20EE602

Hall Ticket Number:

III/IV B.Tech (Regular) DEGREE EXAMINATION

July/August, 2023 — **Electrical & Electronics Engineering**

Sixth Semester — **Power Quality**

Time: Three Hours — **Maximum:** 70 Marks

Answer question 1 compulsory. **(14X1 = 14Marks)**

Answer one question from each unit. **(4X14=56 Marks)**

			CO	BL	M
1	a)	What are the causes for interruptions?	CO1	L1	1M
	b)	Define Voltage sag?	CO1	L1	1M
	c)	What are the power quality standards?	CO1	L1	1M
	d)	List out the causes of sag	CO2	L1	1M
	e)	What is transient overvoltage?	CO2	L1	1M
	f)	What do you mean by capacitor switching?	CO2	L1	1M
	g)	What is the cause of harmonics?	CO3	L1	1M
	h)	Define odd harmonics?	CO3	L1	1M
	i)	What is the need of filters in power system?	CO3	L1	1M
	j)	What is the importance of improving power quality?	CO4	L1	1M
	k)	Write the importance of Shunt injection.	CO4	L1	1M
	l)	What is flicker meter?	CO4	L1	1M
	m)	How the switching transient effects the load?	CO2	L1	1M
	n)	List out any two applications of DVR?	CO4	L1	1M
		Unit-I			
2	a)	Explain briefly about long duration and short duration voltage variations.	CO1	L2	7M
	b)	Summarize the impact of poor power quality on utility and consumers	CO1	L2	7M
		(OR)			
3	a)	Discuss in detail about transients and waveform distortion related to the power quality	CO1	L3	7M
	b)	What is the impact of transient on power quality?Classify the transients that occur in power systems.	CO1	L2	7M
		Unit-II			
4	a)	Discuss the following causes of over voltages i. Switching the loads on or off ii. Capacitor switching	CO2	L3	7M
	b)	Describe in detail about the sag performance evaluation indices.	CO2	L2	7M
		(OR)			
5	a)	Explain the various methods of protection against utility system lightning?	CO2	L2	7M
	b)	Illustrate the phenomena of impulsive transients and oscillatory transients?	CO2	L2	7M
		Unit-III			
6	a)	What are effects of harmonics? Explain harmonic distortion evaluation procedure?	CO3	L2	7M
	b)	Illustrate the control techniques for the mitigation of harmonics?	CO3	L3	7M
		(OR)			
7	a)	Explain the function of active filters and how it overcomes the drawbacks of passive filter in controlling harmonics?	CO3	L2	7M
	b)	Explain the harmonic sources from commercial and industrial loads?	CO3	L2	7M
		Unit-IV			
8	a)	Explain the operation of Distribution Static Compensator (DSTATCOM) used for sag mitigation?	CO4	L2	7M
	b)	Distinguish between series and shunt compensators?	CO4	L3	7M
		(OR)			
9	a)	Explain the principle of DVR operation used for sag mitigation?	CO4	L2	7M
	b)	Sketch the line diagram of unified power quality conditioner and explain its operation in power quality improvement.	CO4	L3	7M

Each question carries 1 mark

1.a) What are the causes for interruptions?

Ans. Interruptions can be the result of power system faults, equipment failures, and control malfunctions.

1.b) Define voltage sag?

Ans. A sag is a decrease in rms voltage or current between 0.1 and 0.9 pu at the power frequency for durations from 0.5 cycle to 1 min

1.c) What are the power quality standards?

Ans.

Standards	Description
IEEE Standards 519-1992	Harmonic control in Electrical Power System
IEEE Standards 1159-1995	Monitoring Electrical Power Quality
IEEE Standards 1100-1999	Powering and Grounding Sensitive Electronic Equipment
IEC 61000-3-2	Limits for Harmonics Current Emission

1.d) List out the causes of sag.

Ans. 1. Faults due to short circuits.
2. Switching load.
3. Starting of large motors.
4. Transformer energizing

1.e) What is transient overvoltage?

Ans. Transient over voltages can be generated at high frequency (load switching and lightning), medium frequency (capacitor energizing), or low frequency

1.f) What do you mean by capacitor switching?

Ans. Capacitor switching is one of the most common switching events on utility systems. Capacitors are used to provide reactive power (in units of vars) to correct the power factor, which reduces losses and supports the voltage on the system

1.g) What is the cause of harmonics?

Ans.

Power converters, fluorescent lamps and Arcing Devices, Non-Linear loads, Adjustable speed drives.

1.h) Define odd harmonics?

Ans. Odd harmonics are harmonics in which frequencies are odd numbers such as 150, 250, 350 Hz, etc. in the fundamental frequency of 50 Hz.

1.i) What is the need of filters in power system?

Ans.

Filters can be used to filter out harmonics in the power system which are significantly below the switching frequency of the filter.

1.j) What is the importance of improving power quality?

Ans.1.Poor Power quality Damages consumers equipments and effect equipment life.
2. Bad Power quality causes severe health hazards
3. Poor voltage and high currents with harmonics causes heating's and high losses.
4. Increase system losses.
5. The Reliability of power supply a affected due to relay operations, Frequent faults and Equipment failure.

1.k) Write the importance of Shunt injection.
Ans. Shunt injection, also known as shunt compensation or shunt active power compensation, is an important technique used in power systems to improve power quality, voltage stability, and overall system efficiency.

1.l) What is flicker meter?
Ans. Flicker meters measure flicker in terms of the fluctuating voltage magnitude and its corresponding frequency of fluctuation. Electric arc furnaces and arc welding usually cause lights to flicker.

1.m) How the switching transient effects the load?
Ans.
Switching transient effects can have significant impacts on electronic loads. A switching transient is a temporary disturbance or variation in voltage, current, or power that occurs when a switch (such as a transistor or relay) changes its state from on to off or vice versa.

1.n) List out any two applications of DVR?
Ans. The dynamic voltage restorer is also used to mitigate the damaging effects of voltage sag, voltage swells, voltage unbalance and other waveform distortions.

