

# GUJARAT TECHNOLOGICAL UNIVERSITY

## BE-4 SEMESTER – OLD PAPER – S22 TO W25 – QUESTION BANK ANSWER

Subject Name & Code:

**POWER ELECTRONICS (3140915)**

**(Disclaimer:** The purpose of these AI-generated responses is just education and reference. Utilise them to grasp topics and structure, but always rewrite in your own words and double-check)

### UNIT 3: DC-AC CONVERTERS (INVERTERS)

#### REPEATED QUESTIONS

**R1a. Explain three-phase inverter in 120° conduction mode with waveforms. (7 marks)**

*Appeared in: S25(7), S24(7) OR, S23(7) OR, W25(7), W23(7), W22(7)*

**Ans:**

Three-phase voltage source inverter (VSI) with six switches (MOSFET/IGBT/thyristor with antiparallel diodes). In **120° conduction mode**, each switch conducts for 120° per cycle. At any instant, only two switches conduct (one from upper group, one from lower group), leaving one phase floating.

**Circuit:** Three legs – leg A (S1 top, S4 bottom), leg B (S3 top, S6 bottom), leg C (S5 top, S2 bottom). Load star-connected.

**Switching sequence (60° intervals):**

- 0–60°: S1, S6 conduct  $\rightarrow V_{an} = +V_{peak}/2, V_{\beta n} = -V_{peak}/2, V_{cn} = 0$  (floating via diode)
- 60–120°: S1, S2  $\rightarrow V_{an} = +V_{peak}/2, V_{cn} = -V_{peak}/2, V_{\beta n} = 0$
- 120–180°: S3, S2  $\rightarrow V_{\beta n} = +V_{peak}/2, V_{cn} = -V_{peak}/2, V_{an} = 0$  ... continues for all 6 intervals.

**Line-to-line voltage waveforms:** Six-step quasi-square wave. Amplitude of fundamental =  $(\sqrt{3}/\pi) \times V_{dc}$ .

**Phase voltage:** Stepped waveform with three levels ( $+V_{dc}/2, 0, -V_{dc}/2$ ).

**Advantages:** Simple commutation, no shoot-through risk.

**Disadvantages:** Poor utilization of DC bus (only 86.6% of fundamental compared to 180°).

**Real-world application:** Low-cost motor drives (fans, pumps), UPS systems.

[DG PROMPT]

**Title:** Three-Phase Inverter – 120° Conduction Mode Waveforms

**Description:** Draw six graphs stacked vertically, same time axis (0 to 360°).

1. Gate signals for S1, S3, S5 (top switches) – each high for 120°, spaced 120° apart.
2. Gate signals for S4, S6, S2 (bottom) – complementary to tops but with 60° offset.
3. Phase voltage  $V_{an}$  – three levels:  $+V_{dc}/2$  (0-60°), 0 (60-120°),  $-V_{dc}/2$  (120-180°), 0 (180-240°),  $+V_{dc}/2$  (240-360°)? Actually careful: 120° mode gives  $V_{an} = +V_{dc}/2$  when S1 on,  $= -V_{dc}/2$  when S4 on,  $= 0$  when neither. Show six 60° intervals.
4. Line voltage  $V_{\alpha\beta}$  – amplitude  $V_{dc}$ , width 120°, symmetric.

**R1b. Explain three-phase inverter in 180° conduction mode with waveforms. (7 marks)***Appeared in: S25(7) OR***Ans:**

In **180° conduction mode**, each switch conducts for 180° (half cycle). Three switches conduct at any time (one from each leg – either all top or two top + one bottom, etc.). This produces continuous three-phase sinusoidal-like line voltages.

**Switching pattern:**

- 0–60°: S1, S5, S6 on →  $V_{an} = +V_{dc}/2$ ,  $V_{\beta n} = -V_{dc}/2$ ,  $V_{cn} = -V_{dc}/2$ ? Actually careful: With 180° mode, each leg's top and bottom never overlap. For leg A: S1 on 0-180°, S4 on 180-360°. So phase voltage  $V_{an}$  is  $+V_{dc}/2$  for first 180°,  $-V_{dc}/2$  for next 180°. That's a square wave. Line voltages become quasi-square with 120° width and amplitude  $V_{dc}$ .

