KKR & KSR INSTITUTE OF TECHNOLOGY & SCIENCES
(Approved by AICTE, Delhi, Affiliated to JNTU, Kakinada)

Department of Electrical and Electronics Engineering

Name of Faculty: Dr. M. Amarendra **Class:** IV-I B.Tech (EEE)

Name of Course: Special Electrical Machines (R13) Year**: 2017-18**

1. Preamble:

This is an advanced course on electrical machines. Students will be exposed to various special machines which are gaining importance in industry. This course covers topic related to principles, performance and applications of these special machines including switched reluctance motors, stepper motors, permanent magnet motors, linear motors and electric motors for traction drives.

2. Learning Objective:

1. To explain theory of operation and control of switched reluctance motor
2. To explain the performance and control of stepper motors and their applications.
3. To describe the operation and characteristics of permanent magnet dc motor.
4. To distinguish between brush dc motor and brush less dc motor.
5. To understand the significance of electrical motors for traction drives.

3. Syllabus:

UNIT-1 SWITCHED RELUCTANCE MOTOR

Principle of operation- Design of stator and rotor pole arc-Power converter for switched reluctance motor-control of switched reluctance motor.

UNIT-2 STEPPER MOTOR

Construction-Principle of operation-Theory of torque production-Hybrid stepper motor-variable reluctance stepper motor-open loop and closed loop control.

UNIT-3 Permanent Magnet DC Motors

Construction-principle of working-Torque equation and equivalent circuits-performance characteristics-moving coil motors.

UNIT-4 Permanent Magnet Brushless DC Motors

Construction-principle of operation-Theory of brushless dc motor as variable speed synchronous motor- sensor less and sensor based control of BLDC motor.

UNIT-5 Linear Motors

Liner Induction Motor: Construction-principle of operation-applications
Linear synchronous Motors: Construction-principle of operation-applications

UNIT-6 Electric Motors for traction drives

AC motors-DC motors- Single sided liner induction motor for traction drives-comparison of AC and DC traction.

4. Pre-revisit Courses :

- ✓ Electrical Machines-I
- ✓ Electrical Machines-II
- ✓ Electrical Machines-III
- ✓ Power Electronics
- ✓ Power semiconductor drives

5. Course Outcomes:

Course Code	Course Outcome	Taxonomy Level
C422.1	Explain theory of operation and control of switched reluctance motor	Comprehension (TL2)
C422.2	Explain the performance and control of stepper motors, and their applications	Application (TL3)
C422.3	Describe the operation and characteristics of permanent magnet dc motor	Comprehension (TL2)
C422.4	Distinguish between brush dc motor and brushless dc motor.	Analysis (TL4)

C422.5	Explain the theory of travelling magnetic field and applications of linear motors	Application (TL3)
C422.6	Analyze the significance of electrical motors for traction drives	Analysis (TL4)

6. CO-PO MAPPING

Course Code	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C423.1	3	2	1	1	1							1
C423.2	3	2	1	2	1							2
C423.3	3	3										
C423.4	2	1										2
C423.5	3	2	2	2								
C423.6	3	2										2

3 – High 2- Moderate 1- Low

7. CO-PSO MAPPING

PSO-1: Able to utilize the knowledge of Power Electronics in collaboration with Electrical Machines to provide an engineering solution in the areas related to Electrical Drives.

PSO-2: To develop new cutting edge Technologies in Power Systems associated with efficient conversion and control of electrical power.

PSO-3: Able to use software for design, simulation and analysis of electrical systems

Course Code	PSO1	PSO2	PSO3
C414.1	3		
C414.2	3		
C414.3	1		
C414.4	2		
C414.5	2		
C414.6	2		