UNIT-I

2.a) Explain briefly about long duration and short duration voltage variations.[7M]
Ans.

long duration voltage variations: Explanation [3M]

When the rms value of voltage deviates for duration more than 1 minute, it is termed as long duration voltage variation.
Sources: Load variations, System switching operation

It may be categorized into following types.
Over Voltage:
An overvoltage is an increase in the rms ac voltage greater than 110 percent at the power frequency for duration longer than 1 min.
Sources:
(a) Overvoltage is usually the result of load switching (e.g., switching off a large load or energizing a capacitor bank).
(b) Incorrect tap settings on transformers can also result in system over voltages

Under Voltage:
An under voltage is a decrease in the rms ac voltage to less than 90 percent at the power frequency for a duration longer than 1 min.
Sources: A load switching on or a capacitor bank switching off

Sustained Interruptions: When the supply voltage becomes zero for a period of time in excess of 1 min, the long-duration voltage variation is considered a sustained interruption.

Short-Duration Voltage Variations: Explanation [4M]

When the rms value of voltage deviates for duration less than 1 minute is termed as short duration voltage variation**.**

Each type of variation can be designated as instantaneous,momentary, or temporary, depending on its duration.
Short-duration voltage variations are caused by fault conditions, the energization of large loads which require high starting currents, or intermittent loose connections in power wiring. Depending on the fault

location and the system conditions, the fault can cause either temporary voltage drops (sags), voltage rises (swells), or a complete loss of voltage (interruptions).

Interruption: An interruption occurs when the supply voltage or load current decreases to less than 0.1 pu for a period of time not exceeding 1 min.
Sources: Interruptions can be the result of power system faults, equipment failures, and control malfunctions.

Sags(dips): A sag is a decrease in rms voltage or current between 0.1 and 0.9 pu at the power frequency for durations from 0.5 cycle to 1 min.
Sources:Voltage sags are result of system faults and also can be caused by energization of heavy loads or starting of large motors.

Swells: A swell is defined as an increase to between 1.1 and 1.8 pu in rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min.
Sources:Voltage swells occur from temporary voltage rise on the unfaulted phases duringan SLG fault. Swells can also be caused by switching off a large load or energizing large capacitor bank.

b).Summarize the impact of poor power quality on utility and consumers.[7M]

Ans. Poor power quality can have significant impacts on both utility providers and consumers. Here's a summary of those effects:

Impact on Utility Providers: Explanation [3M]

Increased Operational Costs: Poor power quality leads to system inefficiencies and increased maintenance requirements, which can result in higher operational expenses for utility companies.

Reduced Reliability: Unstable power can cause frequent outages and disruptions, leading to a decline in the overall reliability of the electricity supply, which can harm the utility's reputation.

Strained Infrastructure: Voltage fluctuations and power surges can strain the utility's infrastructure, potentially leading to equipment failures and necessitating costly upgrades or replacements.

Regulatory Compliance Issues: Utility companies are often subject to strict regulations regarding power quality. Failure to meet these standards can result in penalties and legal challenges.

Impact on Consumers: Explanation [4M]

Damaged Electronics and Appliances: Poor power quality, especially voltage fluctuations and surges, can damage sensitive electronic devices and household appliances, leading to expensive repairs or replacements for consumers.

Reduced Productivity: In commercial settings, frequent power interruptions can disrupt operations, leading to reduced productivity and potential financial losses.

Increased Energy Bills: Unstable power can cause energy wastage and inefficiencies, resulting in higher electricity bills for consumers.

Health and Safety Risks: Power quality issues may impact medical equipment, jeopardizing the health and safety of individuals who rely on such devices at home or in healthcare facilities.

Loss of Data: Power disruptions can lead to data loss in computing systems, affecting businesses and individuals who rely on electronic storage and communication.

[OR]

3.a Discuss in detail about transients and waveform distortion related to the power quality[7M]

Ans. **transients Explanation [3M]**

transients can be classified into two categories, 1.Impulsive transients

2.Oscillatory transients

Impulsive Transient

An impulsive transient is a sudden non–power frequency change in the steady-state condition of voltage, current, or both that is unidirectional in polarity (either positive or negative).

Impulsive transients are normally characterized by their rise and decay times.

Due to high frequency nature, the shape of impulsive transients may be changed quickly by circuit components and may have significant different characteristics when viewed from different parts of the power system. They are generally not conducted far from the source.

Impulsive transients can excite the natural frequency of power system circuits and produce oscillatory transients.

Source: lightning

Oscillatory transients

An oscillatory transient is a sudden, non–power frequency change in the steady-state condition of voltage, current, or both, that includes both positive and negative polarity values.

An oscillatory transient consists of a voltage or current whose instantaneous value changes polarity rapidly. It is described by its spectral content (predominate frequency), duration, and magnitude.

Waveform distortion: Explanation [4M]

Waveform distortion is defined as a steady-state deviation from an ideal sine wave of power frequency.
There are five primary types of waveform distortion:
1. DC offset
2. Harmonics
3. Interharmonics
4. Notching
5. Noise

DC offset:
The presence of a dc voltage or current in an ac power system is termed dc offset.
Effects: (a) It may saturate the transformer core causing additional heating and loss of transformer life.
(b) Direct current may also cause the electrolytic erosion of grounding electrodes and other connectors.

Harmonics:
Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the supply frequency (fundamental frequency).
Sources: Non-linear loads
Total Harmonic Distortion is used to measure the effective value of harmonic distortion.

Interharmonics:
Voltages or currents having frequency components that are not integer multiples of the frequency at which the supply system is designed to operate (e.g., 50 or 60 Hz) are called interharmonics.
Sources: Static frequency converter, cycloconverters, induction furnaces, and arcing devices. Power line carrier signals can also be considered as interharmonics.

Notching:
Notching is a periodic voltage disturbance caused by the normal operation of power electronic devices when current is commutated from one phase to another.

