Tagore Engineering College

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Department of Electrical and Electronics Engineering

M.E - Power Electronics and Drives

PX 7103 – Analysis and Design of inverters

I Sem / I year

Question Panel

TAGORE ENGINEERING COLLEGE

Department of Electrical and Electronics

M.E Power Electronics and Drives

SHORT QUESTIONS AND ANSWERS
PX 7103-Analysis of Inverters

UNIT-I

SINGLE PHASE INVERTERS

1. **What is meant by inverter?**
   A device that converts dc power into ac power at desired output voltage and frequency is called an inverter.

2. **What are the applications of an inverter?**
   a. **Adjustable speed drives**
   b. **Induction heating**
   c. **Stand-by aircraft power supplies**
   d. **UPS**
   e. **HVDC transmission**

3. **Why IGBT is very popular nowadays?**
   a. **Lower hate requirements**
   b. **Lower switching losses**
   c. **Smaller snubber circuit requirements**

4. **IGBT is a voltage controlled device. Why?**
   Because the controlling parameter is gate-emitter voltage.

5. **Power MOSFET is a voltage controlled device. Why?**
   Because the output (drain) current can be controlled by gate-source voltage.

6. **What are the different types of power MOSFET?**
   a. **N-channel MOSFET**
   b. **P-channel MOSFET**

7. **How we can get variable output voltage?**
   A variable output voltage can be obtained by varying the input D.C voltage and maintaining the gain of the inverter constant.

8. **Define inverter gain?**
   The inverter gain may be defined as the ratio of the A.C output voltage to D.C input voltage.

9. **What is the main drawback of single phase half bridge Inverter?**
   It requires a 3-wire dc supply.

10. Define Harmonic Factor?

The harmonic factor is a measure of individual harmonic contribution and is given by,

$$HFn=Vn/V1$$

Where V1 is the rms value of the fundamental component and Vn is the rms value of the nth harmonic component.

11. Define Total Harmonic Distortion?

The total harmonic distortion is a measure of closeness in shape between a waveform and its fundamental component.

12. Define Distortion Factor?

DF is a measure of effectiveness in reducing unwanted harmonics without having to specify the values of a second –order load filter.

13. Define Lowest Order Harmonic?

The lowest-order harmonic is that harmonic component whose frequency is closest to the fundamental one, and its amplitude is greater than or equal to 3% of the fundamental component.

14. What is the need to control the output voltage of an Inverter?

The need is,

a) **to cope with the variations of D.C input voltage**
b) **for voltage regulation of inverters**
c) **For the constant volts/frequency control requirement.**

15. What are the methods of voltage control of a single phase Inverter?

a) **Single Pulse Width Modulation**
b) **Multiple Pulse Width Modulation**
c) **Sinusoidal Pulse Width Modulation**
d) **Modified Sinusoidal Pulse Width Modulation**
e) **Phase Displacement control**

16. What is Single Pulse Width Modulation?

In Single Pulse Width Modulation control, there is only one pulse per half cycle and the width of the pulse is varied to control the inverter output voltage.

17. Define Amplitude Modulation Index?

The ratio of Ar to Ac is the control variable and defined as the Amplitude Modulation index and is given as,

$$M=Ar/Ac$$

18. What is Multiple Pulse Width Modulation?

Here the harmonic content can be reduced by using several pulses in each half cycle of output voltage. By this method the distortion factor is reduced significantly compared to that of single pulse modulation.

19. What is Sinusoidal Pulse Width Modulation?

In the case of multiple pulse modulations the width of all the pulses are same but in Sinusoidal Pulse Width Modulation the width of each pulse is varied in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The distortion factor and lower order harmonics are reduced significantly.

20. What is Phase Displacement control?

In this method the voltage control can be obtained by using multiple inverters and summing the output voltages of individual inverters. This type of control is especially used for high power applications, requiring a large number of transistors in parallel.

21. What are the various Harmonic Elimination Techniques?

a) **Harmonic reduction by PWM**
b) **Harmonic reduction by Transformer connections**
c) **Harmonic reduction by stepped wave Inverter.**

22. How is the inverter circuit classified based on commutation circuitry?

i. **Line commutated inverters.**
ii. **Load commutated inverters.**
iii. **Self commutated inverters.**
iv. **Forced commutated inverters.**

23. What are the various types of commutation circuit used in inverter?

a) **Auxiliary commutated inverters**
b) **complementary commutated inverters**

24. What is McMurray Inverter?

It is an impulse commutated inverter which relies on LC circuit and an auxiliary thyristor for commutation in the load circuit. Here two thyristors share a common commutation circuit. It is also called as Auxiliary commutated inverter.

25. What is McMurray-Bedford Inverter?

If two inductors are tightly coupled, firing of one thyristor turns off another thyristor in the same arm. This type of commutation is known as complementary commutation. The circuit is also known as McMurray-Bedford Inverter

UNIT-II

THREE PHASE VOLTAGE SOURCE INVERTERS

1. **Give the basic classification of Inverters?**

   Basically Inverters are classified as,

   a) **Single phase inverter**
   b) **Three phase inverter**

   Further they are classified as,

   a)Voltage Source Inverter
   b)Current Source Inverter

2. **How a three phase inverter can be obtained from a single phase inverter?**

   Three single phase inverters can be connected in parallel to form the configuration of a three phase inverter. The gating signals of single phase inverters should be advanced or delayed by 120 degree with respect to each other in order to obtain three phase balanced voltages.

