Record voltage, current, power, and energy readings for the same duration.
5. Tabulate readings for both cases.
6. Calculate total energy consumption and percentage energy saving.
7. Compare results and discuss reasons for observed differences.

XI. Observation Table

Sr.No.	Parameter	Conventional Condition	Simulated Green Condition
1	Voltage (V)		
2	Current (A)		
3	Power (W)		
4	Time of operation (h)		
5	Energy consumed (kWh)		

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

<u>Note</u>: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. State any three features of a green building.
2. Why are LED lamps more efficient than fluorescent lamps?
3. Calculate the percentage energy saving if energy consumption reduces from 0.40 kWh to 0.25 kWh.
4. List any two non-energy benefits of a green building.

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	Energy Audit Handbook (Buildings)	Methods for EPI/LPD measurement and benchmarking.
2	Manufacturer Data Sheets	Lighting/HVAC efficiency parameters.
3	Utility Tariff Document	₹/kWh rates for cost comparison.

XVII. Suggested Assessment Scheme

Performance Indicators		Weightage (%)
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%
Product related: 10 Marks		**40%**
1	Interpretation of result	10%
2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			Dated Sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.3: Determination of reduction in power consumption in star mode operation of 3 phase Induction motor compared to delta mode.

I. Practical Significance-

Every diploma electrical engineer must understand the difference in power consumption of a three-phase induction motor in star and delta modes. Using a star connection for oversized or lightly loaded motors helps reduce current and conserve energy without replacement. This knowledge promotes efficient motor operation and supports energy-saving practices in industrial systems.

II. Industry or Employer Expected Outcome-

Student can measure, compare, and analyze motor performance in star and delta modes to recommend energy-efficient starting methods and operational practices for industrial applications.

III. Course Level Learning Outcome-

Implement energy conservation techniques in electrical machines.

IV. Laboratory Learning Outcome-

LLO 3.1 Perform an experiment on three phase induction motor both in star and delta mode.

LLO 3.2 Measure the effect of voltage reduction in power consumption.

V. Relevant Affective domain related Outcome

Develop awareness of efficient motor operation practices and encourage responsible use of electrical energy in industrial applications.

VI. Relevant Theoretical Background

A three-phase induction motor can be connected in either star (Y) or delta (Δ) configuration. In delta connection, each phase of the motor receives full line voltage, resulting in higher starting current and torque. In star connection, the phase voltage is reduced to $V_L / \sqrt{3}$, thereby reducing the starting current and torque to approximately one-third of that in delta mode.

Star–delta starting is a common method used to limit inrush current during motor starting, minimizing voltage dips and mechanical stress. Once the motor attains sufficient speed, the connection is changed to delta for normal operation. Understanding these relationships between voltage, current, torque, and power helps in selecting suitable starting methods and conserving energy, especially when motors operate at light or partial loads.

VII. Actual Diagram with equipment specification

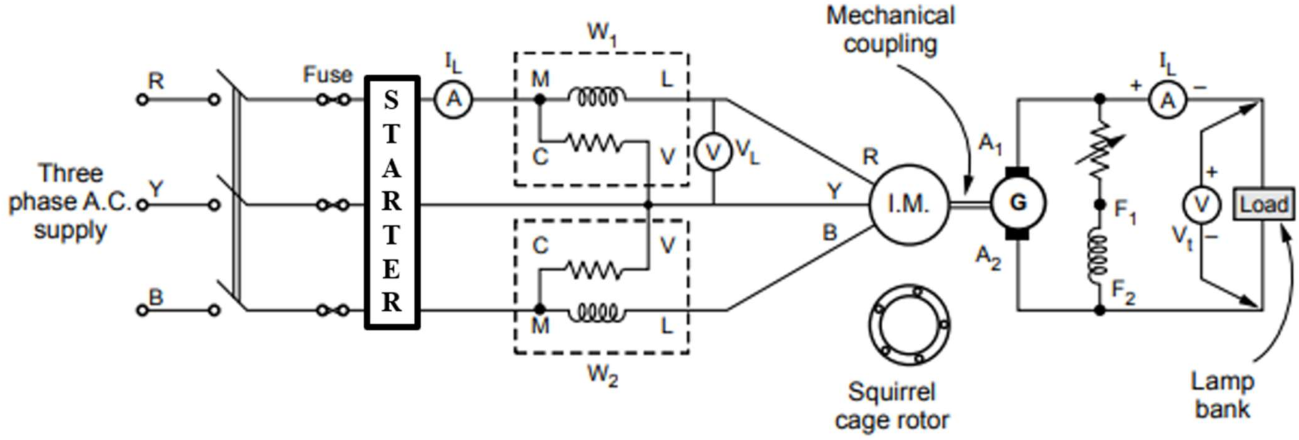

Fig.3.1: Star–Delta Starter Experimental Setup for 3-Phase Induction Motor

This is a suggested setup. Any other alternative with facility to load (and read the load) the induction motor from no load to full load may be used.

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	Three phase Induction motor	3hp,415 V	01	
2	Star-Delta converter	Suitable for the above motor	01	
3	Lamp bank	5 kW	01	
4	Wattmeter	Single phase 5/10Amp, 250/500V, 1500W	02	
5	AC Voltmeter	0-500 V	01	
6	AC Ammeter	0-10 A	01	
7	DC Voltmeter	0-300 V	01	
8	DC Ammeter	0-20 A	01	
9	Rheostat	800 Ohms,1A	01	

IX. Precautions to be followed

1. Ensure the main switch is ‘OFF’ while making connections.
2. Keep the load and starter ‘OFF’ before switching ON the supply.
3. Do not touch live or rotating parts during operation.
4. Apply load gradually and avoid overloading the motor.

X. Procedure

1. Make the connections as per the circuit diagram shown in Fig. 3.1.
2. Keep the main switch and load in the ‘OFF’ position before starting.

3. Switch ON the supply and start the motor in delta mode using the star–delta starter.
4. Note down the readings of voltmeter, ammeter, and wattmeter (or power analyzer) at no load.
5. Gradually apply mechanical load using the Prony brake up to about 30% of full load.
6. For each load step, record all meter readings.
7. Now change the connection of the motor to star mode using the converter or starter.
8. Repeat steps 4 to 6 for star connection.
9. After taking all readings, gradually remove the load and allow the motor to stop.
10. Switch OFF the supply and ensure the setup is safe.

XI. Observation Table

Rated power of the Induction motor, Wr = __________kW

Full load efficiency of Induction motor, ηm = ________(As per name plate details)

Full load efficiency of Generator, ηg = ________(As per name plate details)

	Motor Side			**Generator Side**			**Percentage Loading**	**Efficiency of Induction Motor =** W_{out} / W_{in}
	V_{in} **(Volts)**	I_{in} **(Amp)**	W_{in} **(**$W_1 + W_2$**) (Watts)**	V_{out} **(Volts)**	I_{out} **(Amp)**	$W_{out} = (V_{out}I_{out})/\eta g$ **(Watts)**		
Delta Mode of Operation								
Star Mode of Operation								

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. List the energy conservation techniques in Induction motors.
2. List any two advantages and two limitations of star starting.
3. What will happen if the motor is kept running continuously in star mode under full load?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	Electrical Machines Text / IM Theory	Star–Delta relations, torque–voltage dependency.
2	Two-Wattmeter Method	Measurement of 3-ϕ power and PF.
3	Energy-Efficient Motor Operation Guides	Best practices for low-load operation.

XVII. Suggested Assessment Scheme

Performance Indicators		Weightage (%)
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%
Product related: 10 Marks		**40%**
1	Interpretation of result	10%

2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			**Dated Sign of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.4: Performance of load test on three phase induction motor for different loading conditions and plot the curve.

I. Practical Significance-

Every diploma electrical engineer must understand the performance characteristics of a three-phase induction motor under different loading conditions. Measuring parameters such as input power, current, torque, slip, and efficiency helps in analyzing how the motor behaves in real operating environments. This knowledge enables selection and operation of motors at optimum loading, improves energy efficiency, reduces operating costs, and enhances reliability in industrial applications.

II. Industry or Employer Expected Outcome-

Student can conduct load tests on three-phase induction motors, measure input and output quantities at different loading conditions, plot performance curves (efficiency vs load, slip, torque), and use this data to select and operate motors at optimum loading for energy-efficient and reliable industrial applications.

III. Course Level Learning Outcome-

Implement energy conservation techniques in electrical machines.

IV. Laboratory Learning Outcome-

LLO 4.1 Perform load test on three phase induction motor for different loading conditions.

LLO 4.2 Plot the graph of efficiency verses percentage loading of induction motor.

V. Relevant Affective domain related Outcome

Adopt safe practices while performing motor load tests.

VI. Relevant Theoretical Background

A three-phase induction motor works on electromagnetic induction between stator and rotor. During a load test, current, power, torque, and speed are measured at various loads to determine slip, efficiency, and power factor. The performance curves plotted help evaluate the motor's behavior under different loading conditions.

Synchronous speed: $Ns = 120f/P$ (rpm). Slip: $s = (Ns - N)/Ns$.

Mechanical output power: $Pout = (2\pi NT)/60$ (W), where N in rpm, T in N·m.

Efficiency: $\eta = Pout / Pin$.

At increasing load: current increases, PF increases, slip increases; efficiency rises to near rated then drops.

VII. Actual Diagram with equipment specification

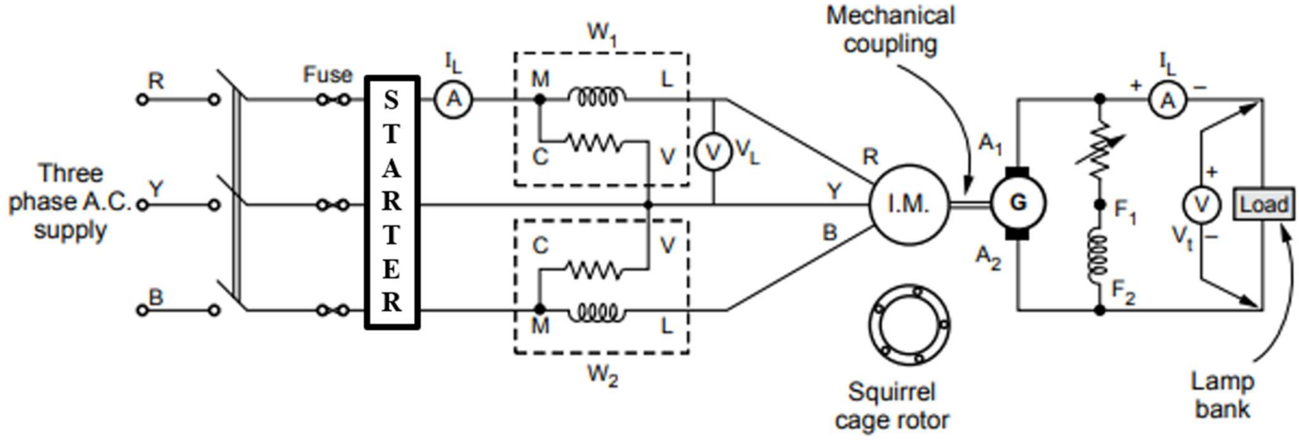

Fig.4.1: Experimental Setup for Load Test on Three-Phase Induction Motor

This is a suggested setup. Any other alternative with facility to load (and read the load) the induction motor from no load to full load may be used.

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	Three phase Induction motor	3hp,415 V	01	
2	Star-Delta converter	Suitable for the above motor	01	
3	Lamp bank	5 kW	01	
4	Wattmeter	Single phase 5/10Amp, 250/500V, 1500W	02	
5	AC Voltmeter	0-500 V	01	
6	AC Ammeter	0-10 A	01	
7	DC Voltmeter	0-300 V	01	
8	DC Ammeter	0-20 A	01	
9	Rheostat	800 Ohms,1A	01	

IX. Precautions to be followed

1. Ensure the main switch is ‘OFF’ while making connections.
2. Keep the load and starter ‘OFF’ before switching ON the supply.
3. Do not touch live or rotating parts during operation.
4. Apply load gradually and avoid overloading the motor.

X. Procedure

1. Make the connections as per the circuit diagram shown in Fig. 4.1.
2. Keep the main switch and load in the ‘OFF’ position before starting.

3. Record nameplate details — rated power (kW), voltage (V), current (A), power factor (cos φ), speed (rpm), and number of poles (P).
   Calculate synchronous speed: Ns=120f / P
4. Make connections as per the circuit diagram. Check wiring, earthing, and ensure no-load condition.
5. Run the motor at no-load and note readings of V, I, P_in, PF, and speed (N).
6. Gradually apply load in steps. At each load, record V, I, Pin, PF, N, and torque (T).
7. Calculate output power, slip, and efficiency for each load.
8. Tabulate the readings and plot the graph of Efficiency (η) vs Percentage Loading.
9. Switch OFF the supply and ensure the setup is safe.