Noise:
Noise is the unwanted electrical signals with broadband spectral content lower than 200 kHz superimposed upon the power system voltage or current in phase conductors, or found on neutral conductors or signal lines.
Sources: Power electronic devices, control circuits, arcing equipment, loads with solid-state rectifiers, and switching power supplies.

b) What is the impact of transient on power quality? Classify the transients that occur in Power systems.[7M]

Explanation [4 M]

Ans. Transients, also known as voltage or current transients are sudden and short-duration fluctuations in voltage or current levels in an electrical system. They can be caused by various factors, such as lightning strikes, switching operations, capacitor bank switching, and equipment faults. These transient events can have a significant impact on power quality, affecting both the supply side and the consumer side of the electrical system. Here are some of the impacts of transients on power quality.

Voltage Fluctuations: Transients can cause rapid and abrupt changes in voltage levels.
Equipment Damage: Sudden spikes in voltage caused by transients can result in overvoltage conditions that surpass the designed operating limits of equipment.

transients can be classified into two categories, **classification [3M]**

1.Impulsive transients

2.Oscillatory transients

a) High-frequency Transients

b) Medium-frequency Transients

c) Low-frequency Transients

Impulsive Transient

An impulsive transient is a sudden non–power frequency change in the steady-state condition of voltage, current, or both that is unidirectional in polarity (either positive or negative).

Oscillatory transients

An oscillatory transient is a sudden, non–power frequency change in the steady-state condition of voltage, current, or both, that includes both positive and negative polarity values.

UNIT-II

4 a) Discuss the following causes of over voltages [7M]

i. Switching the loads on or off

ii. Capacitor switching

Switching the loads on or off: Explanation [3M]

Switching loads on or off can indeed cause overvoltages in an electrical system. These overvoltages are often referred to as transient overvoltages or voltage spikes. Here's how the switching of loads can lead to overvoltages and other related causes
Switching Operations: When large loads such as motors, transformers, or capacitors are switched on or off, they can create sudden changes in current flow. These rapid changes in current result in rapid changes in voltage across the inductive and capacitive elements within the system, leading to transient overvoltages.
Capacitive Charging: Capacitors are energy storage devices that can release their stored energy quickly when switched on. If a capacitor is connected to a load and suddenly switched on, it can discharge its stored energy rapidly, leading to a voltage surge.
Electromagnetic Interference (EMI): Switching operations generate fast-changing currents, which can create electromagnetic interference. EMI can couple with nearby cables and conductors, inducing transient voltages.

Capacitor switching: Explanation [4 M]
Capacitor switching is one of the most common switching events on utility systems. Capacitors are used to provide reactive power (in units of vars) to correct the power factor, which reduces losses and supports the voltage on the system. They are a very economical and generally trouble-free means of accomplishing these goals. Alternative methods such as the use of rotating machines and electronic var compensators are much more costly or have high maintenance costs

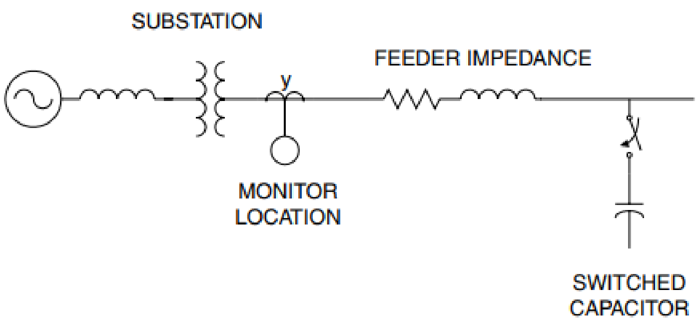


Figure.1. One-line diagram of a capacitor-switching operation corresponding to the waveform in

Figure1. shows the one-line diagram of a typical utility feeder capacitor-switching situation When the switch is closed, a transient similar to the one in Fig.1 may be observed upline from the capacitor at the monitor location. In this particular case, the capacitor switch contacts close at a point near the system voltage peak. This is a common occurrence for many types of switches because the insulation across the switch contacts tends to break down when the voltage across the switch is at a maximum value. The voltage across the capacitor at this instant is zero. Since the capacitor voltage cannot change instantaneously, the system voltage at the capacitor location is briefly pulled down to zero and rises as the capacitor begins to charge toward the system voltage. Because the power system source is inductive, the capacitor voltage overshoots and rings at the natural frequency of the system. At the monitoring location shown, the initial change in voltage will not go completely to zero because of the impedance between the observation point and the switched capacitor. However, the initial drop and subsequent ringing transient that is indicative of a capacitor-switching event will be observable to some degree.

b) Describe in detail about the sag performance evaluation indices.[7M]

Ans. Explanation [3 M] ,Each Indices [1M]

Sag performance evaluation indices are used to quantify the quality of power supply by assessing the severity and frequency of voltage sags, also known as voltage dips or short-duration voltage variations. Voltage sags can have significant impacts on sensitive equipment, leading to disruptions, downtime, and potential equipment damage. Evaluating sag performance helps utility companies, industrial facilities, and other stakeholders understand the power quality level and take corrective actions if necessary. Here are some key indices used for sag performance evaluation:

1. **SAIDI (System Average Interruption Duration Index):** SAIDI represents the average duration of interruptions per customer over a specified time period. It includes the time that customers experience no power (outages) as well as the time they experience voltage sags. SAIDI takes into account the total downtime and is often measured in minutes or hours per customer per year.
2. **SAIFI (System Average Interruption Frequency Index):** SAIFI measures the average number of interruptions per customer over a specified time period. It includes both outages and voltage sags. SAIFI is a unitless index and is usually expressed as interruptions per customer per year.
3. **CAIDI (Customer Average Interruption Duration Index):** CAIDI calculates the average duration of interruptions for customers who experience an interruption. It is the ratio of SAIDI to SAIFI and represents the time taken on average to restore power after an interruption. CAIDI is measured in minutes per interruption.
4. **Customer Average Interruption Frequency Index (CAIFI):** CAIFI is a power quality metric that quantifies the average number of interruptions experienced by a single customer over a specified time period. CAIFI is used to evaluate the reliability of power supply from the perspective of individual customers. It provides insight into how often customers are affected by power outages and voltage sags, allowing utilities and industrial facilities to assess and improve their power distribution systems.

   Mathematically, CAIFI is calculated as the ratio of the System Average Interruption Frequency

   Index (SAIFI) to the System Average Interruption Duration Index (SAIDI)

[OR]

5 a) Explain the various methods of protection against utility system lightning?[7M]

Ans.

