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Power Electronics Interview Questions

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Power semiconductor switches and their gating

1. How does a thyristor turn on, and what keeps it on and what turns it off?

A thyristor turns on when a short gate current pulse triggers regenerative action while the device is forward biased. It then stays on without the gate once the anode current is above the latching current. It turns off only when the anode current falls below the holding current and the device stays reverse biased for its turn-off time.

2. What is the difference between a power MOSFET and an IGBT as a switch?

A power MOSFET is a majority-carrier device: it switches very fast and has low conduction loss at low voltage, but its on-resistance rises steeply with voltage rating. An IGBT injects minority carriers, so it has a lower on-state drop at high voltage and current, but its turn-off current tail makes it slower. Both are voltage controlled at the gate.

3. Why can a thyristor turn off by itself on an AC supply but needs a commutation circuit on a DC supply?

The gate cannot turn a thyristor off. The anode current must fall below the holding current, with reverse voltage applied for the turn-off time. On an AC supply the current passes through zero every cycle, so line commutation does this. A DC supply has no natural zero crossing, so a forced commutation circuit must create one.

4. Why is an RC snubber connected across a thyristor?

The snubber limits the rate of rise of anode voltage, dv/dt. A fast-rising voltage drives a charging current through the junction capacitance, which can act like gate current and turn the thyristor on without a gate pulse. The RC network slows the voltage rise. A small series inductor is used in the same way to limit di/dt.

5. A power device dissipates 50 W. The thermal resistances are 0.5 °C/W from junction to case, 0.2 °C/W from case to heat sink and 1.0 °C/W from heat sink to ambient. The ambient temperature is 40 °C. Find the junction temperature in steady state.

The junction temperature is 125 °C.

> **WORKING**
>
> 1. Total thermal resistance: $R_{th} = 0.5 + 0.2 + 1.0 = 1.7$ °C/W
> 2. Temperature rise: $\Delta T = P R_{th} = 50 \times 1.7 = 85$ °C
> 3. Junction temperature: $T_j = T_a + \Delta T = 40 + 85 = 125$ °C

DC-DC converters

6. What is the output voltage of an ideal buck converter in continuous conduction, and where does the result come from?

In continuous conduction an ideal buck converter gives $V_o = D V_s$, where D is the duty ratio, so the output never exceeds the input. It follows from volt-second balance: in steady state the average inductor voltage over a cycle is zero, so $(V_s - V_o) D T = V_o (1 - D) T$.

7. How does a buck-boost converter differ from a buck converter in output voltage and polarity?

An ideal buck-boost converter in continuous conduction gives $V_o = -DV_s/(1-D)$. The output is inverted, and it can be above or below the input depending on D. A buck converter keeps the polarity and can only step down. In both, the switch is in series with the source, so the input current is pulsed.

8. Why does the voltage gain of a real boost converter stop rising as the duty ratio approaches 1, although the ideal gain keeps rising?

The ideal gain $1/(1-D)$ grows without limit because the inductor has almost no time left to discharge into the load. In a real converter, the resistance of the inductor, switch and diode wastes more of the stored energy as the inductor current grows. The gain therefore reaches a peak and then falls.

9. An ideal buck converter runs from 24 V and gives 12 V at its output. The inductor is 100 µH and the switching frequency is 50 kHz. Conduction is continuous. Find the peak-to-peak inductor current ripple.

The peak-to-peak inductor current ripple is 1.2 A.

WORKING

1. Duty ratio: $D = V_o/V_s = 12/24 = 0.5$
2. During the off time the inductor sees $-V_o$ for $(1-D)T$
3. $\Delta I = \dfrac{V_o(1-D)}{Lf}$
4. $\Delta I = \dfrac{12 \times 0.5}{100 \times 10^{-6} \times 50 \times 10^{3}} = \dfrac{6}{5} = 1.2$ A

10. An ideal boost converter in continuous conduction has a 5 V source, a duty ratio of 0.6 and a 10 ohm load resistor. Find the average input current.

The average input current is 3.125 A.

WORKING

1. Output voltage: $V_o = V_s/(1-D) = 5/0.4 = 12.5$ V
2. Load current: $I_o = V_o/R = 12.5/10 = 1.25$ A
3. Lossless converter, so $V_s I_s = V_o I_o$
4. $I_s = 12.5 \times 1.25/5 = 3.125$ A

Uncontrolled and controlled rectifiers, AC-DC converters

11. What happens to a fully controlled bridge rectifier when the firing angle goes beyond 90 degrees?

With continuous conduction the average output voltage is $(2V_m/\pi)\cos\alpha$, so it becomes negative for $\alpha > 90^\circ$ and the converter works as an inverter. Power then flows from the DC side to the AC supply. This needs a load source, such as a DC machine in regeneration, that keeps the current flowing in the same direction.

12. What is the difference between a fully controlled and a half-controlled single-phase bridge?

A fully controlled bridge uses four thyristors, and its output voltage can be negative, so it works in two quadrants: rectifying and inverting. A half-controlled bridge replaces two thyristors with diodes. The diodes

provide a freewheeling path, so the output voltage never goes negative and it works only as a rectifier.