XI. Observation Table

Load %	**V_L (V)**	**I_L (A)**	**P_{in} (kW)**	**kVA**	**PF**	**Speed N (rpm)**	**Torque T (N·m)**	**P_{out} (kW)**	**Slip s (%)**	**η (%)**
0% (No Load)										
25%										
50%										
75%										
100% (Full Load)										

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. Define slip and state its typical range for normal operation.
2. Why does PF improve with load in induction motors?
3. How would voltage unbalance affect the curves?
4. Why does efficiency peak before full-load?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	Electrical Machines Text / IM Theory	Star–Delta relations, torque–voltage dependency.
2	Two-Wattmeter Method	Measurement of 3-ϕ power and PF.
3	Energy-Efficient Motor Operation Guides	Best practices for low-load operation.

XVII. Suggested Assessment Scheme

Performance Indicators		**Weightage (%)**
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%

Product related: 10 Marks		**40%**
1	Interpretation of result	10%
2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			**Dated Sign of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.5: Comparison of energy conserved in two identical transformers where one is a single phase transformer and the other one comprises of two single phase transformers in parallel operation. (For the same load).

I. Practical Significance-

Transformers are a fundamental component in power distribution, and their efficiency has a significant impact on overall system energy losses. A diploma electrical engineer must understand that under varying load conditions, the efficiency of a transformer changes. By operating two smaller transformers in parallel instead of one large transformer, it is possible to optimize the loading on each, potentially operating them closer to their peak efficiency points. For fluctuating loads, one transformer can be switched off during low-demand periods, drastically reducing core losses and conserving energy. This practical demonstrates the principle of energy conservation through optimal transformer operation.

II. Industry or Employer Expected Outcome-

Student will be able to analyze transformer loading, calculate losses and efficiency, understand parallel operation requirements, and recommend energy-efficient transformer configurations for a given load profile, leading to reduced operational costs in industrial and commercial settings

III. Course Level Learning Outcome-

Implement energy conservation techniques in electrical machines.

IV. Laboratory Learning Outcome-

LLO 5.1 Compare energy conserved in two identical transformers where one is a single-phase transformer, and the other one comprises of two single phase transformers in parallel operation (For the same load).

LLO 5.2 Observe the effect of load sharing on energy consumption.

V. Relevant Affective domain related Outcome

Adopt and recommend energy-efficient operational practices in electrical systems.

VI. Relevant Theoretical Background

When a single transformer supplies a load, its total copper losses are proportional to the square of the load current. In parallel operation, each identical transformer shares the load current approximately equally, resulting in lower current per transformer and hence reduced total copper loss.

For two identical transformers:

$$P_{cu(single)} = I^2 R$$

$$P_{cu(parallel)} = 2 \times \left(\frac{I}{2}\right)^2 R = \frac{I^2 R}{2}$$

Thus, total copper loss is halved when two identical transformers operate in parallel for the same load. This improves efficiency and reduces energy wastage.

VII. Actual Diagram with equipment specification

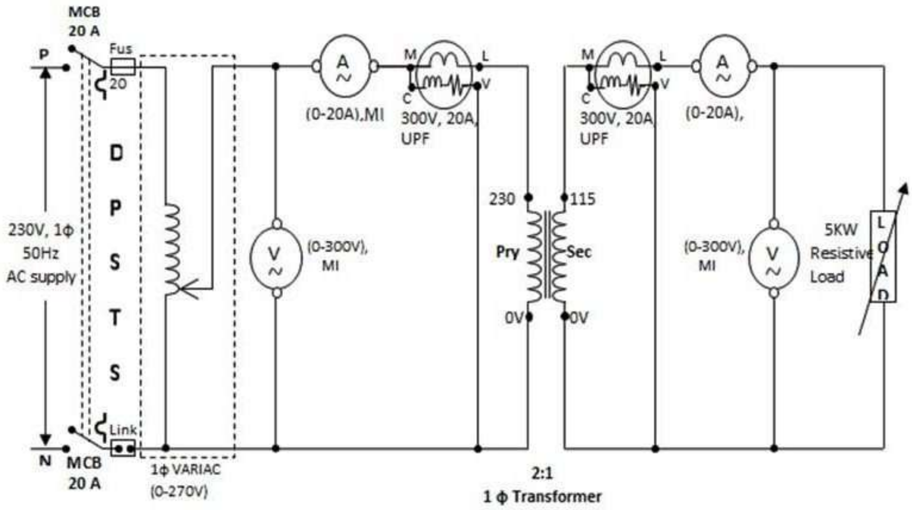

Fig.5.1: Experimental Setup for Single transformer feeding a load.

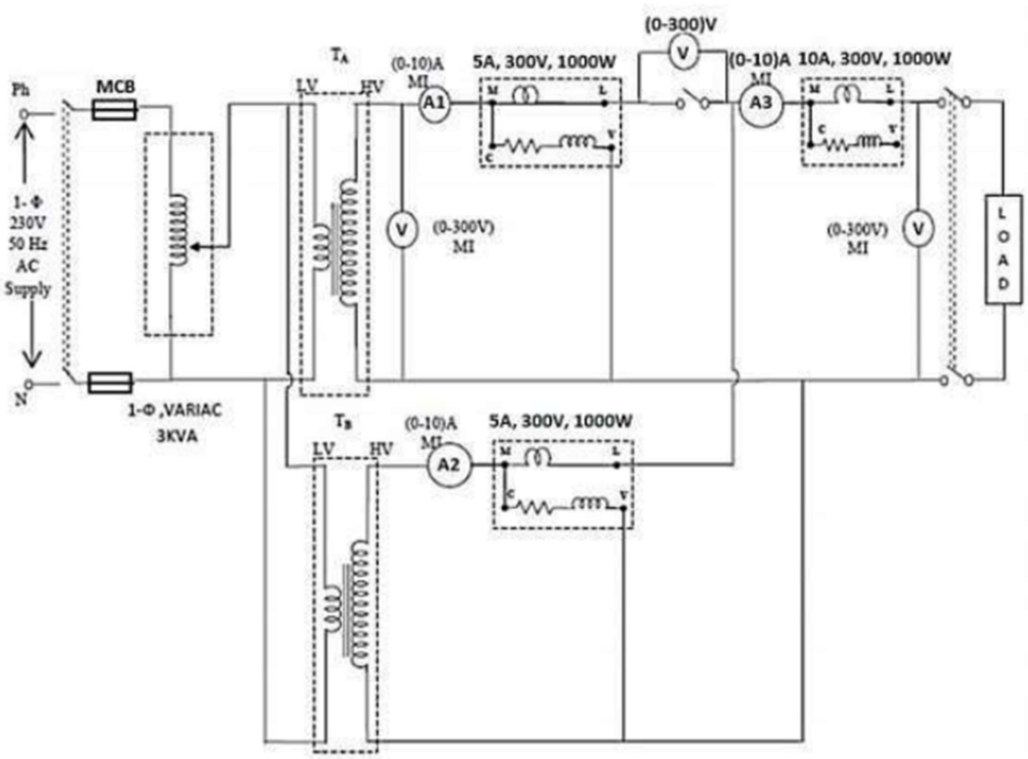

Fig.5.2: Experimental Setup for Two identical transformers connected in parallel feeding the same load.

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	Single-Phase Transformer	2 kVA, 230V/115V	1	
2	Single-Phase Transformers	1 kVA, 230V/115V	2	For parallel operation
3	Variable Resistive Load	0-2 kW	1	
4	AC Voltmeter and Ammeter	--	2 each	
5	Wattmeter	--	2	For input and output power
6	Connecting Wires & Switches	--	As per requirement	

IX. Precautions to be followed

1. Ensure all connections are tight and correct before switching on the supply.
2. Do not exceed the current rating of the transformers.
3. For parallel operation, ensure transformers have the same voltage ratio and polarity before connecting them in parallel.

X. Procedure

A. Test for Single Transformer:

1. Connect the 2kVA transformer to the supply at rated voltage.
2. Apply a specific load (e.g., 25%, 50%, 75%, 100% of full load) using the load bank.
3. For each load point, note the input power (W1), output power (W2) of operation at that load.
4. Calculate efficiency η=Output Power / Input Power × 100% and total losses.

B. Test for Two Transformers in Parallel:

1. Connect the two 1kVA transformers in parallel, ensuring correct polarity and voltage ratio.
2. Apply the same load as in step 1 with both transformers operating.
3. For each load point, note the total input power, output power, and time.
4. For a light load condition (e.g., 25% of total 2kVA load), switch off one transformer. Apply the load to the single 1kVA transformer and note the input power, output power, and time.

C. Calculation of Energy Consumed:

1. For each configuration (Single 2kVA and Parallel 1kVA), calculate the total energy consumed over a hypothetical cycle (e.g., 8 hours at 100% load, 8 hours at 50% load, 8 hours at 25% load).
2. Energy Consumed (kWh) = Input Power (kW) × Time (hours)

XI. Observation Table

A. Observation table for Single Transformer:

Sr. No.	Load (%)	Input Power (W1)	Output Power (W2)	Efficiency (%)	Operation Time (Hours)	Energy Consumed (kWh)
1	25%					
2	50%					
3	75%					
4	100%					

B. Observation table for Two Transformers in Parallel:

Sr. No.	Load (%)	Input Power (W1)	Output Power (W2)	Efficiency (%)	Operation Time (Hours)	Energy Consumed (kWh)
1	25%					
2	50%					
3	75%					
4	100%					

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

<u>Note</u>: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. What conditions must be satisfied for parallel operation of transformers?
2. What are the industrial advantages of using parallel operation of transformers?
3. Why are copper losses reduced when transformers operate in parallel?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	IEEE Std C57.120-1991	Standard for Loss Evaluation of Transformers.
2	"Transformer Engineering" by S.V. Kulkarni and S.A. Khaparde	Book on transformer design and operation.
3	Manufacturer Datasheet for 1kVA and 2kVA Transformers	For rated parameters and loss data.

XVII. Suggested Assessment Scheme

Performance Indicators		Weightage (%)
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%
Product related: 10 Marks		**40%**

1	Interpretation of result	10%
2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			**Dated Sign of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.6: Power factor improvement using APFC.

I. Practical Significance-

Every diploma electrical engineer must analyze the impact of a low power factor in industrial power systems. Operating inductive loads like motors without correction draws excessive reactive power, leading to higher apparent power demand, increased cable losses, and utility penalties. Conducting power factor improvement using a capacitor bank demonstrates how to compensate for this reactive power, reduce line current, and optimize electrical system efficiency. This knowledge is essential for minimizing energy costs, avoiding penalty charges, and enhancing the capacity of existing electrical infrastructure.

II. Industry or Employer Expected Outcome-

Student will be able to analyze low power factor causes, operate an APFC panel, calculate correction capacitance, and maintain a target power factor to optimize plant performance and achieve cost savings.

III. Course Level Learning Outcome-

Implement energy conservation techniques in electrical machines.

Apply energy conservation techniques in electrical installations.

IV. Laboratory Learning Outcome-

LLO 6.1 Improve power factor of given load using APFC.

LLO 6.2 Using APFC for improving power factor.

V. Relevant Affective domain related Outcome

Adopt energy-efficient practices to reduce system losses and promote cost-effective operation in electrical systems.

VI. Relevant Theoretical Background

Power Factor (PF) is the ratio of active power (kW) to apparent power (kVA). Inductive loads like motors cause a lagging PF, increasing system current and losses. Power Factor Correction neutralizes this lag by connecting capacitors in parallel, which supply reactive power locally. This reduces the phase angle, improves the PF, decreases current drawn from the supply, and enhances system efficiency. An Automatic Power Factor Correction (APFC) panel uses a relay to monitor PF and automatically switch capacitor banks to maintain a desired setpoint, ensuring optimal operation under varying load conditions.