Explanation [3 M], Any two methods [4M]

Many power quality problems stem from lightning. Not only can the high-voltage impulses damage load equipment, but the temporary fault that follows a lightning strike to the line causes voltage sags and interruptions. Here are some strategies for utilities to use to decrease the impact of lightning

1.Shielding
2.Line arresters
3.Low-side surges
4.Protecting the transformer.
5.Cable protection

Shielding:

Shielding overhead utility lines is common at transmission voltage levels and in substations, but is not common on distribution lines because of the added cost of taller poles and the lower benefit due to lower flashover levels of the lines. On distribution circuits, the grounded neutral wire is typically installed underneath the phase conductors to facilitate the connection of line-to-neutral connected equipment such as transformers and capacitors.

Shielding is not quite as simple as adding a wire and grounding it every few poles. When lightning strikes the shield wire, the voltages at the top of the pole will still be extremely high and could cause backflashovers to the line. This will result in a temporary fault. To minimize this possibility, the path of the ground lead down the pole must be carefully chosen to maintain adequate clearance with the phase conductors. Also, the grounding resistance plays an important role in the magnitude of the voltage and must be maintained as low as possible.

However, when it becomes obvious that a particular section of feeder is being struck frequently, it may be justifiable to retrofit that section with a shield wire to reduce the number of transient faults and to maintain a higher level of power quality. Figure:1 illustrates this concept

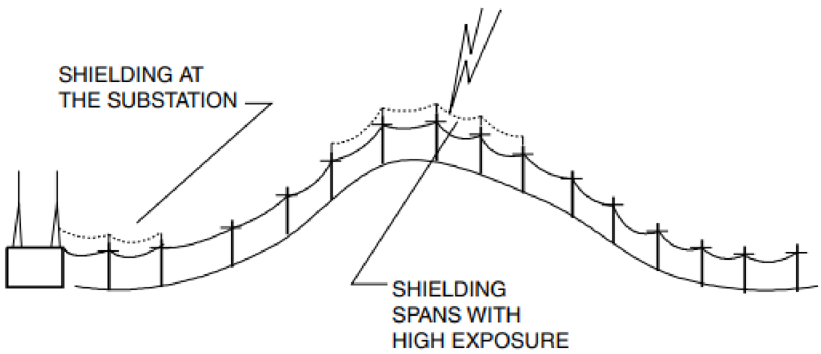


Figure:1Shielding a portion of a distribution feeder to reduce the incidence of temporary lightning-induced faults

Line arresters:

Another strategy for lines that are struck frequently is to apply arresters periodically along the phase wires. Normally, lines flash over first at the pole insulators. Therefore, preventing insulator flashover will reduce the interruption and sag rate significantly. Stansberry6 argues that this is more economical than shielding and results in fewer line flashovers. Neither shielding nor line arresters will prevent all flashovers from lightning. The aim is to significantly reduce flashovers in particular trouble spots. As shown in Fig. 4.30, the arresters bleed off some of the stroke current as it passes along the line. The amount that an individual arrester bleeds off will depend on the grounding resistance. The idea is to space the arresters sufficiently close to prevent the voltage at unprotected poles in the middle from exceeding the basic impulse level (BIL) of the line insulators. This usually requires an arrester at every second or third pole. In the case of a feeder supplying a highly critical load, or a feeder with high ground resistance, it may be necessary to place arresters at every pole. A transient’s study of different configurations will show what is required.

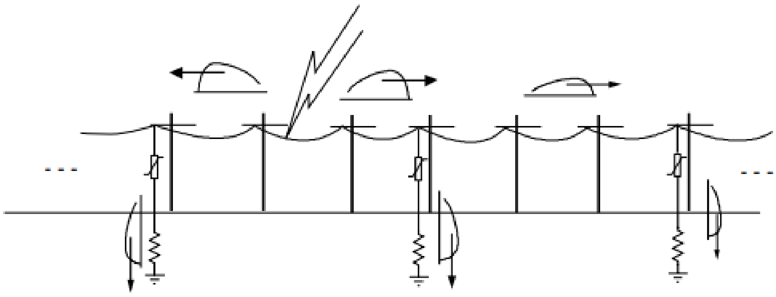


Figure:1Periodically spaced line arresters help prevent flashovers.

b) **Illustrate the phenomena of impulsive transients and oscillatory transients?[7M]**
Ans. impulsive transients Explanation [4 M]
oscillatory transients Explanation [4 M]

An impulsive transient is a sudden, non–power frequency change in the steady-state condition of voltage, current, or both that is unidirectional in polarity (primarily either positive or negative). The most common cause of impulsive transients is lightning. Figure .1 illustrates a typical current impulsive transient caused by lightning. Because of the high frequencies involved, the shape of impulsive transients can be changed quickly by circuit components and may have significantly different characteristics when viewed from different parts of the power system. They are generally not conducted far from the source of where they enter the power system, although they may, in some cases, be conducted for quite some distance along utility lines. Impulsive transients can excite the natural frequency of power system circuits and produce oscillatory transients.