8. Lesson Plan

Sl. No	Lecture No	Topic	Teaching Aid	Text Book/ Reference Book	Page no's in the textbooks
UNIT-I : Stepper Motor					
01	Lecture 01	Introduction to Special Electrical Machines	Glass Board (GB) and Piece of chalk (PC)	T1	1 - 4
02	Lecture 02	Introduction to Stepper Motor	GB and PC	T1 & T2	2 – 4 & 1
03	Lecture 03	Types of Stepper Motor: VRS Motor Construction Working	GB and PC	T2	1-5
04	Lecture 04	Types of Stepper Motor: VRS Motor Control, Multi stack Motor	GB and PC	T2	6-7
05	Lecture 05	Types of Stepper Motor: Permanent Magnet Stepper Motor	GB and PC	T2	8-11
06	Lecture 06	Types of Stepper Motor: Hybrid Stepper Motor	GB and PC	T1	10 - 13
07	Lecture 07	Torque equation	GB and PC	T2	19 - 22
08	Lecture 08	Characteristics of Stepper Motor	GB and PC	T2	22 - 26
09	Lecture 09	Open-loop Control of Stepper motor	GB and PC	T2	26-27
10	Lecture 10	Simulation to implementation of open loop control of stepper motor	PPT	W1	

11	Lecture 11	Closed-loop Control of Stepper motor Application of stepper Motor	GB and PC	T2	27-28
UNIT-II : Switched Reluctance Motor					
12	Lecture 12	Construction of SRM	GB and PC	T2	38- 39
13	Lecture 13	Working Principle of SRM	GB and PC	T2	39-40
14	Lecture 14	Basics of SRM Analysis	GB and PC	T2	41-42
15	Lecture 15	Construction on Pole arc and tooth arc	GB and PC	T2	43
16	Lecture 16	Torque equation and Characteristics	GB and PC	T2	44-46
17	Lecture 17	Power Converters Circuits: Two switching devices per phase	GB and PC	T2	47
18	Lecture 18	Power Converters Circuits: With bifilar winding	GB and PC	T2	48
19	Lecture 19	Control of SRM: Basics	GB and PC	T2	49
20	Lecture 20	Microprocessor based control of SRM	GB and PC	T2	53
UNIT-III : Permanent Magnet DC Motors					
21	Lecture 21	Introduction and Construction of PM DC motor	GB and PC	T1	139
22	Lecture 22	Working Principle Of PMDC motor	GB and PC	T2	66
23	Lecture 23	Torque equation	GB and PC	T2	66
24	Lecture 24	Equivalent circuit	GB and PC	T1	140-141
25	Lecture 25	Performance Characteristics and moving coil meters	GB and PC	T2	68-69
UNIT-IV : Brushless Permanent magnet DC (BLDC) Motors					
26	Lecture 26	Construction	GB and PC	T1	146-147

27	Lecture 27	Working principle	GB and PC	T1	148-151
28	Lecture 28	Types of BLDC	GB and PC	T1	152-153
29	Lecture 29	BLDC motor with 120^0 magnetic arc	GB and PC	T2	78-79
30	Lecture 30	Control of BLDC Motor	GB and PC	T2	82
31	Lecture 31	Microprocessor based control of BLDC	GB and PC	T2	83
32	Lecture 32	DSP based control of BLDC	GB and PC	T2	84
33	Lecture 33	Sensor less control of BLDC motor	GB and PC	T2	85
34	Lecture 34	Applications of BLDC motor	GB and PC	T2	87
UNIT-V : Linear Motors					
35	Lecture 35	Introduction to linear motors	GB and PC	T2	201
36	Lecture 36	Construction of linear induction motor: Axial field motors	GB and PC	T2	202-204
37	Lecture 37	Construction of linear induction motor: TLIM	GB and PC	T2	205
38	Lecture 38	Torque equation	GB and PC	T2	206-207
39	Lecture 39	Goodness Factor	GB and PC	T2	211
40	Lecture 40	Equivalent circuit of LIM and characteristics	GB and PC	T2	212
41	Lecture 41	Construction of Linear Synchronous motor	GB and PC	T2	215
42	Lecture 42	Working of LSM	GB and PC	T2	218-219
43	Lecture 43	Thrust equation of LSM	GB and PC	T2	220-221
44	Lecture 44	Control of LSM	GB and PC	T2	223-224

