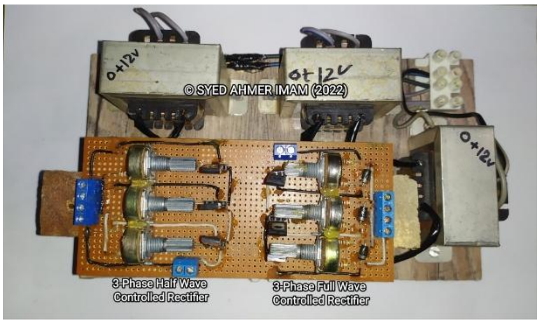
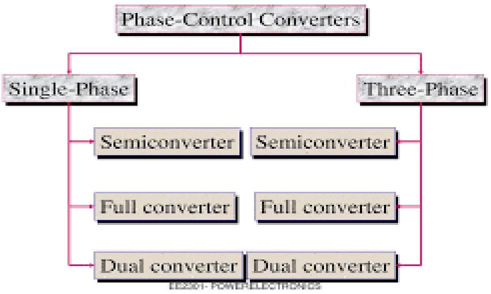
PHASE CONTROLLED CONVERTERS

Basic overview :

Phase controlled converters, also known as phase controlled rectifiers, are power electronic circuits that convert AC power to DC power with the ability to control the output voltage. This control is achieved by manipulating the firing angle (or phase angle) of thyristors (SCRs), which are semiconductor devices that act as switches. By adjusting the firing angle, the output DC voltage and load current can be varied.





Key Concepts:

- **AC to DC Conversion:**

Phase controlled converters convert alternating current (AC) to direct current (DC).

- **Thyristors (SCRs):**

These semiconductor devices are used instead of diodes to enable controlled output voltage.

- **Firing Angle Control:**

The firing angle of the thyristors determines when they turn on, thus controlling the duration of the current flow and the output DC voltage.

- **Commutation:**

Thyristors are turned off naturally (line commutation) or by firing another thyristor in a different part of the converter.

- **Single-Phase and Three-Phase Versions:**

Phase controlled converters can be single-phase (half-wave, full-wave) or three-phase (semi, full, dual converters).

Advantages:

- **Variable Output Voltage:**

The ability to adjust the firing angle allows for a variable DC output voltage.

- **Industrial Applications:**

Commonly used in industrial DC drives for applications where a controllable DC power supply is needed.

- **Simple and Cost-Effective:**

Compared to other converter types, phase controlled converters are relatively simple and less expensive

Applications:

- **DC Motor Drives:** Controlling the speed of DC motors.
- **Battery Chargers:** Regulating the charging voltage of batteries.
- **Industrial Equipment:** Providing a controllable DC power supply for various industrial processes.

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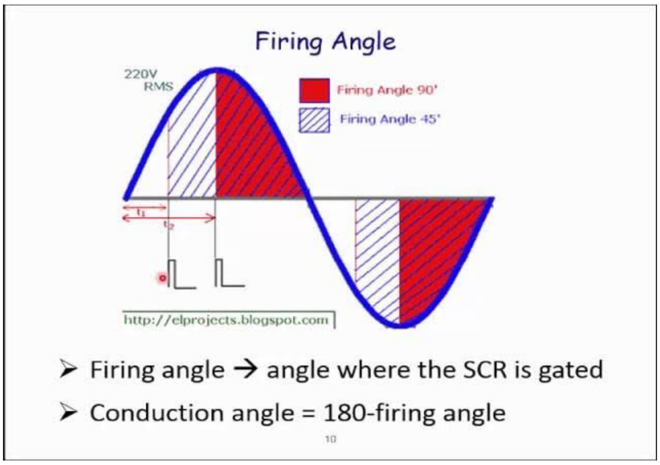
Common interview questions and answers related to phase controlled converters:

1. What is a phase controlled converter?

- **Answer:** A phase controlled converter (or controlled rectifier) is a type of power electronic converter that uses thyristors (SCRs) to control the flow of AC power to a DC load. It's called "phase controlled" because the firing of the thyristors (i.e., when they are switched on) is delayed from the AC input voltage, allowing control over the output DC voltage.