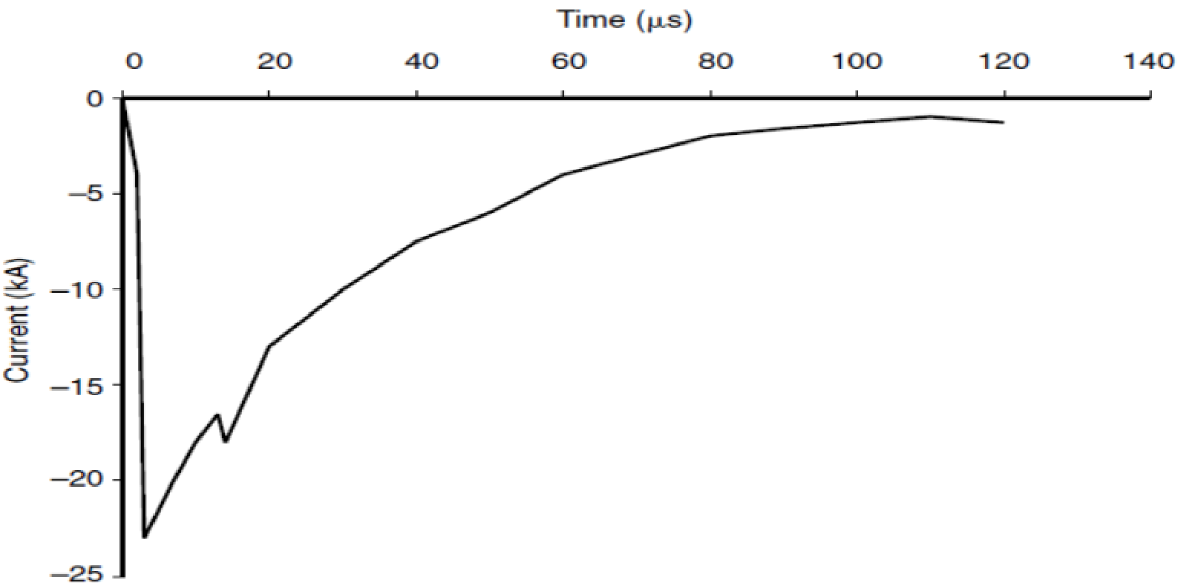


Figure:1 Lightning stroke current impulsive transient.

An oscillatory transient is a sudden, non–power frequency change in the steady-state condition of voltage, current, or both, that includes both positive and negative polarity values. An oscillatory transient consists of a voltage or current whose instantaneous value changes polarity rapidly. It is described by its spectral content (predominate frequency), duration, and magnitude. The frequency ranges for these classifications are chosen to coincide with common types of power system oscillatory transient phenomena. Oscillatory transients with a primary frequency component greater than 500 kHz and a typical duration measured in microseconds (or several cycles of the principal frequency) are considered high-frequency transients. These transients are often the result of a local system response to an impulsive transient. A transient with a primary frequency component between 5 and 500 kHz with duration measured in the tens of microseconds (or several cycles of the principal frequency) is termed a medium-frequency transient. Back-to-back capacitor energization results in oscillatory transient currents in the tens of kilohertz as illustrated in Fig.1 Cable switching results in oscillatory voltage transients in the same frequency range. Medium-frequency transients can also be the result of a system response to an impulsive transient

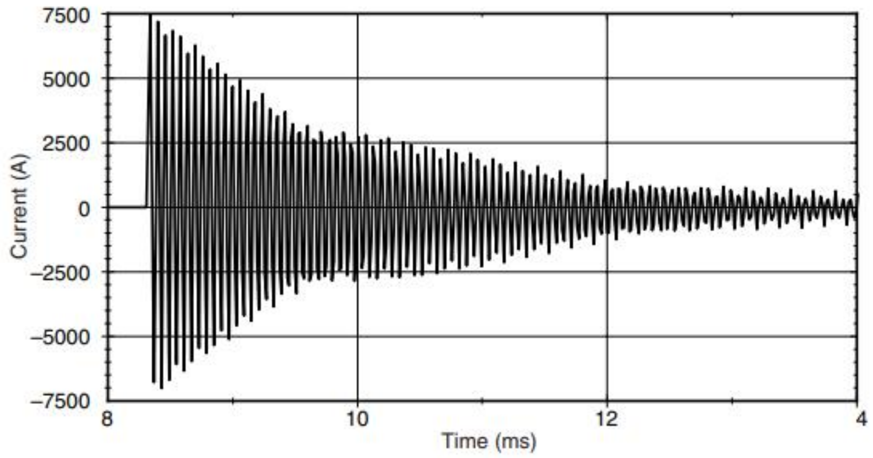


Figure.1 Oscillatory transient current caused by back-to-back capacitor switching.

UNIT-III

6 a) What are effects of harmonics? Explain harmonic distortion evaluation procedure?[7M]

Ans.

Explanation [5M]

Figure[2M]

Harmonic currents produced by nonlinear loads are injected back into the supply systems. These currents can interact adversely with a wide power system equipment, most notably capacitors, transformers, and motors, causing additional losses, overheating, and overloading. These harmonic currents can also cause interference with telecommunication lines and errors in power metering.

The interaction often gives rise to voltage and current harmonic distortion observed in many places in the system. Therefore, to limit both voltage and current harmonic distortion, IEEE Standard 519-1992 proposes to limit harmonic current injection from end users so that harmonic voltage levels on the overall power system will be acceptable if the power system does not inordinately accentuate the harmonic currents. This approach requires participation from both end users and utilities.

End users. For individual end users, IEEE Standard 519-1992 limits the level of harmonic current injection at the point of common coupling (PCC). This is the quantity end users have control over. Recommended limits are provided for both individual harmonic components and the total demand distortion. The concept of PCC is illustrated in Fig. 1. These limits are expressed in terms of a percentage of the end user’s maximum demand current level, rather than as a percentage of the fundamental. This is intended to provide a common basis for evaluation over time.

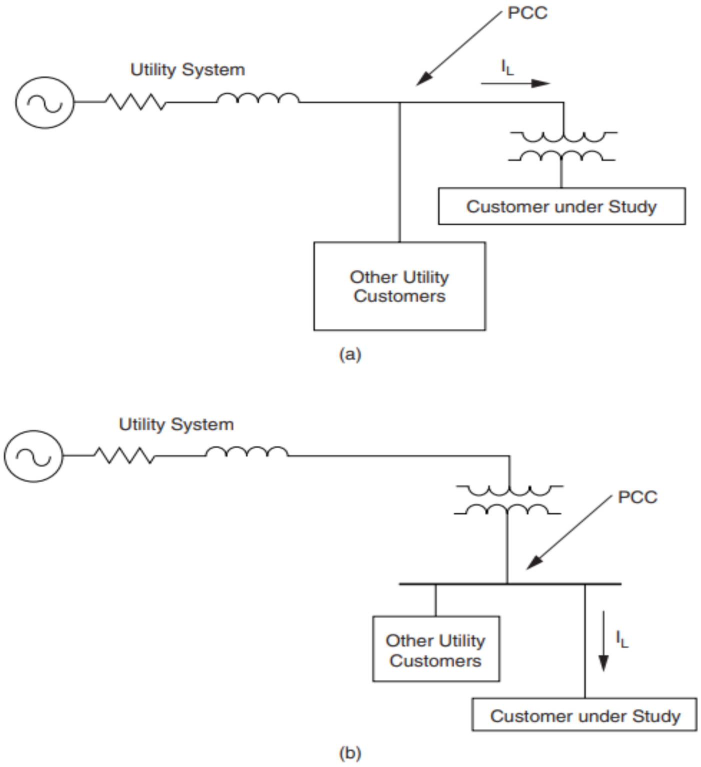


Figure.1 PCC selection depends on where multiple customers are served. (a) PCC at the transformer primary where multiple customers are served. (b) PCC at the transformer secondary where multiple customers are served.