13. Why does source inductance reduce the average output voltage of a controlled rectifier?

Source inductance stops the current from changing instantly, so during commutation the outgoing and incoming devices conduct together (the overlap). In this interval the output voltage is lower than the voltage of the incoming phase. Each commutation therefore loses some volt-seconds, and the average output voltage falls, by an amount that grows with load current.

14. A single-phase fully controlled bridge is fed from 230 V rms, 50 Hz. The load current is constant (highly inductive load) and the firing angle is 60 degrees. Find the average output voltage.

The average output voltage is about 103.5 V.

WORKING

1. Peak supply voltage: $V_m = 230\sqrt{2} = 325.3$ V
2. Continuous conduction: $V_{dc} = (2V_m/\pi)\cos\alpha$
3. $2V_m/\pi = 2 \times 325.3/\pi = 207.1$ V
4. $V_{dc} = 207.1 \times \cos 60^\circ = 103.5$ V

15. What does a freewheeling diode do in a controlled rectifier that feeds an inductive load?

The freewheeling diode carries the load current whenever the rectifier output voltage would go negative, so the load never sees negative voltage. It clamps the output at zero during those intervals and raises the average output voltage. It also lets the thyristors turn off as the supply voltage reverses.

Line-current harmonics, power factor and distortion factor

16. Why does a bridge rectifier draw harmonic currents from the supply when the load current is pure DC?

The diodes or thyristors switch the load between supply lines, so the line current is a non-sinusoidal wave even when the load current is constant. For a single-phase bridge with ripple-free load current the line current is a square wave. It contains only odd harmonics, and the amplitude of order n is $1/n$ of the fundamental.

17. What is the difference between displacement factor and distortion factor?

Displacement factor is $\cos\phi_1$, where ϕ_1 is the phase angle between the fundamental line current and the supply voltage. Distortion factor is I_1/I_{rms}, the fundamental current as a fraction of total rms current. For a sinusoidal supply voltage, power factor is the product of the two.

18. A single-phase fully controlled bridge draws a square-wave line current because the load current is constant. The supply voltage is sinusoidal and the firing angle is 60 degrees. Neglect overlap. Find the input power factor.

The input power factor is about 0.45.

WORKING

1. Square wave of amplitude I_d: $I_1 = 2\sqrt{2}\, I_d/\pi = 0.900\, I_d$ and $I_{rms} = I_d$
2. Distortion factor: $I_1/I_{rms} = 0.900$
3. Displacement factor: $\cos\alpha = \cos 60^\circ = 0.5$
4. Power factor: $0.900 \times 0.5 = 0.45$ (lagging)

19. Why does a phase-controlled rectifier draw reactive power from the supply although the load current is pure DC?

In a fully controlled bridge with ripple-free load current, delaying the firing by α makes the fundamental line current lag the supply voltage by α (ignoring overlap). The displacement factor is then $\cos\alpha$, and the reactive power drawn grows with the firing angle up to 90°. The DC load takes no reactive power itself, so this comes from the control alone.

Inverters and pulse width modulation

20. Why are anti-parallel diodes placed across the switches of a voltage source inverter?

With an inductive load, the load current cannot stop when a switch turns off, and it often lags the output voltage. The diodes give that current a path and return the stored energy to the DC source. Without them the switches would face large voltage spikes, and the output voltage would depend on the load current.

21. How does sinusoidal PWM differ from a square-wave output in a single-phase inverter?

A square-wave output has a fixed amplitude for a given DC voltage and carries low-order harmonics (3rd, 5th, 7th), which are hard to filter. Sinusoidal PWM lets the modulation index set the fundamental amplitude, and moves the harmonics to frequencies near multiples of the carrier, where a small filter removes them.

22. A single-phase full-bridge inverter has a 200 V DC supply and gives a square-wave output of plus and minus 200 V. Find the rms value of the fundamental component of the output voltage.

The rms fundamental output voltage is about 180 V.

WORKING

1. Fourier series of a square wave of height V_{dc}: peak fundamental $= 4V_{dc}/\pi$
2. $4 \times 200/\pi = 254.6$ V
3. rms value: $254.6/\sqrt{2} = 180$ V (that is $0.9\, V_{dc}$)

23. Why does the line-to-line voltage of a three-phase six-step inverter contain no triplen harmonics?

The line voltage is the difference of two pole voltages. Triplen harmonics (3rd, 9th and so on) are in phase in all three pole voltages, so they cancel in the subtraction. The pole voltages have half-wave symmetry, so there are no even harmonics either. The line-to-line voltage therefore contains only harmonics of order $6k \pm 1$, such as the 5th, 7th, 11th and 13th.

24. Why is the ratio of voltage to frequency kept constant when an inverter controls the speed of an induction motor below base speed?

The air-gap flux of the motor is proportional to V/f. Holding the ratio constant keeps the flux at its rated value, so the motor keeps its torque capability as the speed changes, without saturating. At very low

frequency the stator resistance drop matters, so a small voltage boost is added.

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227A Rash Behari Ave, Ballygunge, Kolkata 700019

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