Jharkhand University of Technology
Ranchi, 834010

SYLLABUS

For Diploma Program in

Electrical Engineering/ Electrical & Electronics Engineering

(Effective from 2024-25)

DEPARTMENT OF ELECTRICAL ENGINEERING/
ELECTRICAL & ELECTRONICS ENGINEERING

(3rd – SEMESTER)

BASICS OF ELECTRICAL POWER SYSTEM

Subject code -EEE301

1. RATIONALE

A power system comprises of the various subsystems that include generation, transmission, and distribution and Load. Basic knowledge of Electrical Power System **is essential for student of diploma in electrical Engineering** to work in Generation, transmission and distribution field. An electrical engineering diploma student must be knowledgeable about various sources of energy, construction and operation of conventional and non-conventional power plants, economics of power generation and techniques of transmission and distribution. The study of basic concepts of electrical power generation will help the student to understand various issues associated with Generation, transmission and Distribution.

2. COURSE SKILL SET

The aim of the course is to help the student to attain the following industry identified competency through various teaching –learning experiences

- **Select the site** for Hydroelectric, Thermal, Nuclear, Wind and Solar power plants.
- **Construction and operation** of conventional and non-conventional power plants.

3. COURSE OUT COMES

On successful completion of the course, the students will be able to:

CO1	Describe the Non-renewable energy methods of Generation.
CO2	Describe the Renewable energy methods of Generation.
CO3	Analyze the economic operation of power generation.
CO4	Describe basic elements of the electric transmission and distribution systems.

4. DETAILS OF COURSE CONTENT

The following topics/sub topics is to be taught and assessed in order to develop Unit Skill sets for achieving CO to attain identified skill sets

Session No.	Contents
Unit-I	**Hydroelectric and Thermal power plants**
1	Power sector scenario including generation, transmission, and distribution scenario of India
2	**Introduction-**Importance of electrical power generation. Sources ofenergy available in nature. Conventional and non-conventional sources.
3	**Hydro power plant** -Factors to be considered for selection of site and Classify hydroelectric power plants based on the available head of water, plant capacity, load and construction.
4	General layout of hydro power plant and explain of its components. Meaning of water hammer and its effect.
5	Advantages and Disadvantages of Hydroelectric power plant. Environmental Impact of Hydel power plant
6	**Thermal power plant-** Factors to be considered for selection of site.General layout of thermal (steam) power plant.
7	Working of thermal power plant. Advantages and disadvantages ofThermal power plant. Environmental Impact of Thermal power plants
8	**Activity based Learning** on Hydroelectric and Thermal power plant
Unit-II	**Nuclear, Diesel and Gas turbine power plants**
9	**Nuclear power plant-**Factors to be considered for selection of site and Schematic diagram of nuclear power plant.

Session No.	Contents
10	Construction andworking of Nuclear power plant.
11	Nuclear power plant impacts such as Health physics, nuclear wastes and nuclear waste disposal. Comparison between thermal power plant with nuclear power plant.
12	**Diesel power plant**-Schematic diagram of a Diesel generator unit andmain components. Advantages and Disadvantages of Diesel power plant
13	**Gas turbine power plant-** Schematic diagram of a Gas turbine power plant. Advantages and Disadvantages of Gas turbine plant
14	**Activity based Learning** onNuclear, Diesel and Gas turbine power plants
Unit-III	**Solar photovoltaic system and Wind Power plant**
15	Photovoltaic effect, solar power, Construction of solar cell, solarphotovoltaic module with block diagrams.
16	Construction of photovoltaic panel and PV array with block diagrams.Materials used in solar cells and Solar cells Applications.
17	Classification of solar photovoltaic systems.
18	Stand-alone and grid interactive solar PV system with block diagram
19	Advantages and dis-advantages of PV systems and environmental impactsof solar PV system on environment.
20	Importance of Wind Energy. Explain the origin of Global and local winds.
21	Factors affecting distribution of wind energy on surface of the earth. Factors to be considered for site selection.
22	Nature of winds with neat sketches.
23	Classification of wind turbine generator, Comparison between horizontalaxis and vertical axis wind turbine generator Environmental Impact of wind plants.
24	**Activity based Learning**onSolar PV system and Wind Power plant
Unit-IV	**Biomass Power, Fuel cell and Hybrid PV systems**
25	**Urban waste to energy conversion-** Block diagrammunicipal solid waste (MSW) to energy incineration plant.
26	**Bio Energy**-Describe biomass and sources, conversion process. Importance of biomass energy and its scope. Factors to be considered forsite selection. Line diagram of biomass power plant. Benefits of biomass. Biomass briquetting

Session No.	Contents
27	Bio fuels, electricity generation using biomass. Biogas plants, mention types of biogas plants.
28	**Chemical Energy source:** fuel cells**,** working of fuel cells, classification, applications
29	Hybrid PV systems-Types of hybrid PV systems.
30	Block diagram PV-Wind hybrid system and, PV-fuel cell hybrid system.
31	**Activity based Learning**onBiomass Power, Fuel cell and Hybrid PV systems
Unit-V	**Economics of Power Generation**
32	Related terms: connected load, firm power, cold reserve, hot reserve, spinning reserve.
33	Base load and peak load plants; Load curve, load duration curve, integrated duration curve
34	Cost of generation: Average demand, maximum demand, demand factor, plant capacity factor, plant use factor, diversity factor, load factor and plantload factor.
35	Simple problems on Cost of generation
36	Choice of size and number of generator units, combined operation of power station.
37	**Activity based Learning**onEconomics of Power Generation
Unit-VI	**Basics of Transmission and Distribution**
38	**Transmission:** AC transmission and distribution system with typicalSingle line diagrams with components of the electric supply transmission and distribution systems.
39	Classification of transmission lines: Primary and secondary transmission; standard voltage level used in India
40	Classification of transmission lines: based on type of voltage, voltage level, length and others, Characteristics of high voltage for power transmission.
41	HVDC transmission lines-block diagram, list and explain the functions of main components of HVDC transmission system
42	**AC Distribution**: Components classification, requirements of an ideal distribution system, primary and secondary distribution system.
43	Connection schemes of distribution system- radial, ring main and interconnected systems. Distinguish between Feeder, distributor andservice main.
44	Substation and receiving station and their functions, Classification of substations.
45	Single Line diagram (layout) of 66/11KV Substation,Symbols and functionsof their components.
46	Single Line diagram (layout) of 11KV/400V Sub-Station Symbols and functions of their components.

Session No.	Contents
47	Causes and Impact and reasons of Grid system fault: State grid, national grid, brownout and black out, Sample blackouts at national and international level
48	Explain Black start Restoration
49	Explain Demand side Management
50	Functions of Load Dispatch Centre
51	Functions of Power Generation and Distribution Companies Different electric distribution companies and their functions (BESCOM, MSCOM, HESCOM etc.)
52	**Activity based Learning**onBasics of Transmission and Distribution
	TOTAL

SUGGESTED LEARNING RESOURCES

Reference Books:

Principles of power system by V.K.Mehta and Rohit Mehta S.CHAND
Generation of Electrical Energy, by B.R.Gupta, publisher S.chand& company LTD, New Delhi
Electrical Power Generation, Transmission and Distribution. - S.N.Singh. PHI Publications.
Elements of power station design-M V Deshpande-PHI Publications
Power Plant Engineering - A. K. Raja, New Age International Publisher
Generation Distribution and Utilisation of electric energy by C.L. Wadwa, -New-Age International Publisher
Non-conventional Energy Resources - G.S.Sawhney, PHI publications, second Printing-2014, Delhi-110092.
Non-conventional Energy Resources-B.H.Khan 2 d Edition Tata McGraw hill PVT, New-Delhi.
Solar photovoltaic Technology and systems, - Chetan Singh Solanki, PHI, Delhi-110092.
Generation of Electrical Energy, by B.R.Gupta, publisher S.chand& company LTD, New Delhi
Transmission, distribution and utilization – vol 3 B.L Thereja and A.K.Theraja.
Transmission and Distribution of Electric Power by J.B Gupta Katsons Publications.
Energy Management by Dr. Umesh Rathod, Katson publications

E-resources:

1. https://en.wikipedia.org/wiki/Electricity_generation.
2. https://www.google.com/phindia.com//solarphotovoltaics.
3. https://www.schandgroup.com.
4. https://www.tatamcgrawhill.com
5. https://www.youtube.com/watch?v=daeyoS-PCUA (Generation, distribution and transmission of electrical power)
6. https://www.youtube.com/watch?v=IdPTuwKEfmA (Thermal power plant)
7. https://www.youtube.com/watch?v=zcWkEKNvqCA (Gas turbine power plant)
8. https://www.youtube.com/watch?v=-hooifWJ1jY (Hydroelectric power plant)
9. https://www.youtube.com/watch?v=bQ23kCvokAc (Nuclear power plant)
10. https://www.youtube.com/watch?v=eAX_fK_c8Mc (Diesel power plant)
11. https://www.youtube.com/watch?v=ZLgOoMSlS3Y (Solar)
12. https://www.youtube.com/watch?v=qSWm_nprfqE (wind)
13. https://www.youtube.com/watch?v=VkTRcTyDSyk (Tidal)
14. https://www.youtube.com/watch?v=sZuc4LMtHoY (Wave)
15. https://www.youtube.com/watch?v=OL26yYFmDHU (Ocean thermal)
16. https://www.youtube.com/watch?v=3UafRz3QeO8 (Biogas)
17. https://www.youtube.com/watch?v=nVl17JLn_u0 (Biomass)
18. https://www.youtube.com/watch?v=bXHwnKMchkk (Fuel cell)
19. https://www.youtube.com/watch?v=qjY31x0m3d8 (Transmission lines)
20. https://www.youtube.com/watch?v=WUHcVXjfsxs (Transmission and distribution)
21. https://www.youtube.com/watch?v=R_HGnc63QKU (Power blackout)
22. https://www.pbs.org/wgbh/nova/labs/lab/energy/1/1/ (Alternative energy)

23. We have to create interest among the students through Activity-Based Learning (ABL)
24. Classroom activities will give simultaneous benefits to both students as well as for teachers (students can overcome the difficulty in learning typical course, teachers can deliver a topic in a variety of approaches effectively).
25. Collaborative learning among students will create a healthy learning environment and also emphasize student's performance, teamwork.
26. Any student tries to identify a solution for a given problem but, through collaborative learning with a group of people will give an **optimized** solution to the same **problem.**

ACTIVITY BASED LEARNING:

In order to develop **higher order thinking skills**, it is important to conduct lessons using **activity- based teaching.**

Activity Based Learning **Suggested Activities in Class**
1. Identification of Topic (IOT): • The objective of this activity is to identify, recollect the technical words. • Identification of topic names /part name, parts of an apparatus, a mistake in the content ingiven image.
2. Word search: place technical words, components names of in the 12 x 12 table in various directions (left to right, right to left, top to bottom, bottom to top, diagonally from top to bottom and diagonally bottom to top from both sides (left, right)). The objective of this activity is to search technical words in the course.
3. **Mind map:** Students have to draw a variety of mind maps by interfacing power system topics with aspects of societal, environment, etc. By these mind maps students elevated power system concepts in a different approach, so that they can remember the concepts for a long time. • https://creately.com/diagram/example/i08rf3b52/Mind%20Map%20of%20Hydroelectric%20Dam. • https://durofy.com/mind-map-energy-resources • https://www.brighthubengineering.com/power-plants/17353-electricity-generation-in-power-plants/
4. Mapping/Scratch Cards: Prepare various quiz questions cards, answers cards, and scratchcards. Separate, question cards on the left side, answer cards on the right side and asked batch- wise to map question cards with answer cards. https://www.essentialenergy.com.au/ext/electricity-and-safety-unit/assets/documents/Lesson%204%20-%20Practical%20-%20Generation%20and%20movement%2011.pdf
5. Crossword: create a cross on any of the topics of the course using online resources : https://wordmint.com/public_puzzles/182138 Students have to draw various types of power plants that are exploring their creativity
6. **Preparing Posters/ chart:** students have to prepare posters/ charts on various topics of power system and present in the class.

7. Energy games

Energy Island game
http://siemens.zincmediadev.com/energy/island/index.html **Game on wind and Solar Power Generation**
https://climatekids.nasa.gov/power-up/
Game on Solar Power Generation
https://wonderville.org/asset/solarenergydefenders
Game on wind , Solar Power, Hydel and Geothermal Generation
https://wonderville.org/asset/save-the-world
Game on Generation, Transmission and Distribution
http://www.hydroquebec.com/games/network/flash.html Mange Virtual power Plant and prevent blackout
https://www.next-kraftwerke.com/virtual-power-plant-vpp-simulation/?lang=en Game on Power GRID
https://gamejolt.com/games/powerthegrid/306616 Game on Design Renewable future
https://www.pbs.org/wgbh/nova/labs//lab/energy/research Game on Energy City
https://assets.jason.org/resource_assets/8239/3733/popup.html

8. Case Studies: Through this activity, students will get to know about problems/issues whichare happening/happened in the Power System sector.