b) **Illustrate the control techniques for the mitigation of harmonics?[7M]**
Each Explanation [2 M]

Certainly, here are some common control techniques used for the mitigation of harmonics in electrical and power systems:

1. **Passive Harmonic Filters**: Passive harmonic filters are designed using passive components like inductors, capacitors, and resistors. They are connected in parallel with the load that generates harmonics. These filters create a low-impedance path for the harmonic currents, diverting them away from the power source. Passive filters are effective for specific harmonic frequencies, but their performance can degrade with changes in load and system configuration.
2. **Active Harmonic Filters:** Active harmonic filters use power electronics to actively generate counteracting harmonic currents. These filters sense the harmonic currents generated by the load and inject equal but opposite currents to cancel out the harmonics. Active filters are more versatile than passive filters and can adapt to varying load conditions and harmonic frequencies.
3. **Tuned Passive Filters:** Tuned passive filters are designed to target specific harmonic frequencies. They consist of a combination of inductors and capacitors that resonate at the desired harmonic frequencies, creating a low-impedance path for those harmonics. These filters are effective for applications where specific harmonics need to be controlled.
4. **Hybrid Filters:** Hybrid filters combine both passive and active filtering techniques. They provide the advantages of both passive and active filters, allowing for better adaptability to changing load conditions and a wider range of harmonic frequencies.

7 a) Explain the function of active filters and how it overcomes the drawbacks of passive filter in controlling harmonics?[7M]
Explanation [5 M]
Figure[2M]

Ans. Active filters are relatively new types of devices for eliminating harmonics. They are based on sophisticated power electronics and are much more expensive than passive filters. However, they have the distinct advantage that they do not resonate with the system. Active filters can work independently of the system impedance characteristics. Thus, they can be used in very difficult circumstances where passive filters cannot operate successfully because of parallel resonance problems. They can also address more than one harmonic at a time and combat other power quality problems such as flicker. They are particularly useful for large, distorting loads fed from relatively weak points on the power system.

The basic idea is to replace the portion of the sine wave that is missing in the current in a nonlinear load. Figure 4.31 illustrates the concept. An electronic control monitors the line voltage and/or current, switching the power electronics very precisely to track the load current or voltage and force it to be sinusoidal. As shown, there are two fundamental approaches: one that uses an inductor to store current to be injected into the system at the appropriate instant and one that uses a capacitor. Therefore, while the load current is distorted to the extent demanded by the nonlinear load, the current seen by the system is much more sinusoidal.

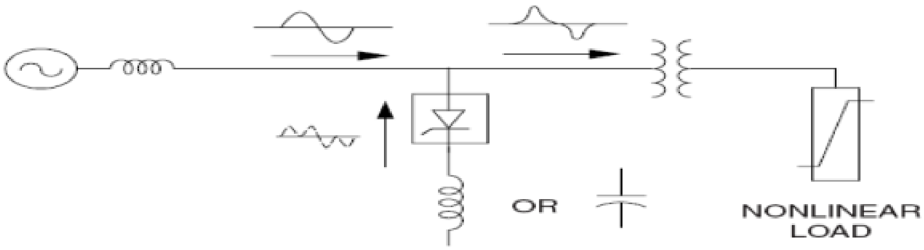


Figure 4.31 Application of an active filter at a load.

Passive filters are designed to address specific harmonic frequencies. If the harmonic spectrum changes due to different loads or operational conditions, the effectiveness of passive filters can decrease. But Active filters can adapt to changing harmonic conditions. They continuously sense and adjust their compensating currents to match the current harmonic content, ensuring effective mitigation regardless of load variations.

7.b) Explain the harmonic sources from commercial and industrial loads?[7M]

Ans. **Expalanation [3M]**

Harmonic sources from commercial loads:

Commercial facilities such as office complexes, department stores, hospitals, and Internet data centers are dominated with high-efficiency fluorescent lighting with electronic ballasts, adjustable-speed drives for the heating, ventilation, and air conditioning (HVAC) loads, elevator drives, and sensitive electronic equipment supplied by single-phase switch-mode power supplies. Commercial loads are characterized by a large number of small harmonic-producing loads. Depending on the diversity of the different load types, these small harmonic currents may add in phase or cancel each other. The voltage distortion levels depend on both the circuit impedances and the overall harmonic current distortion. Since power factor correction capacitors are not typically used in commercial facilities, the circuit impedance is dominated by the service entrance transformers and conductor impedances. Therefore, the voltage distortion can be estimated simply by multiplying the current by the impedance adjusted for frequency. Characteristics of typical nonlinear commercial loads are detailed in the following sections.

