



Government of Karnataka
DEPARTMENT OF COLLEGIATE AND TECHNICAL EDUCATION

Programme	Electrical and Electronics Engineering	Semester	III
Course Code	20EE31P	Type of Course	Programme Core
Course Name	Transformers and Alternators	Contact Hours	8 hours/week 104 hours/semester
Teaching Scheme	L:T:P :: 3:1:4	Credits	6
CIE Marks	60	SEE Marks	40

1.Rationale:

Alternators (AC Generators) are used to generate bulk power in a power plant (Hydel, Thermal or Nuclear). Electrical Transformer is an important component in a power system used to step-up or step-down voltages for transmission and distribution. Alternators and Transformers form the core area in the field of Electrical Engineering and an Electrical Technician shall have the basic knowledge of Alternators and Transformers, viz., constructional features, operation, performance analysis, test, troubleshoot and maintenance process to be followed.

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

CO-01	Explain all the workplace safety regulations to be followed when handling electrical machines.
CO-02	Conduct the performance analysis of transformers and alternators, draw their characteristics and determine the suitability of the given transformer and alternator for the specific application.
CO-03	List all the test parameters, testing procedure and demonstrate the testing and troubleshooting of a given transformer and alternator.
CO-04	Install a given transformer and alternator and define the various preventive maintenance processes to ensure smooth running of the transformer and alternator.

3. Course Content

Week	C O	PO *	Lecture (Knowledge Criteria)	Tutori al (Activit y Criteri a)	Practice (Performance Criteria)	
					3 hours/week	1 hour/ week
1	2	1,4	1.Magnetic circuit, MMF, reluctance and mention their units, Absolute permeability and Relative permeability and mention their units, relationship between Flux, MMF and Reluctance. simple problems on magnetic circuit	Refer Table 1	1.Simulate pure resistive, pure inductive and pure capacitive circuit and observe the phase difference between waveforms of Voltage & Current. OR 1a. Setup pure Inductor circuit. Measure V &I for a range of frequencies, calculate inductive reactance (X_L) and record them in a table. Plot a graph showing X_L as a function of the angular frequency . Observe the phase difference between V and I. 1b. Setup pure capacitor circuit. Measure V &I for a range of frequencies, calculate	
			2. AC fundamentals Concept of capacitive reactance, inductive reactance, and impedance. Current and Power in a pure resistive, inductive and capacitive circuit.			

			3. Current, Power and Power factor of R-L, R-C, R-L-C series and parallel circuits. Concept and Applications of resonance.		capacitive reactance (X_C) and record them in a table. Plot a graph showing X_C as a function of the angular frequency. Observe phase difference between V and I. 2. Simulate R-L, R-C, R-L-C series circuits and observe the phase difference between waveforms of Voltage & Current. OR 2. Set up RLC circuit. a. Measure V & I for range of frequencies and record measurements in table. b. Calculate corresponding impedance (Z), power factor and record in a table. c. Plot graph of Z vs angular frequency and power factor vs angular frequency. c. Estimate resonance frequency graphically and compare with theoretical value.
2	1, 2	1,4	TRANSFORMERS 1. Basics: a. Working Principle of Transformer. b. Construction. c. Operation. 2. Classification of Transformers: a. Based on Construction b. Based on No. of phases c. Based on application Shell and Core type: Construction and application.	Refer Table 1	Demonstrate workplace safety norms to be followed when handling electrical machines. 1a. Identification of different types of transformers based on i. Construction ii. No. of phases iii. Application. 1b. Identification of different parts of transformer
3	1, 2	1,2, 4	3. Main Parts of Transformer: a. Tank b. Core c. Winding d. Insulation: i. Oil ii. Paper e. Bushings (HT/LT/NT) f. Conservator g. OLTC (ON Load/OFF Load Tap Changers) h. Breather i. Safety Devices: i. Pressure Relief Device ii. Buchholz Relay j. Instruments: i. Oil Temperature Indicator (OTI)/Transmitter ii. Winding Temperature Indicator (WTI)/Transmitter iii. Conservator Oil level Indicator/Transmitter	Refer Table 1	2. Identify the terminals of a single-phase transformer, 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.