Transmission and Distribution

Subject code -EEE302

1. Rationale:

Electric power transmission is the bulk movement of electrical energy from a power plant, to an electrical substation. Transmission network is the interconnected lines which facilitate this movement. Efficient transmission involves reducing the currents by stepping up the voltage prior to transmission, and stepping it down at a substation at the far end. Electric power distribution is the final stage in the delivery of electric power, it carries electricity from the transmission system to individual consumers through distribution substation. An Electrical Technician shall have the knowledge of the various T&D systems, components of the T&D systems and constructional features, simulate its performance, losses, distribution line maintenance and substations and shall prepare an estimation using estimation software.

2. Course Outcomes/Skill Sets: On successful completion of the course, the students will be able to

CO-01	Conduct performance analysis of a given transmission and distribution lines in a real/ simulated environment
CO-02	Describe the procedure to install, test and maintain transmission & distribution lines.
CO-03	Prepare the list of equipment/materials with specifications to install a given transmission and distribution system.

3. Course Content

Week	CO	PO*	Lecture (Knowledge Criteria)	Tutorial (Activity Criteria)	Practice (Performance Criteria)
1	1	1,4	1.Vectorial representation of AC quantities. Represent vectors in Rectangular, Trigonometric and Polar forms, Convert Rectangular form into Polar form and vice-versa and problems on R to P and P to R. Arithmetic operations on vectors, problems	Refer Table 1	1. Measure active power, reactive power, apparent power and power factor in a single-phase/ three- phase circuit using appropriate measuring instruments. Ensure improvement of PF by use of capacitor in single-phase/three phase circuit.
			2. Concept of active power, reactive power, apparent power and power factor in AC circuit.		Introduction to simulation software

			calculate active, reactive, apparent power and power factor in a given single/ 3phase phase AC circuit. 3a. Explain KCL and KVL 3b. Explain Thevenin's and Superposition theorem, application of theorems.		1. Verify KCL and KVL using simulation software.
2	1	1,4	1.Various systems for power transmission and distribution: 2 wire AC, 3 wire AC and 3 phase 4 wire AC systems. -Simple Problems -Compare HVAC and HVDC system. **2.Line Constants and Performance:** -Classification of transmission lines based on distance. - Line constants -resistance, inductance and capacitance. -Short transmission line- equivalent circuit 3. Vector diagram of a short transmission line. -Equations for receiving end voltage, efficiency, voltage regulation and power factor. - simple problems	Refer Table 1	1.Simulate a given short transmission line-1 2. Simulate a given short transmission line-2. Find i. Sending end active and reactive power ii. Receiving end active and reactive power. iii. Voltage regulation and Transmission efficiency. compare simulation results with calculated values.**Ref.7(6)**
3	1	4	1. Skin effect, Ferrantic effect transposition of conductor and its necessity. 2. Corona: Phenomena, disruptive and visual critical voltages, corona loss. Advantages and disadvantages of corona. Methods of reducing corona. 3.Explain Transmission and Distribution losses. **Ref.7(9,10,11)**	Refer Table 1	1.Simulation of Ferranti effect. **Ref.7(7)** 2.Solve problems on Transmission and Distribution losses. **Ref.7(8)**
4	1	4	1. Main components of overhead transmission lines (Supports, Cross arms and Clamps. Insulators, Conductors., Guys and Stays., Fuses and Isolating Switches, Continuous Earth Wire etc.). 2. Characteristics and applications of ACSR, AAC, AAAC conductors, types of ACSR and	Refer Table 1	1a. Identify Different components of Overhead Transmission lines. 1b. Identify various conductors viz., All aluminium conductor (AAC), AAAC, ACSR conductor. 2. Identify HT/LT line insulators •Install the shackle type insulator on HT overhead line • Install the pin type insulator on the LT overhead line.

			their applications, compare ACSR, AAC, AAAC conductors. Insulators-suspension, Pin Type, Shackle Type, Disc Type, Guy Strain, Pins for Insulators.		• fasten jumper in cross-arm of pole with pin insulator • fasten the jumper in shackle type insulator • fasten the jumper in the suspension type insulator.
			3. Guy Assembly, G.I. Wire, GO Switches, 11kV Cross-arms, L.T. Line Spacers, spacing between conductor, concept of length of span, sag on overhead line, Guarding, Types of Guarding.		
5	1	4	1. **UNDERGROUND TRANSMISSION LINES**: - Classification of UG cables -General construction of a single core UG cable -Need of HT cables, advantages and disadvantages -Selection of HT and LT underground cable.	Refer Table 1	Comply with safety & IE rules while working on LT/ HT cables. 1a. Identify different types of HT/LT cables. b. Identify different parts of various underground cables. c. Select appropriate cable for given application.
			2.Construction of PVC, Construction of 3 core XLPE cables -Advantages and Disadvantages of Underground Power Cable System.		2a. Practice preparation of cables for termination and joining. b. Demonstrate termination kits and practice on terminations of LT/HT cables. **Ref.7(21)**
			3. Scope of IS 7098-1 and IEC standards for various cables (IEC 60502-1, IEC 60502-2).		
6	1,2	2,4	1.Methods of laying UG cables. Faults in UG cable. **Cable gland-** different types of cable gland, lug, types.	Refer Table 1	1a. Identify various cable single and double glands. and lugs. b. Test the underground cables for open, short circuit & ground fault and also check insulation resistance
			2.Underground Cable Testing		
			3. Bonding and grounding		2.Demonstrate bonding and grounding of raceways, cable assembly and panels.
7	1	4	1**.Substation:** Meaning of substation, Necessity of substation, classification, comparison between outdoor and indoor substation.	Refer Table 1	**In grid map of Karnataka** 1a. Locate 765kV, 400kV, 220kV, 110kV & 66kV Substations b. Locate 400kV, 220kV, 110kV & 66kV transmission lines. c. Locate 400kV HVDC station and Transmission line.

			2. Code of practice related to substation. List the materials required for 66/11 KV substation with their specifications **Ref.7(23,24)**		2a. Read and Interpret Single line/ Layout drawings with Equipment and Protection codes as per ANSI. 2b. Read and Interpret Layout drawings of 220kV, 110kV & 66kV outdoor substations. Interpret various panel wiring drawings of substation equipment
			3.Capacitor banks, specifications and calculation. **Ref.7(17,18, 19)** selection of capacitor bank.		
8	1	4	**Substation Energy meters:** - 1a. Error, precision, accuracy, sensitivity, resolution and tolerance. Types of errors- gross error, random error, systematic error environmental, observation error and instrumental error. 1b. Trivector energy meter Ref.7(12) -Common Meter Reading Instrument (CMRI) **Ref.7(14,15)** -Class of accuracy of energy meters.	Refer Table 1	1a. Demonstrate working of Trivector energy meter, Identify the class of accuracy of given energy meter. Ref.7(12) 1b. Practice on using MRI (Meter reading instrument)
			2. -Standards for electricity metering -Scope of **IS 15707** -Scope of **IEC 62052-11** -Distributed Digital Fault Recorder (DDFR). **Ref.7(16,17)**		2a. Take meter reading by using USB / Optical cable. 2b. Operation of SBM (Spot billing machine).
			3.Maintenance and up keeping of daily Log Sheet at various Substation and energy accounting.		
9	1	2,4	1. **Distribution System**: Single line diagram of AC distribution system, Classification of AC distribution system, connection schemes of distribution system- radial, ring main and interconnected systems.	Refer Table 1	Observe the various components of the **Distribution System** by visiting the MUSS and prepare report Obtain: 1. Number of feeders connected 2. Energy consumption of each feeder 3. Number of DTC meters connected 4. Percentage of distribution losses 5. 11kV Feeders Interruption Details 6. Operation of 11 kV feeders supplying power to IP sets in open delta
			2**.** Feeder, distributor and service main, characteristics of Feeder, distributor and service main.		
			3.Concept of voltage drop in feeders/distributors - simple problem on DC distributor fed at one end.		

10	1,2	2,4	**1. OPERATION OF 11KV/440V DISTRIBUTION SYSTEM-** -List Various components of the 11 kV power system (Components: e.g. transformers, Isolators, CTs, PTs, Circuit breakers, LA's, etc.) -List Various types of Panels & Substation protection systems	Refer Table 1	Observe the various components of the power system by visiting the 11 kV substation and prepare report 1. List the job requirements as per the government policies and regulations 2. Observe the various components of the power system by visiting the11kV substation (Identify various substation equipment viz., isolators, over current relays, earth fault relay, differential relay, REF relay, lightning arresters, Surge counter, wave trap, Reactor, Capacitor bank, Circuit breakers – ACB, SF-6 and VCB etc.) 3. List the materials required for the 11 kV installation 4. Observe the substation erection and installation work 5. Observe the operation of distribution transformer 6. Check the poles set to proper depth, and are properly aligned 7. Observe the erection of channel on the pole 8. Observe the fixing of lightning arrester 9. Check the installation of earth connection as per standard procedure 10. Observe the lifting Observe the lifting of the transformer, to put it on the transformer bed in a safe and efficient manner 11. Observe the connection of low voltage cables" 12. Identify Aerial bundled cables for LT and HT
			2a. Transformer parts and their function. 2b. Specific health and safety precautions which must be taken when carrying out substation installation processes		
			3.Construction of Aerial Bundled (AB) Cables, - advantages and disadvantages, - AB Cables for LT Lines. -, AB Cables for HT Lines		

11	2	2,4	**1. Maintenance schedule for distribution Transformer** a. Explain the terms inspection, preventive maintenance and overhaul. b. Explain recommended schedule for inspection of Distribution transformers. c. Explain recommended schedule for preventive maintenance of Distribution transformers. d. Explain recommended schedule for overhaul of Distribution transformers. **Ref 7(22)**	Refer Table 1	Visit the nearby substation prepare report on 1. Maintenance schedule for distribution Transformer 2. Maintenance schedule for 11kV overhead lines 3. Maintenance schedule for 11kV UG system as per standard format
			2. Maintenance schedule for 11kV overhead lines a. Explain recommended schedule for inspection of 11kV overhead lines b. Explain recommended schedule for preventive maintenance of 11kV overhead lines c. Explain recommended schedule for overhaul of 11kV overhead lines. **Ref 7(22)**		
			3. Maintenance schedule for 11kV UG system a. Explain recommended schedule for inspection of 11kV UG system b. Explain recommended schedule for preventive maintenance of 11kV UG system c. Explain recommended schedule for overhaul of 11kV UG system **Ref 7(22)**		
12	3	2,3	1. Prepare schedule of materials for providing single-phase OH and UG service connection for electrification of a residential building.	Ref table 1	Prepare estimation manually/ using estimation simulation software
			2.List the materials used in transmission lines with their specifications. Classify the types of towers. Prepare a table showing voltage level, ACSR conductor used,		

			number of discs insulators in suspension string and tension string		
			3. Prepare the schedule of materials for the 11 KV single circuit HT line for Rural Electrification."		
13	3	2,3	Estimate for Electrification of newly formed Residential Layout to an extent of 1045 KW including street light, water supply and STP installations. 1. Tapping and Extension 11KV line of (F-11) feeder of 66/11KV MUSS upto the Proposed Layout using Rabbit ACSR Conductor and 3*95 Sqmm XLPE HTUG Cable 2. Extension 11KV line Inside the Proposed Layout using Rabbit ACSR Conductor 3. Providing 11Mtrs Spun Pole Transformer Structure with allied Materials for erection of 3x250KVA and 1x100KVA 5 Star Rated Distribution Transformers on Concrete Bed. 4. Extension of LT Overhead line (3 Phase, 5Wire) inside the layout Premises and Providing Street Light Metering. 5. Calculate HT VR (voltage regulation) and LT VR.		Prepare estimation manually/ using estimation simulation software
Total in hours			**39**	**13**	**52**

Reference:

Sl. No.	Description
1	Transmission, distribution and utilization – vol 3 B.L Thereja and A.K.Theraja.
2	Principles of Power System" by V. K. Mehta, Rohit Mehta S. Chand Publishers, 4th Revised edition 2008
3	Electrical Power Generation Transmission and Distribution by S.N.Singh, PHI Publication
4	Transmission and Distribution of Electric Power by J.B Gupta Katsons Publications.
5	Electric Power Distribution Automation by M.K Khedkar, University Science Press (Laxmi Publications)