**Line voltage**  $V_{\alpha\beta} = V_{an} - V_{\beta n}$ . Since  $V_{an}$  and  $V_{\beta n}$  are square waves shifted 120°,  $V_{\alpha\beta}$  is a stepped wave with 5 levels:  $+V_{dc}$ ,  $+V_{dc}/2$ , 0,  $-V_{dc}/2$ ,  $-V_{dc}$ .

**Fundamental** line voltage magnitude =  $(2/\pi) V_{dc}$ , which is higher than 120° mode.

**Harmonics:** Lower THD compared to 120° mode.

**Comparison with 120° mode:**

- 180° gives higher fundamental output and better DC bus utilization.
- 120° has less chance of shoot-through but lower voltage.

**Real-world application:** High-performance motor drives, industrial inverters.

[DG PROMPT]

**Title:** Three-Phase Inverter – 180° Conduction Mode Waveforms**Description:** Time axis 0-360°.

1. Gate signals for S1, S3, S5 – each high 180°, spaced 120° apart.
2. Phase voltage  $V_{an}$  – square wave:  $+V_{dc}/2$  from 0-180°,  $-V_{dc}/2$  from 180-360°.
3. Line voltage  $V_{\alpha\beta}$  – difference of two square waves: shows pulses of  $V_{dc}$  and  $V_{dc}/2$ , width 60° and 120°.

**R2. Describe SPWM control technique. (4 marks)***Appeared in: S25(4) OR, S24(3) OR, S22(4) OR***Ans:**

**Sinusoidal Pulse Width Modulation (SPWM)** – most common method for voltage control in inverters.

**Principle:** Compare a high-frequency triangular carrier wave ( $f_c$ ) with a low-frequency sinusoidal reference wave ( $f_m$ , 50/60 Hz). When reference > carrier, switch ON; else OFF.

**For single-phase inverter:**

- Two switches in one leg – complementary gating.
- Output pulse train filtered to sine wave.

**For three-phase:** Three reference sine waves 120° apart compared with same carrier → three switching signals for top switches; bottom switches complementary.

**Key parameters:**

- Modulation index  $m_a = V_{ref} / V_{carrier}$  (controls fundamental voltage).
- Frequency ratio  $m_f = f_c / f_m$  (affects harmonics).

**Advantages:** Simple analog implementation, low harmonics at multiples of carrier frequency.

**Disadvantages:** Lower DC bus utilization (max fundamental  $V = 0.5 V_{dc}$  for single-phase).

**Real-world application:** AC motor drives, UPS, solar inverters.

[DG PROMPT]

**Title:** SPWM Generation Principle

**Description:** Draw two waveforms on same time axis:

- Triangular carrier (high frequency, say 5 cycles)
- Sinusoidal reference (one cycle)
- Resulting PWM pulses: high when reference > carrier, low otherwise.

**R3. Describe SVPWM control technique. (7 marks)**

*Appeared in: S25(4), W25(7) OR, W23(7) OR, W22(7) OR → Highest: 7*

**Ans:**

**Space Vector Pulse Width Modulation (SVPWM)** – advanced digital PWM technique for three-phase inverters. Treats three-phase voltages as a single rotating space vector in the complex plane.

**Principle:**

- Eight switching states for three-phase VSI (six active vectors, two zero vectors).
- Desired reference voltage vector  $V_{ref}$  is synthesized by time-averaging two adjacent active vectors and zero vectors within a switching period.

**Steps:**

1. Identify sector (1 to 6) where  $V_{ref}$  lies.
2. Compute duty cycles for two active vectors (T1, T2) and zero vectors (T0).  
 $T1 = T_s * m * \sin(60^\circ - \theta)$ ,  $T2 = T_s * m * \sin(\theta)$ ,  $T0 = T_s - T1 - T2$ , where  $m =$  modulation index.
3. Generate switching sequences (e.g., 0-1-2-7-7-2-1-0 symmetrical).

**Advantages over SPWM:**

- Higher DC bus utilization (15% more fundamental voltage).
- Lower harmonic distortion at same switching frequency.
- Better utilization of DC link.

**Disadvantages:** Complex digital implementation (requires microcontroller/DSP).

**Real-world application:** High-performance motor drives (EVs, industrial robots), grid-tied inverters.

[DG PROMPT]

**Title:** Space Vector PWM – Vector Diagram

**Description:** Draw hexagon with six active vectors (V1 to V6) at  $60^\circ$  intervals, magnitude  $(2/3)V_{dc}$ . Zero vectors V0 and V7 at origin. Draw reference vector  $V_{ref}$  inside a sector (e.g., sector 1 between V1 at  $0^\circ$  and V2 at  $60^\circ$ ). Show decomposition into  $T1/T_s * V1 + T2/T_s * V2$ .

