SAULT COLLEGE OF APPLIED ARTS & TECHNOLOGY

SAULT STE. MARIE, ONTARIO

COURSE OUTLINE

Course Title: POWER ELECTRONICS

Code No.: ELR 236-6

Program: ELECTRICAL TECHNICIAN

Semester: FOUR

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APPROVED: L.P. Arazietto (signature)
Chairperson

Date

POWER ELECTRONICS	ELR 236-5
Course Name	Course Number

PHILOSOPHY/GOALS:

1. To provide a sound understanding of electronically controlled AC and DC motor drive systems.

2. To provide hands-on experience in the operation adjustment and troubleshooting of typical commercial AC and DC drive systems.

METHOD OF ASSESSMENT:

Theory 70%   Laboratory 30%

A - 80 - 100%
B - 66 - 79%
C - 55 - 65%

Student must achieve a satisfactory grade in both theory and laboratory. Final grade between 50 and 54% may have a final 3 hour examination at the discretion of the instructor. If successful, student will be assigned 55%.

TEXTBOOKS:

Power Electronics - Solid-State Motor Control, by R.A. Pearman

COURSE OBJECTIVES

LECTURE	LAB	TOPIC
6	0	Power Electronic Devices Turn on, turn off processes of an SCR including turn on and turn off curves: di/dt and dv/dt turn-on methods Use, characteristics and application of phase control SCRs, inverter (fast switching SCRs) asymmetrical thyristors, reverse conducting thyristors, gate turn-off thyristors, Bipolar power transistors, and power MOSFETS
10	0	Phase Controlled Converters One-quadrant: single-phase two-pulse half-controlled bridge; three-phase half-controlled bridge, three-phase three-pulse midpoint converter with freewheel diode.

Two quadrant: single-phase, two-pulse midpoint converter, single-phase, two-pulse bridge converter; three-phase, three-pulse midpoint converter; three-phase, six-pulse midpoint converter; three-phase, six pulse bridge converter;
Four quadrant: circulating current and circulating current free dual converters.

12 0 Static Frequency Conversion

Advantages of variable frequency AC drives
Requirements of a variable frequency drive
Principle of a single-phase inverter
Voltage control external to and within an inverter (PWM)
Forced commutation techniques
Three-phase inverters, gating and control techniques
voltage and current waveforms
Harmonics, causes, effects and neutralization
Cycloconverters, envelope and phase controlled
Current sourced inverters

6 0 Choppers

Chopper principles
Pulse width modulation, pulse rate modulation and combined pulse width and pulse rate modulation
Forced commutation requirements
Choppers: step-down; step-up; multiphase; bidirectional; and four-quadrant
Classes of commutation
Assessment criteria
Voltage commutation using: parallel capacitor; parallel capacitor-inductor; Morgan circuit; improved Morgan circuit; and Jones circuit
Current commutated choppers
Load commutated choppers
Chopper application

8 0 Firing Circuits

Causes and methods of reducing electrical noise
Firing circuit criteria
Pulse forming
Double pulsing, long pulses, pulse isolation, pulse transformers, optocouplers
Pulse generators
Pulse distribution
Pulse amplification
Phase-shift control
Ramp and pedestal control
Cosine crossing control
Phase locked loop control
Microprocessor control

6	21	DC Motor Control
		Review of the motor characteristics Constant torque, constant kW operation Closed-loop control of DC drives Braking Typical single and three-phase, phase controlled converter drives eg: Silpac, Brown-Boveri and Allen-Bradley Typical phase locked loop drive eg: Seco DC Brushless motors Universal motor control
6	21	AC Motor Control
		Review of polyphase induction motor characteristics and variable frequency control requirements Typical single-and three phase variable frequency Wound rotor induction motor slip power recovery speed control Eddy-current clutch variable speed drives Variable stator voltage speed control Variable speed control of synchronous motors
3		Miscellaneous Applications
		Static excitation systems HVDC systems UPS systems Furnace control Electrochemical applications Static VAR compensation
3		Protection and Cooling
		Overvoltage, overcurrent causes and protection Cooling requirements and methods

POWER ELECTRONIC DEVICES

BLOCK 1 - SPECIFIC OBJECTIVES

1. To recall and explain the turn-on and turn-off process of an SCR, and be able to draw the dynamic turn-on and turn-off curves and identify and define delay time t t , rise time t , reverse recovery time t , gate recovery time t , the critical rate of reapplied forward voltage, and reverse recovery voltage.