6	https://www.youtube.com/watch?v=Knpt6zcK CU
7	http://vp-dei.vlabs.ac.in/Dreamweaver/objective9.html
8	https://www.easycalculation.com/physics/electromagnetism/eletrical-power-transmission-line- power-loss.php
9	https://electricalnotes.wordpress.com/2014/03/01/calculate-technical-losses-of-distribution-line/
10	https://blog.se.com/energy-management-energy-efficiency/2013/03/25/how-big-are-power-line- losses/
11	https://blog.se.com/access-to-energy/2018/06/29/effective-power-distribution-and-asset-monitoring-can-shelve-off-losses-in-transformer-services/
12	https://instrumentationforum.com/t/working-principle-of-trivector-meter/6996
13	https://www.youtube.com/watch?v=ZP-Gv ERN7k, https://www.youtube.com/watch?v=SgMhJQdVONQ
14	https://dhbvn.org.in/staticContent/tender/mm/specification/spec-cmri-453.pdf
15	https://www.youtube.com/watch?v=SgMhJQdVONQ
16	https://www.aimil.com/products/digital-fault-recording-systems
17	https://www.gegridsolutions.com/multilin/catalog/ddfr.htm
18	https://www.watelectrical.com/what-is-a-capacitor-bank-working-and-its-calculation/
19	https://www.gegridsolutions.com/hvmv equipment/catalog/high volt capacitor.htm#Ov7
20	https://www.metartec.com/DataEditorUploads/R8%20-%20Capacitor%20banks%20and%20accessories.pdf
21	https://www.youtube.com/watch?v=oKhKFALKDAE
22	https://kptcl.karnataka.gov.in/storage/pdf-files/epra/mmdsystem.pdf
23	https://kptcl.karnataka.gov.in/storage/pdf-files/epra/Maintenance%20Schedule.pdf
24	https://kptcl.karnataka.gov.in/storage/pdf-files/epra/HAND%20Book%20Of%20manitenance%20Schedule%20For%20Staions%20&Transsion%20Lines.pdf
25	Electrical Design Estimating and Costing. K.B.Raina & K.Battacharya. Khanna Publications
26	Electrical Installation Estimating and Costing. J.B.Gupta, S.K.Kataria and Sons

9. Equipment/software list

Sl. No.	Particulars	Specification	Quantity
1	Trivector energy meter		
2	Common Meter Reading Instrument (CMRI)		
3	Distributed Digital Fault Recorder (DDFR)		
4	SBM (Spot billing machine)		
5	Capacitor Banks		
6	GNU Octave/ SCI LAB /PSCAD /MATLAB software		
7	Electrical Estimation software		

Switchgear and Protection

Subject code -EEE303

1. Rationale:

Electrical switch gears and protective devices are the main components of power systems in any type of industry like power sector, manufacturing, process industry, hospitals, hotels, commercial buildings etc. An electrical and electronics diploma graduate should be capable of testing, commissioning, troubleshooting and maintenance of the electrical switchgears and protection devices.

2. Course Outcomes/Skill Sets: On successful completion of the course, the students will be able to

CO-01	Demonstrate the operation and testing of a given switchgear.
CO-02	Select a switchgear for a given application and list the procedures for preventive maintenance of such a switchgear to ensure it performs optimally.
CO-03	Demonstrate the testing of a protection scheme for a given power system including all its elements (alternators, transformers, bus bars and feeders).
CO-04	Identify accessories of a control panel and demonstrate the testing procedure of a given LV control panel.

3. Course Content:

Week No.	**CO**	**PO***	**Lecture (Knowledge Criteria)**	**Tutorial (Activity Criteria)**	**Practice (Performance Criteria)**
1	1	1,4	1.Meaning of Switch gear, Types-Indoor type and Outdoor type, Essential features of Switchgear, List most commonly used Switchgear equipment and Protective Devices for switching and interruption of current. Importance of power system protection and Necessity of Protective Devices.	Refer table 1	1.Identify various fuse sets viz., HRC, DO, 33KV fuse set, etc.
			2.Sources of Faults, Types of faults, Harmful Effects of short circuit current, Symmetrical and unsymmetrical faults on three-phase systems.		2a. Measure and select the appropriate size of fuse wire. 2b. Test the HRC fuse by performing a Load test.
			3.**Fuse**- Meaning, List the types of fuses with applications, Fuse Element Materials, Desirable features of Fuse elements, Characteristics of fuse. Important Terms: Current Rating of Fuse element, fusing current, fusing factor, Prospective current, cut off current, Pre-Arcing Time, Arcing Time,		

			Breaking Capacity, Total Operating Time. HRC fuses –list the types and applications, general construction and working, Merits and demerits.		
2	1	1,2,4	1.**Circuit Breaker** – Meaning, Classification of Circuit Breakers, list the types -LV, HV types with applications. Explain the terminologies – Circuit Breaker Rating, Arc-Voltage, Arching Time, Pre – Arcing Time, Prospective Current, TRV, Recovery Voltage, RRRV, Total Break Time, Making current, Breaking current, Short circuit rating and Short-time current rating.	Refer table 1	1a. Identify the various types of CB- MCB, ELCB, RCCB, MPCB and MCCB. Trace and locate MCBs used in your institution and note down their specifications. 1b. Dismantle MCCB/ELCB and identify various parts. 1c. Test the MCB and plot its inverse time characteristic curve.
			2.Construction, working principle and applications of ELCB, RCCB, MCCB and MPCB. Concept of **ACCL** (automatic changeover with current limiter).		2a. Troubleshooting and servicing of LT circuit breaker. 2b. Test any commercially available **ACCL.**
			3.MCB- Types, Classification based on trip curves and their application, General construction and working, Characteristics of MCB.		
3	1,2	1,2,4	1.HV Circuit Breaker- working concept. ACB- Working principle, Construction, Merits, Demerits & Applications.	Refer table 1	Visit to Substation. 1a. Identify the parts of circuit breaker and check its operation. 1b. Demonstrate test tripping characteristic of circuit breaker for over current and short circuit current.
			2.VACUUM CB- Working principle, Construction, Merits, Demerits & Applications.		2a. Demonstrate Installation operation and maintenance of SF6 circuit breaker, Vacuum circuit breaker. 2b. Carry out timer test on circuit breakers. 2c. Demo on RMU
			3.SF6 CB- Working principle, Construction, Merits, Demerits & Applications. Concept of RMU (Ring main unit) and LBS (Load Break Switch)		
4	1	1,4	1.**Protective Relay**- Definition, Types of relays, Classification of protective relaying with applications, Meaning of Primary and Back up protections, Desired qualities of Protective Relaying, General Features of protective relays. Important Terms: pick up VA, Hold-on VA, drop out VA and Burden Pickup current, current setting, PSM, TSM, Time -PSM Curve.	Refer table 1	1a. Demonstrate various parts of the relay and ascertain the operation. 1b. Demonstrate setting of pick-up current/ time setting multiplier for relay operation. Ref.7(7)
			2.Construction. Working principle and application of Earth Leakage relay. Meaning of ZCT (Zero-Phase Current		2a. Test the Earth Leakage Relay. (Anyone type). 2b. Test the

			Transformers), **CBCT** (Core balance CT) - construction, working and application.		Electromechanical over current OR **over** voltage relay.
			3.Construction. Working principle and application of Induction type Electro-mechanical Over Current and Overvoltage Relays. Merits and Demerits of Electro- Mechanical relays. List and explain different Testing Methods for Relays		
5	1	1,4	1a. Block diagram and working of Microprocessor/ Microcontroller based Overcurrent Relay. 1b. Causes of over voltages and under voltages, Effects of OV/UV.	Refer table 1	1.Test the Static Over Voltage and Under Voltage Relay and Plot its inverse time – Voltage Characteristics. OR 1.Test static Over Current Relay (Anyone type of static relay).
			2a. Construction, working and application of Static relays- OV/UV relay and OCR relay. 2b. Lightning arresters & surge absorbers - Construction and principle of operation.		2a. Program and test the Numerical Over Current/ Earth Fault Relay for Normal inverse curve for various PSM and TMS and for definite Time operations. 2b. Demonstrate multifunctional numerical relays.
			3a. Construction, working and applications of Numerical Relays. Comparison of Static Relays with Electro-Magnetic Relays and microprocessor/microcontroller-based relays. 3b. Concept of Multifunction Protection numerical Relays.		
6	3	1,4	**Transformer protection:** 1a. Explain Abnormalities & List different types of Faults. 1b. Construction and working of Circulating Current Scheme for Transformers Protection. Ref.7(10)	Refer table 1	1.Test the operation of Buchholz Relay.
			2a. Construction and working of Earth Fault or Leakage Protection Systems for Transformer. 2b. Construction and working Stator Inter Turn Protection for transformers.		2a. Conduct BDVT on Transformer oil. 2b. Demo on Restricted earth fault protection of Transformer.
			3a. Construction and working of Buchholz Relay. 3b. Transformer oil – Electrical properties, desired properties and applications of Transformer oil , BDVT.		
7	3	1,4	1.Alternator Protection-Types of Protection, Explain Abnormalities and List different types of Faults.	Refer table 1	Simulate/Test Alternator protection scheme.
			2.Construction and working of Differential protection for Alternators.		

			3.Construction and working of Balanced Earth Fault Protection for Alternators.		
8	3	1,4	**Feeder Protection:** 1a. Explain abnormalities and list different types of Faults. 1b. Time Graded Over Current Protection on transmission line.	Refer table 1	1.Simulate/Test the operation Distance Relay.
			2a. Construction and working of Differential Pilot – Wire Protection. 2b. Discuss Basic principle of Distance Protection.		2.Simulate/Test the operation of Differential Relay.
			Bus–Bar Protection: 3a. Explain Abnormalities & List different types of Faults. 3b. Construction and working of Differential Protection of Bus -Bars.		
9	1,3		1.List Testing methods of Circuit Breaker, Explain type test and routine test & maintenance.	Refer table 1	1.Test the operation of the LV circuit breaker.
			2.List & Explain Testing methods of CT's & PT's and Maintenance of Relays.		2. Demonstrate Substation earthing.
			3.Explain Substation Earthing (Solid, Resistance and Reactance Earthing), -Neutral Earthing-Importance and types -Explain Principle and applications Peterson coil.		
10	4	2,3,4	1.Control Panel –Meaning, Types/various forms, construction of typical control panel. **Power gears-** Isolators, SFU (switch fuse unit), change over switch, selector switch.	Refer table 1	Typical low voltage power distribution panel- Identify and study the types of contactors- Power contactors and auxiliary contactors. Dis-assemble, perform preventive maintenance, service, assemble and test the contactors. Testing of control panel a. Visual test b. Insulation test c. Testing of control circuit. d. Testing of power circuit e. Conduct Logic tests
			2.Contactors – types, configuration and their specifications, various control accessories like PB switches, Indicators.		
			3.Explain various sections of control panel- Incoming section, outgoing section, busbar section.		
11	4	4	1.**Metering section** – Energy meter, Trivector meter, multi-function meter.		1.Install and test Multifunction meter.
			2.**Various auxiliary relays**: lockout, DC failure relay, TCS (trip circuit supervision relay), contact multiplier relay. -Safety interlocks.		2a. Identify and test various Auxiliary relays 2b. Demonstrate(video) Interlocking operation.
			3.Significance and importance of: IEC 61439 standards ANSI Device numbers		

12	1,4	4	1.**Motor Control Centre (MCC):** working, typical specification and application: Motor protection relay		1.Test the Motor Protection Relay.
			2a. Working, typical specification and application: Thermal Overload Relays 2b. Working, typical specification and application: Bimetal Relays -Direct / CT operated.		2.Test the operation of Thermal OLR
			3.Scope of IEC standard IEC 60947-4-1		
13	4	4	1.APFC (Automatic power Factor Control panel) - construction and working.		1.Test the operation of APFC.
			2.AMF (Automatic mains failure) panel - Construction and working.		2.Test the operation of AMF panel.
			3.STP (Standard Temperature Pressure Control) panel- Construction and working.		
Total in hours			**39**	**13**	**52**

Reference:

