ESO203A – Introduction to Electrical Engineering (3-1-2-0-13)

1. Course Objectives

This course aims at the basics of circuit analysis for AC circuits, and introduce the principles of AC and DC machines.

2. Prerequisites

3. Course Contents

Single Phase Circuits 4 lectures

2. R, L, C elements, constituent relationships, notion of impedance, series & parallel resonance.

3. Writing loop and node equations. Suitable examples to illustrate the method in time and phasor domain are discussed.

4. Superposition principle, network with two different frequencies, Thevenin and Norton equivalents, Miller's theorem, maximum power transfer theorem.

5. Definitions of instantaneous, active and reactive powers, direction of power flow complex power, power factor and its improvement, effective power with multiple frequencies.

Three Phase Circuits 3 lectures

6. Three phase balanced sources and load. Star and delta configurations. Floating and grounded neutrals, the earth connection, line and phase voltages and currents, phasor diagrams of three phase quantities, balanced and unbalanced loads.

7. Power in three phase circuits: basic definition, instantaneous power in balanced and unbalanced loads, average three-phase power, complex power

8. Measurement of three phase power using wattmeters, the two-wattmeter method, measurement of energy.

Self & Mutual Inductance 1 lecture

9. Notion of Self-inductance, magnetically coupled circuit elements, mutual inductance, coefficient of coupling, dot convention for the sign of mutual inductance, rewriting circuit equations to include mutually coupled elements.

Basic Magnetic Circuit & mutual coupling 4 lectures

10. Magnetic materials, relative permeability, B-H curve, magnetic cores and their shapes, laminated cores, ampere's law and ampere turns, notion of flux linkages, ,magnetic equivalent circuit, notion of reluctance of magnetic path, expression for flux, self-inductance and its relationship with physical dimensions, effect of air gap and saturation.

11. Faraday's law, multiple windings on common core, two-winding transformer, the ideal transformer as a circuit element, flux and current in voltage excited transformer. Effect of load on the secondary winding. Notion of leakage inductance and magnetizing inductance.

12.. Derivation of the equivalent circuit using mutual inductance and equivalent secondary current. Power loss in magnetic core due to hysteresis and eddy currents, loss representation in equivalent circuit

13. Electrical equivalent circuit as a dual of the magnetic circuit, representation using equivalent circuit referred to a winding (primary or secondary.

Equivalent Circuit, Regulation, Efficiency 3 lectures

14. Notion of rating of a transformer, load voltage calculation under different loading conditions, load voltage regulation, calculation of losses and efficiency, variation of efficiency with load.

15. Determination of equivalent circuit parameters: resistance measurement, the open circuit test and the short circuit test.

16. Basic configuration of three phase transformer, core construction, single phase equivalent circuit and per phase calculation. Power and distribution transformers. All day efficiency of a distribution transformer.

C.T., P.T., Special transformers 1 lecture

17. Voltage and current excitation of a magnetic core, current transformer and potential transformer for measurement purposes, load matching transformers, welding transformers, isolation transformers.

Basic geometry Of AC & DC machines 1 lecture

18. The geometry of a radial flux, axial current machine, stator and rotor assembly, relative size of air gap, slotted armature for holding conductors, field due to windings on salient poles, common flux patterns,2pole & multi-pole, magnetic equivalent circuit, need for sliding contacts.

DC MACHINES: (6 lectures)

Commutator Action 1 lecture

19. Evolution of commutator: Slip ring, split ring, multiple split rings leading to commutator.

Voltage equation derived from flux density and velocity, definition of flux/pole, pole arc, pole pitch; the frequency of induced voltage, parallel paths, lap and wave winding, example of a winding scheme, equivalent circuit of a closed armature.

Generator model 2lectures

20. Generator equivalent circuit, methods of excitation, back torque of generator, open circuit characteristics (E_g vs. I_f), external characteristics (V_t vs. I_L) of separately excited generator.

21. Characteristics of shunt generator, voltage build-up at start, critical field resistance, voltage collapse after maximum load, compounding for flatter characteristic.

Motor model 2 lectures

22. Convention for armature current direction, motor equivalent circuit, derivation of the characteristic of Torque versus Speed for separately excited motor, balance of motor torque and load torque, torque-speed characteristics of different types of load

23. Field excitation using shunt field winding, series field windings and permanent magnets. Derivation of the characteristic of Torque versus Speed for series motor, universal motor, qualitative appreciation of armature reaction, interpoles and compensating winding.

Starting & Speed Control 1lecture

24. Need for starting resistance, 3 point starter, speed control using armature voltage variation and field weakening, dynamic and regenerative braking.