1.Single-phase power supplies
2. Fluorescent lighting
3. Adjustable-speed drives for HVAC and elevators

Harmonics sources from industrial loads: **Expalanation [4M]**

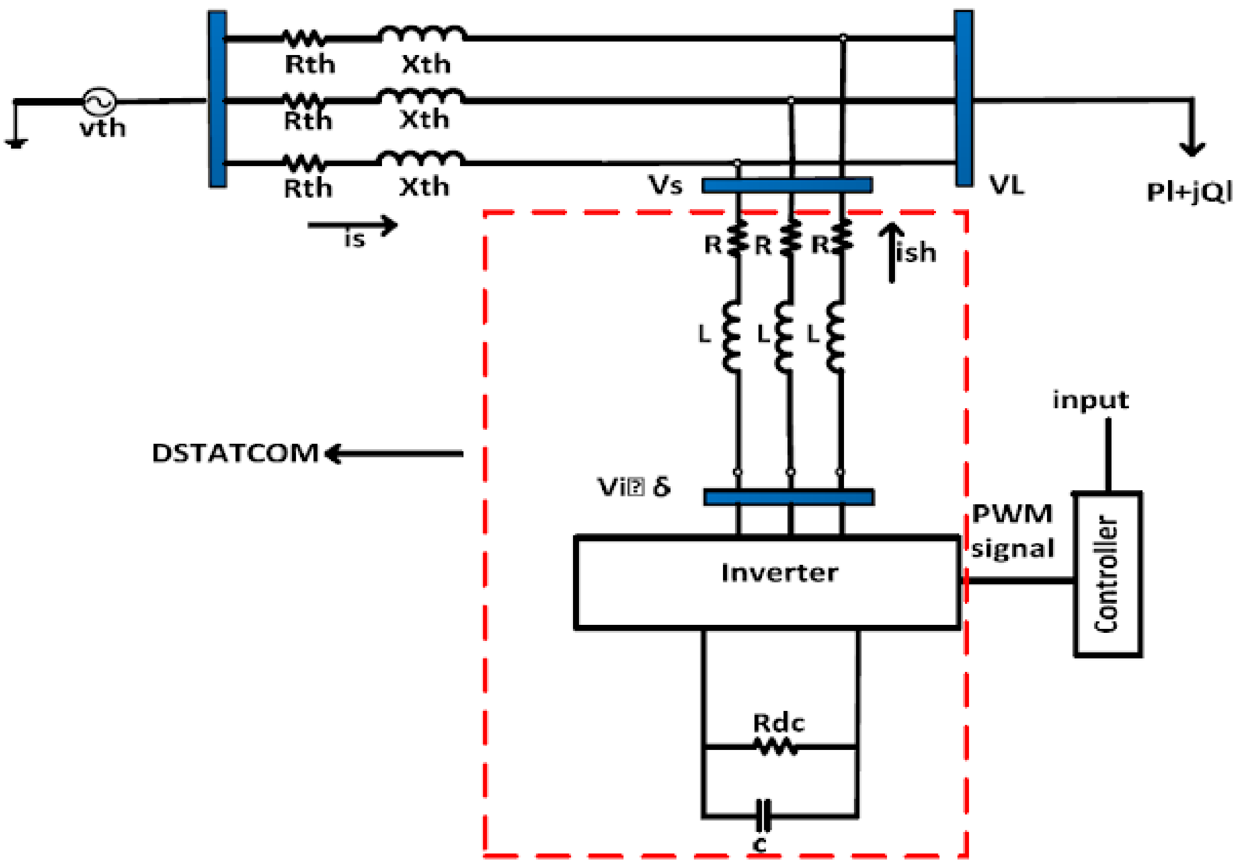
Modern industrial facilities are characterized by the widespread application of nonlinear loads. These loads can make up a significant portion of the total facility loads and inject harmonic currents into the power system, causing harmonic distortion in the voltage. This harmonic problem is compounded by the fact that these nonlinear loads have a relatively low power factor. Industrial facilities often utilize capacitor banks to improve the power factor to avoid penalty charges. The application of power factor correction capacitors can potentially magnify harmonic currents from the nonlinear loads, giving rise to resonance conditions within the facility. The highest voltage distortion level usually occurs at the facility's low-voltage bus where the capacitors are applied. Resonance conditions cause motor and transformer overheating, and mis operation of sensitive electronic equipment.

Nonlinear industrial loads can generally be grouped into three categories:
1.Three-phase power converters
2.Arcing devices
3.Saturable devices

UNIT-IV

8 a) **Explain the operation of Distribution Static Compensator (DSTATCOM) used for sag mitigation?[7M]**

Ans.
Explanation [4 M]
Figure[3M]



The D-STATCOM is basically one of the custom power devices. It is nothing but a STATCOM but used at the Distribution level.
The D-STATCOM is a voltage or current source inverter based custom power device connected in shunt with the power system. It is connected near the load at the distribution systems. The key component of the D-STATCOM is a power VSC that is based on high power electronics technologies.
Basically, the D-STATCOM system is comprised of three main parts: a VSC, a set of coupling reactors and a controller.
The basic principle of a D-STATCOM installed in a power system is the generation of a controllable ac voltage source by a voltage source converter (VSC) connected to a dc capacitor (energy storage device).
The ac voltage source, in general, appears behind a transformer leakage reactance. The active and reactive power transfer between the power system and the D-STATCOM is caused by the voltage difference across this reactance.

The D-STATCOM is connected in shunt with the power networks at customer side, where the voltage-quality problem is a concern.
All required voltages and currents are measured and are fed into the controller to be compared with the commands.

The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBTs, which are used at the distribution level) of the power converter accordingly.
The ac voltage control is achieved by firing angle control. Ideally the output voltage of the VSC is in phase with the bus voltage.
the D -STATCOM is to provide voltage regulation at the load point and mitigate the voltage sag generated when the load is increased. The system is considered to be operating under balanced conditions and both loads are linear.

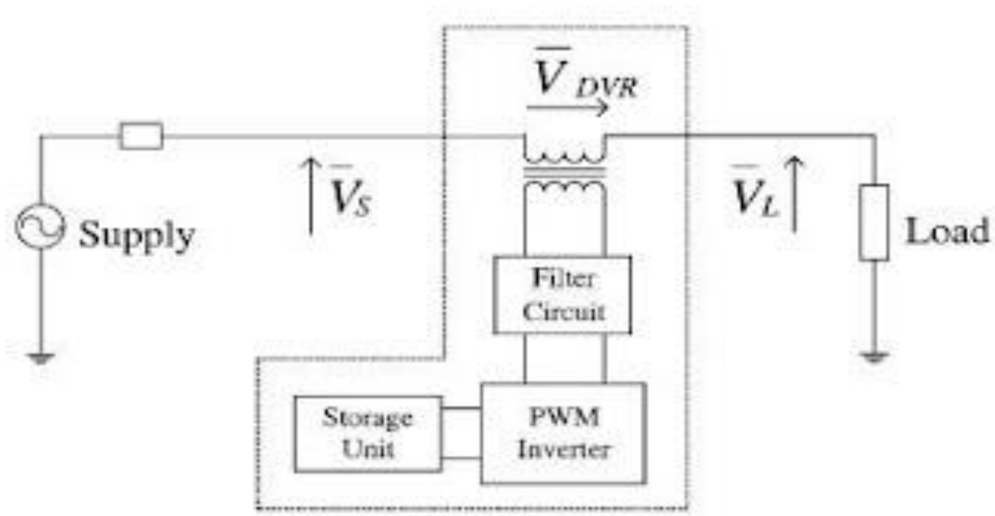
b) **Distinguish between series and shunt compensators? [7M]**
Ans. **Any 5 points [7M]**