Sl. No.	Description
1	Principles of Power System" by V. K. Mehta, Rohit Mehta S. Chand, 4th revised edition 2008
2	Power System Protection and Switchgear by Buvanesh A Oza, Nirmalkumar C Nair, Rases P Mehta and Vijay H Makwana, McGraw HILL Education (India Pvt. Ltd) Newdelhi
3	J.B.Gupta "Switchgear & Protection", (edition), Katson Publisher,2008
4	MadhavaRao T.S., 'Power System Protection - Static Relays', McGraw Hill, New Delhi,2nd Edition, 21st reprinted, 2008.
5	Handbook of Switchgears by BHEL
6	Testing, commissioning, operation and maintenance of electrical equipment by Sunil S Rao, Khanna Publications
7	Protection relay: Power system protection - YouTube
8	Transmission Line Protection (21) - YouTube
9	Restricted Earth Fault Protection|REF relay working principle - YouTube
10	TRANSFORMER PROTECTION|ELECTRICAL TECHNOLOGY AND INDUSTRIAL PRACTICE - YouTube
11	MOTOR PROTECTION|PROTECTION OF INDUCTION MOTOR|ELECTRICAL TECHNOLOGY AND INDUSTRIAL PRACTICE - YouTube
12	Bus Bar Protection|Busbar Differential Protection|How busbar is protected - YouTube
13	Directional Over current relay|Protection of parallel lines|Directional over current protection - YouTube
14	Distance Protection|Transmission Line Protection|Impedance protection|Protection of line - YouTube
15	Differential protection in power transformer - YouTube
16	Protection of transformer - YouTube
17	Differential protection - YouTube
18	Transformer Differential Protection: Challenges and Solutions - YouTube
19	GENERATOR PROTECTION|PART 1|GENERATOR CONNECTION|GENERATOR EARTHING|GENERATOR FAULTS - YouTube
20	Earth Leakage Relay - ELR / How to Wire ELR & CBCT with MCCB / Working Principle of ELR - YouTube
21	Over current relay CDG 31 - YouTube

22	Smart WiFi Circuit Breaker Automatic Remote-Control Protection for Solar and any other appliances https://www.youtube.com/watch?v=m1r-78m51ds

Equipment/software list

Sl. No.	Particulars	Specification	Quantity
1	Different types of fuses (kit-kat fuse, cartridge fuse, glass fuse etc.) (For identification experiment)		
2	Single pole MCB	6 A ,220 V	
3	Single-phase ELCB	6A ,220 V 30 mA	
4	MCCB (for study / identification experiment only)	125 A 415V	
5	MPCB (Motor Protection Circuit Breaker) of any low current rating (for study / identification experiment only)	3 Phase 415 V	
6	Automatic changeover with current limiter (ACCL)		
	Air circuit breaker		
8	DPST and SPST knife switches or 2 pole, 3way, 6A selector switch		
9	DPST and SPST knife switches or 2 pole, 3way, 6A selector switch	10A or 16 A or 32 A, 415 V	
10	3 phase auxiliary contactor - any model with 2NO + 2 NC.	10 A , 415 V	
11	Single-phase Auto transformer	Single-phase Auto transformer	
12	Transformer (for voltage injection purpose)	240V/500V	
13	Transformer (for current injection purpose)	240V/24V, 20A	
14	Rheostats	45ohms 8.5 A, 100 ohms 5 A, 300 ohms 2.5 A	
15	Thermal Overload Relay	3 Phase 415 V, 0-4.5 or 0-6 A or 0-10 A	
16	Motor Protection Relay	3 HP, 3 Ph Induction Motor.	
17	Digital Time Interval Meter (Digital stop watch may also be used as alternative)	0-999 ms, 0-99.9 sec, 0-99.9 min	
18	Single-phase preventer (phase failure relay)		
19	Lock out relay with 2 NO and 2 NC (any low rating model).		
20	Electro-mechanical Relay Trainer Kit or module with 4 mm banana pin sockets and patch cords. (TYPE - Over Load Relay or Over Voltage Relay or Under Voltage Relay or Earth Fault Relay		
21	Static Relay (OLR or OVR or UVR or EFR – ANY ONE) Trainer Kit or module with 4 mm banana pin sockets and patch cords.		
22	Numerical relay or Digital relay (OLR or OVR or UVR or EFR – ANY ONE)-Trainer Kit or module with 4 mm banana pin sockets and patch cords.		
23	Buchholz Relay		
24	AUX. Current source / current injection kit suitable for the above trainer kits with 4 mm banana pin sockets and patch cords.	15A	

25	AUX Voltage source / voltage injection kit suitable for the above trainer kits with 4 mm banana pin sockets and patch cords.	220 V AC /110 V DC	
26	Fuse and MCB testing- trainer kit		
27	P-spice/ GNU-Octave/MatLab		
27	Multifunction meter		
28	Trivector meter	3- phase	
29	TCS(trip circuit supervision relay 24/30/48 V DC 110-125/220-250 V DC/AC		
30	Lock out Relay		

Analog and Digital Electronics

Subject code -EEE304

1. Rationale:

Analog Electronic circuits are used to amplify, process and filter analog signals which are continuously variable, using amplifiers, Oscillators, switching circuits, operational amplifiers etc. Digital electronic circuits are usually made from large assemblies of logic gates. This digital logic circuitry is based on a binary system which has only two voltage levels, Low and High viz., Digital computers. Any intelligent electronic system is built by a combination of analog and digital circuits hence, it is imperative for any aspiring Technician to acquaint with the concepts of analog and digital electronics.

2. Course Outcomes/Skill Sets: *On successful completion of the course, the students will be able to*

CO-01	Identify the components of a given electronic circuit, list the uses and characteristics of the components and test the components to ensure they are in working condition.
CO-02	Use datasheets to list the alternative electronic components for a given electronic circuit ensuring the results/output remains the same.
CO-03	Build an electronic circuit for a given application and demonstrate its working either in real or a simulated environment.
CO-04	Test a given circuit for desired result/outcome, identify the problem and troubleshoot to obtain the desired result/output.

3. Course Content

Week	CO	PO*	Lecture (Knowledge Criteria)	Tutorial (Activity Criteria)	Practice (Performance Criteria)
1	1	1,4	**ANALOG ELECTRONICS** 1.Passive components (Resistor, Inductors and capacitors): Introduction, symbols, units, types/classification, identification, selection and applications.	Refer Table 1	1a. Identify the different types of resistors. 1b. Measure the resistor values using colour code and verify the reading by measuring in the multimeter. 1c. Identify the power rating of carbon resistors by their size 1d. Identify different inductors and measure the values using LCR meter. 1e. Identify the different capacitors and measure capacitance of various capacitors using LCR meter.

			2.Semiconductors: Meaning, list semiconductor materials (Si, Ge,GaAs). -list characteristics of semiconductors. -Draw covalent bond diagram: Si, Ge, GaAs -Intrinsic Semiconductors-Two types of flow (free electrons & holes) Ref 7(1)		2a. Preparation of components, use of soldering iron and lead and flux. 2b. Standard Soldering practice to connect the components on base-board /PCB/assembly board (follow soldering standard).
			3.Doping a Semiconductor- Explain two types of Extrinsic Semiconductors (n-type and p-type). -concept of majority carrier and minority carriers. -Diode- formation, depletion region. Ref7(1)		
2	2,3	1,4	1. Diode-VI Characteristics, types, ratings and applications. Zener diode- reverse bias characteristics, voltage Regulation, shunt voltage regulator and their applications.	Refer Table 1	1a. Study and interpret data sheets of diodes and Zener diodes. 1b. Execute testing of given diode using multimeter and determine forward to reverse resistance ratio. 1c. Construct and test Zener based voltage regulator circuit.
			2.Bipolar Junction Transistors (BJT): Structure, Types, symbols, Construction, operation of (NPN/PNP) transistors. BJT Configurations, Transistor currents, alpha, beta and relationship between alpha and beta.		2a. Identify different transistors with respect to different package type, B-E-C pins, power, switching transistor, heat sinks etc b. Obtain output characteristics of BJT in CE configuration in physical mode. **OR** Simulate output characteristics of BJT in CE configuration **Ref.7(6)**
			3. CE input and output characteristics- cut off, saturation, and active regions. -Transistor biasing- definition, importance, list types. - Explain Voltage divider bias. Transistor as a switch in CE mode. -Stabilisation, thermal runaway, heat sink. **Ref.7(7).**		
3	1,3	1,4	1. FET- types. MOSFET- definition, types, symbols, N type enhancement mode- construction, working, MOSFET characteristics	Refer Table 1	1a. Identify terminals of a MOSFET and test. b. Obtain output characteristics of MOSFET in physical mode. **OR** Simulate output characteristics of MOSFET.
			2. MOSFET as switch, ratings.		2.Construct and test MOSFET application circuit (MOSFET as a switch)

			3. List applications of MOSFET, Differentiate between BJT and MOSFET		
4	3,4	1,4	1. Rectifiers- half wave, centre tapped FWR, efficiency, ripple factor, PIV. Filters- definition, necessity, C and PI filters.	Refer Table 1	1a. Identify the different types of fixed +ve and –ve regulator ICs and the different current ratings (78/79 series) 1b. Build +5V 1A DC Power Supply. **OR** Build +12V 1A DC Power Supply **Ref.7(8,9,10)**
			2. Regulated power supply- block diagram and applications. Regulator- working of 7805, mention operating voltages of 7809, 7812, 7905, 7912 Op-amp regulator, 723 regulators (Transistorized & IC based).		2a. Identify different heat sinks for IC based regulators b. Identify the parts, trace the connection and test the DC regulated power supply with safety. c. Troubleshoot and service a DC regulated power supply.
			3. Testing and Troubleshooting of Regulated Power Supply. **Ref.7(11,12)**		
5	1,3	1,4	1. Working of LED, IR LEDs, Photodiode, photo transistor and their characteristics and applications. Opto-couplers, circuits with Opto-Isolators. LASER diodes-characteristics and applications.	Refer Table 1	1a. Identify the different types of LEDs and IR LEDs. 1b. Identify optocoupler input/output terminals and measure the quantum of isolation between the terminals 1c. Construct a circuit to switch lamp load using phototransistor
			2.Amplifier- faithful amplification, classification based on configuration, power, and frequency		2. Construct and test a common emitter amplifier with and without bypass capacitors. **Ref.7(13)**
			3. Transistor CE amplifier with biasing, Working of Push pull amplifier.		
6	1,3	1,4	1. OPAMP– block diagram, operation, Characteristics, applications, μA 741 pin diagram.	Refer Table 1	1. Construct and test OP AMP as a Summer. Use an Analog IC tester to test the Analog ICs.
			2.OPAMP applications– inverting, differentiator. Integrator, summer, voltage follower, and comparator.		2. Construct and test Astable timer circuit using IC 555. Construct and test mono stable timer circuit using IC 555. **Ref.7(14)** Use an Analog IC tester to test the Analog ICs
			3. Timer– block diagram, pin diagram of IC 555, duty cycle, time-delay, Applications, A stable and Monostable multi-vibrators using IC 555.		
7	3	1,2	**DIGITAL ELECTRONICS** 1. Definitions- bit, nibble, byte, word, and parity bit. Number system- definition, types, radix, decimal, BCD, binary and hexadecimal.	Refer Table 1	1. Solve problems on number system

			2. Binary number system, Binary arithmetic: addition, subtraction, multiplication and division Complements: 1's, 2's.		2. Solve problems on conversion.
			3. Hexadecimal- addition, subtraction, Conversion- decimal to binary, decimal to hexadecimal		
8	3	1,2,4	1. Boolean variable, complement, Boolean function, expression, truth table. Boolean Algebra- rules and laws. **Ref.7(15)**	Refer Table 1	1. An electronic telephone exchange is being powered by a normal power supply. However, looking at the criticality of the exchange, a power backup generator is also installed, which can supply power in case of power failure. An alarm circuit is to be designed. There will be two LEDs (one green and the other red) on the front panel of the exchange, such that the green LED glows when power supply is available. In case of failure of power supply, the exchange draws its power from a generator, and in this case, the green LED goes OFF and the RED LED glows. In case, the generator also goes down, both green LED and red LED go OFF and a buzzer starts ringing indicating that there is a major failure. Design and implement this control circuit for both the LEDs and the buzzer.
			2.Logic gates NOT, AND, OR- definition, symbol, Boolean equation, truth table and working. Logic gates NAND, NOR, EX-OR- definition, symbol, Boolean equation, truth table and working. De Morgan's theorems- statement and equations		2. Akshay's Automated Cafeteria orders a machine to dispense coffee, tea, and milk. Design the machine so that it has a button (input line) for each choice and so that a customer can have at most one of the three choices. Diagram the circuit to ensure that the "at most one" condition is met. Implement the Circuit
			3. Karnaugh's map up to three variables- Simplification and drawing logic diagrams.		
9	1,3	1,4	1. COMBINATIONAL LOGIC CIRCUITS- Half adder- block diagram, logic diagram using AND and XOR, truth table and working.	Refer Table 1	1a. Construct Half Adder circuit using ICs and verify the truth table 1b. Construct Full adder with two Half adder circuits using ICs and verify the truth table. Use a digital IC tester to test the digital ICs
			2. Full adder- block diagram, logic diagram using AND, OR and XOR, truth table and working.		2. Construct a circuit to verify the truth table of 4:1 multiplexer using IC 74153 and 1:4 Demultiplexer using IC 74139. Use a digital IC tester to test the digital ICs
			3. Multiplexer and Demultiplexer, 4:1 MUX, 1: 4 DEMUX List real life applications of MUX and DEMUX		