VII. Actual Diagram with equipment specification

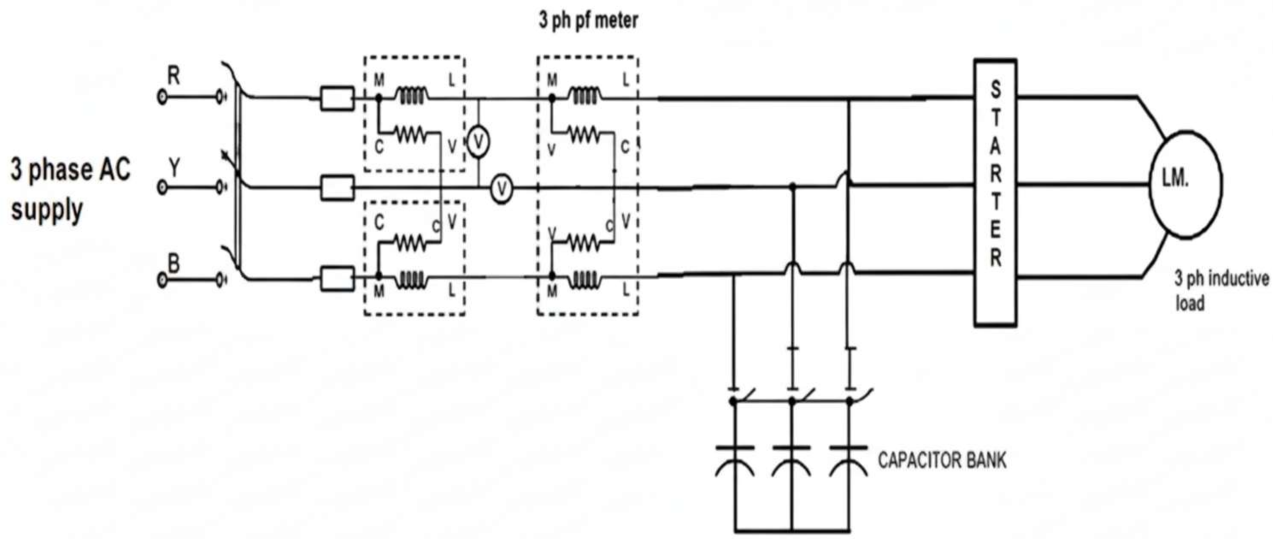

Fig.6.1: Experimental Setup for Power Factor Improvement using Capacitor Bank

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	Three-phase Induction motor	3 HP 415 Volts	01	
2	AC Voltmeter	0 – 500V	01	
3	AC Clamp-on Ammeter	0-20A	01	
4	PF meter	Three-phase, 5/10A, 300/600V	01	
5	Wattmeter	Single-phase, 5/10A, 300/600V	02	
6	Capacitor Bank	3-phase, 50Hz, 1 kVAR (in steps of 0.2 kVAR)	01	
7	Starter	DOL Starter	01	
8	Connecting Wires	--	As needed	

IX. Precautions to be followed

1. Ensure all connections are tight and correct before switching on the supply.
2. The capacitor bank must be connected in parallel with the load.
3. Start with the capacitor bank switch in the OFF position.
4. Never short the terminals of a capacitor.
5. Discharge the capacitors completely after disconnecting the supply.

X. Procedure

1. Make the connections as per the circuit diagram.
2. Keep the switch of the capacitor bank in the OFF position.
3. Switch "ON" the supply.
4. Start the Induction motor at no load or light load.
5. Note down the readings of current at the supply side (Before capacitor bank) and load side (after capacitor bank) using a clamp-on ammeter.
6. Note down the readings of wattmeters, the PF meter, and the voltmeter.
7. Switch ON the switches of the appropriate capacitor bank in steps.
8. For each step, note down all meter readings. (Take a minimum of four readings).
9. Switch OFF the capacitor bank one by one.
10. Stop the Motor.
11. Switch "OFF" the supply.

XI. Observation Table

Sr. No.	**Capacitor Bank**	**Supply Voltage (V) Volts**	**Supply Current (Is) Amps**	**Load Current (I_L) Amps**	**Total Active Power (P)** $W_1 + W_2$ **Watts**	**PF meter Reading cos Ø**	**Total Reactive power,Q, VAR** $\sqrt{3}(W_1 - W_2)$	**Line PF = $\cos(\tan^{-1}(Q/P))$**

Power factor calculation:

Power factor correction capacitor's capacitance calculation:

$$S_{corrected\ (kVA)} = \frac{P_{(kW)}}{PF_{corrected}}$$

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

<u>Note</u>: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. Write the advantages of power factor correction.
2. Write different methods by which power factor can be improved.
3. Write the advantages of APFC unit.
4. Explain what happens if the capacitor bank is oversized, leading to a leading power factor.

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	IS 13399:1992	Indian Standard for Power Factor Correction Equipment.
2	"Utilization of Electrical Power" by K. Bhawan & E. Srinivas	Book covering power factor and its improvement.

XVII. Suggested Assessment Scheme

Performance Indicators		Weightage (%)
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%
Product related: 10 Marks		**40%**
1	Interpretation of result	10%
2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			Dated Sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.7: Power factor improvement using static capacitor.

I. Practical Significance-

Every diploma electrical engineer must be proficient in techniques to improve the power factor of electrical installations. A low lagging power factor, caused by inductive loads, results in increased current, higher energy losses, and greater operational costs. This practical provides hands-on experience with the fundamental method of power factor correction by connecting a static capacitor in parallel with an inductive load. This skill is essential for optimizing energy usage, reducing electricity bills, and enhancing the capacity of power distribution systems in any industrial or commercial setting.

II. Industry or Employer Expected Outcome-

Student will be able to correct low power factor using capacitors to reduce electricity bills and optimize electrical system performance.

III. Course Level Learning Outcome-

Implement energy conservation techniques in electrical machines.

Apply energy conservation techniques in electrical installations.

IV. Laboratory Learning Outcome-

LLO 7.1 Improve power factor of given load using static capacitor.

LLO 7.2 Calculate the value of capacitor to change from initial power factor to desired power factor.

V. Relevant Affective domain related Outcome

Adopt energy-efficient practices to reduce system losses and promote cost-effective operation in electrical systems.

VI. Relevant Theoretical Background

Power Factor (PF) is the ratio of active power (kW) to apparent power (kVA). Inductive loads cause the current to lag the voltage, resulting in a lagging PF less than 1. This increases the current required for the same useful power, leading to higher losses and inefficiencies. Power Factor Correction is achieved by connecting a static capacitor in parallel with the load. The capacitor draws a leading current that cancels the lagging reactive component of the load current. This reduces the phase angle, increases the power factor, and decreases the total current drawn from the source.

VII. Actual Diagram with equipment specification

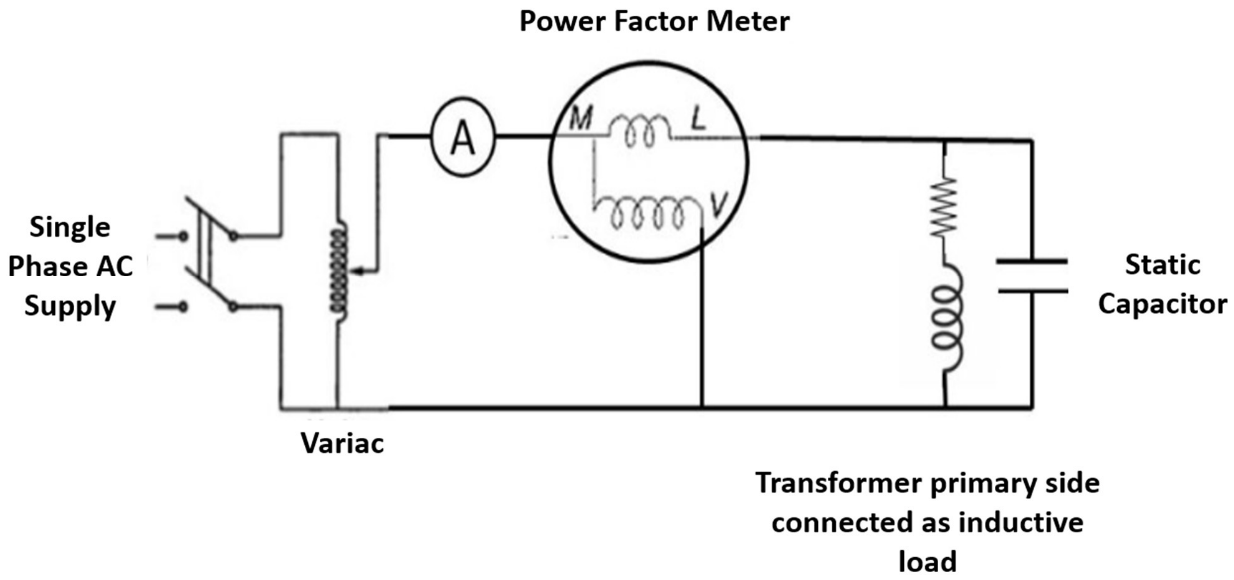

Fig.7.1: Experimental Setup for Power Factor Improvement using Static Capacitor

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	Inductive Load	--	1	
2	Static Capacitors	AC rated, 440V (e.g., 4µF, 8µF, 12µF)	3	
3	Variac (Auto-transformer)	0-270V, 5A	1	
4	AC Voltmeter	0-300V	1	
5	AC Ammeter	0-2A	1	
6	Single-Phase Wattmeter	2.5/5A, 300V	1	
7	Power Factor Meter	Single-Phase	1	
8	DPST Switch	5A, 250V	1	
9	Connecting Wires	--	As required	

IX. Precautions to be followed

1. Ensure all connections are tight and correct before switching on the supply.
2. The capacitor bank must be connected in parallel with the load.
3. Start with the capacitor bank switch in the OFF position.

4. Never short the terminals of a capacitor.
5. Discharge the capacitors completely after disconnecting the supply.

X. Procedure

1. Connect the circuit as per the diagram with the given inductive load.
2. Keep the capacitor switch in the OFF position.
3. Switch “ON” the main supply. Gradually increase the Variac output to the rated voltage of the load.
4. Note down the readings of the voltmeter (V), ammeter (I), wattmeter (P), and power factor meter. This is your initial, uncorrected reading.
5. Switch “OFF” the supply. Connect one capacitor in parallel with the load via the DPST switch.
6. Switch “ON” the supply and set the Variac back to the rated voltage. Switch "ON" the capacitor.
7. Note down all the readings again. Observe the change in the supply current and power factor.
8. Repeat steps 5 to 7 for different capacitor values.
9. After taking all readings, switch "OFF" the capacitor, reduce the Variac to zero, and then switch "OFF" the main supply.

XI. Observation Table

Sr. No.	Capacitor (µF)	Voltage V (V)	Current I (A)	Power P (W)	Power Factor (P/VI)
1					
2					
3					
4					

Sample Calculation

1. Initial Power Factor (without capacitor):
   $PF_1 = P / (V \times I)$ = _______ / (_______ × _______) = _______
2. To find Capacitor value to get PF = 0.95:

- Find the initial angle: $\varphi_1 = \cos^{-1}(PF_1) = \cos^{-1}($ ______ $)$ = ______ °
- Find the desired angle: $\varphi_2 = \cos^{-1}(0.95)$ = ______ °
- Use the formula: $C = P \times (\tan \varphi_1 - \tan \varphi_2) / (2 \pi f V^2)$
- Substitute values: C = ______ × (tan ______ - tan ______) / (2 × 3.14 × 50 × ______²)
- Calculated Capacitor Value, C = _______ µF

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. What is the main reason for a low power factor in industries?
2. Why do we connect the capacitor in parallel with the load and not in series?
3. If we add too much capacitance, what happens to the power factor?
4. Name two appliances in your home that cause a low power factor.

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	IS 13399:1992	Indian Standard for Power Factor Correction Equipment.
2	"Utilization of Electrical Power" by K. Bhawan & E. Srinivas	Book covering power factor and its improvement.

XVII. Suggested Assessment Scheme

Performance Indicators		Weightage (%)
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%
Product related: 10 Marks		**40%**
1	Interpretation of result	10%
2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			Dated Sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.8: Power factor improvement using IPFC.

I. Practical Significance-

Every diploma electrical engineer must be proficient in operating automated systems for maintaining optimal energy efficiency in industrial plants. The Intelligent Power Factor Controller (IPFC) represents an advanced, fully automatic solution for dynamic power factor correction. Unlike static capacitor banks, the IPFC uses intelligent logic to continuously monitor the electrical system and instantaneously switch capacitor steps to maintain a pre-set power factor under fluctuating load conditions

II. Industry or Employer Expected Outcome-

Students will be able to measure, monitor, and improve the power factor of a given load using an Intelligent Power Factor Controller.

III. Course Level Learning Outcome-

Apply energy conservation techniques in electrical installations.

IV. Laboratory Learning Outcome-

LLO 8.1 Improve power factor of given load using IPFC.

LLO 8.2 Using IPFC for improving power factor.

V. Relevant Affective domain related Outcome

Adopt energy-efficient practices to reduce system losses and promote cost-effective operation in electrical systems.