			3. Problems on emf equation, transformer on NO-load and ON-load conditions.		2.Determine the efficiency and regulation of a single-phase transformer by direct loading.
4	1, 2	1,4	<p>1. Losses in Transformer</p> <p>-List Various losses in a transformer. - Voltage regulation and efficiency in the transformer.</p> <p>- Write an equation for voltage regulation and efficiency.</p> <p>-Condition for maximum efficiency.</p> <p>- All day efficiency.</p> <p>-Problem on all-day efficiency.</p> <p>2. Pre-determine the Regulation and Efficiency of 1-ph transformer by conducting O.C. and S.C. tests.</p> <p>3.Necessity and conditions for parallel operation.</p> <p>- Parallel operation of single phase transformers with their load sharing.</p>	Refer Table 1	<p>Follow Safety rules and Safe working practices.</p> <p>1. Pre-determine the regulation and efficiency of a single-phase transformer by conducting O.C. and S.C. tests, draw the equivalent circuit.</p> <p>2.Parallel operation of two single-phase transformers and analyse load sharing pattern for a given KVA rating.</p>
5	1, 2	1,2, 4	<p>1.Generation of 3-ph voltage, phase sequence, Star and Delta Connection in 3-ph system, Relation between line voltage and phase voltage in 3-ph Star, Relation between line voltage and phase voltage in 3-ph Delta system. Equation for a 3-ph power</p> <p>2. Working principle & construction of three-phase transformers. Connection type:</p> <ul style="list-style-type: none"> i. Star-Delta ii. Delta-Star iii. star-star iv. Delta-Delta v. Open delta vi. Scott. <p>3. Vector Group</p> <ul style="list-style-type: none"> i. Brief introduction of Vector Grouping ii. Type of Vector group: <ul style="list-style-type: none"> a. Yy0, Dd0 b. Yd1, Dy1 c. Yd6, Dy6 d. Yd11, Dy11. <p>Problems on 3 phase star and delta circuits.</p>	Refer Table 1	<p>Follow Safety rules and Safe working practices</p> <p>1. Identify the terminals of a three-phase transformer, 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.</p> <p>2.Connect three single-phase transformers for three-phase operation of delta-delta/ delta-star/ star-star/ star-delta. Measure phase and line voltages.</p>
6	2, 3	4	<p>1. Special purpose transformers</p> <p>Construction and working of current transformer (CT). Ref.7.2(9)</p>		<p>Follow Safety rules and Safe working practices</p> <p>1a. Identify different types of special purpose transformers.</p> <p>1b. Measure high current & voltage using CT and PT.</p>

			2. Construction, working of potential transformer (PT)		2a. Ratio and polarity test on CT and PT 2b. Verify the voltage of autotransformer with different tapings. Ref.7(10,11,12)
			3. Construction, working of Pulse, Toroidal, Isolation transformer and Auto transformer		
7	1, 2	2,4	1. Study Code of practice for selection, installation and maintenance of transformers. IS 10028 2. Study IS 1180 and IS 2026 standards: a. scope of IS 1180 and IS 2026 b. List transformers covered and not covered by IS 1180 c. List manufacturer of IS 1180 transformers. 3. IEC 60071-1 to IEC 60071-12 standards for power transformers	Refer Table 1	Follow Safety rules and Safe working practices 1. Practice on use of IS/IEC standards. 2. Practice on use of IS/IEC standards
8	1, 3	4	1. Testing and Troubleshooting of given transformer-1 2. Testing and Troubleshooting of given transformer -2 3. Installation and Commissioning of transformer	Refer Table 1	Follow Safety rules and Safe working practices 1. Demonstrate testing and troubleshooting of given transformer/Visit to nearby transformer test centre Ref.7(13) 2. Demonstrate installation and commissioning of Transformer.
9	1, 2	2,4	1a. Working principle and construction of DC generator. 1b. Alternator: working principle, Construction of salient pole and non-salient pole alternator. 2. Full pitch Armature windings and Fractional pitch Armature windings. Advantages and disadvantages of Full pitch and Fractional pitch Armature windings. 3. Relationship between P,N,f and Derivation of emf equation, Simple problems on E.M.F equation.	Refer Table 1	Follow Safety rules and Safe working practices 1a. Identify parts of the DC generator and build up voltage of the shunt generator. 1b. Identify the parts of an Alternator, note down the nameplate details and interpret it. 2. Identify the terminals, and test the field and armature windings of an Alternator for open circuit, short circuit and ground faults using test lamp /megger, check insulation resistance, Identify and locate the possible faults and suggest remedies.
10	1, 2	4	1. Armature reaction in an alternator with sketches, Effects of p.f of load on armature reaction and Effects of	Refer Table 1	Follow Safety rules and Safe working practices

