POWER ELECTRONICS

ENEE 302

Year/Part: III/I(3-1-1.5)

Teaching Schedule				Examination Scheme						Total
				Theory			Practical			
L	T	P	Total	Assessment Marks	Final Duration (Hrs)	Final Marks	Assessment Marks	Final Duration (Hrs)	Final Marks	
3	1	1.5	5.5	40	3	60	25	0	0	125

Depth Codes

E-Explanation	C-Circuit	D-Definition	DM-Demonstration
DV-Derivation	DW-Drawing	P-Proof	I-Illustration
NUM-Numerical	PRG-Programming	S-State	ACT-Activity-based Learning
MP- Mini Project	EXP-Experiment	REV-Review / Recap	PS- Problem Solving
QA- Question Answer	Q- Quiz	ST- Surprise Test	MT-Mid Term Test

Unit	Topic/Subtopic	Depth Code	Description of Depth	Actual Plan L	Actual Plan T	Actual Plan P	Week
1	**1. Introduction**			**2**	**0**		**1**
	1.1. Concept of Power Electronics	D, E, DW	• Define and explain the basic concept of power electronic subject with some schematic diagrams.	0.5			
	1.2 Applications of Power Electronics	E, DW	• Briefly Explain the application power electronic circuits in power system, drives with closed loop control with schematic conceptual diagram. No mathematical derivation	0.5			
	1.3 Advantages and disadvantages of power electronics converters	E, DW	* Briefly describe Advantages - easy and flexible control of power system, drives, renewable energy technology. * Briefly describe Disadvantages - harmonics due to. waveform chopping, needs harmonic filters or compensator	0.5			
	1.4 Introduction to Power Electronic System.	E, DW	* Briefly describe the function of power electronic circuits- Rectifier, Inverter, DC chopper, AC voltage controller, Cycloconverter	0.5			
2	**2. Power Electronics Devices**			**6**	**2**		**1,2,3**
	2.1 Power Diode: 2.1.1Construction and Operating characteristics 2.1.2 Schockley Diode Equation 2.1.3 Turn On transient and Turn off transient	E,DW,DV C, P	* Explanation of constructional detail as P-N junction device, reversed biased mode, forward biased mode, V-I chac curve, Schockley Diode Equation and its physical interpretation, Reverse break down region. * Turn-ON transient: explanation with turn ON chac curve, turn On time. * Turn Off transient: explanation with reverse recovery chac curve, reverse recovery time, soft recovery and abrupt recovery, softness factor, reverse recovery charge (Q_{RR}) Peak reverse current (I_{RR}) and it's mathematical equation derivation.	1	0.5		

Unit	Topic/Subtopic	Depth Code	Description of Depth	Actual Plan L	Actual Plan T	Week
	2.2 Thyristor 2.2.1 Construction and Operating characteristics 2.2.2 Turn On characteristics 2.2.3 Thyristor Turn Off Process - Natural commutation and forced commutation 2.2.4 di/dt and dv/dt protections 2.2.5 Thyristor Firing Circuits - with isolation transformer, pulse train generator, opto-coupler 2.2.6 Advantages, disadvantages and applications of Thyristors	E,DW, C, P	• Constructional detail of Thyristor as PNPN junctions device. • Reverse connection mode: explanation with V-I chac curve, reverse leakage current, reverse break over voltage. • Forward connection mode: explantion with V-I Chac curve, forward leakage current, VI-curve with gate signal, latching current, holding current. • Turn-ON characteristics: explanation with turn ON chac curve, delay time, rise time, turn ON time. • safe turning with gate signal • Thyristor turn Off processor: explanation with turn Off Chac curve, Natural commutation, forced commutation. • di/dt protection: it's requirement, explanation of di/dt protection circuit • dv/dt protection: it's requirement, explanation of dv/dt protection with snubber circuit. • Thyritor firing circuit: requirement of isolation circuit between gate signal control circuit and main power circuit. • Isolation circuit with pulse transformer: explanation with circuit diagram. • Isolation circuit with pulse train generator: explanation with circuit diagram. • Isolation circuit with opto-coupler: explanation with circuit diagram. • Explanation of advantages, disadvantages and applications of Thyristors	2		
	2.3 TRIAC 2.3.1 Construction and Operating characteristics 2.3.2 Advantages, disadvantages and applications of Thyristors	E, C	• Explanation of TRIAC construction with PNPN structure • Explanation of operation with V-I characteristic curve. • Explanation of advantages, disadvantages and applications of TRIAC.	0.5		
	2.4 Gate Turn Off Thyristor (GTO) 2.4.1 Construction and Operating characteristics 2.4.2 Advantages, disadvantages and applications of GTO	E, C	• Explanation of GTO construction with PNPN structure • Explanation of operation with V-I characteristic curve. • Explanation advantages, disadvantages and applications of GTO	0.5		
	2.5 Bi-polar Junction Transistor (BJT): 2.5.1 Construction, Operating characteristics and operation as a switch 2.5.2 Base drive circuits 2.5.4 Advantages, disadvantages and applications of BJT	E,C	• Explanation of NPN transistor in common emitter configuration with output chac curve and use it as switch by operating in saturation region. • Requirements of base drive circuit • Base drive circuit with pulse transformer as isolation circuit. • Base drive circuit with Opto-Coupler as isolation circuit. • Explanation of advantages, disadvantages	1		

