	b)	Interpret the importance of power quality measurement system.	L2	CO5	5 M
OR					
11	a)	Interpret resurgence of DG in modern power systems.	L2	CO5	5 M
	b)	Illustrate how DG integration affects low-voltage distribution networks.	L3	CO5	5 M

Code: 23EE6501

III B.Tech - I Semester - Honors Examinations - NOVEM

ELECTRIC POWER QUALITY
(HONORS in ELECTRICAL & ELECTRONICS ENGINEERING)

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1.a)	Apply the principle of overvoltage protection to suggest a device for lightning protection.	L3	CO2
1.b)	Identify any four power quality measuring instruments.	L2	CO5
1.c)	Define Total Harmonic Distortion (THD).	L1	CO3
1.d)	Illustrate the sources of flicker in power systems.	L3	CO4
1.e)	Explain the difference between power quality and voltage quality.	L2	CO1
1.f)	Demonstrate a common passive filter configuration for harmonic mitigation.	L3	CO4
1.g)	Identify the main sources of over voltages in power systems.	L2	CO2
1.h)	Infer the function of a power quality analyzer.	L2	CO5
1.i)	Illustrate the purpose of capacitors for voltage regulation.	L3	CO3
1.j)	List the common types of power quality problems.	L1	CO1

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Explain the concept of power quality and discuss its importance in modern power systems.	L2	CO2	5 M
	b)	Explain the significance of power frequency variations and their impact on sensitive loads.	L2	CO2	5 M
		OR			
3	a)	Interpret the causes and consequences of voltage unbalance in power systems.	L3	CO2	5 M
	b)	Classify the types of transients in power systems and describe their effects.	L2	CO2	5 M
		UNIT-II			
4	a)	Explain the different strategies in utilities that are to be used in order to decrease the impact of lightning.	L2	CO4	5 M
	b)	Interpret the issues of ferroresonance and switching transient problems with loads, and suggest mitigation methods.	L3	CO2	5 M
		OR			
5	a)	Explain any 2 different devices used for over voltage protection.	L4	CO4	5 M
	b)	Infer the sources of transient overvoltages in power systems.	L2	CO4	5 M

		UNIT-III			
6	a)	Illustrate the role of end-user capacitor applications in improving power quality.	L3	CO2	5 M
	b)	Interpret the causes of voltage flicker and its impact on consumer equipment.	L3	CO3	5 M
		OR			
7	a)	Demonstrate why voltage regulation is essential for both utilities and end-users.	L2	CO3	5 M
	b)	Illustrate the common devices used for voltage regulation.	L2	CO2	5 M
		UNIT-IV			
8	a)	Explain the devices used for controlling harmonic distortion and explain their functions.	L2	CO4	5 M
	b)	Interpret the concept of Point of Common Coupling (PCC) and its importance in harmonic studies.	L2	CO3	5 M
		OR			
9	a)	Explain about the phenomena of current distortion and voltage distortion under the presence of harmonics.	L2	CO4	5 M
	b)	Explain about any two common sources of harmonics in electrical systems.	L2	CO4	5 M
		UNIT-V			
10	a)	Illustrate the major power quality issues caused by DG integration.	L2	CO5	5 M

Code: 23EE6501

III B.TECH – I SEM REGULAR EXAMINATIONS NOVEMBER 2025

ELECTRIC POWER QUALITY (HONORS)

ELECTRICAL & ELECTRONICS ENGINEERING

SCHEME OF VALUATION

Duration : 3 hours **Max.Marks:70**

Part - A

1a)	Any 1 device for lightning protection	2M
1b)	Any 4 power quality measuring instruments	2M
1c)	THD Definition	2M
1d)	Any two sources of Flicker	2M
1e)	Any 1 difference between power quality, voltage quality	2M
1f)	Need or importance of passive filter Various designs of passive filters(any one)	1M 1M
1g)	Any 2 sources of over voltages	2M
1h)	Function of power quality analyzer	2M
1i)	Any 1 purpose of capacitor for voltage regulation	2M
1j)	Any 2 types of power quality problems	2M