2. Explain the concept of firing angle in phase controlled converters.

- **Answer:** The firing angle (α) is the delay between the natural conduction of the AC voltage and the time when the thyristor is triggered to conduct current. A larger firing angle results in a lower DC output voltage.



3. How does the firing angle affect the output DC voltage in a single-phase half-controlled converter?

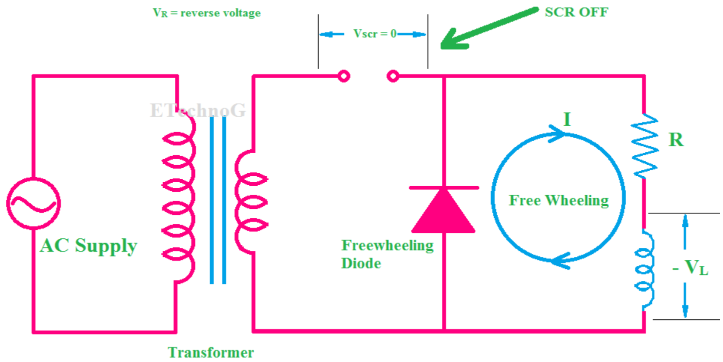
- Answer: In a half-controlled single-phase converter, the output DC voltage (Vdc) is directly related to the firing angle (α). The formula for Vdc is: Vdc = (Vmax/π)
- (1 + cosα), where Vmax is the peak value of the AC input voltage.

4. What is the difference between a half-controlled and a fully controlled converter?

- **Answer:**
    - **Half-controlled converter:** Only one thyristor is used per phase, allowing for conduction during only one half-cycle of the AC input. It can only be used for positive voltage and current quadrants.
    - **Fully controlled converter:** Two thyristors per phase are used, allowing for control over both positive and negative voltage and current quadrants.
    - **Advantage:** Full converters can perform regenerative braking, while semi-converters cannot.

5. What is a free-wheeling diode (FWD) and why is it used in converter circuits?

- **Answer:** A free-wheeling diode is a diode connected in parallel with the load. It provides a path for the load current to continue flowing even when the thyristors are turned off, which helps to improve the input power factor and reduce voltage spikes.

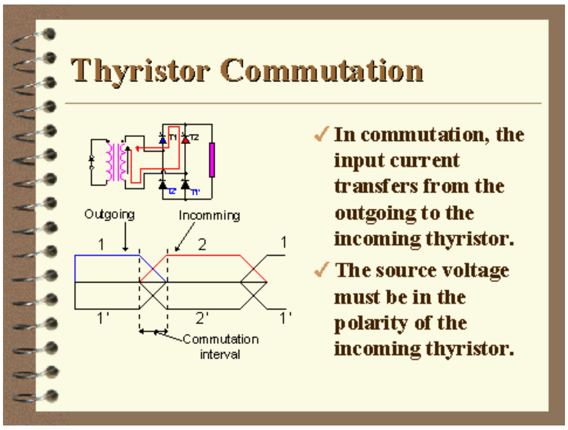


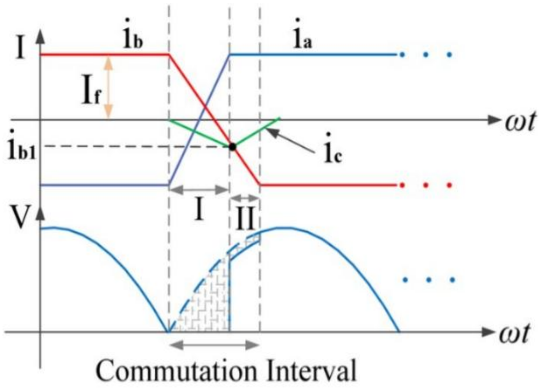
6. What are the advantages and disadvantages of using a phase controlled converter?