**R4. Explain cause of harmonics in inverter output and effects of switching frequency on harmonic spectrum. (7 marks)**

*Appeared in: S24(7), S22(7), W25(4) OR → Highest: 7*

**Ans:**

**Causes of harmonics in inverter output:**

1. **Square or quasi-square waveform** – ideal inverter output is not pure sine due to switching.
2. **Switching frequency and its multiples** – PWM creates harmonics at carrier frequency and sidebands.
3. **Dead time** – inserted to prevent shoot-through, causes low-order harmonics.
4. **Non-ideal DC bus** – ripple voltage modulates output.
5. **Asynchronous PWM** – subharmonics when  $f_c/f_m$  not integer.

**Effects of switching frequency ( $f_{sw}$ ) on harmonic spectrum:**

- **Low  $f_{sw}$  (e.g., 50 Hz – square wave):**
  - Harmonics at odd multiples of fundamental (3rd, 5th, 7th...), large magnitude.
  - Filtering difficult, high THD ( $\approx 48\%$  for square wave).
- **Medium  $f_{sw}$  (e.g., 1–5 kHz – PWM):**
  - Harmonics shift to carrier frequency and sidebands ( $f_c \pm k \cdot f_m$ ).
  - Low-order harmonics reduced significantly.
- **High  $f_{sw}$  (e.g., > 20 kHz – above audible range):**
  - Easier filtering (smaller L,C), lower acoustic noise.
  - However, increased switching losses and EMI.

**Trade-off:** Higher  $f_{sw}$  improves harmonic spectrum but reduces efficiency.

**Real-world application:** Design of output filters (LC) and selection of IGBTs/MOSFETs.

[DG PROMPT]

**Title:** Harmonic Spectrum vs Switching Frequency

**Description:** Two frequency-domain plots.

- Low  $f_{sw}$ : tall bars at 50, 150, 250 Hz ...
- High  $f_{sw}$ : small low-frequency bars, clusters of harmonics centered at  $f_c$ ,  $2f_c$ , etc.

### R5. Compare 120° and 180° conduction modes. (4 marks)

*Appeared in: S22(3), W24(4)*

**Ans:**

| Parameter                          | 120° Mode                                   | 180° Mode                             |
|------------------------------------|---------------------------------------------|---------------------------------------|
| Conduction period per switch       | 120°                                        | 180°                                  |
| Switches ON at any time            | 2 (one upper, one lower)                    | 3 (any combination)                   |
| Phase voltage waveform             | 3-level stepped                             | Square wave                           |
| Line voltage waveform              | Quasi-square (width 120°)                   | 5-level stepped                       |
| Fundamental line voltage magnitude | $(\sqrt{3}/\pi) V_{dc} \approx 0.55 V_{dc}$ | $(2/\pi) V_{dc} \approx 0.637 V_{dc}$ |
| DC bus utilization                 | Lower                                       | Higher                                |
| Harmonics                          | Higher THD                                  | Lower THD                             |
| Complexity of gating               | Simple                                      | Simple                                |
| Shoot-through risk                 | Less                                        | Slightly more                         |

**Application preference:** 180° for higher voltage requirement; 120° for simple low-power drives.



### OTHER IMPORTANT QUESTIONS

#### O1. Explain working of half-bridge inverter with R-L load using waveforms. (7 marks)

*Appeared in: S22(7)*

**Ans:**

**Half-bridge inverter** – simplest single-phase inverter using two switches (S1, S2) and two capacitors (C1, C2) across DC input ( $V_{dc}/2$  each). Load connected between midpoint (A)

and neutral (O).

**Operation (resistive-inductive load):**

- **S1 ON, S2 OFF ( $0 \rightarrow T/2$ ):** A connected to  $+V_{dc}/2$ . Current rises through load.
- **S1 OFF, S2 OFF (dead time):** Load current freewheels through diode across S2 (negative voltage  $-V_{dc}/2$  if current still positive? Actually: For inductive load, when S1 turns off, current continues through D2 to  $-V_{dc}/2$ , so output voltage becomes  $-V_{dc}/2$ .)
- **S2 ON, S1 OFF ( $T/2 \rightarrow T$ ):** A connected to  $-V_{dc}/2$ . Current reverses.
- **S2 OFF, S1 OFF:** Freewheeling through D1 to  $+V_{dc}/2$ .