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			and applications of BJT.			
	2.6 Metal-Oxide Semi-conductor Field Effect Transistor (MOSFET) 2.6.1 Construction, Operating characteristics and operation as a switch 2.6.2 Advantages, disadvantages and applications of BJT	E, C	• Constructional detail of MOSFET with PNP structure. • Explanation with output chac curve to use as switch. • Explanation of advantages, disadvantages and applications of MOSFET • Comparison between BJT and MOSFET .	0.5		
	2.7 Insulated Gate Bipolar Transistor (IGBT) 2.7.1 Construction, Operating characteristics and operation as a switch 2.7.2 Advantages, disadvantages and applications of IGBT	E, C	• Explanation of construction with PNP structure • Explanation of operation as switch. • Explanation of advantages, disadvantages and applications of IGBT.	0.5		
3	**AC to DC Single Phase Converters**			**10**	**3**	**3,4,5**
	3.1 Single phase half wave un-controlled rectifier with resistive load: Operating theory and waveforms, Average and RMS values of output voltage, Efficiency, Ripple factor, Fourier analysis of output voltage.	D, E, C, DW, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple voltage, ripple factor, efficiency, transformer utilization factor(TUF), input side power factor. • Fourier Analysis of Output voltage waveform.	1		
	3.2 Single phase half wave un-controlled rectifier with inductive load: Operating theory and waveforms, Average and RMS values of output voltage, Load current equation.	D, E, C, DW,DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage. • Derivation of load current equation by solving differential.	1		
	3.3 Single phase half wave rectifier with capacitor filter : Operating theory and waveforms, Ripple factor	E, C, DW,DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Ripple factor.	1		
	3.4 Single phase full wave un-controlled rectifier with center tap transformer: Operating theory and waveforms, Average and RMS values of output voltage, Efficiency, Ripple factor, Fourier analysis of output voltage.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple voltage, ripple factor, efficiency, input side power factor. Fourier Analysis of Output voltage waveform.	1		
	3.5 Single phase full wave bridge rectifier with resistive load: Operating theory and waveforms, Average and RMS values of output voltage.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple voltage, ripple factor.	1		