3. **Why the transformer secondary is normally connected in wye?**

   The transformer secondary is normally connected in wye to eliminate triplen harmonics (n= 3, 6, 9 …) appearing on the output voltages.

4. **What are the drawbacks of three phase inverter obtained from a single phase inverter?**

   - **It requires three single phase transformers, 12 transistors, and 12 diodes.**
   - **If the output voltages of single phase inverters are not perfectly balanced in magnitudes and phases, the three phase output voltages will be unbalanced.**

5. **What are the two types of control signals applied to the transistor?**

   The two types of control signals applied to the transistors are,

   a) **180 degree conduction**
   b) **120 degree conduction**

6. **What is 180 degree conduction?**

   In 180 degree conduction, three transistors remain on at any instant of time and each transistor conducts for 180 degree. There are six modes of operation in a cycle and the duration of each mode is 60 degree.

7. **What is 120 degree conduction?**

   In 120 degree conduction, only two transistors remain on at any instant of time and each transistor conducts for 120 degree. There are three modes of operation in one half cycles.

8. **Give the gating sequence for 180 degree and 120 degree conduction?**

   The gating sequence for 180 degree conduction is 123, 234, 345, 456, 561, and 612.

   The gating sequence for 120 degree conduction is 61, 12, 23, 34, 45, 56, and 61.

9. Why 180 degree conduction is more effective than 120 degree conduction?

180 degree conduction is more effective than 120 degree conduction because in 120 degree conduction, one transistor conducts for 120 degree so the transistors are less utilized as compared to that of 180 degree conduction for the same load condition.

10. Give the voltage and current relation for star and delta connection?

For star connection,

$$V_L = \sqrt{3} V_{ph}$$

$$I_L = I_{ph}$$

For delta connection,

$$V_L = V_{ph}$$

$$I_L = \sqrt{3} V_{ph}$$

11. Compare 180 degree and 120 degree modes of conduction?

S.No	180 degree conduction	120 degree conduction
1.	Each device conduct for 180 degree	Each device conduct for 120 degree
2.	Three devices conduct in one interval	Two devices conduct in one interval
3.	Cross conduction is possible	Cross conduction is not possible
4.	Devices are better utilized	Devices are under utilized
5.	Output power is higher because of higher voltage levels	Output power is less because of lower voltage levels

12. What are the methods of voltage control of a three phase Inverter?

a. **Single Pulse Width Modulation**
b. **Multiple Pulse Width Modulation**
c. **Sinusoidal Pulse Width Modulation**
d. **Modified Sinusoidal Pulse Width Modulation**
e. **Phase Displacement control**

13. What is meant by PWM control?

In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as PWM control.

14. What are the advantages of PWM control?

a. **The output voltage can be obtained without any additional components.**
b. **Lower order harmonics can be eliminated or minimized along with its output voltage control. As the higher order harmonics can be filtered easily, the filtering requirements are minimized.**

15. What are the methods of voltage control of a three phase Inverter with improved performance?

i)Trapezoidal Modulation
ii) Staircase Modulation
iii) Stepped Modulation
iv) Harmonic Injection Modulation
v) Delta Modulation

16. What is meant by Trapezoidal Modulation?

The gating signals are generated by comparing a triangular carrier wave with a modulating trapezoidal wave.

17. Define triangular factor?

The trapezoidal wave can be obtained from a triangular wave by limiting its magnitude to + or – Ar which is related to the peak value Ar(max) by,

$$Ar=\sigma.Ar(max)$$

Where σ is called the triangular factor.

18. Give the relation between Triangular factor and Modulation Index?

$$M=Ar/Ac= [\sigma.Ar(max)]/Ac$$

Where,

Ar- Amplitude of reference signal
Ac- Amplitude of carrier signal
σ - triangular factor

19. Write the merits and demerits of stepped Modulation?

The stepped wave is not a sampled approximation to the sine wave. It is divided in to specify intervals say 20 degree with each interval being controlled individually to control the magnitude of the fundamental component and to eliminate specific harmonics. This type of control gives low distortion, but higher fundamental amplitude compared to that of normal PWM control.

20. What is meant by hysteresis Modulation?

In this type of modulation, a triangular wave is allowed to oscillate within a defined window Δv above and below the reference sine wave Vr. The inverter switching function, which is identical to the output voltage Vo is generated from the vertices of the triangular wave Vc. This is called as delta modulation or Hysteresis modulation.

21. Which type of voltage control can be used for motor control and why?

The delta modulation can control the ratio of voltage to frequency which is a desirable feature in A.C motor control.

22. What is the need for Harmonic Elimination Technique?

The Harmonic Elimination Techniques which are suitable only for fixed output, voltage increase the order of harmonics and reduce the sizes of output filter.

23. What are the various Harmonic Elimination Techniques?

a. Harmonic reduction by PWM

b. Harmonic reduction by Transformer connections

c. Harmonic reduction by stepped wave Inverter.

24. Define Harmonic Injected Modulation?

Here the modulating signal is generated by injecting selected harmonics to the sine wave. This type of modulation reduces the amount of over modulation. It also provides a higher fundamental amplitude and low distortion of the output voltage.

25. Write the merits and demerits of staircase Modulation?

This is an optimized PWM technique and is not recommended for fewer than 15 pulses in one cycle. Also this type of control provides a high quality output voltage with a fundamental value of up to 0.94Vs.

UNIT-III
CURRENT SOURCE INVERTERS

1. What is meant by commutation?

It is the process of changing the direction of current flow in a particular path of the circuit. This process is used in thyristors for turning it off.