- **Advantages:**
    - **Versatile:** Allows for control of output DC voltage and power.
    - **Simple:** Relatively simple circuit compared to other converter types.
    - **Cost-effective:** Thyristors are relatively inexpensive.
- **Disadvantages:**
    - **Harmonics:** Can introduce harmonics into the AC input supply.
    - **Power Factor:** Input power factor can be poor, especially at low output voltages.
    - **Turn-off time limitations:** Thyristors have limitations in their turn-off time, which can impact performance.

7. Explain the concept of commutation in thyristors.

- **Answer:** Commutation is the process of switching the current flow from one thyristor to another. It is essential for the operation of phase controlled converters and ensures that the load current can continue to flow even when a thyristor is turned off.



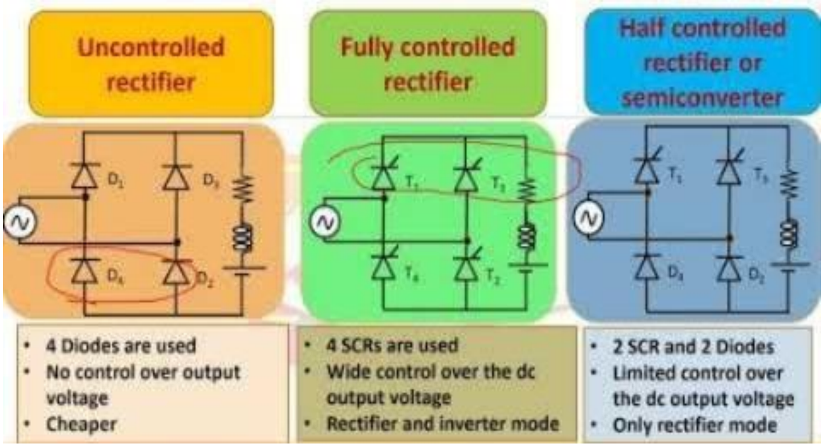


8. What are the applications of phase controlled converters?

- **Answer:**
    - **DC Motor Drives:** Used to control the speed and torque of DC motors.
    - **Battery Charging:** Used to regulate the voltage and current for charging batteries.
    - **Power Supplies:** Used to convert AC power to DC power for various applications.
    - **Welding Machines:** Used to control the welding current.

9. What is the difference between a semi-converter and a full converter?

- **Answer:** A semi-converter uses only one thyristor per phase, while a full converter uses two thyristors per phase.



Let us dive deep into the topic to develop an in depth understanding :

SECTION 1: RECTIFIERS AND CONVERTERS

1. What is a freewheeling diode?

Ans: A freewheeling diode, also called a bypass or commutating diode, is connected across motor terminals to dissipate energy stored in motor inductance and to maintain motor current continuity when the thyristors are blocked. It also protects against transient overvoltages.

2. What is the relationship of Vdc and Vac in terms of firing angle α for half-controlled and full-controlled converters?

Ans:

- **Half-Controlled Converter:**
  $V_{dc}=[V_m/\pi](1+\cos\alpha)$
- **Full-Controlled Converter:**
  $V_{dc}=[2V_m/\pi]\cos\alpha$

3. What are the drawbacks of half-wave rectifier circuits?

Ans: The output voltage is not smooth DC, contains harmonics, and results in poor performance. Thus, their use is limited to low-power applications (up to 500 W).

4. What is the necessity of DC choke coil and freewheeling diode in a converter circuit?

Ans: The choke coil slows the current decay during freewheeling, ensuring current continuity. The freewheeling diode dissipates energy stored in inductance when the thyristors are off, improving performance.

5. Why is the input power factor of a single-phase half-controlled bridge rectifier higher than that of a fully controlled bridge rectifier for the same firing angle?

Ans: In a full-bridge rectifier, energy from inductance can be returned to the supply, reducing power delivered to the load. In a half-controlled rectifier, energy flows to the load through the freewheeling diode, improving power factor.

6. Why are three-phase half-wave drives not commonly used in industrial applications?

Ans: Due to the presence of a DC component in the supply current, which causes distortion and poor power quality.