VI. Relevant Theoretical Background

An Intelligent Power Factor Controller (IPFC) is an automated system designed to maintain a desired power factor setpoint without manual intervention. It consists of a microprocessor-based relay with intelligent algorithms that continuously measure the system's power factor. If the measured PF deviates from the set value (e.g., 0.98 Lag), the controller automatically energizes or de-energizes contactors to connect or disconnect capacitor steps from the network. This provides dynamic compensation for rapidly changing loads, ensuring that the power factor remains consistently high at all times, which is not possible with fixed capacitor banks. The IPFC's intelligent switching prevents both under-correction (lagging PF) and over-correction (leading PF), thereby optimizing the electrical system's performance and efficiency.

VII. Actual Diagram with equipment specification

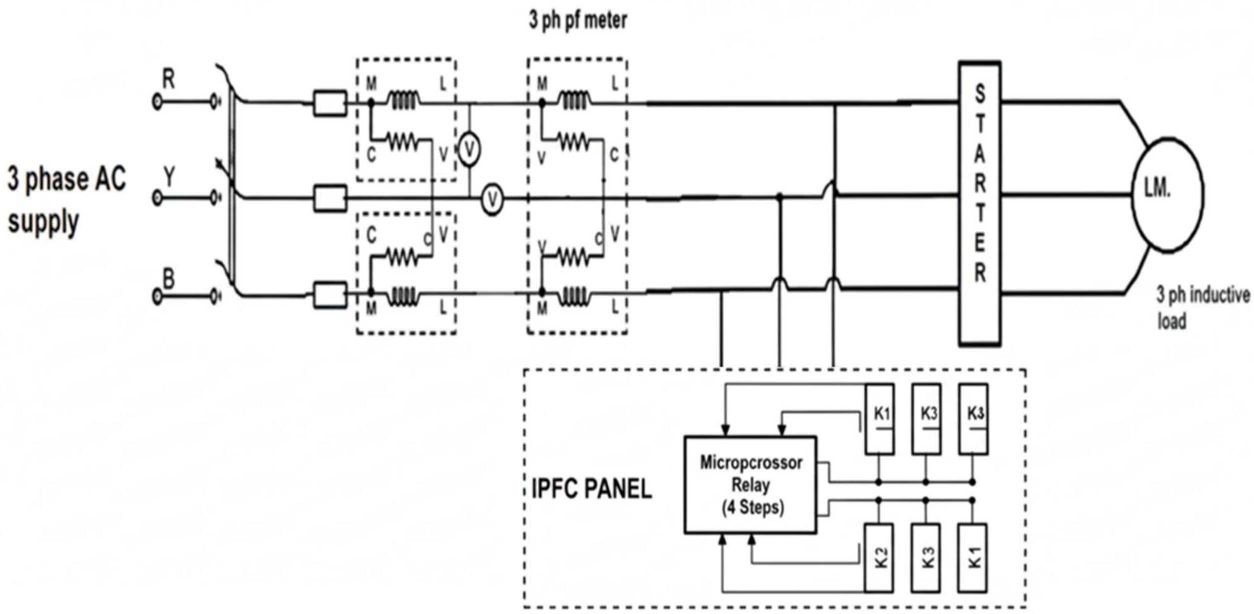

Fig.8.1: Experimental Setup for Power Factor Improvement using IPFC

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	Three-phase Induction motor	3 HP, 415 Volts	1	
2	IPFC Panel	3-Phase, 4-Step, 415V, 50Hz	1	
3	AC Voltmeter	0 – 500V	1	
4	AC Clamp-on Ammeter	0-20A	1	
5	PF meter	Three-phase, 5/10A, 300/600V	1	
6	Wattmeter	Single-phase, 5/10A, 300/600V	2	
7	Starter	DOL Starter	1	
8	Connecting Wires	--	As needed	

IX. Precautions to be followed

1. Ensure all connections are tight and correct before switching on the supply.
2. The IPFC panel must be connected in **parallel** with the load.

3. Do not tamper with the internal components of the IPFC panel.
4. Set the desired power factor value on the controller as per the laboratory instructions.

X. Procedure

1. Make the connections as per the circuit diagram.
2. Ensure the IPFC panel is switched OFF.
3. Switch "ON" the main supply.
4. Start the Induction motor at no load.
5. Note down the readings of voltmeter, ammeter, wattmeters, and PF meter. (This is the uncorrected power factor).
6. Switch ON the IPFC panel. Observe the intelligent operation as it starts connecting capacitor steps.
7. Once the PF stabilizes close to the set value, note down all the meter readings again.
8. Apply a mechanical load to the motor. Observe how the IPFC intelligently responds by connecting additional capacitor steps.
9. Note down the final stable readings under this loaded condition.
10. Gradually remove the load and observe the automatic disconnection of capacitor steps by the IPFC.
11. Stop the Motor.
12. Switch "OFF" the IPFC panel and then the main supply.

XI. Observation Table

Sr. No.	Operating Condition	IPFC Status	Supply Voltage (V)	Supply Current (Is) Amps	Total Active Power (P) Watts	PF Meter Reading	No. of Capacitor Steps Connected
1	Motor at No Load	OFF					
2	Motor at No Load	ON					
3	Motor at Full Load	OFF					
4	Motor at Full Load	ON					

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

<u>Note</u>: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. What is the principle of operation of an Intelligent Power Factor Controller?
2. How does IPFC differ from a conventional APFC panel?
3. Why are CT polarity and phase sequence important in IPFC connections?
4. What are the benefits of maintaining unity power factor in an electrical system?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	IS 13399:1992	Indian Standard for Power Factor Correction Equipment.
2	Manufacturer's Manual for IPFC Panel	For specific setup, programming, and operation.

XVII. Suggested Assessment Scheme

Performance Indicators		Weightage (%)
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%
Product related: 10 Marks		**40%**
1	Interpretation of result	10%
2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			Dated Sign of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No.9: Comparison of power consumption of different types of Tube Light with choke, electronic ballast and LED lamps by direct measurement.

I. Practical Significance-

Every diploma electrical engineer must understand the power consumption characteristics of different types of lighting equipment used in residential, commercial, and industrial applications. Conventional tube lights with magnetic choke consume more power due to losses in the ballast, while electronic ballast and LED lamps operate with higher efficiency and better power factor. This practical enables direct measurement and comparison of power consumption, efficiency, and cost benefits of these lighting technologies.

II. Industry or Employer Expected Outcome-

Students will be able to measure and compare power consumption of different tube lights, identify energy-efficient lighting systems, and estimate energy and cost savings.

III. Course Level Learning Outcome-

Apply energy conservation techniques in electrical installations.

IV. Laboratory Learning Outcome-

LLO 9.1 Compare power consumption of different types of Tube Light with choke, electronic ballast and LED lamps by direct measurement.

V. Relevant Affective domain related Outcome

Adopt energy-efficient lighting practices and promote replacement of outdated lighting systems to conserve electricity.

VI. Relevant Theoretical Background

Lighting systems convert electrical energy into visible light, but their efficiency varies based on the technology used. Conventional fluorescent lamps and modern LED lamps differ in their construction, control gear, and operating principle. These differences directly affect their power consumption, power factor, and illumination output.

1. **Fluorescent Tube Light with Choke (Magnetic Ballast):** It uses an inductive choke to limit the current through the lamp. The choke causes additional losses, low power factor, and higher power consumption.
2. **Fluorescent Tube Light with Electronic Ballast:** It operates at high frequency using an electronic circuit, reducing copper and iron losses. This results in improved efficiency, low heat generation, and nearly unity power factor.
3. **LED Tube Light:** It works on the principle of electroluminescence using light-emitting diodes. LEDs have minimal losses, very high luminous efficiency, and consume the least power for the same illumination.

VII. Actual Diagram with equipment specification

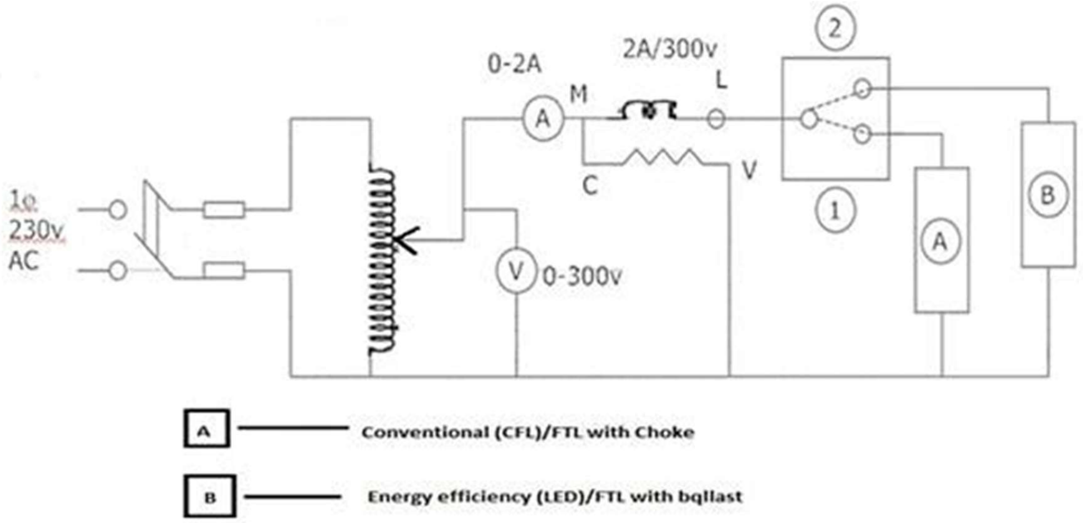

Fig.9.1: Experimental Setup for Comparison of power consumption of different types of Tube Lights

VIII. Resources required

Sr. No.	Particulars	Specification	Quantity	Remark
1	1-Phase Auto Transformer	2KVA, 0-250V	1	
2	AC Ammeter	0-1-2/0-2.5-5 Amp	2	

3	AC Voltmeter	0-300 Volt	1	
4	Wattmeter(LPF)	1-2/300,2.5-5/300	2	
5	Lux-meter	Digital type	1	
6	FT with induction choke	230V,50Hz	1	
7	FT with electronic ballast	230V,50Hz	1	
8	LED lamps of Different ratings	18W / 20W, 230V	1	
9	Two way piano switch	5Amp/230Volt	1	

IX. Precautions to be followed

1. Ensure all lamps are rated for 230 V AC and are correctly wired.
2. Check all connections before energizing the circuit.
3. Avoid touching live terminals while lamps are ON.
4. Record readings only after the lamp stabilizes (2–3 minutes).

X. Procedure

1. Make the connection as per the circuit diagram.
2. Check and adjust the zero settings of all meters.
3. Keep the auto-transformer at zero position and switch ON the supply.
4. Adjust the voltage to the rated voltage of the lamps (230V).
5. Keep the two-way switch at position 1.
6. Note down all meter readings and measure illumination with lux-meter for Table 1.
7. Reduce the voltage and note the minimum ignition voltage.
8. Change the two-way switch to position 2.
9. Repeat steps 6 and 7 for the other lamp types.
10. Switch OFF the supply after completing all measurements.

XI. Observation Table

A. Electrical Parameters & Performance Measurement

Sr. No.	Lighting System	Voltage (V)	Current (I)	Power (W)	Power Factor	Illumination (Lux)
1	FTL-18W + Magnetic Ballast					
2	FTL-18W + Electronic Ballast					
3	LED Tube Light (18W equivalent)					

B. Technical Specifications & Cost Analysis

Sr. No.	Lighting System	Lamp Efficacy (lm/W)	CRI	Rated Life (Hours)	Purchase Cost (₹)	Annual Energy Cost (₹)*
1	FTL-18W + Magnetic Ballast					
2	FTL-18W + Electronic Ballast					
3	LED Tube Light (18W equivalent)					

*Assumptions: 10 hours/day operation, 300 days/year, Electricity rate ₹ 8/kWh

XII. Result

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XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

<u>Note</u>: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. Why is the power factor of choke-type fluorescent lamps poor?
2. How does electronic ballast improve power factor?
3. Compare efficiency and life expectancy of LED vs fluorescent lamps.
4. What are the advantages of using LED lighting in industries?
5. How does lighting retrofitting contribute to energy conservation?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	BIS Lighting Standards	Guidelines on lamp efficiency and PF
2	BEE Lighting Handbook	Energy-efficient lighting practices
3	Manufacturer Data Sheets	Power, PF, and lumen data of different lamps

XVII. Suggested Assessment Scheme

Performance Indicators		Weightage (%)
Process related: 15 Marks		**60%**
1	Identification of basic construction material	30%
2	Recording of Observations	30%
Product related: 10 Marks		**40%**
1	Interpretation of result	10%
2	Answer to practical related questions.	20%
3	Submission of report in time	10%
Total : 25 Marks		**100%**

Marks Obtained			Dated Sign of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No.10: Comparison of reduction in power by replacement of lamps in a classroom / laboratory by energy efficient lamps.