			armature reaction on terminal voltage. 2. Procedure for conducting O.C & S.C. tests on an alternator with circuit arrangements.		Determine regulation of 3-phase alternator by conducting O.C & S.C tests by EMF method.
			3. Effective resistance, leakage reactance & synchronous reactance. Calculate the synchronous impedance by O.C. & S.C test results. Equation for the no-load terminal voltage at different power factors. Voltage regulation definition and methods.		
11	1, 2	4	1. Vector diagram of alternator on Load at different power factors. 2. Necessity and Conditions for parallel operation of three-phase alternators. 3. Parallel operation of three-phase alternators using synchroscope.	Refer Table 1	Follow Safety rules and Safe working practices Conduct parallel operation of 3-ph alternators by Dark Lamp OR Bright Lamp OR Synchroscope method.
12	1, 2	4	1. Meaning and types of excitations. Static excitation system Ref.7(14) 2. Effect of unequal voltage on load sharing. Effect of change in excitation and prime mover input power on distribution of load. 3. Hunting and its prevention in alternators. Necessity of cooling in alternators. Cooling agents. – Hydrogen cooling.		Follow Safety rules and Safe working practices 1. Demo (Video) on Static excitation system. Ref.7(14)
13	1, 4	4	1. Maintenance of the transformer. 2. Installation and Maintenance of alternator. Ref.7(15) 3. Construction of an Energy efficient transformer. -Star rating of a transformer. -Benefits Of Higher Efficiency in Transformers. -Calculate Cost saving by buying an energy efficient transformer.		Follow Safety rules and Safe working practices 1a. Perform general preventive maintenance of the transformer. 1b. Demonstrate installation of Alternator and Perform general preventive maintenance of Alternators. Ref.7(16) 2a. Demo on different energy efficient transformers. 2b. Visit (or Virtual visit) to the transformer manufacturing industry.
Total in hours			39	13	52

*PO= Program Outcome as listed and defined in year 1 curriculum and CO-PO mapping with strength (Low/Medium/High) has to be mapped by the course coordinator. (Above only suggestive).

Table 1: Suggestive Activities for Tutorials: (The List is only shared as an example and not inclusive of all possible activities of the course. Student and Faculty are encouraged to choose activities that are relevant to the topic and on the availability of such resources at their institution)

Sl No.	week	Activity
1	1	<p>I. Explain the importance of resonance and its application. For a given RLC circuit.</p> <ul style="list-style-type: none"> i. calculate voltage across R, L and C. ii. calculate Net Reactance. iii. calculate the resonance frequency. iv. At a given resonance frequency, calculate net reactance and voltage across L and C. <p>II.</p> <ol style="list-style-type: none"> 1. Explain Principles of induction and inductive reactance. 2. Explain self and mutual induction. 3. Explain behaviour of the inductor at low and High frequencies.
2	2	<p>I</p> <ol style="list-style-type: none"> 1. Explain Magnetic field around a current carrying conductor, Cork Screw Rule and Right-Hand Thumb Rule. 2. Explain Faraday's laws of electromagnetic induction. 3. Explain self-induced EMF and Mutually induced EMF and their application. 4. Differentiate dynamically induced and statically induced EMF. 5. Explain Lenz's law. 6. Explain Right hand and Left-hand Fleming's rule. <p>II</p> <p>Study the construction of a given 1kVA transformer and identify material presently used for lamination and insulation in different types and sizes of transformer. List Differences between Aluminium and copper used as winding materials in transformers.</p>
3	3	<p>I. Construct and test 220/12V ,1A Step-down transformer.</p> <p>II. For a given single-phase transformer;</p> <ol style="list-style-type: none"> 1. Calculate No-load power consumed and no-load power factor, 2. Calculate active and reactive components of No-load current 3. Draw the vector diagram for the transformer on No- load and ON-load conditions. 4. Explain the reasons for the low power factor.
4	4	<p>I. For a given transformer</p> <ol style="list-style-type: none"> 1. List the different losses in a transformer 2. Methods of reducing iron losses and copper losses. 3. Explain variations of transformer efficiency against various load power factors. 4. Explain methods to enhance the life of the Transformers. <p>II.</p> <ol style="list-style-type: none"> 1. Explain construction and working of On-load tap changing (OLTC) transformer