		UNIT -I	
2	(a)	Concept of power quality Importance of power quality	2.5M 2.5M
	(b)	Importance of power frequency variations Impact on sensitive loads	4M 1M
3	(a)	Causes of voltage unbalance Consequences/ impact in power systems	2.5M 2.5M
	(b)	Classification Any two types with explanation EACH: 2.5M	5M
		UNIT -II	
4	(a)	Any two different strategies in utilities to reduce impact of lightning with explanation EACH 2.5M	5M
	(b)	Issues related to ferroresonance with loads, mitigation methods Switching transient problems, mitigation methods	2.5M 2.5M
5	(a)	Any two devices for overvoltage protection with explanation EACH 2.5M	5M
	(b)	Any two sources of transient overvoltages with explanation EACH 2.5M	5M
		UNIT -III	
6	(a)	Role of end user capacitor applications in improving power quality	5M
	(b)	Any two causes of voltage flicker with explanation EACH 2.5M	5M
7	(a)	Importance of voltage regulation for utilities Importance of voltage regulation endusers	2.5M 2.5M
	(b)	Any two common devices for voltage regulation with explanation EACH 2.5M	5M

		UNIT -IV	
8	(a)	Any two devices for controlling harmonics with explanation EACH 2.5M	5M
	(b)	Concept of PCC Importance in harmonic studies	2M 3M
9	(a)	Explanation about current distortion Explanation about voltage distortion	2.5M 2.5M
	(b)	Any two sources of harmonics with explanation EACH 2.5M	5M
		UNIT -V	
10	(a)	Any two major power quality issues caused by DG with explanation EACH 2.5M	5M
	(b)	Importance of power quality measurement system	5M
11	(a)	Resurgence of DG	5M
	(b)	Any two affects of DG in Low voltage distribution networks with explanation EACH 2.5M	5M

Code: 23EE6501 **PVP 23**

III B.TECH – I SEM REGULAR EXAMINATIONS NOVEMBER 2025

ELECTRIC POWER QUALITY (HONORS)

ELECTRICAL & ELECTRONICS ENGINEERING

KEY

Duration: 3 hours **Max.Marks:70**

PART-A

1. a) Surge arresters are used for lightning protection

b) Oscilloscope, Power Quality Analyzer, Harmonic Analyzer, Spectrum Analyzer

c) Total Harmonic Distortion (THD) is a measure of the distortion in a voltage or current waveform caused by the presence of harmonic frequencies (integer multiples of the fundamental frequency).

d) Arc furnaces, welding machines, large motor starting, wind turbines and house hold equipment rapidly changing load are some of the sources of flicker in power system.

e) Power quality is a broad term refers to the overall electrical environment including voltage, current, and frequency and waveform characteristics. Voltage quality focuses specifically on the quality of the voltage waveform supplied to the load.

f) The most common type of passive filter is the sin gle-tuned "notch" filter. This is the most economical type and is frequently sufficient for the application. It may be single tuned, 1st order high pass, 2nd order high pass.

g) The most common source of severe overvoltage's are direct lightning strikes on transmission lines, Switching Surges, Faults and Sudden Load Rejection

h) A Power Quality Analyzer is an advanced instrument used to measure, record, and analyze disturbances and electrical parameters in power systems.

i) Capacitors are widely used in power systems especially in distribution networks and industrial plants because they help maintain proper voltage levels under varying load conditions. Their key purpose is to provide reactive power and thereby improve voltage stability.

j) The common power quality problems are voltage sags, voltage swells, interruptions, transients, harmonics, voltage flicker, voltage unbalance, and long-duration overvoltages/undervoltages.

PART-B

UNIT I

2. a) The quality of power has often been characterized as —clean or —dirty. Clean power refers to power that has sinusoidal voltage and current without any distortion and operates at the designed magnitude and frequency.