**Waveforms:**

- Output voltage  $V_{ao}$ : square wave  $\pm V_{dc}/2$ .
- Load current: sinusoidal-like due to  $L$  filtering, with exponential rise/fall.

**Output RMS voltage:**  $V_o(\text{rms}) = V_{dc}/2$ .

**Fundamental RMS:**  $V_1(\text{rms}) = (2/\pi) \times (V_{dc}/2) = V_{dc}/\pi \approx 0.318 V_{dc}$ .

**Advantages:** Simple, only two switches.

**Disadvantages:** Requires split DC supply, lower output voltage.

**Real-world application:** Low-power UPS, small induction heating.

[DG PROMPT]

**Title:** Half-Bridge Inverter with R-L Load

**Description:** Circuit: Two series capacitors across  $V_{dc}$  (midpoint O). Two switches S1 (top) and S2 (bottom). Load R-L between A (junction of S1/S2) and O. Waveforms:  $V_{ao}$  square wave,  $i_L$  sinusoidal-like.

**O2. Describe full-bridge single-phase voltage source inverter with circuit and waveforms. (7 marks)**

*Appeared in: S24(7) OR, S23(7)*

**Ans:**

**Full-bridge inverter (H-bridge)** – four switches (S1, S2, S3, S4) with antiparallel diodes. Load connected between points A and B.

**Operation modes (bipolar PWM or square wave):**

**Square wave ( $180^\circ$  conduction per leg):**

- $0-T/2$ : S1, S4 ON  $\rightarrow V_{ab} = +V_{dc}$
- $T/2-T$ : S2, S3 ON  $\rightarrow V_{ab} = -V_{dc}$

**Output voltage:** square wave  $\pm V_{dc}$ .

**RMS output voltage**  $= V_{dc}$ .

**Fundamental RMS**  $= (2\sqrt{2}/\pi) V_{dc} \approx 0.9 V_{dc}$ .

**For R-L load:** Current lags voltage. Freewheeling diodes conduct during off intervals.

**Advantages:** Double output of half-bridge, no split supply.

**Applications:** Single-phase UPS, motor drives, induction heating.

[DG PROMPT]

**Title:** Full-Bridge Single-Phase VSI

**Description:** Circuit:  $V_{dc}$  positive to S1 and S3; negative to S2 and S4. Load between junction of S1/S2 (A) and S3/S4 (B). Waveforms: Square wave output  $V_{AB} \pm V_{dc}$ .

**O3. What is PWM? State advantages and disadvantages. (3 marks)**

*Appeared in: S24(3) OR, W22(3) OR*

**Ans:**

**Pulse Width Modulation (PWM)** – technique to control average voltage or power by varying duty cycle of a fixed-frequency pulse train.

**Advantages:**

- Efficient (low switching loss)
- Easy digital control
- Reduces harmonics in inverter output
- Enables variable voltage/frequency control

**Disadvantages:**

- Generates EMI at switching frequency
- Requires filtering
- Higher switching losses at high frequencies
- Complexity in analog implementation

**O4. Describe unipolar and bipolar PWM for inverter. (4 marks)**

*Appeared in: S22(4) OR, W25(3) OR*

**Ans:**

**Bipolar PWM (single-phase full-bridge):**

- One triangular carrier compared with sine reference.
- Switches in same leg complementary; opposite legs switched together.
- Output voltage  $V_{a\beta}$  alternates between  $+V_{dc}$  and  $-V_{dc}$ .
- Harmonic energy at carrier frequency and sidebands.

**Unipolar PWM:**

- Two triangular carriers (one positive, one negative) or two references? Actually:
- Uses two comparators: one for S1/S2 leg (positive reference), another for S3/S4 leg (negative reference).
- Output  $V_{a\beta}$  alternates between  $+V_{dc}$ , 0,  $-V_{dc}$  (three levels).
- Effective switching frequency doubles, lower harmonics.
- More complex.