5	5	<p>I For a given Star connected three-phase circuit.</p> <ol style="list-style-type: none"> 1. calculate line voltage, phase voltage, line current and phase current. 2. Calculate active power, reactive power, apparent power and power factor. <p>For a given Delta connected three-phase circuit.</p> <ol style="list-style-type: none"> 1. calculate line voltage, phase voltage, line current and phase current. 2. Calculate active power, reactive power, apparent power and power factor. <p>II</p> <ol style="list-style-type: none"> 1. Explain construction of oil cooled power and distribution Transformers. 2. Explain different types of cooling used to cool the transformer. 3. Explain the properties and types of transformer oil. 4. Explain the process of transformer painting and need for painting. <p>III</p> <ol style="list-style-type: none"> 1.Explain construction of solar transformers. 2.Explain Vacuum Pressure Impregnated Transformer (VPI)
6	6	<p>Study CT and PT</p> <ol style="list-style-type: none"> 1. Compare and contrast current transformer (CT) with potential transformer (PT) 2. Explain different tests conducted on CT and PT. 3.Explain installation and commissioning of current transformer/ potential transformer. 4.Explain repair/ replacement and maintenance of CT and PT.
7	7	<p>Study the Codes of practice IS 1180.</p> <ol style="list-style-type: none"> 1. Explain Measurement of No-load Loss and Current. 2. Explain connection and phase displacement symbols for three-phase transformers 3. Rating plate details
8	8	<p>Study the Codes of practice as per IS 10028 for selection, installation and maintenance of transformers and explain typical tests carried out before commissioning the transformer.</p>
9	9	<ol style="list-style-type: none"> 1. Properties of magnets and their materials, preparation of artificial magnets, significance of electromagnetism, types of cores. 2. Explain types of DC generators with circuit representation. 3. Explain Conditions for voltage build up in shunt generator.
10	10	<p>Study harmonics generated in Generators and Transformers</p> <ol style="list-style-type: none"> 1. List harmonics generated in generators and Transformers 2. Explain long term effects caused by harmonics 3. Limits and levels imposed on odd harmonics by IEC and IEEE 4. Explain how Improved winding configurations can reduce harmonics in generators
11	11	<p>Study the latest technological changes in this course and present the impact of these changes on industry.</p> <p>Study the data centre generators and</p> <ol style="list-style-type: none"> 1.List requirements for Data centre generators 2. Specifications of typical Data Centre generator 3. Method employed to reduce harmonic content 4. Protection and cooling method 5.Applicable IEC standards
12	12	<p>Study the latest technological changes in this course and present the impact of these changes on industry.</p> <p>Study the Watchdog Low Temperature Rise Transformers (three-phase and single-phase) and Non-linear transformers.</p>

		<ol style="list-style-type: none"> 1. List the features of watchdog transformer 2. Advantages of watchdog transformer 3. Typical specification of watchdog transformer 4. List features of Non-linear transformer and its application
13	13	Study the latest technological changes in this course and present the impact of these changes on industry.

4. CIE and SEE Assessment Methodologies

Sl. No	Assessment	Test Week	Duration In minutes	Max marks	Conversion
1.	CIE-1 Written Test	5	80	30	Average of three tests 30
2.	CIE-2 Written Test	9	80	30	
3	CIE-3 Written Test	13	80	30	
4.	CIE-4 Skill Test-Practice	6	180	100	Average of two skill test reduced to 20
5	CIE-5 Skill Test-Practice	12	180	100	
6	CIE-6 Portfolio continuous evaluation of Tutorial sessions through Rubrics	1-13		10	10
Total CIE Marks					60
Semester End Examination (Practice)			180	100	40
Total Marks					100

5. Format for CIE written Test

Course Name	Transformers and Alternators	Test	I/II/III	Sem	III
Course Code	20EE31P	Duration	80 Min	Marks	30

Note: Answer any one full question from each section. Each full question carries 10 marks.

Section	Assessment Questions	Cognitive Levels	Course Outcome	Marks
I	1			
	2			
II	3			
	4			
III	5			
	6			

Note for the Course coordinator: Each question may have one, two or three subdivisions. Optional questions in each section carry the same weightage of marks, Cognitive level and course outcomes.