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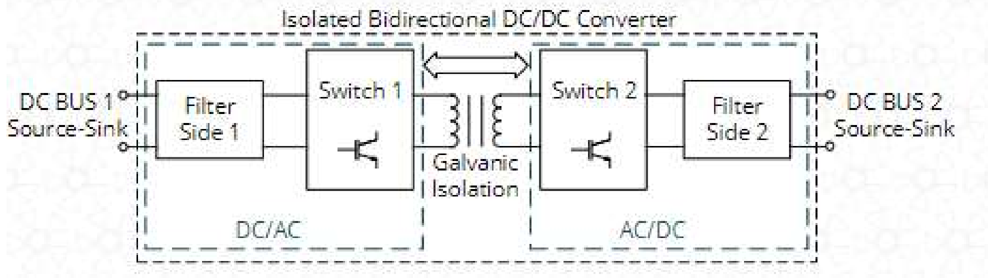
	3.6 Single phase full wave bridge rectifier with inductive load: Operating theory and waveforms, Average and RMS values of output voltage, Ripple Factor, Input current Harmonics.	E,C, DV	• Explanation of operating principle with circuit diagram and associated waveforms for R-L load • Derivation of equations for Average and RMS value of output voltage. • Explanation of operating principle with circuit diagram and associated waveforms for Highly inductive load • Derivation of equations for Average and RMS value of output voltage, Ripple factor, efficiency. • Fourier analysis of input AC current	1		
	3.7 Single phase half wave controlled rectifier with resistive load: Operating theory and waveforms, Average and RMS values of output voltage, Ripple factor, Fourier analysis of output voltage.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple factor, input power factor. • Fourier analysis of output voltage.	0.5		
	3.8 Single phase full wave controlled rectifier with resistive load: Operating theory and waveforms, Average and RMS values of output voltage Ripple factor, Fourier analysis of output voltage.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple factor, input power factor. • Fourier analysis of output voltage.	0.5		
	3.9 Single phase full converter with highly inductive load: Operating theory and waveforms, Average and RMS values of output voltage Ripple factor, Input current harmonics, Fourier analysis of output voltage and input AC current, input displacement factor, distortion factor, Input harmonic factor, Total Harmonics Distortion (THD), input power factor.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple factor. • Fourier analysis of output voltage and input AC current. • Define- input displacement factor, distortion factor, input harmonic factor, THD, input power factor	1		
	3.10 Input power factor improvement: Extinction angle control, Symmetrical angle control, multiple pulse width control	E, C, DV	• Extinction angle control- explanation of operating principle with circuit diagram and associated waveforms, derivation of formula for average value, RMS value, Ripple factor, drawback of the method. • Symmetrical angle control- explanation of operating principle with circuit diagram and associated waveforms, gate signal generating logic, derivation of formula for average value, RMS value, Ripple factor, Fourier analysis of output voltage and ac input current. • Multiple pulse width control - explanation of operating principle with circuit diagram and	2		

Unit	Topic/Subtopic	Depth Code	Description of Depth	Actual Plan L	Actual Plan T	Week
			associated waveforms, gate signal generating logic, calculation of switching instant, Average and RMS values.			
4	**4. Three phase AC to DC Converters**			**6**	**2**	**6,7**
	4.1 Three phase single way un-controlled rectifier with resistive load: Operating theory and waveforms, Average and RMS values of output voltage, Ripple factor, Fourier analysis of output voltage.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple voltage, ripple factor. Input power factor • Fourier Analysis of Output voltage waveform.	1		
	4.2 Three phase un-controlled bridge rectifier with resistive load: Operating theory and waveforms, Average and RMS values of output voltage, Ripple factor, Fourier analysis of output voltage.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple voltage, ripple factor. Input power factor • Fourier analysis of output voltage	1		
	4.3 Three phase single way controlled rectifier with resistive load and highly inductive load: Operating theory and waveforms, Average and RMS values of output voltage, Ripple factor, Fourier analysis of output voltage.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple voltage, ripple factor. • Fourier analysis of output voltage	1		
	4.4 Three phase controlled bridge rectifier with resistive load: Operating theory and waveforms, Average and RMS values of output voltage, Ripple factor.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average and RMS value of output voltage, ripple voltage, ripple factor.	1		
	4.5 Three phase full converter with highly inductive load: Operating theory and waveforms, Average and RMS values of output	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average value of output voltage, operation in rectification mode and inversion mode	1		
	4.6 Twelve pulses of operation of three-phase full converter	E, C	• Explanation of operating principle with circuit diagram of series connection of two 3-phase full converter with highly inductive load and associated waveforms. • Derivation of equations for Average value of output voltage.	0.5		
	4.7 Series connection of full converter.	E, C, DV	• Explanation of operating principle with circuit diagram of single phase full converter and associated waveforms. • Explanation of operation in rectification mode and inversion mode.	0.5		