2. What are the types of commutation?

a. **Natural commutation**
b. **Forced commutation**

3. What is meant by natural commutation?

Here the current flowing through the thyristor goes through a natural zero and enable the thyristor to turn off.

4. What is meant by forced commutation?

In this commutation, the current flowing through the thyristor is forced to become zero by external circuitry.

5. What is meant by voltage commutation?

In this process, a charged capacitor momentarily reverse biases the conducting thyristor and turn it off.

6. What is meant by current commutation?

In this process, a current pulse is made to flow in the reverse direction through the conducting thyristor and when the net thyristor current becomes zero, it is turned off.

7. What is meant by load commutation?

In this process, the load current flowing through the thyristor either becomes zero or is transferred to another device from the conducting thyristor.

8. What is meant by inverter?

A device that converts dc power into ac power at desired output voltage and frequency is called an inverter.

9. What are the applications of an inverter?

a. **Adjustable speed drives**
b. **Induction heating**
c. **Stand-by aircraft power supplies**
d. **UPS**
e. **HVDC transmission**

10. What are the main classifications of inverter?

a. **Voltage Source Inverter**
b. **Current Source Inverter**

11. What is meant a series inverter?

An inverter in which the commutating elements are connected in series with the load is called a series inverter.

12. What is meant a parallel inverter?

An inverter in which the commutating elements are connected in parallel with the load is called a parallel inverter.

13. How is the inverter circuit classified based on commutation circuitry?

a. **Line commutated inverters.**
b. **Load commutated inverters.**
c. **Self commutated inverters.**
d. **Forced commutated inverters.**

14. What is meant by McMurray inverter?

It is an impulse commutated inverter which relies on LC circuit and an auxiliary thyristor for commutation in the load circuit.

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In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as PWM control.

16. What are the advantages of PWM control?

a. **The output voltage can be obtained without any additional components.**
b. **Lower order harmonics can be eliminated or minimized along with its output voltage control. As the higher order harmonics can be filtered easily, the filtering requirements are minimized.**

17. Why thyristors are not preferred for inverters?

Thyristors require extra commutation circuits for turn off which results in increased complexity of the circuit. For these reasons thyristors are not preferred for inverters.

18. How output frequency is varied in case of a thyristor?

The output frequency is varied by varying the turn off time of the thyristors in the inverter circuit, i.e. the delay angle of the thyristors is varied.

19. Give two advantages of CSI.

a. **CSI does not require any feedback diodes.**
b. **Commutation circuit is simple as it involves only thyristors.**

20. Why diodes should be connected in antiparallel with the thyristors in inverter circuits?

For RL loads, load current will not be in phase with load voltage and the diodes connected in antiparallel will allow the current to flow when the main thyristors are turned off. These diodes are called feedback diodes.

21. What is meant a series inverter?

An inverter in which the commutating elements are connected in series with the load is called a series inverter.

22. What is meant a parallel inverter?

An inverter in which the commutating elements are connected in parallel with the load is called a parallel inverter.

23. What are the applications of a series inverter?

It is commonly used for fixed output applications such as,

a. **Ultrasonic generator.**
b. **Induction heating.**
c. **Sonar Transmitter**
d. **Fluorescent lighting.**

24. What are the applications of a CSI?

a. **Induction heating**
b. **Lagging VAR compensation**
c. **Speed control of ac motors**
d. **Synchronous motor starting.**

25. Compare CSI and VSI.

S. No.	VSI	CSI
1.	Input voltage is maintained constant	Input current is constant but adjustable
2.	The output voltage does not depend on the load	The output current does not depend on the load
3.	The magnitude of the output current and its waveform depends on the nature of the load impedance	The magnitude of the output voltage and its waveform depends on the nature of the load impedance
4.	It requires feedback diodes	It does not requires feedback diodes
5.	Commutation circuit is complicated i.e. it contains capacitors and inductors.	Commutation circuit is simple i.e. it contains only capacitors.

UNIT-IV
MULTILEVEL INVERTERS

1. **What is meant by two level inverter?**

   The voltage source inverters produce an output voltage or current with levels either zero or +/- Vdc. They are known as two level inverter.

2. **What are the drawbacks of two level inverter?**

   To obtain a quality output voltage or a current waveform with a minimum amount of ripple content, they require high switching frequency along with various PWM methods. In high power and high voltage applications these two level inverters, however have some limitations in operating at high frequency mainly due to switching losses and constraints of device ratings.

3. **What is multilevel Inverter?**

   Increasing the number of voltage levels in the inverter without requiring higher ratings on individual devices can increase the power ratings. The unique structure of multilevel voltage source inverters allows them to reach high voltages with low harmonics without the use of transformers or series connected synchronized switching devices.

4. **Which constitute the energy tank for the inverter and why?**

   Series connected capacitors constitute the energy tank for the inverter providing some nodes to which the multilevel inverter can be connected. Each capacitor has the same voltage Em and is given by,

   $$Em = Vdc/(m-1)$$

5. **How many capacitors are needed for an m-level inverter?**

   An m-level inverter needs (m-1) capacitors.

6. **Define output phase voltage?**

   Output phase voltage can be defined as voltages across output terminals of the inverter and the ground point denoted by O.