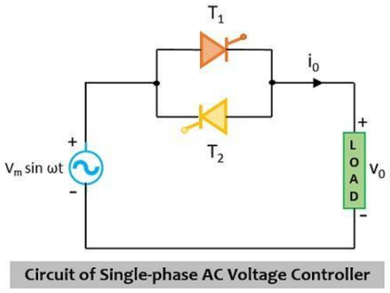
7. Why is a semiconverter system preferred for DC series motor drives?

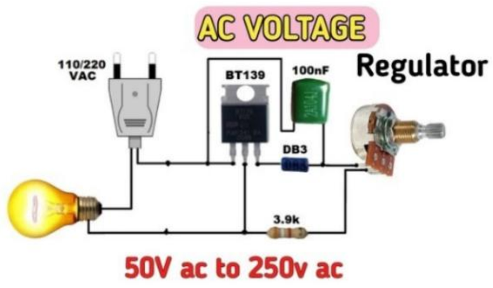
Ans: It maintains continuous current via freewheeling, offering better performance than full converters for DC series motors.

SECTION 2: AC VOLTAGE CONTROLLERS (REGULATORS)

8. Why are AC regulators preferred over conventional methods for AC motor voltage control?

Ans: Due to high efficiency, compact size, and faster control using thyristors.





9. What is the difference between on-off control and phase control in AC voltage controllers?

Ans:

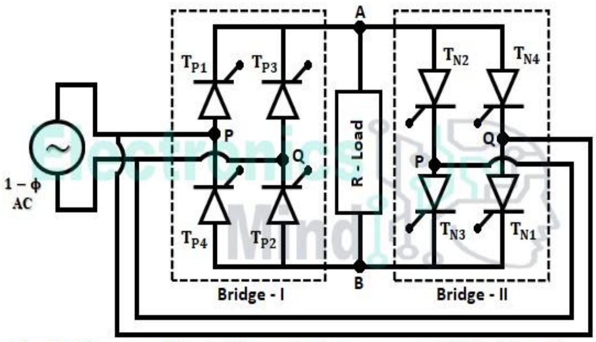
- **On-Off Control (Integral Cycle Control):** Motor connected for a whole number of AC cycles.
- **Phase Control:** Motor connected for part of each AC cycle.

SECTION 3: CYCLOCONVERTERS

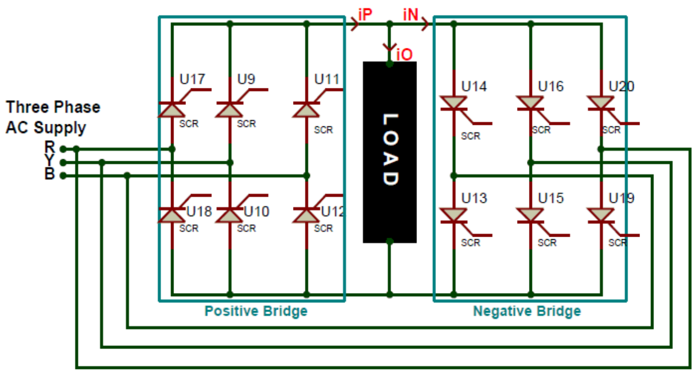
10. What is a cycloconverter?
Ans:
A cycloconverter is a power electronic device that directly converts AC power of one frequency into AC power of a lower frequency without any intermediate DC stage. It uses controlled switches like thyristors.

11. What are the types of cycloconverters?
Ans:

- Step-down Cycloconverter: Output frequency is lower than input frequency.
- Step-up Cycloconverter: Output frequency is higher than input (rarely used).
- Based on phase:
  - Single-phase to single-phase
  - Three-phase to single-phase
  - Three-phase to three-phase



Single Phase to Single Phase Cycloconverter With R-Load



Three phase to three phase cycloconverter

12. What are the main applications of cycloconverters?
Ans:

- Speed control of large AC motors in rolling mills, cement mills, and ship propulsion.
- Low-frequency applications like induction heating.
- Variable-frequency drives for synchronous and induction motors.