I. Practical Significance-

This practical is crucial for understanding the direct impact of replacing conventional lighting with energy-efficient alternatives. It demonstrates measurable energy savings, which is a fundamental strategy in reducing electricity bills and carbon footprint in residential, commercial, and industrial settings.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Apply energy conservation techniques in electrical installations.

IV. Laboratory Learning Outcome-

LLO 10.1 - Determine the reduction in power consumption by replacement of different lamps in a classroom / laboratory by energy efficient lamps.

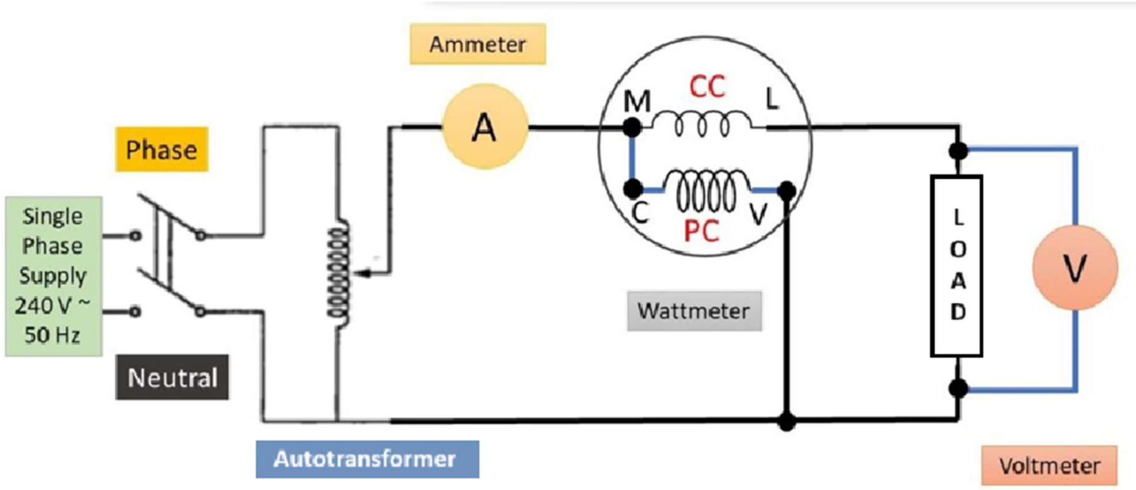
V. Relevant Affective domain related Outcome

Demonstrate responsibility towards energy conservation and environmental sustainability by adopting efficient lighting practices.

VI. Relevant Theoretical Background

Lighting accounts for a significant portion of electricity consumption in buildings. Conventional lighting sources like Incandescent bulbs and Fluorescent Tubes (with magnetic chokes) have low efficacy (lumens/watt) and high power consumption. Energy-efficient lamps like LED (Light Emitting Diode) and CFL (Compact Fluorescent Lamp) provide the same or better illumination (lumens) while consuming significantly less power. This experiment involves measuring and comparing the power consumed by different types of lamps to quantify the energy savings achieved by retrofitting with efficient lighting.

VII. Actual Diagram with equipment specification



Loads

VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Wattmeter	Single Phase, 300V, 5A/10A	1	
2	Voltmeter	MI, AC, 0-300V	1	
3	Ammeter	MI, AC, 0-5A	1	
4	Incandescent Bulb	60W, 230V	1	

5	CFL Lamp	15W, 230V (Equivalent to 60W Incandescent)	1	
6	LED Lamp	9W, 230V (Equivalent to 60W Incandescent)	1	
7	Lamp Holder	--	1	
8	Connecting Wires	--	As required	

IX. Precautions to be followed

1. Ensure all connections are tight and correct before switching ON the supply.
2. Do not touch live terminals or bare wires.
3. Handle the lamps carefully to avoid breakage.
4. Do not exceed the voltage and current ratings of the meters.
5. Switch OFF the supply before changing the lamp under test.

X. Procedure

1. Connect the circuit as per the diagram.
2. Insert the 60W Incandescent bulb into the lamp holder.
3. Switch ON the supply and allow the lamp to glow for a few minutes.
4. Note down the readings of Voltmeter (V), Ammeter (I), and Wattmeter (W).
5. Switch OFF the supply and replace the Incandescent bulb with the 15W CFL lamp.
6. Switch ON the supply, let it stabilize, and note down the readings of V, I, and W.
7. Switch OFF the supply and replace the CFL lamp with the 9W LED lamp.
8. Switch ON the supply and note down the readings of V, I, and W.
9. Switch OFF the supply and disconnect the circuit.

XI. Observation Table

SN	Type of Lamp	Voltage (V) in Volts	Current (I) in Amps	Power (W) in Watts	Illumination Level (Optional - if Lux meter available)
1	Incandescent (60W)	230			
2	CFL (15W)	230			
3	LED (9W)	230			

XII. Result

The power consumption for different lamps was measured successfully.

- Power consumed by Incandescent Lamp = ______ **W**
- Power consumed by CFL Lamp = ______ **W**
- Power consumed by LED Lamp = ______ **W**

The LED lamp consumes the least power, resulting in maximum energy conservation.

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. Why does an LED lamp consume less power than an incandescent lamp for the same light output?
2. Calculate the annual energy saving (in kWh) by replacing one 60W incandescent lamp used for 10 hours/day with a 9W LED lamp. (Assume energy cost is ₹5/kWh, also calculate annual cost saving).
3. What is the meaning of "luminous efficacy"? Compare the typical efficacy of incandescent, CFL, and LED lamps.
4. Apart from power consumption, list two other advantages of LED lamps over CFLs.

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://www.beeindia.gov.in/	Bureau of Energy Efficiency (BEE)
2	https://www.mahaurja.com/	MEDA - Energy Conservation Programs
3	https://www.energy.gov/energysaver/lighting-choices-save-you-money	LED Lighting Information

XVII. Suggested Assessment Scheme

Performance Indicators	**Weightage (%)**
Process related: 15 Marks	**60%**
1 - Circuit connection and setup	30%
2 - Recording of Observations	30%
Product related: 10 Marks	**40%**
1 - Interpretation of result	10%
2 - Answer to practical related questions.	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.11: Tariff for industrial consumer for reducing the electricity bill.

I. Practical Significance-

This practical is essential for understanding how industrial consumers can significantly reduce their electricity costs by selecting appropriate tariff structures. It demonstrates the financial impact of energy conservation measures and helps in making informed decisions about electricity consumption patterns to minimize electricity bills while maintaining operational efficiency.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Use Co-generation and relevant tariff for reducing losses in facilities.

IV. Laboratory Learning Outcome-

LLO 11.1 - Suggest suitable tariff for energy conservation and reduction of energy bill for an industrial customer.

LLO 11.2 - Interpreting electricity bill of an industrial consumer.

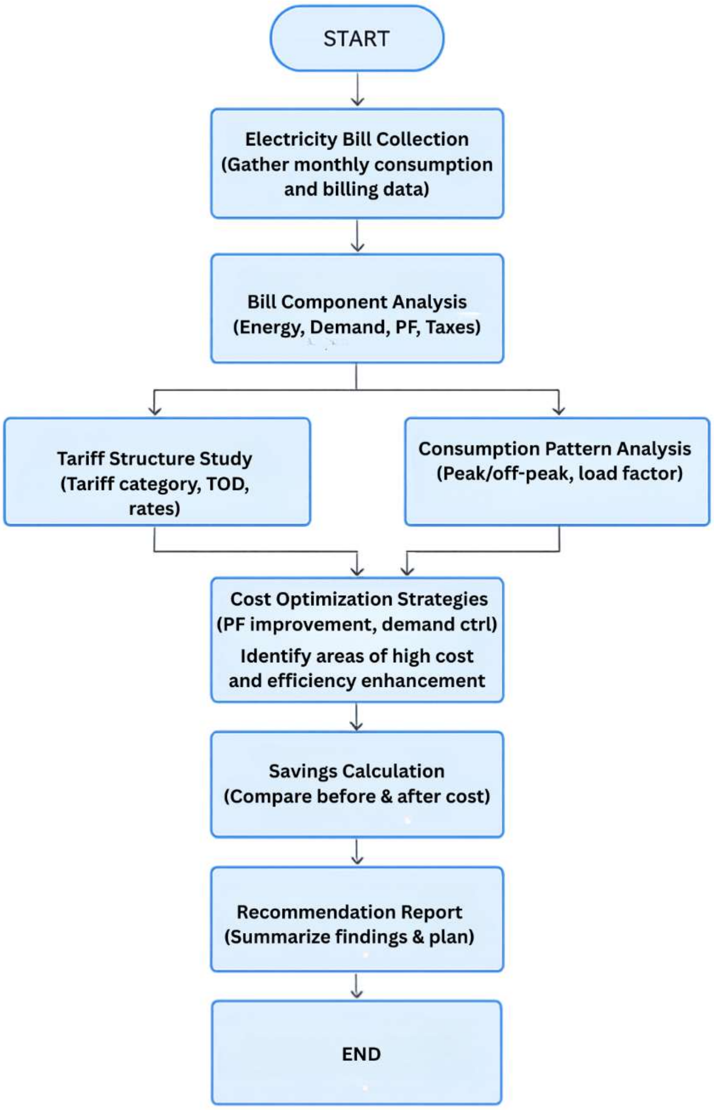
V. Relevant Affective domain related Outcome

Demonstrate analytical thinking and financial acumen in selecting optimal energy tariff structures for cost optimization.

VI. Relevant Theoretical Background

Electricity tariffs for industrial consumers are structured to reflect the cost of supplying electricity, including generation, transmission, and distribution costs. Industrial tariffs often include components like Fixed/Demand Charges, Energy Charges, Power Factor Penalties, Time-of-Day rates, and Maximum Demand charges. By analyzing consumption patterns, load factor, and power factor, industries can select the most economical tariff structure. Strategies such as load shifting, power factor improvement, and demand management can lead to substantial cost savings while promoting energy conservation.

VII. Actual Diagram / Flowchart



VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Sample Industrial Electricity Bills	Recent bills from different tariff categories	3-4	
2	Tariff Rate Chart	From local electricity distribution company	1	
3	Calculator	Scientific	1	

4	Computer with Spreadsheet Software	MS Excel/LibreOffice Calc	1	Optional
5	Load Data	Industrial consumer load pattern	1 set	
6	Power Factor Measurement Data	From electrical department	1 set	

IX. Precautions to be followed

1. Use actual and recent electricity bills for accurate analysis.
2. Verify tariff rates from official sources of the electricity distribution company.
3. Ensure all calculations are double-checked for accuracy.
4. Maintain confidentiality of sensitive industrial data.
5. Consider all components of the electricity bill in the analysis.

X. Procedure

1. Collect 3-4 sample electricity bills of industrial consumers from different tariff categories.
2. Study the tariff structure provided by the electricity distribution company.
3. Analyse the bill components: Fixed charges, Energy charges, Demand charges, Power factor penalties/savings.
4. Calculate the electricity cost for each bill using the applicable tariff rates.
5. Identify opportunities for cost reduction through:
    - Load shifting to off-peak hours
    - Power factor improvement
    - Demand management
    - Changing tariff category if beneficial
6. Prepare a comparative statement showing potential savings.
7. Document recommendations for tariff optimization.

XI. Observation Table

SN	Parameter	Current Bill	After Optimization	Savings
1	Maximum Demand (kVA)			
2	Energy Consumption (kWh)			
3	Load Factor (%)			
4	Power Factor			
5	Fixed/Demand Charges (₹)			
6	Energy Charges (₹)			
7	Power Factor Penalty/Rebate (₹)			
8	Total Bill Amount (₹)			

XII. Result

The analysis of industrial electricity tariff was successfully completed.

- Current electricity bill amount = ______ ₹
- Optimized electricity bill amount = ______ ₹
- Potential monthly savings = ______ ₹
- Potential annual savings = ______ ₹

  The optimized tariff structure and conservation measures show significant cost reduction.

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. What is the significance of power factor in industrial electricity billing? How does it affect the electricity bill?
2. Differentiate between fixed charges and energy charges in industrial electricity tariff.
3. What is Time-of-Day (TOD) tariff? How can an industrial consumer benefit from it?
4. Calculate the annual savings if an industry reduces its maximum demand from 1000 kVA to 900 kVA, given that the demand charge is ₹300/kVA/month.