10	1,3	1,4	1. Encoders and Decoders- definition, applications. Seven segment display- working	Refer Table 1	1. Construct a circuit to display 0-9 digits using standard Seven segment display with the help of decoder/ driver IC 7446/ or 7447. Use a digital IC tester to test the digital ICs.
			2. FLIP-FLOPS: S-R flip-flops, Clocked RS flip flop- block diagram, truth table, logic diagram.		2a. Identify different Flip-Flop (ICs) by the number printed on them 2b. Verify the truth tables of Flip-Flop ICs (RS, D, T, JK, MSJK) by connecting switches and LEDs.
			3. D flip- flop, JK flip-flop and T Flip-flop and Master JK flip-flop - block diagram, truth table, logic diagram.		
11	1,3	1,4	1. Shift Registers- definition, types and applications. Four-bit SISO using D Flip flops- block diagram, truth table and operation		1. Construct and test a four-bit SIPO register.
			2.Four-bit SIPO, PISO and PIPO shift registers using D flip flops- block diagram, truth table and operation.		2.Construct and test four-bit PIPO register.
			3.Counters- definition, modulus concept, timing diagram, types and applications		
12	3,4	1,4	1.Four-bit binary asynchronous counter- block diagram using JK flip flops, truth table, timing diagram and working		1. construct and test 4-bit Asynchronous binary up /down counter (IC **74LS193)**
			2. Four-bit decade asynchronous counter- block diagram using JK flip flops, truth table, timing diagram and working.		2. Rig up and test the truth table of Decade Asynchronous Counter (IC 74LS90)
			3.Three-bit synchronous up counter- block diagram, truth table, timing diagram and working.		
13	1,3	1,4	1.Digital to Analog converters: Binary weighted Resistor, DAC- block diagram and operation.		1.Construct and test (Binary weighted Resistor) Digital to Analog converter circuit.
			2. D/A converter specifications: resolution, accuracy and conversion speed. -Selection criteria for DAC		2.Construct and test the Analog to Digital

			3. Analog to Digital converters: Successive Approximation ADC- block diagram and operation. -Selection criteria for ADC		converter circuit. **Ref.7(16,17)**
Total in hours			**39**	**13**	**52**

Reference:

Sl. No.	Description
1	Electronic Devices and Circuits theory by Robert L. Boylestad Louis Nashelsky
2	Electronics Principles by Malvino, Mc. Graw Hill, Third edition. 2000.
3	Electronics Devices and Circuits by Allen Mottershead, PHI Learning Pvt. Ltd., First Edition
4	Electronics Principles and applications by Charles A Schuler and Roger L Tokhiem, Sixth Edition, Mc. Graw Hill, 2008. 2. 3.. 4.. 5.
5	Electronics Analog and Digital by I. J. Nagrath, PHI Learning Pvt. Ltd., 2013 Edition
6	Linear Integrated Circuits by Ramakant A. Gayakwad, PHI Learning Pvt. Ltd., Fourth Edition.
7	https://www.youtube.com/watch?v=nCqQhqLTmxw
8	https://bestengineeringprojects.com/automatic-cut-off-power-supply/
9	https://www.circuitstoday.com/5v-power-supply-using-7805
10	http://www.ide.iitkgp.ac.in/Pedagogy view/example.jsp?USER ID=70
11	https://bestengineeringprojects.com/noise-free-dual-polarity-12v-power-supply-circuit/
12	https://bestengineeringprojects.com/problem-and-troubleshooting-of-power-supply/
13	https://bestengineeringprojects.com/regulated-power-supply-troubleshooting/
14	http://ee.cet.ac.in/downloads/Notes/ECLab/04-CE%20Amplifier.pdf
15	https://bestengineeringprojects.com/adjustable-dual-timer-circuit-using-555-timer-ic/

16	https://www.iitg.ac.in/cseweb/vlab/Digital-System-Lab/experiments.php
17	https://www.ti.com/lit/ds/symlink/dac0808.pdf?ts=1613370064634&ref url=https%253A %252F%252Fwww.google.com%252F
18	https://www.mepits.com/project/336/diy-projects/diy-project-digital-thermometer
19	Work sheets digital 1. https://www.liveworksheets.com/un1107740kg 2. https://nohoacsl.weebly.com/uploads/1/1/2/2/112297219/ digital electronics worksheet.pdf
20	https://inst.eecs.berkeley.edu/~ee100/su07/handouts/EE100-MultiSim-Tutorial.pdf
21	http://eceweb1.rutgers.edu/~psannuti/ece223/Manual-for-multisim.pdf

Equipment/software list

Sl. No.	Particulars	Specification	Quantity
1	DC Regulated power supply	(0-30V, 2A)	
2	DC Regulated Dual power supply	(+/- 15V,2A)	
3	DC Regulated Dual power supply	(+/- 5, 1A)	
4	Cathode Ray Oscilloscope	Dual trace, 25 MHz.	
5	Signal Generator / Function generator	(5V P-P, 200mA)	
6	DC Voltmeter	(0-1V)	
7	DC Voltmeter	(0-10V)	
8	DC Voltmeter	(0-30V)	
9	DC Ammeter	(0 -100mA)	
10	DC Ammeter	(0 -10mA)	
11	DC Ammeter	(0 -100mA)	
12	Digital Multimeter-	31 /2" 06	
13	Analog Multimeter		
14	LCR meter		
15	Decade resistance box	(4 Dial)	
16	Decade capacitor box	(4 Dial)	
17	Analog IC Trainer Kit		
18	Digital Trainer kit		
19	Digital IC Tester.		
20.	Electronic Circuit Simulation Software (Multi sim/P spice/ LT spice/GNU-Octave/ Mat Lab-Simulink)		

(4th – SEMESTER)

Electric Motors

Subject code -EEE401

1. Rationale:

Electric motors impact almost every aspect of modern living through the use of various Appliances. They are used at some point in the manufacturing process of nearly every conceivable product that is produced in modern factories and has nearly unlimited number of applications. An Electrical Technician is expected to Analyse the performance and select a particular motor for an application followed by testing, troubleshooting and maintenance of the same.

2. Course Outcomes/Skill Sets:

On successful completion of the course, the students will be able to

CO-01	Conduct performance analysis of a given electrical motor, draw its characteristics and determine the right motor for a specific application.
CO-02	Select, Install and test the motor to be used for a specific application.
CO-03	Describe test parameters, testing procedures and demonstrate the troubleshooting of a given electric motor to ensure it performs optimally.
CO-04	Construct power circuit and control circuits using appropriate components /devices to control the given electric motor.

3. Course Content

Week	CO	PO*	Lecture (Knowledge Criteria)	Tutorial (Activity Criteria)	Practice (Performance Criteria)
1	1	1,4	1. **DC Motors:** Working principle, back emf & voltage equation- simple problems.	Refer Table1	**Follow Safety rules and Safe working practices (Demo)** 1. Identify the terminals, and test the field and armature windings of a DC machine for open circuit, short circuit and ground faults using test lamp /megger, check the insulation resistance, identify and locate the possible faults.
			2. Types of motor-circuit diagram with voltage equation. -meaning of Torque -torque developed by D.C motors, torque equation [no derivation] -torque- speed relationship		2. Control the Speed of the DC shunt motor by Armature voltage control. Plot the graph.
			3a. Characteristics of D.C. Motors -Torque – Speed, Speed – Load and Torque – Load Characteristics. 3b. Methods of speed control: – shunt field control –Armature or Rheostatic control		
			-Voltage control		

2	1	1,2,4	1. **Induction Motors**: Working principle of induction motor. Rotating magnetic field produced by polyphase supply.	Refer Table1	**Follow Safety rules and Safe working practices** 1a. Identify the parts of the 3- phase squirrel cage induction motor, test it for open circuit, short circuit and ground faults using a test lamp / megger, check the insulation resistance, identify and locate the possible faults. Suggest remedies. 1b. Connect forward & reverse a 3-phase squirrel cage induction motor.
			2. Construction of stator, squirrel cage rotor and phase wound rotor. Slip, frequency of rotor current. Problems.		2a. Identify the parts of 3 phase slip ring induction motor, test it for open circuit, short circuit and ground faults using test lamp/megger, check the insulation resistance, identify and locate the possible faults. Suggest remedies. **Ref.7(5)** 2b. Connect forward & reverse a 3-phase slip ring induction motor.
			3. Starting torques of squirrel cage and slip ring induction motor with expression. Condition for max starting torque. Effect of change in supply voltage on starting torque.		
3	1	1,4	1. Equation for torque under running conditions. -Draw torque – slip curves. -Relationship between full load torque and maximum torque, starting torque and maximum torque	Refer Table1	**Follow Safety rules and Safe working practices** 1. Plot the Speed-Torque (Slip Vs Torque) Characteristics of 3-Phase Induction motor by mechanical loading (Brake-drum apparatus). Use Power Quality Analyzer & Motor Analyzer to measure various parameters. **Ref.7(6)**
			2. Explain Equivalent circuit of an induction motor.		
			3. Relationship between rotor power input, rotor copper loss, and Mechanical power developed and slip. -Problems on the above.		2. Determine the efficiency of 3-phase squirrel cage induction motor by no load test/ blocked rotor test and brake test. Use Power Quality Analyzer & Motor Analyzer to measure various parameters.
4	1	1,4	1. **Starters:** Necessity of starters and list the various types of starters. Main criteria for the selection of the starting method.	Refer Table1	1a. Identify the parts of a DOL starter, test its parts, locate faults if any. Suggest remedies.
			2a. Construction, working and troubleshooting of D.O.L. Starter. 2b. Construction, working and troubleshooting of star-delta Starter.		1b. Connect, Start, Run and Reverse the direction of rotation of 3-phase Induction Motor using DOL starter. **Ref.7(7)**

			3a. Construction and working of Soft Starter. 3b. Maintain, service and troubleshoot the AC motor starter		**Follow Safety rules and Safe working practices.** 2a. Identify the parts of a Star- Delta starter, test its parts and locate faults if any. Suggest remedies Trace the start terminals and end terminals of three-phase windings and mark the terminals u1,v1,w1 and u2,v2,w2 Connect, Start, Run and Reverse the direction of rotation of 3-phase Induction Motor using star delta starter. 2b. Maintain, service and troubleshoot the AC motor starter
5	1,3	2,4	1. Speed Control of induction motor: - Change of applied voltage method. - Change of number of poles.	Refer Table1	**Follow Safety rules and Safe working practices.** 1. Speed control of IM using any one method, Use of Power Quality Analyzer & Motor Analyzer to measure various parameters.
			2. Speed Control of induction motor: - Change of frequency - Rheostat control method.		2a. Testing, troubleshooting and Servicing of three-phase Induction motors. 2b. Perform general preventive maintenance on 3-ph Induction motor. **Ref.7(8,9,10,11)**
			3. Testing and troubleshooting procedure of three-phase Induction motor. -General preventive maintenance procedure of three- phase Induction motors.		
6	1	1,4	1. **Synchronous Motors**: Working principle, construction, and method of starting of synchronous motor. -Compare the synchronous motor with the induction motor.	Refer Table1	**Follow Safety rules and Safe working practices** 1. Start, Run and Reverse the direction of rotation of the synchronous motor.
			2.Effect of increased load with constant excitation. - Effect of change in excitation at constant load.		2. Plot V and inverted V curves for synchronous motor, Use Power Quality Analyzer & Motor Analyzer.
			3. Effect of excitation on armature current & power factor.		
7	1	1,2,4	1. Effect of excitation on leading, lagging and zero power factor.	Refer Table1	1. Demonstrate troubleshooting of synchronous motors.
			2. Synchronous condenser and its application. **Ref.7(19).**		2. Case study of Synchronous condenser.
			3. Hunting and phase swinging, losses and methods of starting of synchronous motors.		