13. Why are cycloconverters preferred in low-speed, high-power motor drives?
Ans:
They provide low-frequency output with smooth control and high efficiency. Since they avoid intermediate DC conversion, losses are minimized and the system becomes more robust and cost-effective for large motors.

14. What are the disadvantages of cycloconverters?
Ans:

- Complex control circuitry
- Large number of thyristors
- Output contains harmonics and may need filters
- Limited to output frequencies less than or equal to one-third of the input frequency

15. What is the difference between a cycloconverter and an inverter?
Ans:
A cycloconverter converts AC to AC of a lower frequency without an intermediate DC link, while an inverter converts DC to AC. Cycloconverters are mainly used for low-speed, high-power applications, whereas inverters are more common in variable-frequency drives.

16. Can a cycloconverter operate in both motoring and braking modes?
Ans:

Yes. A cycloconverter can allow bidirectional power flow, enabling both motoring and regenerative braking operations, especially in full-controlled three-phase cycloconverter-fed motor drives.

17. What is circulating current mode and non-circulating current mode in cycloconverters?
Ans:

- Circulating Current Mode: Both positive and negative converters operate simultaneously, causing circulating currents that need reactors.
- Non-Circulating Current Mode: Only one converter conducts at a time, avoiding circulating currents but requiring precise control.

18. What kind of control techniques are used in cycloconverters?
Ans:

- Phase angle control of thyristors
- Sequence control (positive and negative converters operate in a timed sequence)
- Modulation techniques for smoother output

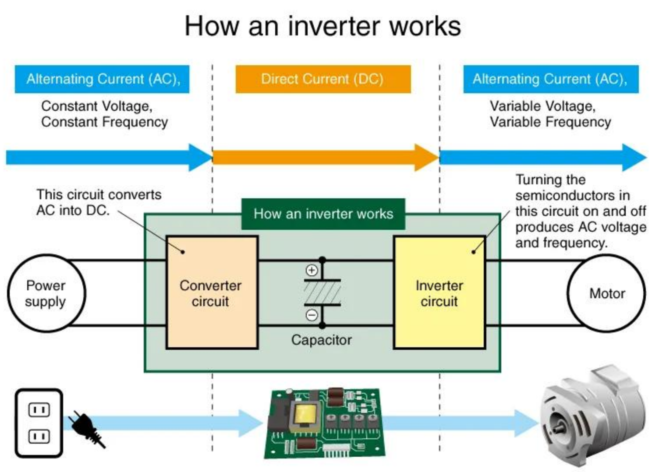
19. What are the applications of cycloconverters?

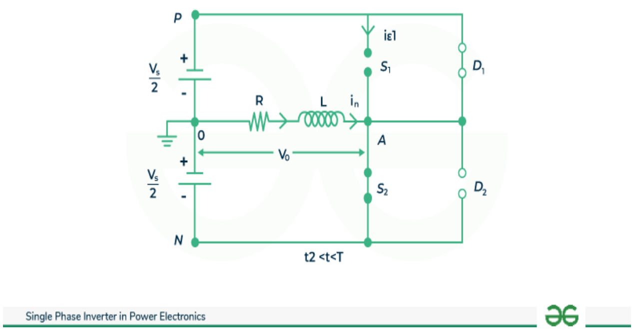
Ans: Used in large motors, gearless drives in cement mills, ball mills, etc.

SECTION 4: INVERTERS

20. What is an inverter?

Ans: A device that converts DC into AC of desired frequency and voltage. It is used for both small and high-power applications.





21. What are some industrial applications of inverters?

Ans:

- Adjustable-speed AC drives
- Induction heating
- Standby aircraft power
- HVDC transmission

22. How are inverters classified?

Ans:

- Single-phase or Three-phase
- Voltage Source or Current Source
- Series, Parallel, or Bridge Type

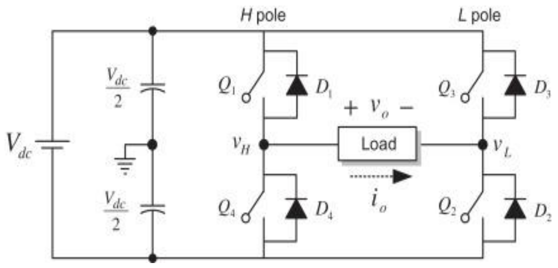
23. Why are bridge circuits popular for inverter operation?