7. **What are the conditions needed for the structure of multilevel inverter?**

   The topological structure of multilevel inverter must

   i) **have less switching devices as far as possible**
   ii) **be capable of withstanding very high input voltage for high power applications**
   iii) **have lower switching frequency for each switching device**

8. **Write the features of multilevel inverter?**

   The features of multilevel inverters are,

   i) **The output voltage and power increase with number of levels**
   ii) **The harmonic content decreases as the number of levels increases and filtering requirements are reduced**
   iii) **In the absence of any PWM techniques, the switching losses can be avoided.**

9. What are the advantages of multilevel inverter?

The advantages are,

- **i) They are suitable for high voltage and high current applications**
- **ii) They have higher efficiency because the devices can be switched at a low frequency**
- **iii) Power factor is close to unity**
- **iv) No EMI problem exists**

10. Give the classification of multilevel inverter?

The multilevel inverters can be classified in to three types,

- **i) Diode-clamped multilevel inverter**
- **ii) Flying-capacitors multilevel inverter**
- **iii) Cascade multilevel inverter**

11. What is Diode-Clamped multilevel inverter?

A Diode-clamped multilevel (m-level) inverter typically consist of (m-1) capacitors on the DC bus and produces m levels on the phase voltage.

12. What are the devices required for an m-level inverter in Diode-Clamped Multilevel inverter?

An m-level inverter leg requires (m-1) capacitors, 2(m-1) switching devices and (m-1)(m-2) clamping diodes.

13. What are the features of diode-Clamped Multilevel inverter?

The main features are,

- **i) High voltage rating for blocking diodes**
- **ii) Unequal switching device rating**
- **iii) Capacitor voltage unbalance**

14. What are the advantages of diode-Clamped Multilevel inverter?

The advantages of diode-Clamped Multilevel inverter are,

- **i) When the number of levels is high enough, the harmonic content is low enough to avoid the need for filters.**
- **ii) Inverter efficiency is high because all devices are switched at the fundamental frequency.**
- **iii) The control method is simple.**

15. What are the disadvantages of diode-Clamped Multilevel inverter?

The major disadvantages of diode-Clamped Multilevel inverters are,

- **i) Excessive clamping diodes are required when the number of levels is high**
- **ii) It is difficult to control the real power flow of the individual converter in multi-converter systems.**

16. What are the rules governing the switching of an m-level inverter?

The following rules govern the switching of an m-level inverter,

- **i) At any moment, there must be (m-1) neighboring switches that are on**
- **ii) For each two neighboring switches, the outer switch can only be turned on when the inner switch is on**

iii) **For each two neighboring switches, the inner switch can only be turned off when the outer switch is off.**

17. Write the features of Flying-Capacitors Multilevel Inverter?

The main features of Flying-Capacitors Multilevel Inverters are,

i) **Large number of capacitors**
ii) **Balancing capacitor voltages**

18. What are the advantages of Flying-Capacitors Multilevel Inverter?

The advantages of Flying-Capacitors Multilevel Inverters are,

i) **Large amounts of storage capacitors can provide capabilities during power outages.**
ii) **These inverters provide switch combination redundancy for balancing different voltage levels.**
iii) **Like the diode-clamp inverter with more levels, the harmonic content is low enough to avoid the need for filters.**
iv) **Both real and reactive power flow can be controlled.**

19. What are the disadvantages of Flying-Capacitors Multilevel Inverter?

The disadvantages of Flying-Capacitors Multilevel Inverters are

i) **An excessive number of storage capacitors is required when the number of levels is high. High level inverters are more difficult to package with the bulky power capacitors and are more expensive too.**
ii) **The inverter control can be very complicated and the switching frequency and switching losses are high for real power transmission.**

20. What is cascaded multilevel inverter?

A cascade multilevel inverter consist of a series of H-Bridge inverter units. The general function of this multilevel inverter is to synthesize desired voltage from several separate DC sources, which may be obtained from batteries, fuel cells or Solar cells.

21. What are the features of Cascaded Multilevel inverter?

The features of Cascaded Multilevel inverters are,

i) **For real power conversions from AC to DC and then DC to AC, the cascaded inverters need separate DC sources.**
ii) **Connecting DC sources between two converters in a back to back fashion is not possible because a short circuit can be introduced when two back to back converters are not switching synchronously.**

22. What are the advantages of Cascaded Multilevel inverter?

The advantages of Cascaded Multilevel inverters are,

i) **Compared with the Diode-clamped and Flying-capacitor inverter, it requires the least number of components to achieve the same number of voltage levels.**
ii) **Optimized circuit layout and packaging are possible because each level has the same structure and there are no extra clamping diodes or voltage balancing capacitors.**

23. What are the disadvantages of Cascaded Multilevel inverter?

The disadvantage of Cascaded Multilevel inverter is, it needs separate DC sources for real power conversions, thereby limiting its applications.

24. Give the applications of Multilevel Converter?

The most common applications of multilevel converter include,

i) Reactive power compensation

ii) Back-to-back intertie

iii) Variable speed drives

25. Define SVG?

When a multilevel converter draws pure reactive power, the phase voltage and current are 90 degree apart, and the capacitor charge and discharge can be balanced. Such a converter, when serving for reactive power compensation, is called a Static-VAR Generator (SVG).

UNIT-V
RESONANT INVERTERS

1. **What is the need for resonant pulse inverter?**

   The switching devices in converters with a PWM control can be gated to synthesize the desired shape of the output voltage or current. But at high switching frequency, the switches are subjected to a high voltage stress, and the switching power loss also increases. The disadvantages of PWM control can be eliminated by using resonant pulse inverter.

2. **Define resonant pulse inverter?**

   If the switching devices are turned on and off when the voltage across a device or its current becomes zero.i.e. The voltage and current are forced to pass through zero crossing by creating an LC-resonant circuit is called as resonant pulse inverter.