Unit	Topic/Subtopic	Depth Code	Description of Depth	Actual Plan L	Actual Plan T	Week
5	**5. DC Chopper**			**6**	**2**	**8,9**
	5.1 Step down DC chopper with resistive load: Operating theory and waveforms, Average and RMS values of output voltage, Output power, Effective input resistance, Constant frequency mode of operation, variable frequency mode of operation.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Gate pulse generation logic • Derivation of equations for Average and RMS value of output voltage, ripple factor, output power, effective input resistance. • Illustration of constant frequency mode and variable frequency mode.	1		
	5.2 Step down DC chopper with DC motor load: Operating theory and waveforms, load current equation, Average load current.	E, C, DV	• Explanation of operating principle with circuit diagram with R-L load and associated waveforms. • Mathematical analysis of ON period and OFF period. • Derivation of equations for Average value of load current. • Explanation of operating principle with circuit diagram with DC motor load and associated waveforms. • Mathematical analysis of ON period and OFF period. • Derivation of equations for Average value of load current.	1		
	5.3 Step up chopper with resistive load.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average value of output voltage.	1		
	5.4 Buck-Boost converter	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average value of output voltage	1		
	5.5 Bi-directional dc to dc converter: operating principle, step-up and step-down operation, application in electric vehicle	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for Average value of output voltage and power. • Application in electric vehicle with illustration of bi-directional power flow.	1		
	5.6 Chopper classification: type-A, Type-B,Type-C,Type-D,Type-E	E, C	• Explanation of 4-quadrant operation of a DC motor • Explanation of Operating principle of Type-A,B,C,D,E with circuit diagram.	1		

Note: 5.5 Bi-directional dc to dc converter shall be covered with only following circuit topology of isolated bi-directional dc-dc converter:



Unit	Topic/Subtopic	Depth Code	Description of Depth	Actual Plan L	Actual Plan T	Week
6	**Inverter**			**10**	**4**	**10-12**
	6.1Single phase inverter with square wave AC output and resistive load: Operating theory and waveforms, RMS value of Output voltage. Fourier analysis of output voltage	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for RMS value of output voltage. • Fourier analysis of output voltage waveform.	2		
	6.2 Single phase inverter with square wave AC output with R-L load and AC motor load:	E, C, DV	• Explanation of operating principle with circuit diagram with R-L load and associated waveforms. • Mathematical derivation of equation of load current for positive and negative half cycles. • Fourier series of load current. • Explanation of operating principle with circuit diagram with AC motor load and associated waveforms. • Mathematical derivation of equation of load current for positive and negative half cycles.	2		
	6.3 Three-phase Inverter 6.3.1Three-phase inverter with 180^0conduction mode with six-steps square wave output and resistive load 6.3.2Three-phase inverter with 120^0conduction mode with six-steps square wave output and resistive load 6.3.3 Fourier Analysis of 3-phase Inverter output voltage, Positive, Negative and Zero sequence series.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms of Line voltage, neutral voltage and per phase voltage for 180deg conduction mode. • Explanation of operating principle with circuit diagram and associated waveform of per phase voltage for 120deg conduction mode • Fourier analysis of 3-phase inverter's output voltage and representing the Fourier series as sum of positive, negative and zero sequence phasors.	3		
	6.4 Pulse Width Modulated (PWM) inverter 6.4.1 Single pulse width modulation 6.4.2 Multiple pulse width modulation 6.4.3 Sinusoidal pulse width modulation	E, C, DV	• Explanation of necessity of PWM for output voltage control. • Explanation of single pulse width modulation method with circuit diagram and control circuit for gate pulse generation, calculation of RMS value of output voltage. • Explanation of multiple pulse width modulation method with circuit diagram and control circuit for gate pulse generation, calculation of RMS value of output voltage.	2		

			• Explanation of sinusoidal pulse width modulation method with circuit diagram and control circuit for gate pulse generation, calculation of switching instants using N/R method, Fourier analysis of output voltage, calculation of RMS value of output voltage.			
	6.5 Current source inverter	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equation for output voltage.	1		