AC MACHINES: (13lectures)

Sinusoidally Distributed Winding & Revolving Magnetic Field In AC machines (2lectures)

25. Nature of air gap field due to winding on the stator: Field due to single coil, winding distributed over slots, production of approximately sinusoidal flux density distribution, axis of the winding,

26. Three phase winding with axes at 120 degrees, relation between current and flux density, revolving magnetic field due to balanced three phase current in three phase winding, multiple pole pairs, electrical and mechanical angle.

Induction Motors (6)

Principle 1 lecture

27.Construction of cage and wound rotors, frequency of induced current, qualitative explanation of revolving magnetic field due to rotor currents, definition of slip, torque production by interaction of stator and rotor fields, motor and generator action

Equivalent Circuit & Performance calculations 3 lectures

28. Derivation of induction motor equivalent circuit using transformer analogy, variation of equivalent rotor resistance with slip, expression for torque, the torque-slip characteristic,

29. Calculations using equivalent circuit: variation of starting torque with rotor resistance,, stable operating point, expression for pull-out torque, reason for pull out,

30. Determination of equivalent circuit parameters: No load test, blocked rotor test.

Methods for the starting of induction motors: DOL and reduced voltage starting, resistance adjustment in wound rotor motors

Single Phase Motor, Basic Principle 2 lectures

31.Single phase induction motor windings, main and auxiliary winding, methods of generating phase difference between two windings, production of revolving field, starting and running characteristics, capacitor start and capacitor run motors.

32. Equivalent circuit of single phase motor using double revolving field theory, forward and backward torque, torque-slip characteristic.

SYNCHRONOUS MOTOR & GENERATOR (5)

Basic Principle 1 lecture

33. Stator winding similar to induction motor, salient and cylindrical rotor field windings, damper winding, machine connected to infinite bus, relation between speed and no of poles, generated e.m.f, phase angle as the adjustable variable, equivalent of rotor current on stator side, generator and motor action.

Equivalent circuit, Phasor diagram & Power Angle   2 lectures

34. Synchronous Motor: Equivalent rotor current i'_f , derivation of factor n, equivalent circuit assuming ideal stator, convention for direction of stator current for motor & generator action, , phasor diagram, relative position of i'_f and i_m, torque angle β, power factor variation by adjustment of field current, V-curves,

35. Air gap power, and expression for torque, action of damper winding for starting and damping of oscillations,

Synchronous Generator: Generator action, role of mechanical power input and field excitation, Thevenin equivalent, Synchronous reactance, phasor diagram, torque angle β,

Expression for complex air gap power.

Torque Calculations & tests for determination of parameters   2 lectures

36. Torque Expressions for generator and motor action: Operation from constant voltage bus, torque in terms power angle β. Alternate expressions for current excitation using stator current and angleδ.

37. Parameter Determination: Open circuit characteristic (E_g versus I_f), air gap line, effect of saturation, short circuit test, calculation of synchronous reactance from O.C.C and S.C.C, measurement of field and armature losses.

Special Topics   3 Lectures

These may be chosen from topics below.

(i) Stepper Motors,

(ii) HV cables

(iii)Circuit Interruption devices

(iv)Distribution systems and safety.

4. Instructor

Soumya Ranjan Sahoo (srsahoo@iitk.ac.in)

5. Venue (for 2017-18 Sem 2)

Lecture - L16, Lecture Hall Complex

Tutorial – T103 – T109, Tutorial Block

Lab –

6. Time (for 2017-18 Sem 2)

Lecture - 12 noon to 1.00pm (M,W,Th)

Tutorial – 5.00 pm to 6.00 pm (F)

Lab – 2.00 pm to 4.00 pm (M,T,W,Th)

7. Assignments

Assignments will be given at regular intervals for understanding the concepts taught during the lectures. The assignments will not be used for grading and for practice only.

8. Evaluation Scheme

- Mini Quizzes (6 nos.) – Total weightage – 10%
- Major Quizzes (2 nos.) – Total weightage – 20%
- Mid Semester Exam – Weightage – 25%
- End Semester Exam – Weightage – 30%
- Lab evaluations – Weightage – 15%

Please note that all exams are compulsory. Missing the EndSem exam will lead to an Incomplete (I) grade in the course. The grade (I) will be converted to a suitable grade if the absentee takes the Make-up EndSem exam after suitable permission(s) from the required authority. In case the absentee does not appear for the Make-up EndSem for whatsoever reason, the grade (I) will be converted to grade (F).

9. References

A few reference books are listed below:

- Fundamentals of electric circuits, Alexander and Sadiku
- Introductory Circuit Analysis, R. L. Boylestad
- Electric machinery fundamentals, Stephen J Chapman
- Electric Machinery, A. E. Fitzgerald, Charles Kingsley Jr., Stephen D. Umans
- Engineering Circuit Analysis, Hayt, Kemmerly and Durbin
- Principles and applications of electrical engineering, Giorgio Rizzoni

Please note that the references are not limited to above mentioned books.