series compensators	shunt compensators
Series compensators connected in series inject the voltage and control the current	Shunt compensators connected in shunt inject the current and control the voltage
Series compensation lowers the critical or collapse voltage. Thus changes of voltage collapse are reduced.	Shunt compensation provides a better control of voltage profile.
Losses in series compensation are lower the in shunt compensation.	it is effective even in off peak conditions.
Series compensation improves system stability both steady state and transient state	Shunt compensation provides fast control over temporary overvoltages.
Series compensation is effective only during heavy loads. During light load conditions shunt compensation has to be provided.	Its overload capability is limited.
Series compensation is somewhat cheaper than shunt compensation.	It is more expensive than a series compensation scheme.
Whenever an outage occurs on a line with series compensation, the series compensation has to be removed. This may cause the overloading of other parallel lines.	To reduce the overall cost, it is preferable to use a mechanically switched capacitor bank in addition to shunt compensation

[OR]

9 a) Explain the principle of DVR operation used for sag mitigation?[7M]

Ans.
Explanation [4 M]
Figure[3M]



Fig;1 dynamic voltage restorer is one of the most effective PQ devices in solving voltage sag problems

The basic principle of the dynamic voltage restorer is to inject a voltage of required magnitude and frequency, so that it can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted.
the capability of injection voltage by DVR system is 50% of nominal voltage. This allows DVRs to successfully provide protection against sags to 50% for durations of up to 0.1 seconds. Furthermore, most voltage sags rarely reach less than 50%.
Generally, it employs a gate turn off thyristor (GTO) solid state power electronic switches in a pulse width modulated (PWM) inverter structure.
The DVR can generate or absorb independently controllable real and reactive power at the load side. In other words, the DVR is made of a solid state DC to AC switching power converter that injects a set of three phase AC output voltages in series and synchronism with the distribution and transmission line voltages.

The source of the injected voltage is the commutation process for reactive power demand and an energy source for the real power demand.
*The energy source may vary according to the design and manufacturer of the DVR. Some examples of energy sources applied are DC capacitors, batteries.

b) **Sketch the line diagram of unified power quality conditioner and explain its operation in power quality improvement.[7M]**

Ans. **Explanation [4 M]**
Figure[3M]

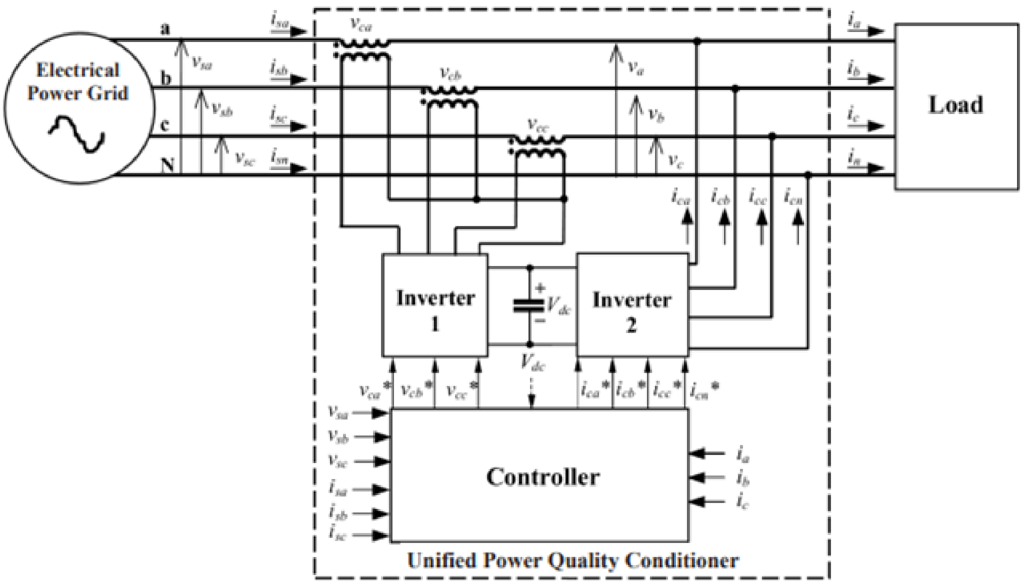


Figure:1 Single line diagram of unified power quality conditioner

The Unified Power Quality Conditioner (UPQC) combines the Shunt Active Power Filter with the Series Active Power Filter, sharing the same DC Link, in order to compensate both voltages and currents, so that the load voltages become sinusoidal and at nominal value, and the source currents become sinusoidal and in phase with the source voltages.

In the case of three-phase systems, a three-phase UPQC can also balance the load voltages and the source currents, and eliminate the source neutral current. Figure 1 shows the electrical scheme of a Unified Power Quality Conditioner for a three-phase power system.

From the measured values of the source phase voltages (Vsa , Vsb , Vsc) and load currents (Ia , Ib , Ic), the controller calculates the reference compensation currents (Ica * , Icb * , Icc * , Icn *) used by the inverter of the shunt converter to produce the compensation currents (Ica , Icb , Icc , Icn).

Using the measured values of the source phase voltages, and source currents (Isa , Isb , Isc), the controller calculates the reference compensation voltages (Vca * , Vcb * , Vcc *) used by the inverter of the series converter to produce the compensation voltages (Vca , Vcb , Vcc).

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