Unit	Topic/Subtopic	Depth Code	Description of Depth	Actual Plan		Week
				L	T	
7	**AC voltage Controller**			**5**	**2**	**13-14**
	7.1 Single phase AC voltage controller with resistive load: Operating theory and waveforms, RMS values of output voltage, Output power, Fourier analysis of output voltage waveform.	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Derivation of equations for RMS value of output voltage. • Fourier analysis of output voltage waveform.	1		
	7.2 Single phase AC voltage controller with R-L inductive load: Operating theory and waveforms, Load current equation RMS values of output voltage and load current.	E, C, DV	• Explanation of operating principle with circuit diagram with R-L load and associated waveforms. • Mathematical derivation of equation of load current. • Equation for RMS value of output voltage.	1		
	7.3 Single phase AC voltage controller with induction motor load: Operating theory and waveforms, Load current equation RMS values of output voltage and load current.	E, C, DV	• Explanation of operating principle with circuit diagram with induction motor load and associated waveforms. • Mathematical derivation of equation of load current. Equation for RMS value of output voltage.	1		
	7.4 Three phase AC voltage controller with resistive load: Operating theory and waveforms, RMS values	E, C, DV	• Explanation of operating principle with circuit diagram and associated waveforms. • Equation for RMS value of output voltage.	1		
	7.5 Cyclo-converter: 7.5.1 Single phase step-down cyclo-converter 7.5.2 Three phase to single phase step-down cyclo-converter 7.5.3 Three phase to three phase step-down cyclo-converter	E, C, DV	• Explanation of operating principle of single phase step-down cyclo-converter with circuit diagram and associated waveforms, Fourier series of output voltage. • Explanation of operating principle of three phase to single phase step-down cyclo-converter with circuit diagram and associated waveforms. • Explanation of operating principle of three phase to three phase step-down cyclo-converter with circuit diagram and associated waveforms.	1		

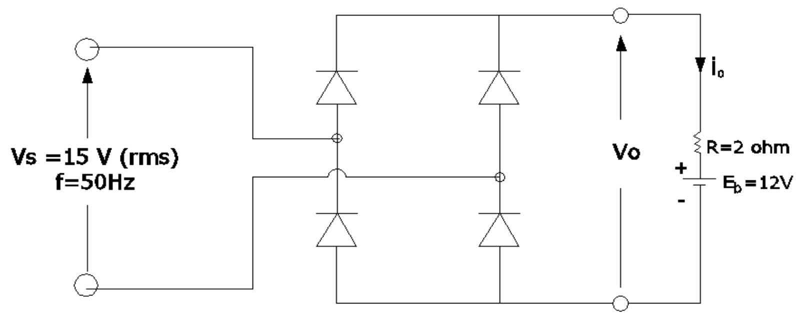
POWER ELECTRONICS

ENEE 302

Attempt All questions

QN1 a) Explain how a transistor can be used as a static switch. Describe a base current signal generating circuit using an opto-coupler. [6]

b) The figure below shows a full-wave rectifier circuit used to charge a 12V battery through a 2 ohm resistor. [6]



I) Draw the waveform of output voltage V_0 and Charging current i_0

II) Calculate the average and rms value of charging current.

III) Power supplied to the battery

IV) Power output from the rectifier

V) Efficiency of the charging system

QN2 a) Explain the operation of a single phase full converter circuit with highly inductive load with neat circuit diagram and associated waveforms. If the load current is constant and equal to 20Amp, draw the waveform input ac current i_S for firing angle of 30^0 and calculate the fundamental component of i_S. [6]

b) Explain the operation of step up dc chopper and derive the equation for output voltage. [6]

QN3 a) Explain the operation of a three phase single way controlled rectifier circuit with highly inductive load. Derive the expression for Average value of the output voltage. Also draw the waveform of output voltage for firing angle of 90^0. [6]

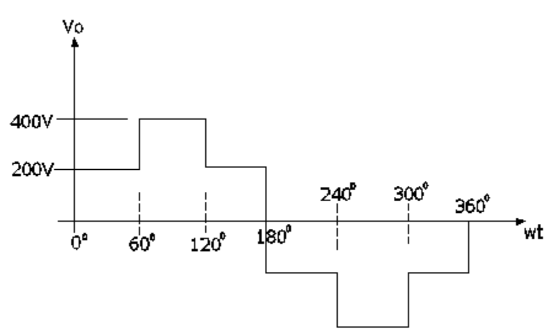
b) Describe the series operation of two single phase full converter to obtain high output voltage. [6]

QN4 *a)* Explain the operation of single phase ac voltage controller with resistive load. If the input voltage is 220V, 50 Hz, calculate the RMS value of output voltage for firing angle of 90^0. [6]

b) Explain the operation of single phase cyclo-Converter with circuit diagram and necessary waveforms. [6]

QN5 a) Explain the operation of a three phase Sinusoidal PWM inverter with neat circuit diagram and associated waveforms. How switching instants for inverter switch pair of a phase are determined. [6]

b) Figure below shows the waveform of output voltage (per phase) of three phase inverter. Calculate RMS value and peak value of fundamental component of the output voltage. [6]



(***Note:*** *Number of questions and distribution of marks are indicative only.*)