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GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

Faculty of Engineering

Department of Electrical, Electronic and Telecommunication Engineering

B.Sc. Engineering Degree

Semester 6 Examination – September 2022

(Intake 37 - EE/ET/MC)

EE 3213 – POWER ELECTRONICS AND APPLICATIONS I

Time allowed: 3 Hours 23 September 2022

INSTRUCTIONS TO CANDIDATES:

This paper contains 7 questions on 6 pages.
Answer any FIVE Questions only.
This is a closed book examination.

This examination accounts for 70% of the module assessment. The total maximum mark attainable is 100. The marks assigned for each question & sections thereof are indicated in square brackets.

If you have any doubt as to the interpretation of the wording of a question, make your own decision, but clearly state it on the script.

All Examinations are conducted under the rules & regulations of the University

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Question 1

a) A single-phase full-bridge diode converter is operating on 50 Hz, 230 V single phase AC supply. The converter output feeds a 80 Ω resistive load. Assume diodes and the AC supply to be ideal.
Determine,

(i) Mean value of load voltage. [02]
(ii) Peak to peak ripple in output voltage. [02]
(iii) Peak current through a diode. [02]

b) Converter in (a) above is then modified by connecting a 1000 μF capacitor in parallel with the converter output. Determine the new values of,

(i) Mean load voltage. [04]
(ii) Peak to peak ripple in output voltage. [04]
(iii) Peak current through a diode. [04]

Comment on the results in (a) and (b). [02]

Question 2

a) Three-phase, full-bridge AC to DC diode-converter is operating on 400 V, 50 Hz three-phase AC supply. The converter delivers 25 A constant current to an inductive load. You may ignore the internal impedance of the AC supply. Assume ideal diodes.
Determine,

(i) Mean value of the output DC voltage. [02]
(ii) Peak to peak ripple in output voltage. [02]
(ii) RMS value of the fundamental component of AC side line-current. [02]
(iii) RMS value and frequency of the lowest order harmonic in AC side line current. [04]

b) Three-phase, dual-series-bridge AC to DC diode-converter is powered by 400V, 50 Hz, three-phase AC supply via a *Dd0y1* three-phase transformer of line-voltage ratio 2:1:1, so that the input voltages to the two bridges have a 30° phase shift. The converter system delivers 25 A constant current to an inductive load. You may ignore the internal impedance of the AC supply and the transformer. Assume ideal diodes.
Determine,

(i) Mean value of the output DC voltage. [02]
(ii) Peak to peak ripple in output voltage. [02]
(ii) RMS value of the fundamental component of AC side line-current. [02]
(iii) RMS value and frequency of the lowest order harmonic in AC side line current. [04]

Question 3

a) A three phase, full-bridge AC to DC thyristor-converter is operating on 400 V, 50 Hz, three phase AC supply. The converter delivers 6 kW of power to an inductive load at 420 V DC (mean). Supply side inductance is 2 mH per phase. You may assume that the output current is constant and ripple free.
Calculate,

(i) Delay (firing) angle for thyristors. [04]
(ii) Conduction overlap angle. [04]
(iii) RMS value of the fundamental component of input line current. [04]

b) For the converter in (a) above, sketch the following waveforms indicating appropriate values.

(i) Output voltage. [03]
(ii) Line-line voltage at the converter input (PCC) showing deep and shallow notches. [03]

Describe briefly how the depths of voltage notches at the PCC in (ii) above are modified in practice to comply with utility standards. [02]

Question 4

a) Single-phase voltage source inverter is operated with sinusoidal unipolar-PWM control, with carrier-ratio 48, depth of modulation 0.8 and reference frequency 50 Hz. Input DC voltage to the inverter is 420 V. Determine,

(i) RMS value of the fundamental component of output voltage. [03]
(ii) Lowest order of significant harmonics in the output voltage [02]
(iii) Switching frequency of inverter. [02]

Why do we often prefer unipolar PWM over bipolar PWM in practice? [03]

b) Three-phase, voltage source inverter is operated with Regular sampled PWM control, with carrier-ratio 49, depth of modulation 0.8 and reference frequency 50 Hz. Sinusoidal reference signal is sampled at successive positive peaks of the triangular carrier. Positive-going zero-crossing of the reference signal is taken at a quarter sampling interval after the 0th sampling instant. Calculate the timing of switching signals S_a, S_b & S_c over the 18th sampling-period. [10]

Question 5

a) Three-phase voltage source inverter is operated with square-wave (six-step) control. Take DC input-voltage as V_d. Give the following waveforms corresponding to balanced three-phase operation.

(i) Switching signals S_a, S_b & S_c for the legs *A*, *B* & *C* of the inverter. [04]
(ii) Phase voltage output. [04]

b) The output of the inverter in (a) above is connected to a balanced, three-phase, star-connected load with each phase having 20 Ω resistance in series with 40 mH inductance. Input DC voltage is 420 V and switching cycle time is 24 ms.

(i) Calculate and sketch the waveform of load current in phase-*a*. [08]
(ii) Sketch the waveform of input current at the DC supply, giving values. [04]

Question 6

a) A single-phase VSI with input DC voltage V_d is delivering an output current $I_m \sin(\omega t)$ to an inductive load using hysteresis current control with hysteresis band ΔH.

(i) Give the waveform of output current, indicating running ripple and the tolerance band. [05]
(ii) Why the carrier-assisted current control is considered better over the hysteresis current control in practice? [03]

b) Three-phase voltage source inverter is operated with Square Wave PWM with carrier ratio 9 and depth of modulation 0.7. Input DC voltage is 600 V. Synchronization between square-wave reference signals and triangular carrier signal is done in such a way that the positive-going rising-edge of the square-wave coincides the negative-going zero-crossing of the carrier.

(i) Construct the line-line voltage waveform at the output. [05]
(ii) Determine the magnitude and angular-width in degrees for ON and OFF states of voltage pulses in the waveform in (i) above. [04]
(iii) Determine the RMS value of the fundamental component of the line-line voltage. [03]

Question 7

a) Define the term Voltage Utilization for a PWM voltage source inverter. [02]
Determine the value of Voltage Utilization for a three-phase sinusoidal PWM inverter. [04]

b) How the Voltage utilization is improved when a third-harmonic signal component is added to sinusoidal three-phase reference signals in a sinusoidal three-phase inverter? [03]
Why this third-harmonic is not re-appeared at the output voltage? [03]

c) Give a circuit that can be used to modify sinusoidal three-phase reference signals appropriately, in order to increase Voltage utilization without over-modulation for a sinusoidal three-phase inverter. [04]

d) Explain briefly why it is necessary to increase the carrier-ratio when delivering low-frequency output voltage by a PWM voltage source inverter operated with constant V to f control. [04]

End of Question Paper