**Comparison:** Unipolar gives lower THD and less EMI but requires more accurate control.

**O5. Classify voltage control techniques of inverter and explain any one. (4 marks)**

*Appeared in: S25(3) OR, W23(4)*

**Ans:**

**Classification of voltage control techniques:**

1. **Pulse Width Modulation (PWM) methods:**
  - Single-pulse, multiple-pulse, SPWM, SVPWM
2. **Phase-shift control (for series-resonant inverters)**
3. **DC link voltage control (using front-end chopper)**
4. **Selective Harmonic Elimination (SHE)**

**Explanation of SPWM (most common) – see R2 above.**

**O6. State advantages & disadvantages of CSI & VSI. (4 marks)**

*Appeared in: W25(4), W23(4)*

**Ans:**

| Feature         | VSI (Voltage Source Inverter)     | CSI (Current Source Inverter)   |
|-----------------|-----------------------------------|---------------------------------|
| DC source       | Voltage source (capacitor)        | Current source (large inductor) |
| Output waveform | Voltage controlled                | Current controlled              |
| Advantages      | Simple, low cost, high efficiency | Short-circuit protection,       |

|               |                                                         |                                    |
|---------------|---------------------------------------------------------|------------------------------------|
| Feature       | VSI (Voltage Source Inverter)                           | CSI (Current Source Inverter)      |
|               |                                                         | regenerative capability            |
| Disadvantages | Needs feedback diodes, no direct overcurrent protection | Large inductor, slower response    |
| Applications  | UPS, motor drives (low/medium power)                    | High-power motor drives, grid-tied |

**O7. Explain difference between line commutated and force-commutated inverters. (3 marks)**

*Appeared in: W22(3)*

**Ans:**

- **Line commutated inverter:** Uses AC line voltage to turn off thyristors (natural commutation). Works only when connected to an AC grid. Used in grid-tied applications.
- **Force commutated inverter:** Uses additional commutation circuits (capacitors, auxiliary thyristors) to turn off devices. Required for standalone or variable frequency drives. Allows self-commutation.

**Key difference:** Line commutated relies on external AC; force commutated does not.

**O8. Define Harmonic Factor, THD, LOH, DF. (4 marks)**

*Appeared in: S23(4) OR*

**Ans:**

- **Harmonic Factor (HF<sub>n</sub>)** – Ratio of RMS value of nth harmonic to fundamental:  

$$HF_n = V_n / V_1$$
- **Total Harmonic Distortion (THD)** – Measure of waveform distortion:  

$$THD = (\sqrt{\sum V_n^2} / V_1) \times 100\% \text{ for } n=2 \text{ to } \infty$$
- **Lowest Order Harmonic (LOH)** – The harmonic with the smallest frequency above fundamental that has significant magnitude (e.g., 3rd in three-phase inverters).
- **Distortion Factor (DF)** – Weighted THD that accounts for harmonic order:  $DF = (\sqrt{\sum (V_n / n)^2} / V_1) \times 100\%$ . Lower DF means easier filtering.

**O9. Explain the principle of pulse width modulation for inverter. (3 marks)**

*Appeared in: W25(3)*

**Ans:**

PWM principle: A high-frequency carrier (triangular) is compared with a low-frequency reference signal (sine wave). When reference > carrier, output switch is ON; otherwise OFF. The duty cycle varies sinusoidally, producing a pulse train whose average voltage follows the reference. After low-pass filtering, a sine wave is obtained. This controls both voltage magnitude and frequency.

**O10. Discuss bipolar PWM techniques in detail. (4 marks)**

*Appeared in: S25(4)*

**Ans:**

In bipolar PWM for single-phase full-bridge inverter:

- Same triangular carrier for both legs.
- Leg A: S1 on when  $V_{ref} > V_{carrier}$ , S2 off (complementary).
- Leg B: S3 on when  $-V_{ref} > V_{carrier}$ ? Actually, bipolar uses single reference: S1

and S4 turn on together when  $V_{ref} > V_{carrier}$ ; S2 and S3 turn on when  $V_{ref} < V_{carrier}$ .

- Output voltage  $V_{AB}$  alternates between  $+V_{dc}$  and  $-V_{dc}$ .
- Switching frequency = carrier frequency.
- Harmonic spectrum: sidebands around carrier frequency and multiples.
- Simple but higher THD than unipolar.

**O11. Determine applications of inverters in power system. (4 marks)**

*Appeared in: S22(4) OR*

**Ans:**

- **UPS (Uninterruptible Power Supply)** – provides backup AC power.
- **Adjustable speed drives (ASD)** – for induction motors (fans, pumps, conveyors).
- **Renewable energy systems** – solar inverters (PV to grid), wind turbine converters.
- **HVDC transmission** – inverter station for DC to AC conversion.
- **Induction heating** – high-frequency inverters.
- **Electric vehicles** – traction inverters.
- **Grid-tied battery storage** – bidirectional inverters.