3. **What are the classifications of resonant pulse inverter?**
   - **i) Series-resonant inverter**
   - **ii) Parallel-resonant inverter**
   - **iii) Class E resonant converter**
   - **iv) Class E resonant rectifier**
   - **v) Zero voltage switching(ZVS) resonant converters**
   - **vi) Zero current switching(ZCS) resonant converters**
   - **vii) Two-quadrant ZVS resonant converters**
   - **viii) Resonant DC-link inverters**

4. **What is series resonant inverter?**

   The resonating components and switching device are placed in series with the load to form an under-damped circuit. The current through the switching devices falls to zero due to the natural characteristics of the circuit.

5. **Give the applications of series resonant inverter?**
   - **i) Induction Heating**
   - **ii) Sonar transmitter**
   - **iii) Fluorescent Lighting**
   - **iv) Ultrasonic generators**

6. **What is the necessary condition for series resonant oscillation?**

   The series resonant circuit formed by L,C and load must be under damped. That is,

   $$R^2 < (4L/C)$$

7. **What is the dead zone of a resonant inverter?**

   The load current must be zero and T1 must be turned off before T2 is fired. Otherwise a short circuit condition results through the thyristors and DC supply. Therefore the available off time known as the dead zone must be greater than the turn-off time of thyristors.

8. Write the basic classification of series resonant inverter?

The series inverter may be classified in to two categories:

i) Series resonant inverters with unidirectional switches

ii) Series resonant inverters with bidirectional switches

9. What are the drawbacks of resonant inverter with unidirectional switches?

For the resonant inverter with unidirectional switches, the power devices have to be turned on in every half cycle of output voltage. This limits the inverter frequency and the amount of energy transfer from the source to the load. In addition the devices are subjected to high peak reverse voltage.

10. How we can overcome the drawback of resonant inverter with unidirectional switches?

The drawbacks of resonant inverter with unidirectional switches can be overcome by connecting an antiparallel diode across a device.

11. Why reverse conducting thyristor (RCT) is preferred for series resonant inverter?

In a resonant inverter, the diode should be connected as close as possible to the thyristor and the connecting leads should be minimum to reduce any stray inductance in the loop formed by T1 and D1. Because any inductance in the diode path would reduce the net reverse voltage across the terminals of T1, and T1 may not turn off. So a reverse conducting thyristor (RCT) is normally used.

12. What are the two modes of operation in a resonant inverter with bidirectional switches?

The inverter can be operated in two different modes,

i) Non overlapping

ii) Overlapping

13. What is overlapping mode?

In an overlapping mode, a device is fired, while the current in the diode of the other part is still conducting. Although overlapping operation increases the output frequency, the output power is increased.

14. What is non-overlapping mode?

In a non overlapping mode, the firing of a transistor device is delayed until the last current oscillation through a diode has been completed.

15. Define parallel resonant inverters?

A parallel resonant inverter is the dual of a series resonant inverter. It is supplied from a current source so that the circuit offers high impedance to the switching current.

16. What is the need to control the output voltage of an Inverter?

The need is, to cope with the variations of D.C input voltage, for voltage regulation of inverters, for the constant volts/frequency control requirement.

17. How we can control the voltage of resonant inverter?

The quasi-resonant inverter (QRI) is normally used for output voltage control. QRI can be considered as a hybrid of resonant and PWM converters. The switch current or voltage waveforms are forced to oscillate in a quasi-sinusoidal manner.

18. Why diodes should be connected in antiparallel with the thyristors in inverter circuits?

For RL loads, load current will not be in phase with load voltage and the diodes connected in antiparallel will allow the current to flow when the main thyristors are turned off. These diodes are called feedback diodes.

19. Define class E resonant inverter?.

A class E resonant inverter uses only one transistor and has low-switching losses, yielding a high efficiency of more than 95%. It is normally used for low power applications requiring less than 100 W, particularly in high frequency electronic lamp ballasts.

20. Define ZVS resonant converter?

The switches of a zero-voltage-switching (ZVS) resonant converter turn on and off at zero voltage. The capacitor C is connected in parallel with the switch S1 to achieve ZVS.

21. Define ZCS resonant Converter?

The switches of a zero-current-switching (ZCS) resonant converter turn on and off at zero current. The inductor L is connected in series with a power switch S1 to achieve ZCS.

22. Compare ZVS and ZCS?

ZCS- It can eliminate the switching losses at turn off and reduce the switching losses at turn on. The capacitive turn on loss is proportional to the switching frequency. This also increases the switching loss and noise. Another limitation is that the switches are under high current stress, resulting in higher conduction loss.

ZVS- It eliminates the capacitive turn on loss. It is suitable for high frequency operation. Without any voltage clamping, the switches are subjected to excessive voltage stresses, which is proportional to the load.

23. What is resonant DC-link inverter?

In resonant DC-link inverter, a resonant circuit is connected between the DC input voltage and the PWM inverter, so that the input voltage to the inverter oscillates between zero and a value slightly greater than twice the DC input voltage.

24. What is the need for active clamp inverter?

The DC-link resonant cycle is normally started with a fixed value of initial capacitor current. This causes the voltage across the resonant DC link to exceed 2Vs, and all the inverter devices are subjected to this high voltage stress.