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://www.mahadiscom.in/consumer/tariff/	MSEDCL Tariff Structure
2	https://www.beeindia.gov.in/	Bureau of Energy Efficiency
3	https://www.mahaurja.com/	MEDA Energy Conservation

XVII. Suggested Assessment Scheme

Performance Indicators	**Weightage (%)**
Process related: 15 Marks	**60%**
1 - Data collection and analysis	30%
2 - Recording of Observations	30%
Product related: 10 Marks	**40%**
1 - Interpretation of result	10%
2 - Answer to practical related questions	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.12: Tariff for commercial consumer for reducing the electricity bill.

I. Practical Significance-

This practical helps commercial consumers understand how to analyze their electricity bills and select optimal tariff structures to minimize costs. It demonstrates how energy management strategies can lead to significant financial savings in commercial establishments like offices, malls, and hospitals.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Use Co-generation and relevant tariff for reducing losses in facilities.

IV. Laboratory Learning Outcome-

LLO 12.1 - Suggest suitable tariff for energy conservation and reduction of energy bill for a commercial customer.

LLO 12.2 - Interpreting electricity bill of a commercial customer.

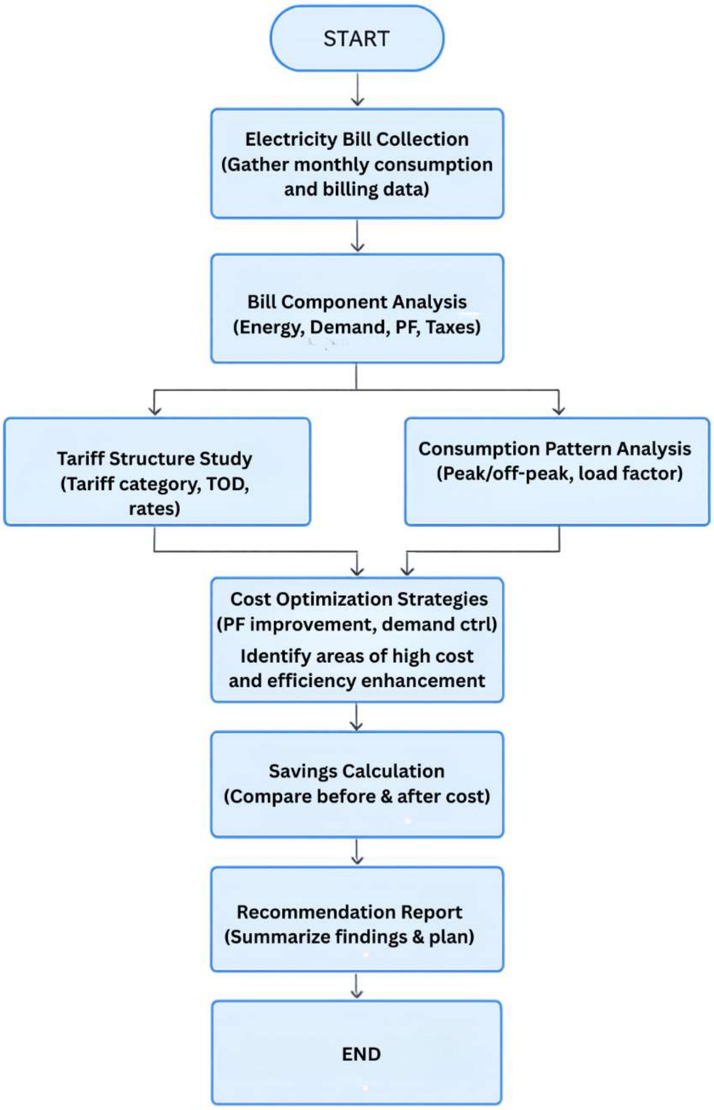
V. Relevant Affective domain related Outcome

Develop financial literacy and strategic thinking in energy management for commercial sustainability.

VI. Relevant Theoretical Background

Commercial electricity tariffs are designed for establishments like offices, shopping malls, hotels, and hospitals. These tariffs typically include fixed charges, energy charges, and sometimes demand charges and power factor clauses. Commercial consumers can reduce costs through load management, energy-efficient equipment, and selecting appropriate tariff categories. Understanding time-of-use rates and seasonal variations can help shift non-essential loads to off-peak hours for better economics.

VII. Actual Diagram / Flowchart



VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Sample Commercial Electricity Bills	Recent bills	3-4	
2	Commercial Tariff Chart	From electricity distributor	1	
3	Calculator	Scientific	1	
4	Computer with Excel	MS Office	1	
5	Load Consumption Data	Commercial establishment	1 set	
6	Operating Hours Schedule	Commercial facility	1	

IX. Precautions to be followed

1. Use actual commercial electricity bills for realistic analysis
2. Verify current tariff rates from official sources
3. Consider all bill components in calculations
4. Maintain data confidentiality
5. Validate calculations through cross-checking

X. Procedure

1. Collect 3-4 sample electricity bills from different commercial establishments
2. Study the commercial tariff structure from electricity distribution company
3. Analyze bill components: fixed charges, energy charges, demand charges, penalties
4. Calculate electricity cost using applicable tariff rates
5. Identify optimization opportunities through:
    - Load shifting to off-peak hours
    - Equipment efficiency improvements
    - Power factor correction
    - Tariff category change
6. Prepare comparative cost analysis
7. Document recommendations with potential savings

XI. Observation Table

SN	Parameter	Current Bill	After Optimization	Savings
1	Contract Demand (kVA)			
2	Energy Consumption (kWh)			
3	Fixed/Demand Charges (₹)			
4	Energy Charges (₹)			
5	Time-of-Day Charges (₹)			
6	Total Bill Amount (₹)			
7	Effective Rate per Unit (₹/kWh)			

XII. Result

The commercial electricity tariff analysis was completed successfully.

- Current monthly electricity bill = ______ ₹
- Optimized monthly electricity bill = ______ ₹
- Monthly savings achievable = ______ ₹
- Annual savings potential = ______ ₹

  Appropriate tariff selection and energy management show substantial cost reduction.

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. What are the main differences between commercial and industrial electricity tariffs?
2. How can a shopping mall benefit from time-of-day tariff structure?
3. Calculate the annual savings if a commercial establishment reduces its monthly consumption from 50,000 kWh to 45,000 kWh, with energy charge of ₹8/kWh.
4. What is contract demand and how does it affect commercial electricity bills?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://www.mahadiscom.in	MSEDCL Commercial Tariff
2	https://beeindia.gov.in	BEE Energy Efficiency

XVII. Suggested Assessment Scheme

Performance Indicators	Weightage (%)
Process related: 15 Marks	**60%**
1 - Data collection and analysis	30%
2 - Recording of Observations	30%
Product related: 10 Marks	**40%**
1 - Interpretation of result	10%
2 - Answer to practical related questions	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.13: Tariff for residential consumer for reducing the electricity bill.

I. Practical Significance-

This practical enables residential consumers to understand their electricity bills and adopt strategies to reduce energy costs. It demonstrates how simple changes in consumption patterns and appliance usage can lead to significant savings in household electricity expenses.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Use Co-generation and relevant tariff for reducing losses in facilities.

IV. Laboratory Learning Outcome-

LLO 13.1 - Suggest suitable tariff for energy conservation and reduction of energy bill for a residential customer.

LLO 13.2 - Interpreting electricity bill of a residential customer.

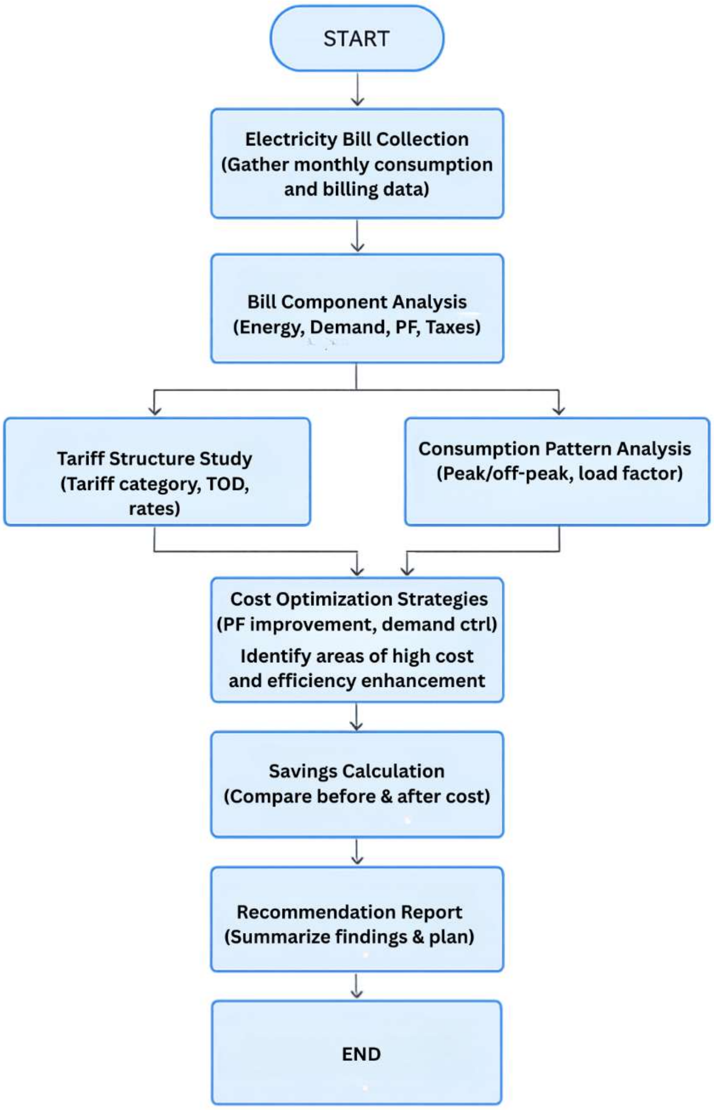
V. Relevant Affective domain related Outcome

Develop responsible energy consumption habits and financial awareness in household electricity management.

VI. Relevant Theoretical Background

Residential electricity tariffs typically follow a slab-based system where the per-unit cost increases with higher consumption levels. Many utilities offer time-of-day (TOD) tariffs for residential consumers with different rates for peak and off-peak hours. Understanding these tariff structures helps consumers optimize their electricity usage by shifting high-consumption activities to off-peak hours and managing overall consumption to stay within lower tariff slabs.

VII. Actual Diagram / Flowchart



VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Sample Residential Electricity Bills	Different consumption levels	3-4	
2	Residential Tariff Chart	Current slab rates	1	
3	Calculator	Basic/Scientific	1	
4	Computer with Excel	MS Office	1	Optional

5	Appliance Power Consumption Data	Common household appliances	1 set	
6	Usage Pattern Data	Daily routine schedule	1	

IX. Precautions to be followed

1. Use actual residential electricity bills for authentic analysis
2. Verify current residential tariff rates from utility company
3. Consider seasonal variations in consumption
4. Account for all electricity-consuming appliances
5. Maintain privacy of personal consumption data

X. Procedure

1. Collect 3-4 sample residential electricity bills showing different consumption levels
2. Study the residential tariff structure and slab rates
3. Analyze bill components: slab-wise charges, fixed charges, taxes
4. Calculate electricity cost using applicable slab rates
5. Identify optimization opportunities through:
    - Shifting high-consumption activities to off-peak hours
    - Replacing inefficient appliances with star-rated ones
    - Managing consumption to stay within lower slabs
    - Utilizing solar energy for daytime needs
6. Prepare comparative cost analysis
7. Document recommendations with potential savings

XI. Observation Table

SN	Parameter	Current Bill	After Optimization	Savings
1	Total Units Consumed (kWh)			
2	Slab-wise Consumption			
3	Fixed Charges (₹)			
4	Energy Charges (₹)			
5	Time-of-Day Charges (₹)			
6	Taxes and Duties (₹)			
7	Total Bill Amount (₹)			
8	Effective Rate per Unit (₹/kWh)			

XII. Result

The residential electricity tariff analysis was completed successfully.

- Current monthly electricity bill = ______ ₹
- Optimized monthly electricity bill = ______ ₹
- Monthly savings achievable = ______ ₹
- Annual savings potential = ______ ₹

  Strategic consumption management shows significant cost reduction.

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. Explain how slab-based tariff system works for residential consumers and its impact on electricity bills.
2. Calculate the savings achieved by reducing monthly consumption from 350 units to 300 units under a typical residential slab tariff.
3. What are the benefits of time-of-day tariff for residential consumers?
4. How can a residential consumer effectively utilize off-peak hours to reduce electricity costs?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://www.mahadiscom.in	MSEDCL Residential Tariff
2	https://beeindia.gov.in	BEE Star Rating

XVII. Suggested Assessment Scheme

Performance Indicators	Weightage (%)
Process related: 15 Marks	**60%**
1 - Data collection and analysis	30%
2 - Recording of Observations	30%
Product related: 10 Marks	**40%**
1 - Interpretation of result	10%
2 - Answer to practical related questions	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.14: Estimation of Energy saved by improving power factor and load factor for given case.