2. To recall and explain the effects of di/dt and how it can be minimized by external reactance, by changes in the cathode geometry and gate pulse waveform.

3. To recall and explain the effects of dv/dt and how it can be minimized.

4. To recall and explain with the aid of sketches the requirements and methods of gate circuit protection.

5. To recall and explain with the aid of sketches the application of thyristors in series for high voltage operation, and the modifications necessary to obtain satisfactory steady-state and transient operation, and the requirements and methods of obtaining simultaneous gating of the series thyristors.

6. To recall and explain with the aid of sketches the application of thyristors in parallel for high current operation, the methods of ensuring current sharing and the requirements and methods of obtaining simultaneous gating of the paralleled thyristors.

7. To recall and explain with the aid of sketches the requirements and methods of protecting thyristors against over voltage and over current, the significance of the I t rating of semiconductor fuses and the thyristor.

8. To recall and explain the use of fast recovery diodes in high frequency and switching applications.

9. To recall and explain the characteristics and principles of inverter thyristors, asymmetrical thyristors, reverse conducting thyristors, gate turn-off thyristors, bipolar power transistors, and power MOSFETs.

BLOCK 3 - CONTINUED

12. To be able to explain the basic operation of cycloconverters in the circulatin current and circulating current free modes of operation.

13. To be able to explain with the aid of waveforms, the waveforms and application of envelope cycloconverters.

14. To be able to explain with schematics and a block diagram the cosine crossing method of firing control of a phase controlled cycloconverter.

15. To be able to recall the advantages and disadvantages of a cycloconverter as compared to a dc link converter for variable frequency motor control.

16. To be able to recall and explain with sketches and waveforms the operation of current sourced inverter.

BLOCK 2 - PHASE CONTROLLED CONVERTERS

1. To recall and explain with the aid of sketches and waveforms the following types of two-quadrant phase controlled converters:
   a) single-phase, two-pulse midpoint converter
   b) single-phase, two-pulse bridge converter
   c) three-phase, three-pulse midpoint converter
   d) three-phase, six-pulse midpoint converter
   e) three-phase, six-pulse bridge converter

   with particular emphasis on:
   i) the effects of varying the firing delay angle upon the mean output DC voltage and the input power factor to the converter
   ii) explaining the operation of the converter with an active load, as a rectifier and synchronous inverter with continuous and discontinuous loading.
   iii) the relative merits of each type of converter
   iv) the effects of source reactance upon the converter performance, and be able to explain commutation overlap and its effects
   v) the effects of resistive and inductive loads upon the converter performance
   vi) the effects of increasing the pulse number

2. To recall and explain with the aid of sketches and waveforms the following types of one-quadrant phase-controlled converters.
   a) single-phase, two-pulse half-controlled bridge converter
   b) three-phase, three-pulse half-controlled bridge converter
   c) three-phase, three-pulse midpoint converter with a freewheel diode

3. To be able to recall the application of a dual converter in four-quadrant operation and explain with the aid of sketches operation in the circulating current and circulating current free modes of operation.