25. Give the relation between clamp factor, tank period and resonant frequency?

The clamp factor k is related to the tank period T_k and resonant frequency Wo by,

TkWo = 2[cos-1(1-k)+√k(2-k)/(k-1)]

TAGORE ENGINEERING COLLEGE

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

M.E POWER ELECTRONICS AND DRIVES

I SEM / I YEAR

UNIT 1 QUESTION BANK

PART A

1. Mention two applications of inverters?

2. Why is IGBT Preferred for inverters?

3. Write the difference methods for control the output of output voltage in inverters.

4. What is meant by complementary commutation?

5. Compare half bridge and Full bridge inverters.

6. What are the types of voltage control methods in inverters?

7. What is the ratio between third harmonics content to the fundamental in the line voltage of three phase voltage source inverters?

8. Mention the advantage of Space vector Modulation?

9. Compare MOSFET and IGBT.

10. Enumerate the advantages possessed by PWM techniques.

11. Define inverter Gain?

12. Define VFI from CFI?

13. Define Switching characteristics of an IGBT?

14. Mention the Methods available for the voltage control of inverters?

15. What is Sinusoidal PWM?

16. What is Single Pulse Width PWM?

17. State Advantages of IGBT over MOSFET?

18. What should be the pulse width for the elimination of 3rd Harmonics in the output voltage Waveform of single phase inverter?

19. What are the Methods used to control the output voltage in a three phase inverters?

20. Write down the equation giving the design values of commutating components of a modified MC Murray Inverter?

PART B

1. The single phase half bridge inverter has a resistive load of $R = 2.4\Omega$ and the dc inout voltage is $V_s = 48V$.Determine
   I. RMS O/P Voltage at the fundamental frequency.
   II. The output Power.
   III. Average and Peak currents of each transistor.
   IV. The peak reverse blocking voltage of each transistor. Derive expression used. **(16)**
2. Explain Modified MC Murray Half Bridge Inverter With Necessary Circuit and Waveforms. **(16)**
3. A single phase Full bridge inverter may be connected to a load consisting of
   - R
   - RL
   - RLC Under damped
   - RLC Over damped

   For all these loads, Draw the load voltage and load current Waveform under the steady state operating condition. Discuss the nature of these waveforms. Also indicate the conduction of the various elements of the inverter circuit. Is it Possible for this inverter to have load commutation? **(16)**
4. A single phase full bridge inverter is connected to the dc source of V_s. Resolve the output voltage into Fourier series. **(8)**

5. A single phase full bridge inverter delivers power to a RLC load with $R = 3\Omega$ and $X_L = 12\Omega$.The Bridge Operates with a periodicity of 0.2ms. Calculate the value of C so that load commutation is achieved for the thyristor. Turn off time is $12\mu s$.Factor is 2.Assume the load current to contain only the fundamental component. **(8)**
6. Discuss the various Performance Parameters for practical inverter circuits. **(8)**
7. What is the Sinusoidal PWM? Explain With required Waveforms and discuss the effects of over modulation. **(8)**
8. Explain the Circuits and Waveform, the difference techniques available for reduction of harmonics in the inverter output voltage. **(16)**
9. Explain voltage control of Single phase inverter by Symmetrical multiple pulse Modulation PWM techniques. **(10)**
10. A single phase full bridge inverter supplies a RL load ($R = 10\Omega$, $L = 10mh$). The supply voltage is 100v .Find the power given to the load and the average supply current. Sketch the Waveforms. **(6)**
11. What is unipolar pulse width Modulation? Explain how this technique is used in the single phase full bridge inverters. Also discuss about the harmonic spectrum of the load voltage. **(16)**
12. Derive the performance parameters of single phase full bridge inverter. **(16)**
13. Explain Various Harmonics Elimination methods in single phase inverter. **(16)**

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

M.E – POWER ELECTRONICS AND DRIVES

PX – 7103 ANALYSIS AND DESIGN OF INVERTERS
UNIT II

QUESTION BANK

1. What is the ratio between third harmonic content to the fundamental in the line voltage of three phase voltage source inverters?
2. Mention the advantages of Space vector modulation?
3. What is the different method for control of output voltage in inverters?
4. What is meant by Complementary Commutation?
5. What is Sinusoidal PWM?
6. What is Single phase PWM?
7. Define Voltage Gain.
8. What are the methods used to control the output voltage in a three phase inverter?
9. Compare 120 degree mode with 180 degree operation of a three phase inverter.
10. What is Modulation Index?

PART B

1. Explain the working principle of space vector Modulation three phase inverter with necessary Waveform and circuits.
2. A 3 phase inverters delivers powers to a resistive load from a 450 V dc source. For a star connected load of 10 ohm /phase. Determine for both 180 degree an 120 degree mode of operation.
    a. RMS value of load current.
    b. RMS value of Thyristor current.
    c. Load power
3. Discuss the principle of working of a three phase voltage source inverter. Draw a phase and line voltage waveform on the assumptions that each thyristor conducts for 120 degree and the resistive load is delta connected. Derive expression for Rms value of line voltage phase voltage and fundamental phase voltage.
4. Explain in detail the space vector modulation for voltage control of three phase inverter. Draw the constriction of inverter space vector, space vector of 3 phase bridge inverter

showing reference voltage trajectory voltage vectors and corresponding reference phase voltage wave. Tabulate the summary of inverter switching state and also plot the construction of symmetrical pulse pattern for three phases.

5. Discuss the principle of working of a three phase voltage source inverter. Draw phase voltage and line voltage waveform on the assumptions that each thyristor conducts for 180 degree and the resistive load is star connected. Derive the expression for Rms value of line voltage phase voltage and fundamental phase voltage.
6. Explain in details the space vector modulation technique for three phase inverter. Draw the relevant diagrams. Discuss the design consideration for sinusoidal waveform.
7. With a neat circuit diagram and waveform explain the working of 180 degree conduction mode operation of three phase inverter with delta connected load.
8. Discuss the principle of working of a three phase voltage source inverter. Draw a phase and line voltage waveform on the assumptions that each thyristor conducts for 120 degree and the resistive load is star connected. Derive expression for Rms value of line voltage phase voltage and fundamental phase voltage.