Ans: They eliminate the need for an output transformer and are easily extendable to multiphase systems.

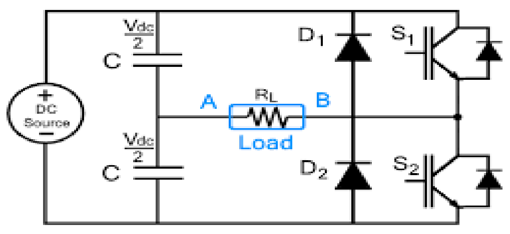
24. What is the difference between single-phase half-bridge and full-bridge inverter circuits?

Ans:

- **Half-bridge:** Uses 2 thyristors and 2 diodes, but needs a 3-wire DC supply.
- **Full-bridge:** Uses 4 thyristors and 4 diodes, does not require a 3-wire supply.



Full Bridge Inverter



Typical Half H-Bridge Inverter

25. Why are 3-phase inverters more common than parallel single-phase inverters for industrial applications?

Ans: 3-phase inverters are more efficient, require fewer components (6 thyristors and 6 diodes), and do not need multiple transformers like parallel single-phase systems.

26. What are the two modes of operation of a 3-phase inverter?

Ans:

- 120° Conduction Mode
- 180° Conduction Mode

Intervals (degree)	120 degree commutation: Transistor "on"	Polarities A	B	C	180 degree commutation: Transistor "on"	Polarities A	B	C
0 - 60	T1, T6	+	0	-	T1,T4,T5	+	-	+
60 - 120	T3, T6	0	+	-	T1,T4,T6	+	-	-
120 - 180	T3, T2	-	+	0	T1,T3,T6	+	+	-
180-240	T5, T2	-	0	+	T2,T3,T6	-	+	-
240-300	T5, T4	0	-	+	T2,T3,T5	-	+	+
300-360	T1, T4	+	-	0	T2,T4,T5	-	-	+

Switch Sequences

27. Compare the two modes of operation of 3-phase inverters.

Ans:

- **120° Mode:** More reliable, reduces risk of two series thyristors conducting.
- **180° Mode:** Higher utilization factor but more complex.

28. Why is controlling the output voltage of an inverter important?

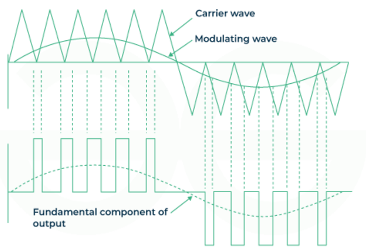
Ans:

- To adjust for input DC voltage fluctuations
- To compensate internal voltage drops
- For variable speed drives (voltage-speed control)

SECTION 5: PWM TECHNIQUES IN INVERTERS

29. What is Pulse Width Modulation (PWM)?

Ans: A technique where output voltage control is achieved by changing the width of constant amplitude pulses.



Pulse-width modulation (PWM)