45	Lecture 45	Applications of LSM	GB and PC	T2	225
UNIT-VI : ELECTRIC MOTORS FOR TRACTION DRIVES					
46	Lecture 46	Working of AC motors and its characteristics brief review	GB and PC	R1	1244-1245
47	Lecture 47	Applications of AC motors for traction	GB and PC	W2	
48	Lecture 48	Working of DC motors and its characteristics brief review	GB and PC	R1	996-998
49	Lecture 49	Applications of DC motors for traction	GB and PC	W3	
50	Lecture 50	Single sided liner induction motor for traction drives	GB and PC	W4	
51	Lecture 51	Comparison of AC and DC traction.	GB and PC	W5	
52	Tutorial 1	Discussion on Assignment-1			
53	Tutorial 2	Discussion on Assignment-2			
54	Tutorial 3	Discussion on unit-1 old university question Papers			
55	Tutorial 4	Discussion on unit-1 old university question Papers			
56	Tutorial 5	Discussion on unit-2 old university question Papers			
57	Tutorial 6	Discussion on unit-2 old university question Papers			
58	Tutorial 7	Discussion on unit-3 old university question Papers			
59	Tutorial 8	Discussion on unit-3 old university question Papers			
60	Tutorial 9	Discussion on unit-4 old university question Papers			
61	Tutorial 10	Discussion on unit-4 old university question Papers			
62	Tutorial 11	Discussion on unit-5 old university question Papers			
63	Tutorial 12	Discussion on unit-5 old university question Papers			
64	Tutorial 13	Discussion on unit-6 old university question Papers			

Text Books:

1. "Special Electrical Machines" – by K Venkata ratnam University press, 2009, New Delhi.
2. "Special Electrical Machines" –E.G Janardhan, PHI Learning private limited, 2014

Reference Books:

R1) Electrical Technology Volume II – by B. L. Theraja, A. K. Theraja, S. Chand Publishing company, 2010.

Website References:

S.No.	Topic	Website References
1	Control of Stepper motor simulation	Https://in.mathworks.com/help/daq/examples/control-stepper-motor-using-digital-outputs.html
2	DIRECT-DRIVE INDUCTION MOTOR FOR RAILWAY TRACTION APPLICATIONS	Http://www.acad.ro/sectii2002/proceedings/doc2011-3/11-Dordea.pdf
3	Railway Traction	Http://cdn.intechopen.com/pdfs/34430/intech-railway_traction.pdf
4	Equivalent Circuits for Single-Sided Linear Induction Motors	Http://ieeexplore.ieee.org/document/5565477/
5	AC TRACTION VS DC TRACTION	Http://www.republiclocomotive.com/ac-traction-vs-dc-traction.html

9. Important Question Bank to University Examination:

Unit-1

1 a) Explain the principle of operation of Switched Reluctance Motors.
b) Discuss the torque production mechanism in Switched Reluctance Motors.

2 a) List the main features of Switched Reluctance Motors.
b) Explain the procedure in designing stator and rotor pole arc for switched Reluctance motor.

3 a) Explain different power converter configurations for Switched reluctance motor
b) Explain briefly design aspects of Switched reluctance motor

4 What are the advantages and disadvantages of Switched reluctance motors and mention the applications of Switched reluctance motors

5 a) What is the need for position feedback in the operation of switched reluctance motor? Explain.
b) With a neat circuit diagram, explain the asymmetric bridge converter for a four-phase 8/6 switched reluctance motor.

6 a) What is magnetic reluctance? Bring out the relationship between inductance and reluctance.
b) With a neat waveform, explain the variation of inductance with rotor position.

7 a) Explain different power converter configurations for Switched Reluctance Motor.
b) What are the effects of saturation in SRM?

Unit-2

1 a) Explain single stack VR stepper motors b) What is Bifilar winding? Explain its significance.

2 a) List out areas of applications & suitability of stepping motors.
b) Explain different types of variable reluctance stepping motors.

3 a) Explain constructional details of stepper motors
b) Explain multi- stack VR stepper motors.

4 a) Describe constructional aspects of stepper motor b) What are hybrid stepping motors? Explain.

5 a) Define and explain holding torque and detent torque of a stepper motor.
b) What are permanent magnet stepper motors? Explain its construction and operation.

6 a) With a neat diagram, explain the constructional details of an eight stator pole, six rotor pole stepper motor. Also discuss its operation.
b) List different applications of stepper motors.

7 a) Explain the construction and operation of a variable reluctance stepper motors.
b) What is a step angle? Explain. c) Define stepping rate of a stepper motor.

8 a) A stepper motor has a step angle of 1.8° and is driven at 400pps. Determine i) Resolution, ii) Motor speed and iii) number of pulses required to rotate the shaft through 54°.
b) Compare between stepper motors and switched reluctance motor. b) Explain the operation of a variable reluctance stepping motor.