BLOCK 3 - STATIC FREQUENCY CONVERSION

1. To recall that the advantages of a variable frequency AC drive system are:
   a) most SCIMs may be operated up to 200 Hz
   b) speed control ranges of 20:1 are obtainable
   c) the SCIM has a high dynamic response
   d) a wide range of standard motors are available
   e) open-loop speed control may be used
   f) synchronized multi-motor easily obtained
   g) four-quadrant operation easily obtained

2. To recall that an induction motor slip is proportional to frequency and that to obtain a constant torque output, a constant V/Hz ratio must be maintained to prevent overheating and core saturation, and be able to explain the operation under variable frequency conditions in terms of torque-slip and torque-speed curves.

3. To recall the advantages of static frequency conversion versus a variable frequency motor alternator drive.

4. To recall and be able to explain the principle of operation of a single-phase inverter and the production of an alternating emf with the aid of waveforms, and the function of the feedback diodes and commutation requirements.

5. To be able to explain with sketches and waveforms the control of the inverter output voltage by means of
   a) input DC voltage control
   b) voltage control within the inverter by
      i) pulse width control
      ii) pulse width modulation

   and the advantages and disadvantages of each method.

6. To be able to explain the principles of forced commutation using McMurray and McMurray-Bedford impulse commutation techniques.

7. To be able to recall and explain with the aid of schematics and waveforms the operation of a six-step, three-phase inverter, and discuss the advantages, disadvantages and gating requirements for three and two thyristors in conduction at the same time.

8. To be able to explain with the aid of schematics and waveforms the technique of harmonic neutralization.

9. To recall that a cycloconverter is an ac-ac frequency changer and is most effective when operated in the frequency range of 0 to 1/3 of source frequency, and that the major advantages of a cycloconverter are an improved efficiency by the elemination of the dc link converter, voltage control is achieved within the converter, and it is line commutated.

10. To be able to explain with the aid of a schematic and waveforms the principle of operation of a single-phase phase controlled converter and the methods of frequency and voltage control.

11. To be able to recall the basic circuit configurations of a three-pulse, six-pulse cycloconverter.

BLOCK 4 - DC-DC CONTROL (CHOPPERS)

1. To recall the basic principles of a chopper and the three basic control techniques, namely, pulse width modulation, pulse rate modulation, and combined pulse width and rate modulation.

2. To recall the four requirements for successful forced commutation.

3. To be able to explain with the aid of sketches and waveforms the operation of the following types of choppers (1) basic step-down chopper, (2) the basic step-up chopper, (3) multi-phase choppers, (4) bidirectional choppers, and (5) four-quadrant choppers.

4. To recall the two classes of commutation, namely, load and forced (voltage and current).

5. To recall the criteria by which a chopper circuit is assessed.

6. To be able to explain with the aid of sketches and waveforms the following methods of voltage commutation including their features; (1) parallel capacitor; (2) parallel capacitor-inductor; (3) the Morgan circuit; (4) the improved Morgan circuit; and; (5) the Jones circuit.

7. To be able to explain with the aid of sketches and waveforms a current commutated chopper.

8. To be able to explain with the aid of sketches and waveforms the operation of a load commutated chopper.

BLOCK 5 - FIRING CIRCUITS

1. To recall the causes and methods of reducing electrical noise.

2. To recall the criteria which should be net by firing circuits.

3. To recall that the shape, amplitude and duration of a firing pulse is determined by the gating requirements of the thyristor and the connected load.

4. To recall the need for double pulsing and long pulses, pulse isolation, pulse transformers, optocouplers and their application to firing circuits.

5. To recall and explain the major components of the block diagram of a firing circuit.

6. To be able to explain with the aid of sketches and waveforms the following pulse train generators made from (1) inverters; (2) Schmitt triggers; (3) monostable multivibrators; (4) monolithic IC timers; and pulse burst generators made from (1) monostable multivibrators; (2) Schmitt triggers and gates; and (3) monolithic IC timers.

7. To be able to explain with the aid of sketches and waveforms the following methods of pulse distribution: (1) from free running pulse generators (2) pulse train distribution, and (3) pulse burst distribution.