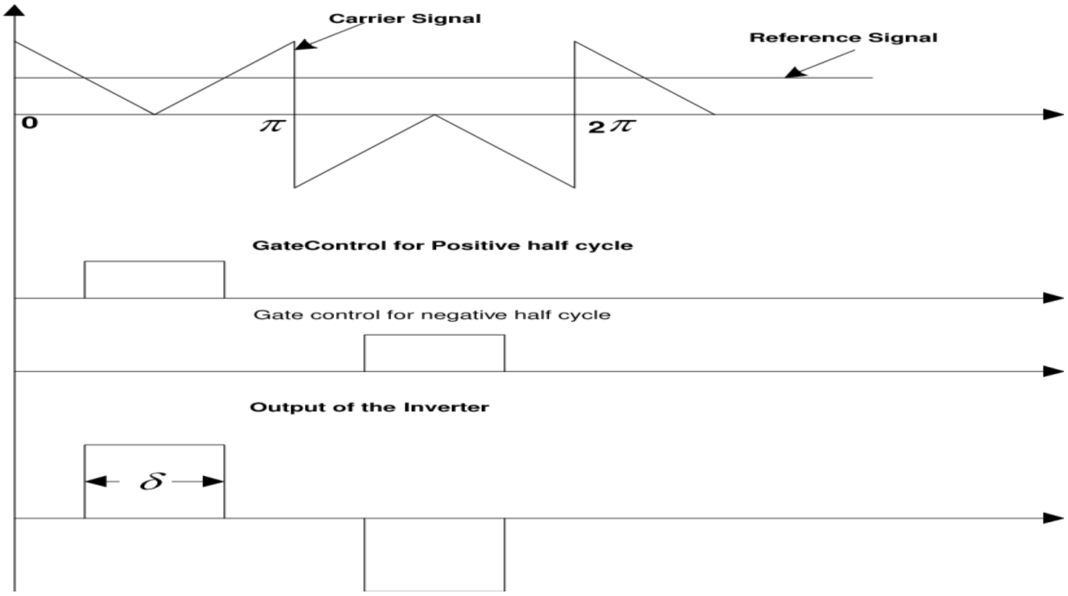
30. What are the advantages of PWM?

Ans:

- No need for additional components
- Reduces lower-order harmonics
- Easier filtering due to higher-order harmonics

31. What is single-pulse width modulation? What is its disadvantage?

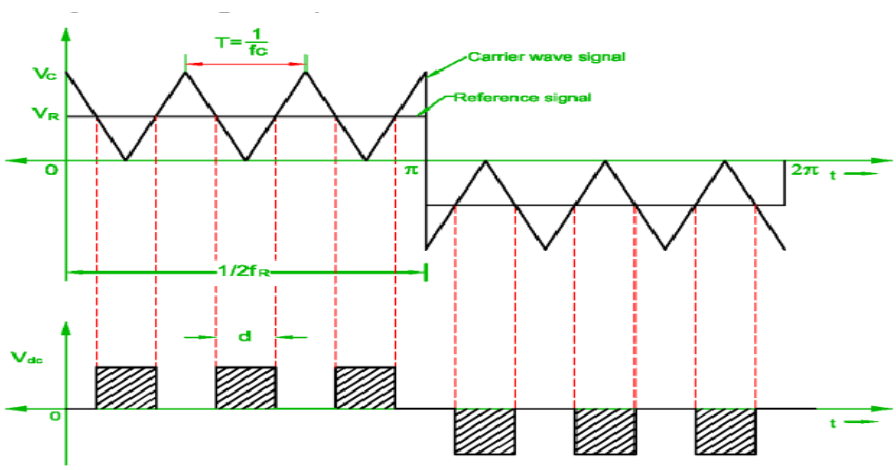
Ans: In this method, one pulse per half cycle is used. The pulse width is varied to control output. Main disadvantage is high harmonic content.



32. What is multiple-pulse width modulation? List its advantages and disadvantages.

Ans: Multiple pulses are used per half cycle with equal spacing.

- **Advantages:** Better voltage control and harmonic reduction
- **Disadvantages:** Increased switching losses, requires high-grade thyristors



33. What is sinusoidal-pulse width modulation?

Ans: Similar to multiple PWM, but the pulse width varies sinusoidally based on the amplitude of a sine wave. This technique results in better harmonic performance.