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M.E POWER ELECTRONICS AND DRIVES

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UNIT III QUESTION BANK

PART A

1. Why is converter grade SCRs is used in CSI?
2. Draw the equivalent circuit of single Phase ASCI for any one half cycle.
3. Mention the need for L filter before CSI.
4. Feedback diodes are not required for CSI. Why?
5. List two applications of current source inverter.
6. Describe Current Pulsations.
7. Compare VSI and CSI.
8. Draw the block diagram of three phase CSI system with AC input.
9. Write relation between input and output voltage frequencies of a single phase capacitor commutated Current Source Inverter.
10. What is the function of series connected diodes in an ASCI?

PART B

1. A single phase ASCI feed a resistive load. Describe its working with the appropriate circuit and waveforms. Find also the circuit turn off time for the thyristor.
2. In a Single phase ASCI with a inductive load SCRs T3, T4 are conducting a constant current =10A. If T1 and T2 are turned on at t=0 to force commute T3, T4; find the time required for the load current to fall zero. Lad L=10mh and Commutating capacitance C=6mh. Find also the total commutation interval and the circuit turn off time for each of the SCRs.
3. Draw the power circuit diagram of single phase capacitor commutated current source inverter with R load. Explain its analysis in detail. Derive the expression for output voltage, current and average value of input voltage. Also describe the design considerations.

4. A single phase auto sequential commutated current source inverter feeds an R load. Describe its working with appropriate circuit and waveforms. Also find the circuit turn off time for the thyristor.
5. With Circuit diagram and waveform. Explain the operation of single phase capacitor commutated current source inverter with R load. Discuss the design consideration for sinusoidal wave output.
6. Describe a single phase ASCI with L load .Write appropriate expression governing its performance and prove that the total circuit turn off time for this inverter is given by

$$t_c = (1+\frac{\pi}{2})\sqrt{LC}$$

   Sketch the waveform for gating signals, Capacitor voltage and current and load current. Find also the circuit turn off time for thyristor.
7. Explain the working of a single phase CSI supplying a R load.
8. Explain the working of three phase ASCI.
9. With neat sketch, explain the working principle of single phase Capacitor Commutated CSI.
10. Explain the 6 step CSI operation with L load.

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UNIT 4 QUESTION BANK

PART A

1. Give the Different type of Multi level inverters?
2. Mention the applications of Multi level inverter?
3. How selective harmonics elimination is achieved in multilevel inverters?
4. What is the main disadvantage of diode clamped multilevel inverters?
5. List the merits and demerits of cascaded H bridge multilevel inverters.
6. What is a flying capacitor?
7. What is the main feature of the cascaded multilevel inverter?
8. Compare various types of multilevel inverter
9. In a M level diode clamped inverter how many main switching devices and clamping diodes are present?
10. Mention the possible applications of multi-level inverter.

PART B

1. A single phase diode clamped inverter has m=5 Find the peak voltage and current ratings of didoes and switching devices if V_{dc} = 5kv and $i_0 = 50\sin(\theta - \frac{\pi}{3})$
2. Explain the five level capacitor clamped multilevel inverter with necessary circuit and waveforms.
3. Draw and explain the operation of a four level diode clamped multilevel inverter. Write the inverter relationship for R phase. Derive the expression for transistor voltage, freewheeling diode current, capacitor junction current and clamping diode current.
4. **(a)** Compare and contrast the different configurations of multilevel inverters based on the various aspects involved in their design.

(b) What is an asymmetric multilevel inverter? Explain how more output voltage is obtained with less number of H bridge cells.

5. Draw and explain the diode clamped type MLI and discuss characteristics.

6. Draw and explain the Cascaded type MLI and discuss characteristics.

7. Explain the single phase 5 level DCML inverter.

8. Explain the single phase 5 level FCML inverter.

9. Explain the operation of FCML inverter in details.

10. How are the MLI used for reactive power compensator and controlling the flow the power between two systems? Discuss.

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UNIT 5 QUESTION BANK

PART A

1. What are resonant converters? List their merits over switched converters.
2. Write the various categories of resonant converters.
3. What is the necessity for resonant inverters?
4. What is the advantage of using bidirectional switches in resonant inverter switches?
5. What are the limitations of basic series resonant inverter?
6. Draw the gain versus frequency characteristics of a series loaded series resonant converter.
7. What is resonant pulse converter?
8. How is the output voltage controlled in a series resonant inverter?
9. What is the value of fundamental voltage under quasi square wave control?
10. What is the need for modifications in series inverter?

PART B

1. Explain the principle of class E resonant inverter with a neat diagram and its waveform.
2. Explain the single phase parallel inverter with a neat diagram and its waveform.
3. Explain the operation of class E resonant converter with relevant circuits and waveform in optimum and non-optimum modes.
4. Describe the operation of resonant DC link inverters with zero voltage switching. Draw necessary circuits and waveforms.
5. Explain the operation of series resonant inverter with unidirectional switches. Draw relevant circuit and waveform for various modes of operation.
6. A class E resonant operates at resonance and has $V_s = 12v$ and R=10 ohm. The switching frequency is $f_s = 25khz$. Determine the optimum values of L, C, C_e and L_e. Also calculate damping factor and f_o. Assume that Q = 7.
7. Write short notes on resonant dc-link inverters.
8. Explain the working principle of series resonant inverter.