I. Practical Significance-

This practical demonstrates how improving power factor and load factor can lead to significant energy savings and cost reduction in electrical systems. It provides quantitative analysis skills essential for energy auditors and electrical engineers to optimize system performance and reduce electricity bills.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Apply energy conservation techniques in electrical installations.

Use Co-generation and relevant tariff for reducing losses in facilities.

IV. Laboratory Learning Outcome-

LLO 14.1 - Estimate energy saving by improving power factor and load factor for given case.

V. Relevant Affective domain related Outcome

Develop analytical skills and systematic approach to energy optimization in electrical systems.

VI. Relevant Theoretical Background

Power factor improvement reduces reactive power consumption, decreases line losses, and avoids penalty charges from utilities. Load factor improvement indicates better utilization of electrical infrastructure by maintaining consistent load rather than peak demands. Both factors directly impact energy efficiency and cost optimization. Power factor correction is achieved using capacitors or synchronous condensers, while load factor improvement involves load management and scheduling strategies.

VII. Actual Diagram / Flowchart

Draw Flowchart

VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Power Analyzer Data	From industrial/commercial facility	1 set	
2	Load Curve Data	Daily/weekly patterns	1 set	

3	Calculator	Scientific	1	
4	Computer with Excel	MS Office	1	
5	Tariff Sheet	With PF penalty clauses	1	
6	Capacitor Bank Data	For PF correction	1 set	

IX. Precautions to be followed

1. Use accurate and recent power consumption data
2. Verify all electrical parameters from reliable sources
3. Consider practical limitations in power factor improvement
4. Account for seasonal variations in load patterns
5. Validate calculations through cross-verification

X. Procedure

1. Collect current electrical parameters: kW, kVA, kVAR, power factor
2. Analyze existing load pattern and calculate current load factor
3. Study tariff structure for power factor penalty/rebate clauses
4. Calculate required capacitor bank for target power factor
5. Estimate savings from:
    - Reduced kVA demand charges
    - Elimination of power factor penalties
    - Reduced I^2R losses in system
    - Improved load factor benefits
6. Calculate payback period for capacitor investment
7. Document recommendations with quantitative savings

XI. Observation Table

SN	Parameter	Current Value	After Improvement	Improvement
1	Power Factor			
2	Load Factor (%)			
3	Maximum Demand (kVA)			
4	kVAR Requirement			
5	Energy Losses (kWh/month)			
6	PF Penalty/Rebate (₹/month)			
7	Demand Charges (₹/month)			

XII. Result

The energy savings estimation through power factor and load factor improvement was completed successfully.

- Current monthly electricity cost = ______ **₹**
- Optimized monthly electricity cost = ______ **₹**
- Monthly savings achievable = ______ **₹**
- Annual savings potential = ______ **₹**
- Simple payback period for investment = ______ **months**

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. Explain how poor power factor increases electricity costs for industrial consumers.
2. Calculate the capacitor bank rating required to improve power factor from 0.75 to 0.95 for a 100 kW load.
3. What is the relationship between load factor and maximum demand charges?
4. How does power factor improvement reduce technical losses in the electrical system?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://www.beeindia.gov.in	BEE Energy Management
2	https://www.energy.gov/energysaver	Power Factor Improvement
3	https://www.electricaltechnology.org	Electrical Calculations

XVII. Suggested Assessment Scheme

Performance Indicators	**Weightage (%)**
Process related: 15 Marks	**60%**
1 - Data collection and analysis	30%
2 - Recording of Observations	30%
Product related: 10 Marks	**40%**
1 - Interpretation of result	10%
2 - Answer to practical related questions	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.15: Preparation of Energy audit questionnaire for the given facility.

I. Practical Significance-

This practical develops the essential skill of creating comprehensive energy audit questionnaires, which forms the foundation for systematic energy assessment. A well-structured questionnaire ensures no aspect of energy consumption is overlooked during audits and helps in collecting consistent data across different facilities.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Carryout energy audit for electrical system.

IV. Laboratory Learning Outcome-

LLO 15.1 - Prepare a sample energy audit questionnaire for a given facility.

V. Relevant Affective domain related Outcome

Develop systematic thinking and attention to detail essential for professional energy auditing practices.

VI. Relevant Theoretical Background

An energy audit questionnaire is a structured tool that helps auditors collect comprehensive data about energy consumption patterns, equipment efficiency, operational practices, and potential conservation opportunities. It covers various aspects including electrical systems, thermal systems, building envelope, and operational practices. A well-designed questionnaire ensures consistency in data collection, identifies all energy streams, and helps in benchmarking performance against industry standards.

VII. Actual Diagram / Flowchart

Draw Flowchart

VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Sample Energy Audit Questionnaires	Industrial/Commercial	2-3	
2	Facility Layout Maps	Selected facility	1 set	
3	Computer with Word Processor	MS Word/Equivalent	1	
4	Energy Consumption Data Formats	Monthly/yearly patterns	1 set	
5	Equipment Data Sheets	Major energy-consuming equipment	1 set	
6	BEE Guidelines	Energy audit procedures	1	

IX. Precautions to be followed

1. Ensure questionnaire covers all energy streams (electrical, thermal, renewable)
2. Include both quantitative and qualitative assessment parameters
3. Consider facility-specific requirements and processes
4. Maintain logical flow from general to specific information
5. Ensure clarity and simplicity in question formulation

X. Procedure

1. Study the selected facility type (industrial/commercial/residential)
2. Review sample energy audit questionnaires for similar facilities
3. Identify all energy-consuming systems and equipment
4. Structure the questionnaire into logical sections:
    - Facility general information
    - Energy consumption history
    - Electrical system details
    - Thermal system details
    - Building envelope characteristics
    - Operational practices
    - Maintenance procedures
    - Energy conservation opportunities
5. Develop specific questions for each section
6. Include data recording formats and measurement requirements
7. Review and refine the questionnaire for completeness

XI. Observation Table

SN	Questionnaire Section	Number of Questions	Data Type	Priority Level
1	General Facility Information		Qualitative	High
2	Energy Consumption History		Quantitative	High
3	Electrical Systems		Both	High
4	Thermal Systems		Both	Medium
5	Building Envelope		Both	Medium
6	Operational Practices		Qualitative	Medium
7	Maintenance Procedures		Qualitative	Low
8	Conservation Opportunities		Both	High

XII. Result

The energy audit questionnaire for the selected facility was successfully prepared.

- Total number of sections covered = ______
- Total number of questions formulated = ______
- Quantitative data requirements identified = ______ **parameters**
- Qualitative assessment areas covered = ______ **aspects**

The comprehensive questionnaire ensures systematic energy audit data collection.

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. What are the key sections that must be included in any comprehensive energy audit questionnaire?
2. How does a well-structured questionnaire help in identifying energy conservation opportunities?
3. What is the difference between quantitative and qualitative questions in energy auditing?
4. Why is it important to include operational practices in an energy audit questionnaire?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://beeindia.gov.in	BEE Energy Audit Guidelines
2	https://www.energy.gov/energysaver	Energy Audit Procedures

XVII. Suggested Assessment Scheme

Performance Indicators	**Weightage (%)**
Process related: 15 Marks	**60%**
1 - Questionnaire structure and organization	30%
2 - Completeness of coverage	30%
Product related: 10 Marks	**40%**
1 - Quality of questions formulation	10%
2 - Answer to practical related questions	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.16: Preparation of Energy audit report of electrical department.

I. Practical Significance-

This practical develops the crucial skill of compiling comprehensive energy audit reports, which is essential for documenting findings, recommending energy conservation measures, and communicating results to management. A well-structured audit report serves as the foundation for implementing energy efficiency projects and tracking performance improvements.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Carryout energy audit for electrical system.

IV. Laboratory Learning Outcome-

LLO 16.1 - Prepare energy audit report of your electrical department.

V. Relevant Affective domain related Outcome

Develop professional reporting skills and systematic documentation approach essential for energy management careers.

VI. Relevant Theoretical Background

An energy audit report is a comprehensive document that presents findings from energy assessment, analysis of energy consumption patterns, identification of energy conservation opportunities (ECOs), and recommendations for implementation. It typically includes executive summary, facility description, energy consumption analysis, energy conservation measures, cost-benefit analysis, and implementation plan. The report serves as a decision-making tool for management to prioritize energy efficiency investments.

VII. Actual Diagram / Flowchart

Draw Flowchart

VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Energy Audit Data	Collected from electrical department	1 set	
2	Report Template	Standard energy audit format	1	
3	Computer with Word Processor	MS Word/Equivalent	1	
4	Spreadsheet Software	MS Excel/Equivalent	1	
5	Calculation Sheets	Energy savings calculations	1 set	

6	Photographic Evidence	Equipment and areas audited	As needed	

IX. Precautions to be followed

1. Ensure all data is accurate and properly referenced
2. Maintain logical flow and professional presentation
3. Include both technical and financial analysis
4. Verify all calculations and assumptions
5. Use clear, concise language appropriate for the target audience

X. Procedure

1. Collect and organize all energy audit data and measurements
2. Analyze energy consumption patterns and identify key areas
3. Develop the report structure with main sections:
    - Executive Summary
    - Introduction and Facility Description
    - Energy Consumption Analysis
    - Energy Conservation Opportunities
    - Technical and Financial Analysis
    - Implementation Plan
    - Conclusions and Recommendations
    - Appendices
4. Prepare detailed content for each section
5. Include supporting data, calculations, and photographs
6. Review and refine the report for clarity and completeness

XI. Observation Table

SN	Report Section	Content Elements	Data Requirements	Priority
1	Executive Summary			
2	Facility Description			
3	Energy Analysis			
4	ECOs Identification			
5	Cost-Benefit Analysis			
6	Implementation Plan			

XII. Result

The energy audit report for the electrical department was successfully prepared.

- Total report pages = ______
- Number of energy conservation opportunities identified = ______
- Total investment required = ______ ₹
- Annual savings potential = ______ ₹
- Average payback period = ______ **months**

The comprehensive report provides actionable recommendations for energy efficiency improvement.

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. What are the key elements that must be included in an executive summary of an energy audit report?
2. How does a well-structured implementation plan help in successful execution of energy conservation projects?
3. What financial parameters are crucial for decision-making in energy audit reports?
4. Why is it important to include photographic evidence in energy audit reports?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://beeindia.gov.in	BEE Energy Audit Reporting
2	https://www.energy.gov/energysaver	Energy Audit Guidelines

XVII. Suggested Assessment Scheme

Performance Indicators	Weightage (%)
Process related: 15 Marks	**60%**
1 - Data organization and analysis	30%
2 - Report structure and formatting	30%
Product related: 10 Marks	**40%**
1 - Quality of recommendations	10%
2 - Answer to practical related questions	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.17: Comparison of energy consumption using DOL, star delta and soft starter in a three-phase induction motor.

I. Practical Significance-

This practical demonstrates the significant energy savings and operational benefits achieved by using advanced motor starting methods compared to conventional Direct-On-Line (DOL) starting. It provides hands-on experience in evaluating different motor control techniques essential for industrial energy conservation.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Implement energy conservation techniques in electrical machines.

IV. Laboratory Learning Outcome-

LLO 17.1 - Compare energy consumption using DOL, star delta and soft starter in a three-phase induction motor.

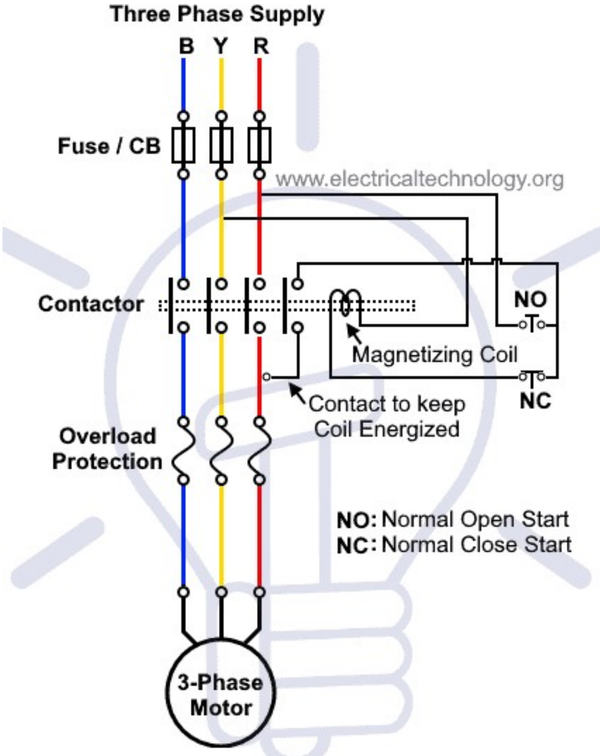
V. Relevant Affective domain related Outcome

Develop technical competence in motor control systems and appreciation for energy-efficient industrial practices.