9 a)Calculate the pulse rate required to obtain a rotor speed of 2400 rpm for a stepper motor having a resolution of 250 steps/rev.
b) A four stack Variable Reluctance stepper motor has a step angle of 1.5°, find the number of its rotor and stator teeth.

10 a) Discuss different modes of excitation of stepper motors.
b) Draw and explain the power converter for stepper motors.

Unit-3

1 a) What is hysteresis loop? How permanent magnets can be selected for dc motors? Explain clearly.
b) Why Permanent magnet machines have high torque /weight ratio? Explain clearly

2 a) List out the reasons why Permanent materials used in DC Machines b) Explain the significance of B-H characteristics of a permanent magnets

3 a) What is electrically commutated DC Motor? Explain its operation. b) Explain the advantages and applications of Permanent Magnet DC Motors.

4 a) Discuss the advantages and disadvantages of permanent magnet motors. b) Draw and explain the equivalent circuit of a permanent magnet DC motor.

Unit-4

1 a) Explain the construction details of radial flux BLDC motor
b) What are the advantages of Brushless DC machines over AC motors and explain the principle of operation of Brushless DC motor

2 a) Explain the constructional details of a PMBLDC motor.
b) Prove that the PM BLDC machines have 15% more power density than the PMSM.

3 What is a BLDC motor? What are its advantages? Give the mathematical modeling of a BLDC motor.

4 a) Compare between PMBLDC motors and PMSM motors. b) List the advantages and applications of BLDC motors.

5 a) Draw and explain the back emf waveforms of a three-phase BLDC motor. b) Explain the commutation process in BLDC machines.

6 a) Compare between BLDC motors and SR motors. b) With a neat block diagram, discuss the closed loop operation of BLDC motor drive.

7 a) Explain the use of hall sensors in the control of BLDC motors.

b) With a neat schematic diagram, explain the speed control of a BLDC motor drive.

8 a) In what way BLDC motor is different from synchronous motor? Explain.
b) Discuss the need for rotor position sensor in BLDC motor operation.

Unit-5

1 a) What are linear motors? Give their applications. b) Explain principle of operation of linear induction motor.

2 a) Explain the construction & working Principle of Linear Induction Motor b) What are advantages & disadvantages of Linear Induction Motor compare to conventional induction motor and also list out the application of Linear Induction Motor.

3 a) List and discuss different types of linear motors. b) Explain the operation of a linear induction motor.

4 a) Compare between linear induction motors and rotary induction motors. b) Discuss the application of linear induction motors for electric traction.

5 a) Explain the operation of short stator linear induction motor. b) Discuss the application of Linear Induction Motors for electric traction.

Unit-6

1 a) Compare AC and DC traction systems and what are merits and demerits b) Explain clearly single sided linear induction motor for the application of traction drive

2 a) What is the selection criterion of motors for electric traction application? explain
b) What are the merits and demerits of ac traction motors compare to dc traction motors

3 a) What are the different types AC motors suitable for electric traction? Explain the reason for selection of the motor b) Explain clearly single sided linear induction motor for traction drive application.

4 a) List and compare different types of motors employed in traction. b) Explain the application of linear motors for traction drives.

5 What are linear induction motors? Explain the use of single sided linear induction motor for traction drives.

6 a) Discuss the main characteristics of traction drives. b) Discuss the suitability of linear induction motors for traction drives.

10. Assignments:

Assignment-1

1. Develop open and closed loop control of SRM by using simulation (MATLAB/Simulink)
2. Develop stepper motor control for any selected configurations by using simulation.

Assignment-2

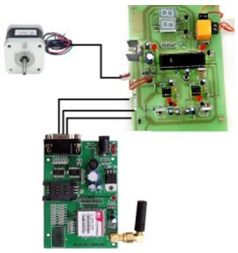
1. Explain the role of BLDC motor for Electric vehicle application with developed model.
2. 8 a) In what way BLDC motor is different from synchronous motor? Explain.

11. Experiments:

1. Stepper motor control by using Digital Controller.
2. Closed loop control of BLDC motor.

12. Mini projects:

1. GSM Stepper Motor Speed & Direction Controller



Resource: http://nevonprojects.com/gsm-stepper-motor-speed-direction-controller-project/

Signature of HOD **Signature of Faculty**