**O12. What is the purpose of connecting diodes in antiparallel with thyristors in inverter circuits? (3 marks)**

*Appeared in: W23(3) OR*

**Ans:**

Antiparallel diodes (feedback diodes) provide a path for inductive load current during switch off-time. They:

1. Allow **freewheeling** of load current when thyristor turns off, preventing voltage spikes.
2. Enable **regenerative operation** – current can flow back to DC source when load voltage reverses.
3. Protect switches from reverse voltage and reduce commutation stress.
4. In VSI, they are essential for R-L loads to maintain current continuity.

**O13. Derive inverter output voltage equation. (4 marks)**

*Appeared in: W22(4)*

**Ans:**

For a single-phase full-bridge inverter with square wave output ( $\pm V_{dc}$ ):

**Instantaneous output voltage:**

$$v_o(t) = \sum_{n=1,3,5,\dots} (4V_{dc} / (n\pi)) \sin(n\omega t) \text{ (for bipolar square wave)}$$

**Fundamental (n=1):**

$$V_1(\text{peak}) = 4V_{dc} / \pi$$

$$V_1(\text{rms}) = (4V_{dc} / \pi) / \sqrt{2} = (2\sqrt{2} V_{dc}) / \pi \approx 0.9 V_{dc}$$

**For three-phase inverter (180° mode, line voltage):**

$$V_{ab}(t) = \sum_{n=1,5,7,11,\dots} (2\sqrt{3} V_{dc} / (n\pi)) \sin(n\omega t)$$

$$\text{Fundamental line RMS: } V_1(\text{rms}) = (\sqrt{6} / \pi) V_{dc} \approx 0.78 V_{dc}$$

**For PWM inverters:**

Fundamental output  $V_1 = m_a \times V_{dc} / 2$  (single-phase) or  $m_a \times V_{dc}$  (three-phase SVPWM gives  $0.577 m_a V_{dc}$ ? Actually standard:  $V_1 = m_a \times (V_{dc} / 2)$  for SPWM with three-phase.)

**O14. Describe positions of space vector on the basis of switching states. (3 marks)**

*Appeared in: S24(3), S22(3)*

**Ans:**

For three-phase VSI, 8 switching states:

- **Active states (6):** (100), (110), (010), (011), (001), (101) – produce voltage vectors of magnitude  $(2/3)V_{dc}$  at  $60^\circ$  intervals.
- **Zero states (2):** (000) and (111) – output zero voltage.

**Positions:**

- V1 (100) at  $0^\circ$
- V2 (110) at  $60^\circ$
- V3 (010) at  $120^\circ$
- V4 (011) at  $180^\circ$
- V5 (001) at  $240^\circ$
- V6 (101) at  $300^\circ$
- V0 and V7 at origin.

These vectors form a hexagon. Any desired reference vector within the hexagon can be synthesized by averaging adjacent active vectors and zero vectors (SVPWM).

### NUMERICAL QUESTION

**N1. The single-phase half-bridge inverter has DC input 100 V, load resistance 10  $\Omega$ . Determine RMS output voltage and fundamental component of RMS value. (4 marks)**  
*Appeared in: S22(4) OR*

**Given:**

$V_{dc} = 100$  V,  $R = 10$   $\Omega$  (resistive load – no L)

**To find:**

1. RMS output voltage ( $V_{rms}$ )
2. Fundamental RMS voltage ( $V_{1rms}$ )

**Formula for half-bridge square wave:**

Output voltage is square wave  $\pm V_{dc}/2 = \pm 50$  V.

**Solution:**

RMS output voltage for square wave = amplitude =  $V_{dc}/2 = 50$  V.

Thus  $V_{rms} = 50$  V.

Fundamental peak voltage (Fourier series for square wave, amplitude  $A = V_{dc}/2 = 50$  V):

$V_1(\text{peak}) = (4A)/\pi = (4 \times 50)/\pi = 200/\pi \approx 63.66$  V

Fundamental RMS =  $V_1(\text{peak})/\sqrt{2} = 63.66 / 1.4142 \approx 45.02$  V.

**Final Answer:**

$V_{rms} = 50$  V,  $V_{1rms} \approx 45.02$  V.

*(If load were R-L, current would lag but voltage remains same.)*

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