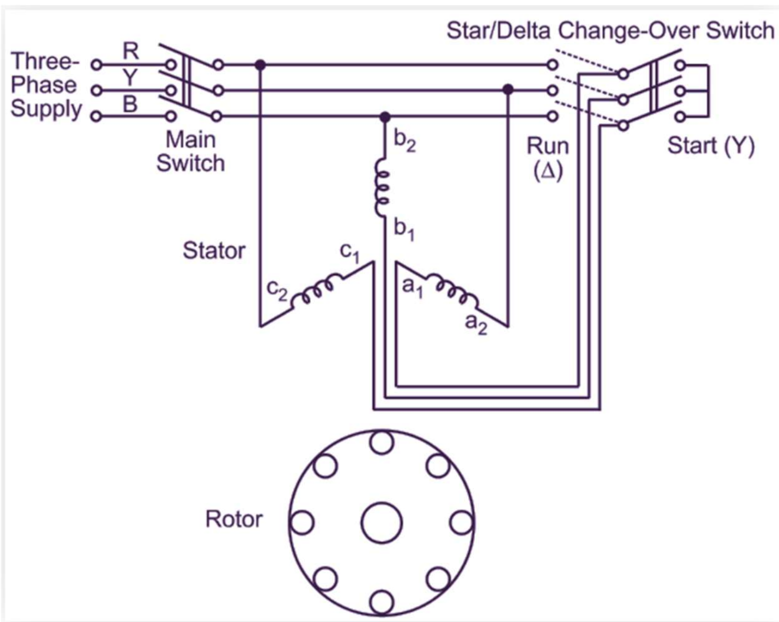
VI. Relevant Theoretical Background

Three-phase induction motors typically draw 5-8 times their rated current during starting when using DOL method. Star-delta starter reduces starting current by connecting the motor in star during starting (reducing voltage to 58%) and switching to delta for running. Soft starters use power electronics to gradually increase voltage and current, providing smooth acceleration and significant energy savings during starting. These methods reduce mechanical stress, improve power quality, and extend motor life while conserving energy.

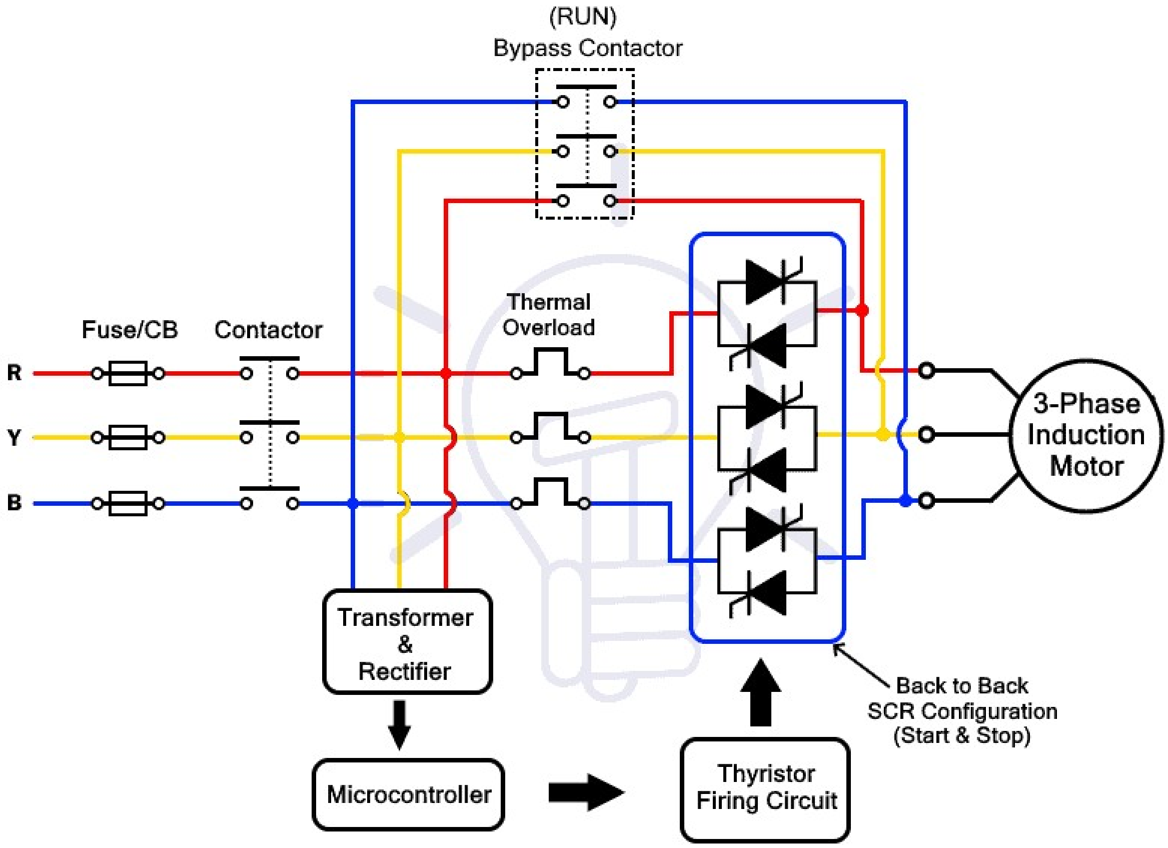
VII. Actual Diagram with equipment specification



Direct Online Starter



Star Delta Stater



Soft Starter

VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Three-Phase Induction Motor	1-5 HP, 415V	1	
2	DOL Starter	Suitable for motor rating	1	
3	Star-Delta Starter	Suitable for motor rating	1	
4	Soft Starter	Electronic, adjustable	1	
5	Power Analyzer	Three-phase, with data logging	1	
6	Clamp Meter	AC, 0-100A	1	
7	Stop Watch	Digital	1	
8	Connecting Wires	As per requirement	Set	

IX. Precautions to be followed

1. Ensure proper earthing of all equipment
2. Verify motor winding connections before starting
3. Set soft starter parameters as per manufacturer guidelines
4. Do not exceed motor rated current during testing
5. Allow cooling period between successive starts
6. Follow lock-out tag-out procedures during connections

X. Procedure

1. Connect the three-phase induction motor with DOL starter arrangement
2. Connect measurement instruments (power analyzer, clamp meter)
3. Start the motor using DOL starter and record:
    - Starting current
    - Starting time
    - Power consumption during starting
    - Voltage dip during starting
4. Switch to star-delta starter configuration
5. Repeat measurements for star-delta starting
6. Connect soft starter and set ramp time (typically 5-15 seconds)
7. Repeat measurements for soft starter
8. Compare all three methods for:
    - Maximum starting current
    - Starting energy consumption
    - Voltage dip
    - Starting smoothness
9. Document observations and calculate percentage savings

XI. Observation Table

SN	Parameter	DOL Starter	Star-Delta Starter	Soft Starter
1	Starting Current (A)			
2	Starting Time (seconds)			
3	Power During Starting (kW)			
4	Voltage Dip (%)			
5	Energy Consumed During Start (kWh)			
6	Peak Power Demand (kVA)			
7	Motor Temperature Rise (°C)			

XII. Result

The comparative analysis of different motor starting methods was completed successfully.

- Maximum starting current reduction with soft starter = **______ %**
- Energy savings during starting with soft starter = **______ %**
- Voltage dip improvement with soft starter = **______ %**
- Starting time variation = **______ %**

  Soft starter demonstrates superior performance in energy conservation and motor protection.

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. Explain why DOL starting causes high starting current in three-phase induction motors.
2. Calculate the percentage reduction in starting current when switching from DOL to star-delta starter.
3. What are the additional benefits of soft starters beyond energy conservation?
4. How does reduced starting current contribute to overall energy efficiency in industrial plants?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://www.safetyculture.com/checklists/energy-audit/	SafetyCulture (iAuditor) templates for energy audits.
2	https://www.energycap.com/	EnergyCAP – official software site for utility tracking and audits.
3	https://beeindia.gov.in/	BEE energy audit tools and accredited auditors list.

XVII. Suggested Assessment Scheme

Performance Indicators	Weightage (%)
Process related: 15 Marks	**60%**
1 - Circuit connections and safety	30%
2 - Accurate data recording	30%
Product related: 10 Marks	**40%**
1 - Comparative analysis quality	10%
2 - Answer to practical related questions	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No.18: Energy audit using energy audit software such as Safety Culture (formally iAuditor) or Energy CAP.

I. Practical Significance-

This practical provides hands-on experience with professional energy audit software tools that are widely used in industry for conducting comprehensive energy assessments. It develops digital literacy skills essential for modern energy auditors and demonstrates how technology can streamline data collection, analysis, and reporting processes.

II. Industry or Employer Expected Outcome-

Implement energy-saving measures and conduct comprehensive energy audits.

III. Course Level Learning Outcome-

Carryout energy audit for electrical system.

IV. Laboratory Learning Outcome-

LLO 18.1 - Energy audit using energy audit software such as Safety Culture (formally iAuditor) or EnergyCAP.

V. Relevant Affective domain related Outcome

Develop proficiency in digital tools and systematic approach to technology-enabled energy management practices.

VI. Relevant Theoretical Background

Modern energy audit software like Safety Culture (iAuditor) and Energy CAP digitalize the entire energy auditing process. These platforms provide standardized templates for data collection, automated calculations for energy savings, cloud-based data storage, and professional reporting capabilities. They help auditors maintain consistency, ensure compliance with standards, and provide actionable insights through data analytics. These tools significantly reduce manual errors and improve the efficiency and accuracy of energy audits.

VII. Actual Diagram / Flowchart

Draw Flowchart

VIII. Resources required

SN	Particulars	Specification	Quantity	Remark
1	Computer/Smartphone	Internet-enabled device	1	
2	Energy Audit Software	SafetyCulture/EnergyCAP trial	1	
3	Internet Connection	Stable broadband	1	
4	Digital Camera	For photographic evidence	1	
5	Measurement Instruments	As needed for audit	Set	
6	Sample Facility Data	For practice audit	1 set	

IX. Precautions to be followed

1. Ensure proper software installation and account setup
2. Verify internet connectivity for cloud-based applications
3. Backup data regularly during the audit process
4. Maintain data security and confidentiality
5. Validate automated calculations manually where critical
6. Follow software-specific guidelines and best practices

X. Procedure

1. Install and set up the selected energy audit software
2. Create user account and explore the software interface
3. Select or customize energy audit template
4. Conduct mock energy audit using sample facility data:
    - Input facility
    - Record energy consumption data
    - Document equipment specifications
    - Capture photographic evidence
    - Identify energy conservation opportunities
5. Use software features for:
    - Automated calculations
    - Data analysis
    - Savings estimation
    - Report generation
6. Review and refine the digital audit report
7. Compare software capabilities and outputs

XI. Observation Table

SN	Software Feature	SafetyCulture	EnergyCAP	Usability Rating
1	Template Customization			
2	Data Analysis Tools			
3	Reporting Capabilities			
4	Mobile Accessibility			
5	Calculation Automation			
6	Cost Estimation Features			
7	Learning Curve			

XII. Result

The energy audit using professional software was successfully completed.

- Software utilized = ______
- Time taken for digital audit = ______ **hours**
- Number of audit parameters recorded = ______
- Automated calculations performed = ______
- Report generation time = ______ **minutes**

  Digital audit tools demonstrated significant efficiency improvements over manual methods.

XIII. Interpretation of results

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XIV. Conclusions and Recommendations (if any)

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XV. Practical Related Questions

[Note] Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.

1. What are the key advantages of using digital software for energy audits compared to manual methods?
2. How does mobile accessibility enhance the efficiency of field energy audits?
3. What features should you look for when selecting energy audit software for an organization?
4. How can audit software help in tracking the performance of implemented energy conservation measures?

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XVI. References/ suggestions for further Reading

Sr.No.	Link	Description
1	https://safetyculture.com/iauditor/	Safety Culture iAuditor
2	https://energycap.com/	Energy CAP Software
3	https://www.energy.gov/energysaver	Energy Audit Tools

XVII. Suggested Assessment Scheme

Performance Indicators	**Weightage (%)**
Process related: 15 Marks	**60%**
1 - Software setup and navigation	30%
2 - Data entry and management	30%
Product related: 10 Marks	**40%**
1 - Quality of digital report	10%
2 - Answer to practical related questions	20%
3 - Submission of report in time	10%
Total : 25 Marks	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	