8. To be able to explain with the aid of sketches and waveforms: (10 the basic BJT pulse amplifier; (2) pulse amplifiers for firing thyristors (3) pulse amplifier loading (4) the equivalent circuit; and (5) losses in pulse amplifiers.

BLOCK 6 - DC MOTOR CONTROL APPLICATIONS

1. To recall that the performance and operation of DC motors is determined by the following relationships:

$$V_a = E_c + I_a R_a \qquad S = E_c/K\emptyset \simeq V_a/K\emptyset$$

$$V_a \simeq E_c = K\emptyset S \qquad T = K\emptyset I_a$$

2. To recall that a separately excited DC motor with variable armature voltage control and constant field excitation operates in the constant torque mode up to base speed, an with constant armature voltage and reduced field excitation the motor operates in the constant kW mode above base speed

3. To recall and be able to explain with the aid of a block diagram the principle of a closed-loop constant torque thyristor phase controlled converter fed DC drive system with particular emphasis on the functions of the ramp, current limit, speed sensing and thyristor firing circuits.

4. To be able to explain with the aid of schematics the complete operation of typical single-phase and three-phase thyristor phase controlled converters, eg: the SILPAC, Allen-Bradley and Brown-Boveri drives.

5. To be able to explain with the aid of schematics the complete operation of the SECO phase-locked loop DC drive.

6. To be able to explain with the aid of schematics the principles of operation of the following chopper drives:
   1. Jones reversible chopper drive
   2. A bidirectional drive
   3. A four-quadrant drive

7. To be able to explain with the aid of a block diagram the operation of a dual converter operating in all quadrants, and be able to explain the firing control logic which permits circulating current free operation.

8. To be able to recall and explain the operation of DC brushless motor driven systems, such as Hall effect and photoelectronic motors.

9. To be able to recall and explain with the aid of schematics half and full wave universal motor electronic control without and with feedback.

BLOCK 7 - AC MOTOR CONTROL APPLICATIONS

1. To be able to recall and explain the basic principles and requirements of variable frequency speed control of three-phase AC motors.

2. To be able to recall and explain with the aid of schematics and waveforms inverter output voltage control using pulse width modulation.

3. To be able to recall and explain with the aid of schematics and waveforms the operation of typical industrial single and three-phase supplied variable frequency inverters.

4. To be able to explain with the aid of a block diagram the principle of wound rotor induction motor slip power recovery speed control.

5. To be able to explain with the aid of a block diagram the principle of operation and control of an eddy current clutch drive variable speed control applied to a squirrel-cage induction motor.

6. To be able to explain with the aid of a schematic reduced voltage methods of controlling the speed of polyphase induction motors.

7. To be able to explain with the aid of sketches the application of variable frequency inverters in starting and controlling the speed of synchronous motors.

BLOCK 8 - MISCELLANEOUS APPLICATIONS

1. To be able to explain with the aid of schematics static excitation systems used in rotor energization and voltage control of large alternators.

2. To be able to explain with the aid of schematics the operating principles of high voltage DC transmission systems.

3. To be able to explain with the aid of block diagrams the principles of change-over and continuous float uninterruptable power supplies.

4. To be able to explain with the aid of schematics the principles of resistance furnace, arc furnace control (DC and AC) and induction furnace control using thyristors.

5. To be able to recall and explain the principles of the following electrochemical applications of power electronics (1) battery charging (2) electrolytic plating and tinning (3) electrophoretic painting, and (5) metal production and refining.

6. To be able to explain with the aid of schematics static VAR compensation.

BLOCK 9 - PROTECTION AND COOLING

1. To be able to explain with the aid of schematics and waveforms the causes of overvoltages and methods of protecting thyristor circuits against the effects of overvoltage.

2. To be able to explain the causes and protection methods against overcurrent in thyristor circuits.

3. To be able to explain the requirement for thyristor cooling and discuss air, liquid and heat pipe methods of cooling.

4 To be able with the use of data sheets carry out heat sink calculations for stud mounted and disc type solid-state devices.