8	1,2	1,4	1. IEC/ NEMA motors, Enclosure protection classes available protection classes are IP23, IP44, IP54 -IEC 60034-4-1:2018 standard for synchronous motors.	Refer Table1	1. Demonstrate different protection classes.
			2. Synchronous reluctance motors. **Ref.7(22).**		2a. Demonstrate Installation of synchronous motor and Induction motor. 2b. Perform general preventive maintenance of sync motors. **Ref.7(20,21)**
			3. Procedure for Installation and Maintenance of sync motors and Induction motor.		
9	1	1,4	1. **Single-phase motors:** Working principle, construction and characteristics. **Ref.7(28).**	Refer Table1	1a. Identify and connect the starting winding, running winding, capacitor centrifugal switch terminals rotation of 1-ph capacitor start Induction Motor. 1b. Start, Run and Reverse the direction of rotation.
			2. Resistance Split phase motor -Capacitor Start Induction motor.		2. Perform general preventive maintenance of 1-ph Induction Motors.
			3. Working Principle & characteristics of Induction Generators and its applications.		
10	1	1,4	1. **Special Machines: Servo motor:** Working, construction and applications, types, speed-torque characteristics, specifications, control mechanism. **Ref.7(29).** Working, construction and applications of Stepper motor and Torque motor and spindle motor.	Refer Table1	1.Identify the parts of special machines: Servo motor, universal motor, stepper motor and brushless DC Motor, and test the coils and windings for its working condition.
			2. Working, construction and applications of Universal motor, Reluctance Motor, Permanent Magnet Synchronous Motor (PMSM).		2. Demonstrate applications of special machines.
			3. Working, construction and applications of Two phase Four Pole Permanent magnet motor, Brushless D.C. Motors, specification for EV motors. **Ref.7(31)**		
11	2,4	2,3	1. Industrial application of motors.	Refer Table1	1. Calculate the total system efficiency by combining the four key components of a motor
			-Select a motor for a given industrial application. **Ref.7(12,13,14)**		system: the motor, drive, transmission and load (e.g., pump, fan, compressor, etc.) by using a motor testing tool(software). **Ref.7(15,16,17,18)**

			2 Motor testing tool for energy efficiency. **Ref.7(25,26,27)**		2.Identify different types of push button switches- single element and two element ON/OFF switches, mushroom head emergency stop switch, illuminated type, key lock type, selector switches and limit switches.
			3. Draw the standard symbols of control components Different types of push button switches- single element and two element ON/OFF switches, mushroom head emergency stop switch, illuminated type, key lock type, selector switches and limit switches.		
12	4	3,4	1. Working principle of Bi-metallic Overload Relay, Time Delay Relays - Electronic timer and electro-mechanical Pneumatic timer and Single- Phase preventer. **Ref 7(32)**		1a. Identify Bi-metallic Over Load Relay, Time Delay Relays - Electronic timer and Electro-mechanical Pneumatic timer and Single-Phase preventer. 1b. Identify the parts of a contactor, number of NOs, NCs, nature of coil supply AC/DC, voltage ratings and current ratings. Note down the technical specifications and terminal identification number
			2.Parts of a contactor, number of NOs, NCs, nature of coil supply AC/DC, voltage ratings and current ratings.		2a. Rig up and test the following applications of logic gates using push button switches, contactor and indicators. a) Starting from two different locations (OR Function) b) Stopping from one position (NOT Function) c) Two hand operation (AND Function) d) Stopping from two different locations (NOT+OR or NOR Functions) e) Stopping if both signals are given (NOT+AND or NAND functions) f) Memory function (Signal is maintained or holding). h. XOR and XNOR operation. 2b. Rig up and test Direct On Line Starter. **Ref 7(33)**
			3.Draw a control circuit for DOL starter and control circuit for forward and reverse operation of a motor with interlocking function using auxiliary contact.		
13	4	3,4	1.Draw a control circuit for forward and reverse operation of a motor with interlocking function using combined auxiliary contact and push buttons.		1.Rig up and test the control circuit for forward and reverse operation of a motor with interlocking function using combined auxiliary contact and push buttons.
			2.Draw a control circuit for a semi-automatic star delta starter.		2.Rig up and test the control circuit for a fully automatic star delta starter. **Ref 7(34)**
			3.Draw a control circuit for a fully automatic star delta starter.		
Total in hours			**39**	**13**	**52**

Reference:

Sl. No.	Description
1	Electrical Technology volume 2 - BL Theraja & A.K.Theraja S.Chand publication.
2	Principles of Electrical Machines by V.K.Mehtha.S.Chand publication.
3	Electrical machines - Theory and Practice by M.N. Bandyopadhyay PHI publication.
4	Electrical Machines by Bhattacharya. Tata McGraw Hill Co. 5. Electrical Machines - J.B.Guptha Kataria & Sons Publications
5	https://search.abb.com/library/Download.aspx?DocumentID=9AKK107991A3212&LanguageCode=en&DocumentPartId=&Action=Launch
6	https://search.abb.com/library/Download.aspx?DocumentID=B5.0205&DocumentPartID=&Action=Launch
7	https://new.abb.com/docs/librariesprovider53/about-downloads/low-voltage-motor-guide.pdf
8	https://assets.new.siemens.com/siemens/assets/api/uuid:8e9204f9-1860-4720-9d6b-2be548d915d0/version:1560800077/troubleshooting-induction-motors.pdf
9	https://www.youtube.com/watch?v=390nOrLHAaw&t=3176s
10	https://www.youtube.com/watch?v=BoFToRcfL0k
11	https://www.youtube.com/watch?v=VCtiehg2pZc
12	h https://motors-pumps.gainesvilleindustrial.com/category/all-categories-electric-motor
13	https://www.controleng.com/online-courses/how-to-specify-motors-for-more-efficient-hvac- systems/
14	https://www.controleng.com/articles/how-to-select-a-motor-for-an-industrial-application/#:~:text=There%20are%20many%20aspects%20to,or%20a%20servo%2Fstepper%20motor.&text=Requirements%20for%20controlling%20motor%20speed%20and%20position%20also%20need%20to%20be%20considered.
15	https://www.iea-4e.org/wp-content/uploads/publications/2015/09/1 emsa pb 20150917.pdf
16	https://www.iea-4e.org/emsa/our-work/emsa-tools/
17	https://www.iea-4e.org/wp-content/uploads/2020/11/quickguide-mst-tool 1.2.pdf
18	https://www.iea-4e.org/wp-content/uploads/2020/11/webinar-2-motor-systems- tool 20151015.pdf

19	https://search.abb.com/library/Download.aspx?DocumentID=9AKK107991A6324&LanguageCode=en&DocumentPartId=&Action=Launch
20	https://search.abb.com/library/Download.aspx?DocumentID=SM103&LanguageCode=en&DocumentPartId=&Action=Launch
21	https://search.abb.com/library/Download.aspx?DocumentID=3BSM900636&LanguageCode=en&DocumentPartId=&Action=Launch
22	https://library.e.abb.com/public/58b63ea623dddaf9c125786800278df5/56- 61%201m103 ENG 72dpi.pdf
23	https://www.youtube.com/watch?v=mgoZSL2u6Jw
24	https://www.se.com/in/en/work/solutions/motor-control-protection/
25	https://www.iea-4e.org/wp-content/uploads/2020/11/MST Example I - anno 2017.pdf
26	https://www.iea-4e.org/wp-content/uploads/2020/11/MST Example II - anno 2017.pdf
27	https://www.iea-4e.org/wp-content/uploads/2020/11/MST Example II - anno 2017 Solution.pdf
28	https://search.abb.com/library/Download.aspx?DocumentID=B5.0205&DocumentPartID=&Action=Launch
29	https://www.motioncontrolonline.org/blog-article.cfm/What-is-a-Brushless-DC-Motor-and-How- Does-It-Work/57
30	https://www.motioncontrolonline.org/blog-article.cfm/What-is-a-Brushless-DC-Motor-and-How- Does-It-Work/57
31	https://circuitdigest.com/article/different-types-of-motors-used-in-electric-vehicles-ev
32	https://www.youtube.com/watch?v=2hsHoMEuS-0
33	https://www.youtube.com/watch?v=AhJRHFfXkdg
34	https://www.youtube.com/watch?v=OtydNtCxYQI

Equipment/software list

Sl. No.	Particulars	Specification	Quantity
1.	Central distribution board with control gear and power supply panel for all M/C.		
2.	Static converter Input-3phase, 440V,50Hz. Output -15kW,0- 220V Continuously variable.		

3.	DC Shunt Motor with mechanical loading (a brake drum) apparatus		
4	3-Phase Squirrel Cage Induction motor with mechanical loading (a break drum) apparatus		
5	Synchronous motor		
6	1-phase Capacitor start Induction motor		
7.	F.HP-motors Universal/hysteresis stepper motor, brushless DC motor, stepper motor, spindle motor , Permanent magnet synchronous motor, Reluctance motor		
8	1-Phase Variacs	220V,5A	
9	3-Phase Variacs	440V,15A	
10	Single-phase IM Various types one in each type		
11	Voltmeters	0-300/600 VAC	
12	Ammeters	0-5/10a AC	
13	Power Quality Analyser and Motor analyser		
14	Motor Testing Tool free software (https://www.iea-4e.org/emsa/our-work/emsa-tools/)		
15	Contactor - 16A, 4POLE, Coil Voltage 220volts/50 hz AC With 2 NO + 2 NC		
16	Timer (Electronic) 10 NO		
17	Push button (ON) 2 element type (1 NO + 1 NC)		
18	Push button (OFF) 2 element type (1 NO + 1 NC)		
19	Different types of Push button Switches (key type, Illuminated type, Emergency trip mushroom head type		
20	Limit Switches		
21	Selector Switches		
22	Thermal Over load relays (0-16A,415V with 1NO+1NC)		
23	MCB 16A, 415V, 4pol		

Power Electronics

Subject code -EEE402

1. Rationale:

Power electronics is the application of solid-state electronics to the control and conversion of electric power. Power semiconductor devices are used to construct converters and inverters in the various applications such as power supplies, Electric drives, Flexible AC Transmission systems and Distribution systems, EV's, Energy storage devices. An Electrical Technician shall apply the knowledge of Power electronics to control and convert Electrical Power for an application.

2. Course Outcomes/Skill Sets: On successful completion of the course, the students will be able to

CO-01	Identify the power electronic devices using relevant datasheets and demonstrate its suitability to produce specified electrical and thermal characteristics.
CO-02	Build a power electronic circuit for a given application, demonstrate its working either in real or simulated environment.
CO-03	Test a given power electronic circuit, identify the problem and troubleshoot to obtain the desired result/output.

3. Course Content

Week	CO	PO*	Lecture (Knowledge Criteria)	Tutorial (Activity Criteria)	Practice (Performance Criteria)
1	1,2	1,4	1. Concept of power electronics, Draw the layer structure of the power diode and explain it. V –I characteristics of power diode.	Refer Table 1	1a. Study and interpret the datasheet of given power diode and BJT. 1b. Test the given Diode and BJT for its working condition. 1c. Simulate VI characteristics of power diode.
			2. Types of power diodes and their applications		2. Simulate output characteristics of Power BJT
			3. Types of Power transistors, BJT output characteristics, BJT as a switch.		
2	1,2	1,4	1. Operation of N-channel enhancement power MOSFET, and its transfer characteristic curve, Application of MOSFET.	Refer Table 1	1a. Study and interpret the datasheet of power MOSFET and IGBT 1b. Identify various Power MOSFET by its number and test by using a multimeter 1c. Identify IGBTs by their numbers and test by using a multimeter.
			2. Structure of IGBT and its characteristics		

			3. Application of IGBT, Compare MOSFET, BJT and IGBT		2a. Simulate the transfer characteristics of power MOSFET and IGBT. 2b. Rig up the circuit of power MOSFET as a switch
3	1,2	1,4	1.Layer diagram of SCR and Concept of two transistor analogy of SCR.	Refer Table 1	1.Test the given SCR for its working condition.
			2. Static V-I characteristic curve of SCR, Enumerate Reverse blocking, Forward blocking, forward conduction mode.		2. Simulate VI characteristics of SCR, GTO and LASCR.
			3. GTO, principle of operation and list its application, layer structure of LASCR and explain its operation.		
4	1,2	1,4	1. Layer structure, operation and characteristics of TRIAC	Refer Table 1	1a. Test the given TRIAC and DIAC for its working condition. 1b. Simulate VI characteristics of TRIAC and DIAC.
			2. 4-Modes of turn on of TRIAC and state the preferred mode of turn-on.		2.Build and test a TRIAC- fan motor speed control circuit.
			3. Operation of DIAC and its V-I characteristic, curve, application of DIAC.		
5	1,2	3,4	1. **SCR Control Circuits:** Methods of turn on of SCR	Refer Table 1	1.Build R firing circuit and determine the maximum firing angle.
			2. General layout of firing circuit.		
			3. R firing circuit and R-C firing circuit with waveforms.		2. Build R – C firing circuit and determine the maximum firing angle.
6	1,2	3,4	1. Construction, operation and characteristics of UJT	Refer Table 1	1.Build and test UJT Relaxation oscillator.
			2. Synchronized UJT pulse trigger circuit with waveform.		
			3. Digital firing scheme with waveforms.		2. Build and Test time delay relay using SCR and UJT.
7	1,2	3,4	1. Commutation, line commutation, forced commutation and methods of forced commutation, Load commutation and complementary commutation.	Refer Table 1	1.Simulate Line commutation and forced commutation circuits and observe waveforms.
			2. Voltage and current ratings of SCR and Reliability of SCR, MTBF.		
			3. How SCR can be protected against overvoltage and over current, di/dt & dv/dt. Different types of mounting of SCR.		2. Construct a snubber circuit for protecting SCR use freewheeling diode to reduce back emf.
8	1,2	4	1. **CONVERTERS:** types of power electronic converters: Single -quadrant semi-converter, two- quadrant full- converter and dual converter.	Refer Table 1	1.Build single-phase full controlled bridge converter for resistive load. Trace the waveforms across SCR and load.
			2. Single-phase full converter RLE type with continuous load current		2. Simulate single-phase Dual