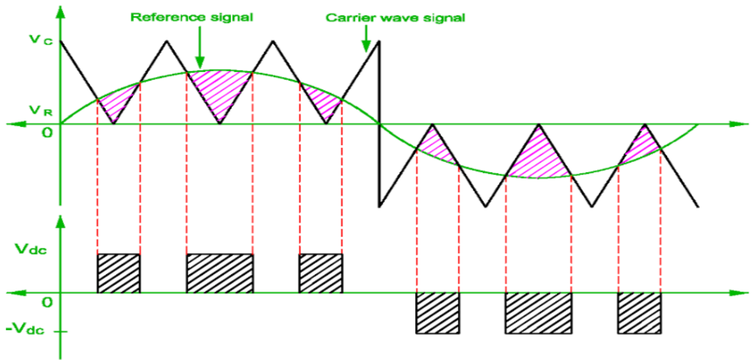


FIG K : SINUSOIDAL PULSE WIDTH MODULATION

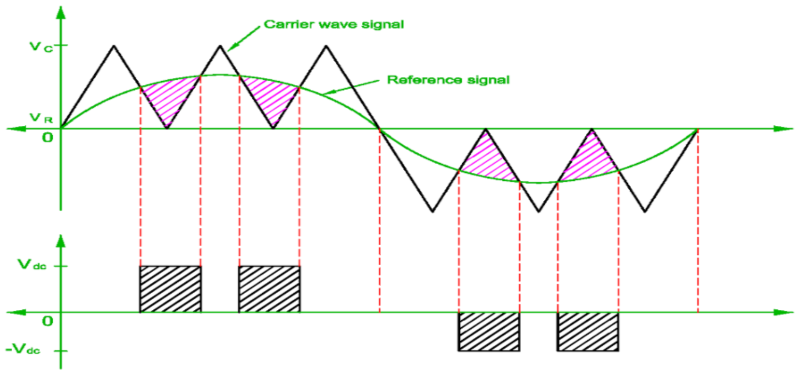


FIG L : SINUSOIDAL PULSE WIDTH MODULATION

SECTION 6: APPLICATION BASED QUESTIONS

34. Why are phase-controlled rectifiers preferred for DC motor speed control?
Ans:
They allow smooth and precise control of the output DC voltage by varying the firing angle of thyristors. Since a DC motor's speed is directly proportional to the supply voltage, adjusting the firing angle enables variable speed control, which is critical in applications like conveyor belts, elevators, and rolling mills.

35. How are phase-controlled rectifiers used in battery charging applications?
Ans:
They provide adjustable DC voltage and current through phase angle control. This helps maintain proper charging profiles (constant current or constant voltage) and prevents overcharging or overheating, especially in industrial or large-scale battery charging systems.

36. What advantage do phase-controlled rectifiers offer in electric traction systems?
Ans:
In traction systems like electric trains or trams, phase-controlled rectifiers enable both forward and reverse power flow and precise control over motor torque and speed. Full converters also allow regenerative braking, improving energy efficiency.

37. Why are phase-controlled rectifiers suitable for electroplating and other electrochemical processes?
Ans:
Electrochemical processes require tightly controlled DC supply. Phase-controlled rectifiers enable precise adjustment of current and voltage, ensuring consistent deposition rates and quality, which is essential in electroplating, anodizing, and electrorefining industries.

38. How do phase-controlled rectifiers contribute to energy savings in heating applications?
Ans:
In resistive heating systems (like furnaces or ovens), instead of ON/OFF switching, phase-controlled rectifiers can regulate power smoothly by adjusting the firing angle. This minimizes power wastage and provides better temperature control.

39. What is the role of a freewheeling diode in phase-controlled rectifier-fed DC motors?
Ans:
A freewheeling diode provides a path for the motor's inductive current when the thyristors turn off. This maintains continuous current flow, avoids voltage spikes, and ensures smoother motor torque and better performance.

40. How are phase-controlled rectifiers applied in HVDC transmission systems?
Ans:
They convert AC to DC at the sending end of HVDC systems and allow controllable power flow. By adjusting the firing angle, the amount of transmitted power and the reactive power drawn from the AC system can be regulated efficiently.

41. Why are full-controlled rectifiers used in regenerative braking systems?
Ans:
Full-controlled rectifiers can operate in both rectification and inversion modes. In regenerative braking, the motor feeds power back to the AC supply, and the converter acts as an inverter, allowing energy recovery and improved efficiency.