6. Rubrics for Assessment of Activity (Qualitative Assessment)

Sl. No.	Dimension	Beginner	Intermediate	Good	Advanced	Expert	Students Score
		2	4	6	8	10	
1		Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	8
2		Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	6
3		Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	2
4		Descriptor	Descriptor	Descriptor	Descriptor	Descriptor	2
		Average Marks= (8+6+2+2)/4=4.5					5

Note: Dimension and Descriptor shall be defined by the respective course coordinator as per the activities

7. 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 by M.N. Bandyopadhyay PHI Learning Pvt. Ltd.
4	Electrical Machines by Bhattacharya. Tata McGraw Hill Co.
5	Electrical Machines - J.B.Gupta Kataria & Sons Publications
6	Generation of Electrical Energy by BR Gupta. S.Chand Publication.
7	Fundamentals of electrical drives - G.K. Dubey Narosa publications.
8	Electrical Machines – Deshpande.
9	http://www.anuraghyd.ac.in/eee/wp-content/uploads/sites/3/power-systems.pdf
10	https://www.youtube.com/watch?v=FQ22UM0zyGs&feature=emb_logo
11	https://www.youtube.com/watch?v=mjLs40e_9YE&feature=emb_logo
12	https://relaytraining.com/wp-content/uploads/2013/07/PT-Testing_Back-to-the-Basics_RelayTraining.com .pdf
13	https://electrical-engineering-portal.com/testing-commissioning-current-transformer
14	https://www.youtube.com/watch?v=34Fj7O_sU9I
15	https://search.abb.com/library/Download.aspx?DocumentID=SM103&LanguageCode=en&DocumentPartId=&Action=Launch
16	https://www.stamford-avk.com/sites/stamfordavk/files/AGN007_C.pdf

8.1 CIE -4 Skill Test Scheme of Evaluation:

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions(week1-week6)		10
2	List the standard safety norms related with electrical machines	1	10
3	Building and Demonstration of the working Circuit including; i. Drawing of circuit diagram using right symbols. 05 ii. Build the circuit as per the circuit diagram 10 iii. Demonstrate the performance/operation of a machine 35 iv. Document the necessary readings of the expected outcome 10	2	60
4	Viva -voce		20
Total Marks			100

8.2 CIE -5 Skill Test Scheme of Evaluation:

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions (week7-week12)		10
2	List the standard safety norms related with electrical machines	1	05
3	Building and Demonstration of the working Circuit including; i. Drawing of circuit diagram using right symbols. 05 ii. Build the circuit as per the circuit diagram 05 iii. Demonstrate the performance/operation of a machine 20 iv. Document the necessary readings of the expected outcome 05	2	35
4	Explain Scope of any one IS standard (1008/1180/2026)	3	10
5	Identify the problem in a given machine and demonstrate the troubleshooting method used to rectify that problem. 10+20	3	30
6	Viva-voce		10
Total Marks			100

8.3 SEE Scheme of Evaluation:

SL. No.	Particulars/Dimension	CO	Marks
1	Portfolio evaluation of Practice Sessions (1-13 week)		10
2	Building and Demonstration of the working Circuit including; i. Drawing of circuit diagram using right symbols. 10 ii. Build the circuit as per the circuit diagram 10 iii. Demonstrate the performance/operation of a machine 15 iv. Document the necessary readings of the expected outcome 05 v. Comply with the standard safety norms related with electrical machines 05	1,2	45
3	Explain the criteria for selection, the process of installation and the importance of timely maintenance and consequences for a machine for a given application 5+10+5+5	4	25
4	Viva-voce		20
Total Marks			100

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

Sl. No.	Particulars	Specification	Quantity
1	Single-phase transformer	2kVA 1:1	3
2	Single-phase transformer	2kVA 1:0.5	2
3	1-ph Variacs	(0-300)V, 5 A	6
4	3-ph Variacs	(0-440)V,15A	2
5	Potential Transformers	220V-75V	2
6	Current Transformers	5A-1A	2
7	Motor (DC Shunt,220V) and Alternator(3-ph,440V) Set		1 Set
8	Loading Rheostats	Lamp Load	2
9	Wire wound Rheostats	Assorted-range	30
10	Analog Tachometers		3
11	Digital Tachometers		3
12	Synchroscope		2
13	Phase sequence indicator		2
14	Portable DC Moving coil ammeter	multirange (0-1-2-5-10-20)	
15	Portable DC Moving coil Voltmeters	multirange (0-2-10-15-30-75-150-300V)	
16	Watt meters (Dynamometer type)	i) LPF 75/300/600V,1/2A ii) UPF 75/300/600V,5/10A iii) UPF 75/300/600V,15/30A	2
17	Frequency meters read type and digital type		2
18	Portable pf meters		
19	Megger	500 V, 1000V, 1500 V	2
20	Earth tester		2
21	Tong tester analog and digital		2 each
22	Multimeters analog and digital		4 each
23	Electrical & Electronics Circuit Simulation software PSpice/ GNU Octave/MatLab	For a batch of 20 students	