9. With sketch discuss the working principle of Class E resonant inverter.
10. Describe the operating principle of parallel resonant inverter.
11. Derive an expression for voltage gain of series loaded series resonant inverter. Also explain how voltage control is carried out.
12. What are the methods used for voltage control of series resonant inverter? Explain any one method in detail.
13. With necessary circuits and waveforms, explain the working principle of class E resonant inverter.

ANALYSIS AND DESIGN OF INVERTERS

ANSWER KEY

UNIT 1

TOPIC	TITLE	PAGE NO	PREFER BOOK
1	Introduction to Self-commutated Switches		**Notes**
	MOSFET	T1 - 137 ; T2 - 29	**T1**
	IGBT	T1 - 147 ; T2 - 34	**T1**
2	Principle and Operation	T1 - 227 ; T2 - 455	**T1**
	Full bridge Half bridge inverter	T1 - 228 ; T2 - 455 T1 - 232 ; T2 - 456	**T1 , T2**
3	Performance Parameters	T1 - 230 ; T2 - 472	**T1**
4	Voltage control of single phase inverter using Various PWM techniques	T1 - 248 ; T2 - 501	**T1**
5	Various Harmonics Elimination Techniques	T1 - 280 ; T2 -511	**T1 , T2**
6	Forced Commutation Thyristor Inverters	T2- 472	**T2**
7	Design of UPS	T1 - 623 ; T2 - 616	**T1 ,T2**

REF BOOKS:

T1 – Muhammad H Rashid “Power electronics circuits, devices and Applications” Third edition

T2 – P.S. Bimbhra “Power Electronics “Fifth Edition

NOTE

Important: Topic 2, 3, 4, 5 (Includes problem)

ANALYSIS AND DESIGN OF INVERTERS

ANSWER KEY

UNIT 2

TOPIC	TITLE	PAGE NO	PREFER BOOK
1	Introduction to 3 phase inverter	T1 - 237 ; T2 - 442	**NOTES**
2	180 degree star	T1 - 239 ; T2 - 442	**T2**
	120 degree star	T1 - 246 ; T2 - 447	**T2**
	180 degree delta		**NOTES**
	120 degree delta		**NOTES**
3	Voltage control of Three phase inverter	T2 - 264	**T2**
	Single , Multi pulse	T2 - 248 ; T2 -250	**T2**
	Sinusoidal PWM	T2- 265	**T2**
	Space vector Modulation	T2 - 271	**T2**
4	Application to Drive system		

REF BOOKS:

T1 – Muhammad H Rashid “Power electronics circuits, devices and Applications” Third edition

T2 – P.S. Bimbhra “Power Electronics “Fifth Edition

NOTE

Important: Topic 2, 3 (Includes problem)

ANALYSIS AND DESIGN OF INVERTERS

ANSWER KEY

UNIT 3

TOPIC	TITLE	PAGE NO	PREFER BOOK
1	Operation of six-step thyristor inverter	T3 - 272	**T3**
	Inverter operation modes	T3 - 274	**T3**
2	Load – commutated inverters	T3 - 277	**NOTES**
3	Single phase (ASCI) & 3 Phase ASCI	T2 – 474 , T3 - 285	**NOTES & T2**
	Current pulsations		**NOTES**
3	comparison of current source inverter and voltage source inverters	T3 - 303	**T3**
4	PWM techniques for current source Inverters.	T3 - 294	**T3**

REF BOOKS:

T1 – Muhammad H Rashid "Power electronics circuits, devices and Applications" Third edition

T2 – P.S. Bimbhra "Power Electronics "Fifth Edition

T3 – B.K BOSE "Modern Power Electronics and Ac Drives "2002.

NOTE

Important: Topic 3 (Includes problem)

ANALYSIS AND DESIGN OF INVERTERS

ANSWER KEY

UNIT 4

TOPIC	TITLE	PAGE NO	PREFER BOOK
1	Multilevel concept	T1 - 237 ; T2 - 442	**NOTES**
2	Diode clamped	T1 - 239 ; T2 - 442	**T2**
	Flying capacitor	T1 - 246 ; T2 - 447	**T2**
	Cascade Type		**NOTES**
	120 degree delta		**NOTES**
3	Comparison of multilevel inverters	T2 - 264	**T2**
4	Application of multilevel inverters	T2 - 248 ; T2 -250	**T2**
5	PWM techniques for MLI	T2- 265	**T2**
6	Single phase Impedance source inverters	T2 - 271	**T2**
	Three phase Impedance source inverters		

REF BOOKS:

T1 – Muhammad H Rashid "Power electronics circuits, devices and Applications" Third edition

T2 – P.S. Bimbhra "Power Electronics "Fifth Edition

NOTE

Important: Topic 2, 4, 6 (Includes problem)

ANALYSIS AND DESIGN OF INVERTERS

ANSWER KEY

UNIT 5

TOPIC	TITLE	PAGE NO	PREFER BOOK
1	Series and parallel resonant inverters	T1 – 353 ; 374	**NOTES**
2	voltage control of resonant inverters	T1 - 377	**T1**
3	Class E resonant Inverter	T1 - 380	**T1**
4	Resonant DC – link inverters.	T1-399	**T1**

REF BOOKS:

T1 – Muhammad H Rashid "Power electronics circuits, devices and Applications" Third edition

T2 – P.S. Bimbhra "Power Electronics "Fifth Edition

NOTE

Important: Topic 1, 3 (Includes problem)