			3.single-phase dual converter and principle of operation.		converter and observe waveforms.
9	1,2	4	1. Gating pulse requirement of three-phase full converters. 2.Three-phase bridge converter and 180 conduction mode with waveforms.	Refer Table 1	1.Test three-phase bridge rectifier module (36MT160) 2. Simulate three-phase Bridge converter and observe waveforms.
10	1,2	4	1. DC Chopper- Step-down and Step-up chopper and its operation. 2. Different chopper configurations- (A, B, C, D and E). 3. Inverter- Types of inverters (VSI and CSI).	Refer Table 1	1.Simulate/Build step-down chopper and observe waveforms. 2. Simulate / Build step-up chopper and observe waveforms.
11	1,2	4	1. Half bridge and full-bridge inverter and its operation. 2. Cycloconverter- Draw the circuit of mid- point Step-down cyclo-converter and its operation with waveforms. 3. Cycloconverter- Draw the circuit of a mid- point step-up cycloconverter and its operation with waveforms.	Refer Table 1	1.Simulate Full-bridge Inverter and observe waveforms. 2.Build and test a inverter. **Ref.7(18)**
12	2,3	2,4	**DC-DC converters:** 1. Working principle of Buck converter (regulator). 2. Working principle of Boost converter (regulator). **Ref.7(9,10,11,12)** 3.Working principle of Buck-boost and flyback converter. **Ref.7(14,15,16,17)**		1a. Build & test IC based - DC –DC converter for different voltages. **Ref.7(8)** 1b. Test the monolithic synchronous buck regulator (MP2305). 2.Test and Troubleshoot regulators. **Ref.7(13)**
13	2,3	2,3,4	1. SMPS and its operation and application. 2. UPS, Battery size and required voltage for UPS 3a. Draw the block diagram of offline online UPS and its operation. 3b. List basic troubleshooting steps for UPS. **Ref.7(21,23)**		1a. Identify various input and output sockets/ connectors of the given SMPS. 1b. Identify major sections/ ICs/components of SMPS. 1c. Troubleshoot given SMPS. **Ref.7(19,20)** 2a. Identify front panel control & indicators of UPS. 2b. Connect battery & load to UPS & test on battery mode. 2c. Open top cover of UPS & identify isolator transformer & UPS transformer & additional circuit other than inverter.

					2d. Identify various circuit boards in UPS and monitor voltages at various test points. 2e. Test UPS under fault condition & rectify fault. **Ref**: **7(22,24)**
Total in hours			**39**	**13**	**52**

Reference:

Sl. No	Description
1	Power Electronics by Dr P S Bimbhra , Khanna Publishers, New Delhi
2	Industrial Electronics and Control Biswanath Paul PHI Publication Edition-II
3	Thyristorised power controllers GK Dubey
4	Power and industrial Electronics by Harish C Rai
5	Power electronics by Mohan Undeland & Robbins, Wiley Publications
6	Modern Power Electronics by P.C.Sen
7	Power Electronics – RaghunathRao
8	https://components101.com/ics/ncp3064-dc-dc-converter-ic
9	https://www.youtube.com/watch?v=4IQBN6Oy8Lg
10	https://www.youtube.com/watch?v=_Rf29oUGpwI
11	https://www.youtube.com/watch?v=vmNpsofY4-U
12	https://www.youtube.com/watch?v=yD7fMylYgXw
13	https://www.youtube.com/watch?v=-3tBw6WSZVM
14	https://www.youtube.com/watch?v=zNfbbPobtus
15	https://www.youtube.com/watch?v=ZiD_X-uo_TQ
16	https://www.youtube.com/watch?v=9--_jaxiXhE
17	https://www.youtube.com/watch?v=Fk-B6OO6GB8https
18	https://www.youtube.com/watch?v=6CsTIPjFZ48 www.youtube.com/watch?v=I8c5DLJgS3o
19	https://www.youtube.com/watch?v=PPLjXkca7eo
20	https://www.powersupplyrepairguide.com/previewsmpsebook.pdf
21	https://www.youtube.com/watch?v=C1BYo88HSU0
22	https://www.youtube.com/watch?v=3oq18dZmb3Q
23	https://www.apc.com/lr/en/faqs/FA279110/
24	https://www.youtube.com/watch?v=lkriUIUdflM https://www.youtube.com/watch?v=JHgKBDoQCyQ
25	https://inst.eecs.berkeley.edu/~ee100/su07/handouts/EE100-MultiSim-Tutorial.pdf
26	http://eceweb1.rutgers.edu/~psannuti/ece223/Manual-for-multisim.pdf
27	https://www.multisim.com/help/getting-started/

Equipment/software list with Specification for a batch of 20 students

Sl. No.	Particulars	Specification	Quantity
1	DC Regulated power supply	(0-300V, 2A)	5
2	DC Regulated Dual power supply	(0-30V,2A)	5
3	Cathode Ray Oscilloscope	Dual trace, 25 MHz.	5
4	Digital Multimeter	31 /2"1-ph	5
5	1-ph Induction Motor	220v,1ph,	1
6	Battery	6 V/12 V 60 AH	2
7	SMPS		5
8	UPS 2kVA	2 kVA	1
Software			
1	GNU-Octave/MatLab/P-spice/Multisim		20 License

Fundamentals of Automation Technology

Subject code -EEE403

1. Rationale:

The aim of this course is to introduce students to the present Industrial Automation scenario in India. The broad knowledge of essential component of present industrial Automation Industry such as Programmable Logic Controller (PLC), Distributed Control System (DCS), Supervisory Control and Data Acquisition (SCADA), industrial drives, human machine interface will enable the students to maintain the above automation controls systems used in the present industry. Thus this course is very important for students who want to use their knowledge of electronic engineering for working in the industrial automation sector.

2. Course Outcomes/Skill Sets: On successful completion of the course, the students will be able to

CO-01	Select a suitable sensor and actuator for a given automation application and demonstrate its use in a specific application.
CO-02	Install, test & control the pneumatic actuators using various pneumatic valves.
CO-03	Develop ladder diagrams for a given application and explain its implementation process using PLC.
CO-04	Describe the concept of SCADA and DCS systems and list their various applications.

3. Course Content

Week	CO	PO*	Lecture (Knowledge Criteria)	Tutorial (Activity Criteria)	Practice (Performance Criteria)
1	1	2,3, 4	1. How do engineers work, technical drawings and parts lists, Circuit diagrams, Flow charts and programs. **Ref.7(1)**	Refer Table 1	Video demonstration on Automation technology
			2. Technical plans and schematic diagrams, Calculations and simulation		
			3. Automation technology as a part of engineering sciences, Key development milestones in the history of automation technology, Effects of automation on people.		
2	1	1,4	1. How a solenoid works- Structure of a solenoid, Applications of solenoids **Ref.7(1)**	Refer Table 1	1.Test a Linear Actuator Solenoid
			2. Solenoids as simple actuators.		2.Install, wire and test digital time delay relay -
			3.How switches work and their structure-Normally open contacts, normally closed contacts, Changeover switches.		
			Relays and contactors-Structure of a relay, Applications of relays, Time relays. **Ref.7(1)**		
3	1	1,4	**1.Sensors: operation, characteristics and application:** Inductive Proximity Sensors, Magnetic Proximity Sensor.	Refer	1a. Identify and test different sensors. 1b. Select a suitable proximity sensor for a given application and wire up the same. **Ref 7(2)**
			2. Capacitive proximity sensors, Optical proximity sensors, Ultrasonic proximity sensors		

			3. Linear Position sensors, Photoelectric sensors. Infrared sensors Limit Switches.	Table 1	2.Develop a relay-based motor control automation such that the motor reverses its direction when the limit switches are activated.
4	1	4	1. Inductive linear transducer, area sensors, flow sensors **Ref.7(1)**		1.Identify and test different sensors.
			2. Temperature sensors, colour sensors, Hall effect sensor		2. Simple Hall effect sensor Latching ON/OFF Relay switch Circuit.
			3a. Pressure sensors -Electronic pressure switches with binary output signal. 3b. Concept of Sensor latching. Latching Digital Hall effect sensor.		
5	2	1,4	1. **Fundamentals of pneumatics-** Individual components in a pneumatic control system and their functions. **Ref.7(1)**	Refer Table 1	1a. Controlling of single- acting cylinder by 3/2 push- button valve/ **solenoid valve** b. Controlling of double-acting cylinder by 5/2 push-button valve/S**olenoid valve** c. Identify industrial applications of Single acting and Double acting cylinder. **Ref 7(3,4)**
			2. Functions and features of actuators (pneumatic cylinders)- Single-acting cylinder, Double-acting cylinders, Speed regulation with single-acting cylinders, Speed regulation with double-acting cylinders.		2 a. Speed control of single-acting cylinders by flow control valve b. Speed control of double-acting cylinders by flow control valve
			3. Functions and features of pneumatic valves- Pneumatic valve designations and symbols, Pneumatic valve actuation types, controlling a single-acting cylinder, Controlling a double-acting cylinder		
6	2	1,4	1. Functions and features of pneumatic drives- Guided cylinders, rodless linear drives and rotary drives. **Ref.7(1)**	Refer Table 1	1. Demonstrate the use of Pneumatic drives (used in small robots)
			2. Pneumatic grippers.		2. Demonstrate the use of Pneumatic grippers.
			3. Pneumatic control system represented in a circuit diagram- Symbol designations in circuit diagrams.		
7	1	1,4	1. **Electric drives:** Physical/technical fundamentals of the DC motor.	Refer Table 1	1. Activate the DC motor using 2 relays to run the motor forward and backward direction.
			2. Activating DC motors		
			3. Working principle of Variable frequency drive.		2. Install and control speed of 3-ph motor using VFD.

8	3	1,4	1. **Fundamentals of control technology**: Meaning of control system, open loop and closed system with examples. Different types of controllers (PLC, CNC, Hard-wired programmed control systems, robot controllers)	Refer Table 1	1.Demonstrate open loop and closed systems observed in everyday life.
			2. How programmable logic controllers (PLCs) work and their structure. Advantages and Disadvantages of PLC. Mathematical fundamentals – basic logic functions-Identity (YES function), Negation (NOT function), Conjunction (AND function), Disjunction (OR function), XNOR and XOR.		
			3. Examples of controller structure.		2. Demonstrate Industrial applications of PLC
9	3	1,4	1. **Programmable logic controllers-** Internal architecture and functional structure. Input/output modules.	Refer Table 1	1.a. Identify Components of PLC b. Identify different types of PLC c. Identify different input and output devices of PLC d. Identify the wiring mode of PLC- sourcing and sinking modes
			2a. List input / output devices of PLC. -List types of PLC. 2b. Functions of Programming equipment (Programmer/monitor)		2.Identify and Install Programming Software and communication driver.
			3a. Explain PLC Programming Languages –Ladder diagram/ Functional Block Diagram /Instruction List/structured text. 3b. Explain scope of f IEC standard for PLC: IEC 61131		
10	3	2,3, 4	1a. **Operation cycle of PLC**: Input scan, Program scan and Output scan. **1b. Operation modes of PLC**: program, run and test modes. Data files and program files.		1.Develop and test the ladder programs for the following motor controls: a) Starting from two different locations (OR Function) b) Stopping from one position (NOT Function)
			2.Configuration of I/Os and Addressing I/Os, study of PLC symbols.		
			3. Procedure for drawing ladder diagram, connection of inputs and outputs to input and output module and entering ladder program into PLC (CPU). Draw the ladder diagram for a simple example of one-contact, one-coil circuit and connection diagram showing how inputs are connected to the input and output module of PLC.		c) Two hand operation (AND Function) d) Stopping from two different locations (NOT+OR or NOR Functions) e) Stopping if both signals are given (NOT+AND or NAND functions) f) Memory function (Signal is maintained or holding) g) Interlocking protection (XNOR/XOR)

					2. Develop and test the ladder program for interlocking two motors, using **PLC simulation software.**
11	3	2,3, 4	1.Most commonly used PLC programming instructions and their applications: XIC, XIO, OTE. Latch, Unlatch		1a. Develop and test ladder program for switching ON motor 1, motor 2 and motor 3 in sequence with some time delay, using **PLC simulation software.** 1b. Develop and test the ladder program of the Alarm system for the following conditions: If one input is ON- nothing happens, if any two inputs are ON- a red light turns ON, If any three inputs are ON- a Hooter/Alarm turns ON, using PLC simulation software.
			2.Describe Timer instructions and their application: Describe Timer On Delay (TON), Timer Off Delay (TOF), Retentive Timer On (RTO)		
			3.Describe counter instructions and their application: COUNT UP, COUNTDOWN, UP/DOWN COUNTER Examples of use of counter and timer instructions.		2a. Develop and test ladder Program for fully Automatic Star-Delta starter, using **PLC simulation software.** 2b. Develop and test ladder Program to control automatic washing machine, using **PLC simulation software.**
12	3	2,3, 4	Wiring sensors to PLC 1. Wiring push button to PLC, and selector switch to PLC		1. Develop and run simple Ladder programs to read sensor status and to control various output. **LED is turned ON when a (proximity sensor) sensor is activated.** i. Draw the ladder diagram ii. Draw PLC wiring diagram. iii. Wire push buttons to input module and LED to output module. iv. Enter the ladder program into the PLC simulator and execute.
					v. If the program is error free, Upload the program into PLC and execute. vi. observe the output

			2.Wiring NPN sensor to PLC		2. Double acting cylinder is used to perform machining operations. Pneumatic cylinder is advanced by pressing two push buttons simultaneously. If any one of the push button is released, cylinder comes back to start position. Draw the pneumatic circuit, PLC wiring diagram and ladder diagram to implement this task.
			3.Wiring PNP sensor to PLC		
13	4	2,3, 4	1.Meaning of SCADA -Functions of each component of SCADA system, -Describe SCADA Hardware and software -Applications of SCADA.		Demonstrate application of SCADA/HMI/DCS
			2.Meaning of HMI and its applications. -Need & types of HMI. -Advantages of HMI. -Various software's used for Programming HMI. -Interfacing HMI and PLC- General block diagram.		
			3. Concept of DCS -Hierarchy of DCS. -Functions of each level of DCS.		
Total in hours			**39**	**13**	**52**

Reference:

Sl. No.	Description
1	https://dlb.sa.edu.au/rehsmoodle/file.php/441/Teachware/563060 Fundamentals of automat ion technology.pdf
2	https://www.festo-didactic.com/ov3/media/customers/1100/566920 leseprobe en 2.pdf
3	https://www.youtube.com/watch?v=ZXANgP-q6b4
4	https://www.festo-didactic.com/ov3/media/customers/1100/566910 leseprobe.pdf
5	https://www.youtube.com/watch?v=GhS1qpHoSX0
6	https://www.youtube.com/watch?v=O-hbGD HsYk
7	**Control of Machines- S.K. Bhattacharya & Brijinder Singh, New Age International Publishers**
8	**Programmable Logic Controllers: John W.Webb, Ronald A.Reis, PHI**
9	**Introduction to PLC by Gary Dunning, Cengage Learning.**
10	**Mechatronics: W.Bolton**
11	https://nptel.ac.in/content/storage2/courses/112106175/downloads/Module%204/SELF%20 EVALAUTION/SE-Lecture%2041.pdf
12	https://accautomation.ca/wiring-push-buttons-and-selector-switch-to-click-plc/
13	https://realpars.com/discrete-sensors-part-1/
14	https://www.automationdirect.com/adc/overview/catalog/sensors -z- encoders
15	https://www.rtautomation.com/technologies/control-iec-61131-3/
16	https://davidrojasticsplc.files.wordpress.com/2009/01/libro-en-espanol.pdf

Equipment/software list with Specification for a batch of 20 students

Sl. No.	Particulars	Specification	Quantity
1	Small compressor	4 bar, 1.5 HP,0-4 bar pressure, 0-10 litres	
2	Linear Actuator Solenoid 12V		
3	Inductive. Proximity Sensors. Magnetic Proximity Sensor, Limit Switches		
4	Capacitive proximity sensors, Optical proximity sensors Ultrasonic proximity sensors		
5	Infrared sensors, Pressure Sensor and Switch		
6	Inductive linear transducer , Area sensors, Flow sensors, Temperature sensors, colour sensors		
7	single-acting cylinder, double-acting cylinder		
8	3/2 and 5/2 push-button valve		
9	3/2 and 5/2 solenoid valve		
10	Flow control valves		
11	Digital time delay relay		
12	Direction control Valve, Double Acting Solenoid		
13	Pneumatic Grippers		
14	FRL (filter, regulator and lubricator) unit		
15	PLC Systems with digital I/P, O/P modules and software	12/24v Dc/relay, 8 Digital Inputs, 4 Digital Outputs, ethernet card standard micro SD card, integrated webserver	
16	Variable frequency drive	3-phase, 1HP, VFD	
17	1 HP induction motor with DOL starter	1 HP	
18	SCADA Software		

Computer Aided Electrical Drafting (CAED)

Subject code -EEE404

1. Rationale:

All equipment, installations, circuits and other electrical and electronic systems in the power and industrial sector need drawings for their manufacturing, installation, operation and maintenance. A technician working in design, shop floor and field area must possess the skill of reading, interpreting different drawings and to use Computer Aided Drawing (CAD) software to draw 2D & 3D Electrical drawings.

2. Course Outcomes/Skill Sets: *On successful completion of the course, the students will be able to*

CO-01	Study a given drawing and list all the electrical elements.
CO-02	Draw a single line diagram and control panel board wiring drawing for a given specification.
CO-03	Draw a winding and assembly drawing for a given machine and translate the assembly 2D drawing into a 3D drawing using CAD software.
CO-04	Draw a simple PLC module drawing for a given requirement using standard symbols.

3. Course Content:

Week	CO	PO*	Lecture (Knowledge Criteria)	Tutorial (Activity Criteria)	Practice (Performance Criteria)
1	1	1,4	1. INTRODUCTION to CAD commands. Practice essential commands like – line types, line weight, scale, unit,	Tutorial hours shall be used to practice drawings.	Practice the basic CAD commands. **Ref .7(1,2,3,4,5)**
			2. Layer, block, insert, explode, purge, table, attribute, quick select		
			3. view, multi-view, break, join, filter, find, pan, list match properties and related commands		
2	1,2	1,4	Single line diagram of 110 KV/11KV MUSS	Tutorial hours shall be used to practice drawings.	1. Single line diagram of 110 KV/11KV MUSS. **Ref .7(10,11)**
			Single line diagram 11KV of Substation		2. Single line diagram of 11KV Substation. **Ref .7(12,13,14)**
3	1,2	1,4	1. Draw and Create BOM (Bill of Material): Electrical wiring of a residential/Hospital building	Tutorial hours shall be used to practice drawings.	1. Draw the wiring layout of residential building/Hospital and generate BOM for a given plan with AEH. **Ref .7(7,8,9)**
			2.Draw and Create BOM (Bill of Material): Electrical wiring of a small workshop		2. Draw a wiring layout of a small workshop with 3 lathes, 1 drilling machine, 1 welding machine, 1

					grinding machine and generate BOM (Bill of Material).
4	1,2	1,4	Motor control Panel board Wiring.	Tutorial hours shall be used to practice drawings.	Draw MCC (Motor Control Centre) Panel board Wiring and create BOM. **Ref .7(15)**
5	1,2	1,4	Design a GA LT panel wiring drawing.	Tutorial hours shall be used to practice drawings.	Design an Electrical General Assembly of LT panel wiring. **Ref .7(16)**
6	1,2	1,4	Developed Winding Diagrams of 3-ph A.C. Machines: Single Layer Double Layer	Tutorial hours shall be used to practice drawings.	1.Develop a winding diagram- A.C. windings-Single Layer **Ref.7(6)** 2.Develop a winding diagram- A.C. windings- Double Layer
7	1,2	1,4	Developed Winding diagram of 1-ph, AC Induction Motor	Tutorial hours shall be used to practice drawings.	Develop a winding diagram for a 1-ph, Induction Motor, make terminal connections for Running & Starting Winding.
8	1,3	1,4	Transformer Assembly-Three-phase	Tutorial hours shall be used to practice drawings.	Three-phase core type 200KVA 33KV/400V transformer front elevation full in section, plan in full section. **Ref .7(18)**
9	1,3	1,4	Assembly drawing- Squirrel cage Induction motor.	Tutorial hours shall be used to practice drawings.	Draw the half end view and half sectional front elevation and half sectional end view for a 3HP 400V 50HZ 3PH 1440 RPM - Squirrel cage Induction motor. **Ref .7(19)**
10	1,3	1,4	Assembly drawing- Rotor of a 15KVA Alternator	Tutorial hours shall be used to practice drawings.	Draw the half sectional end view top half in section and half sectional front elevation for a Rotor of a 15KVA Alternator for a given sketch. **Ref .7(20)**
11	1,3	1,4	Assembly drawing – 4 Pole 25 KVA synchronous motor	Tutorial hours shall be used to practice drawings.	Draw half size half sectional elevation and half sectional end view. **Ref .7(21,22)**
12	3	1,4	3D Drawing- Squirrel cage Induction motor.	Tutorial hours shall be used to practice drawings.	3D view showing different parts. **Ref .7(23)**
13	1,4	1,4	PLC Module	Tutorial hours shall be used to practice drawings.	Design a Simple PLC Module showing I/O points. **Ref .7(24,25)**
Total in hours			**39**	**13**	**52**

Reference:

Sl. No.	Description
1	Computer Aided Electrical Drawing - YOGESH, NAGARAJA,NANDAN PHI Publication
2	Electrical Drafting - S.F. DEVALAPUR
3	https://www.youtube.com/watch?v=pvKVy-eMDYc
4	https://www.youtube.com/watch?v=2ni0AWbloQA
5	https://www.youtube.com/watch?v=wIN61lmZByw
6	https://www.youtube.com/watch?v=OONCU5QbDpU
7	https://www.youtube.com/watch?v=asVQ3ncmqhY
8	https://www.youtube.com/watch?v=X1MsYDEkHpU
9	https://www.youtube.com/watch?v=8DEap6exAB0
10	https://www.youtube.com/watch?v=YXLhvA7dMb4
11	https://www.youtube.com/watch?v=ZRXlWoT-FRU
12	https://www.youtube.com/watch?v=Bk8YOLr0KFM
13	https://www.youtube.com/watch?v=Fa5gYiapD1E
14	https://www.youtube.com/watch?v=cKKvLXaV1g8
15	https://www.google.com/imgres?imgurl=https://5.imimg.com/data5/GZ/CR/MG/SELLER-40839587/capture7-500x500.PNG&imgrefurl=https://www.indiamart.com/proddetail/electrical- ga-general-assembly-design-22445785697.html&docid=t83B C9sNcBtnM&tbnid=nqa2KujeGdTYhM&vet=1&w=500&h=339&hl=en-US&source=sh/x/im#imgrc=nqa2KujeGdTYhM&imgdii=pQlfLt4RiUOsdM
16	https://www.google.com/imgres?imgurl=https://5.imimg.com/data5/GZ/CR/MG/SELLER-40839587/capture7-500x500.PNG&imgrefurl=https://www.indiamart.com/proddetail/electrical-ga-general-assembly-design-22445785697.html&docid=t83B C9sNcBtnM&tbnid=nqa2KujeGdTYhM&vet=1&w=500&h=339&hl=en-US&source=sh/x/im
17	https://www.youtube.com/watch?v=XsKbtm6OtAw
18	https://www.youtube.com/watch?v=fXOwgNYT0hg
19	https://www.youtube.com/results?search_query=Squirrel+cage+Induction+motor++assembly+cad+drawing
20	https://www.youtube.com/watch?v=nk_hmXUtiPk
21	https://www.youtube.com/watch?v=nk_hmXUtiPk
22	https://www.youtube.com/watch?v=rgP0aMth7LM
23	https://www.youtube.com/watch?v=fAN9jxydoMA&t=144s
24	https://www.youtube.com/watch?v=fTjd86ui5iM
25	https://www.youtube.com/watch?v=_0b2YDYFgZA
26	https://bescom.karnataka.gov.in/page/Departments+of+Corporate+Office/Quality%20Standards%20and%20Safety/Drawings/en
27	https://www.electricaltechnology.org/2012/02/star-delta-3-phase-motor-starting.html

Equipment/software list

Sl. No.	Particulars	Specification	Quantity
1	**Personal Computer**	● Operating **System**: 64-bit Microsoft Windows 10. ● Processor: 2.5 GHz (3+ GHz recommended) ● Memory: 8 GB (16GB recommended) ● Disk space: 1TB. ● Display: 1920 x 1080 resolution with True Color.	
2	**Electrical Computer Aided Drafting Software/ AutoCAD Electrical 2021**	**Student edition**	