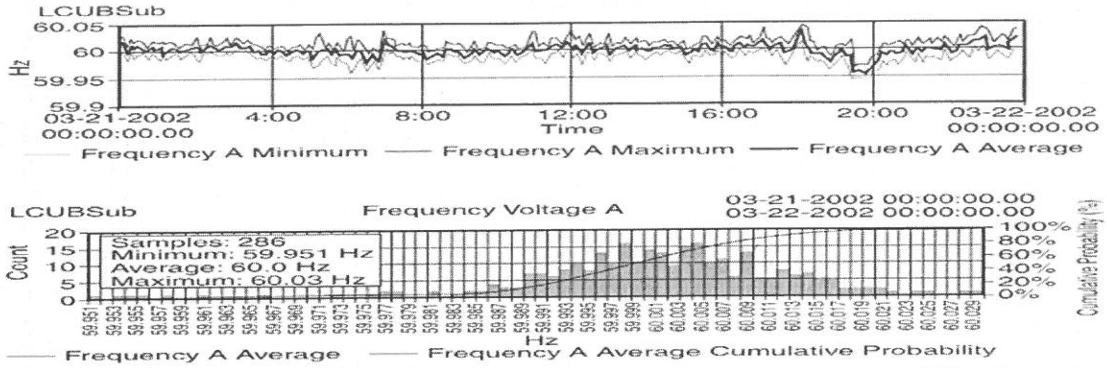
Dirty power describes power that has a distorted sinusoidal voltage and current or operates outside the design limits of voltage, current, and/or frequency. Natural and man-made events in the power system provide sources or initiating events that cause clean power to become dirty. Categories of dirty power quality sources include power system events, nonlinear loads, and poor wiring and grounding. Examples of dirty power quality sources include lightning, adjustable speed drives, and loose connections. Power quality experts prefer not to use the term dirty power but like to instead use the term power quality problems. The source of a power quality problem often causes a disturbance or power quality variation. The disturbance can then affect the operation of end-user equipment. This may seem confusing. To make sense of the confusing causes and effects of power quality problems, the power quality engineer breaks down a power quality problem into three parts: sources (initiating events), causes, and effects of power quality. Both electric utilities and end users of electric power are becoming increasingly concerned about the quality of electric power The term power quality has become one of the most prolific buzzwords in the power industry since the late 1980s. It is an umbrella concept for a multitude of individual types of power system disturbances. The issues that fall under this umbrella are not necessarily new. What is new is that engineers are now attempting to deal with these issues using a system approach rather than handling them as individual problems.

The major reasons for the increased concern:

1. Newer-generation load equipment, with microprocessor-based controls and power devices, is more sensitive to power quality variations than was equipment used in the past.
2. The increasing emphasis on overall power system efficiency has resulted in continued growth in the application of devices such as high-efficiency, adjustable speed motor drives and shunt capacitors for power factor correction to reduce losses. This is resulting in increasing harmonic levels on power systems and has many people concerned about the future impact on system capabilities.
3. End users have an increased awareness of power quality issues. Utility customers are becoming better informed about such issues as interruptions, sags, and switching transients and are challenging the utilities to improve the quality of power delivered.
4. Many things are now interconnected in a network. Integrated processes mean that the failure of any component has much more important consequences

2. b) Power Frequency Variations:

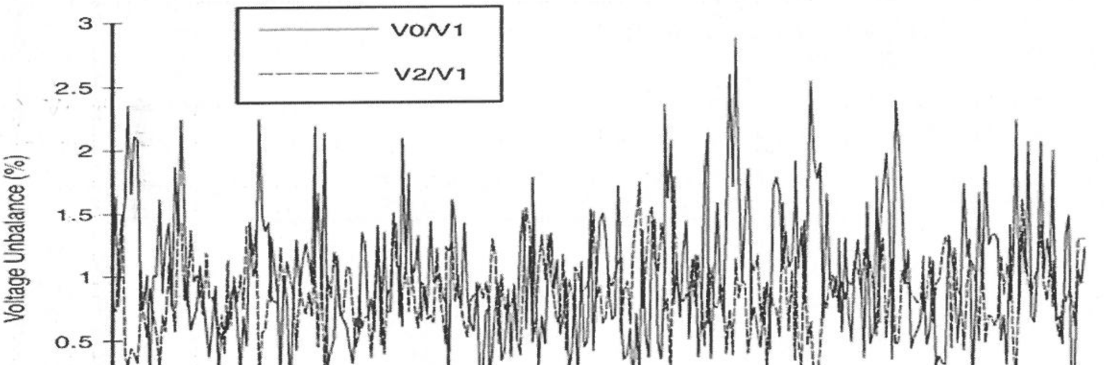
Power frequency variations are defined as the deviation of the power system fundamental frequency from it specified nominal value (e.g., 50 or 60 Hz). The power system frequency is directly related to the rotational speed of the generators supplying the system There are slight variations in frequency as the dynamic balance between load and generation change. The size of the frequency shift and its duration depend on the load characteristics and the response of the generation control system to load changes. Frequency variations that go outside of accepted limits for normal steady-state operation of the power system can be caused by faults on the bulk power transmission system, a large block of load being disconnected, or a large source of generation going off-line. On modern interconnected power systems, significant frequency variations are rare. Frequency variations of consequence are much more likely to occur for loads that are supplied by a generator isolated from the utility system. In such cases, governor response to abrupt load changes may not be adequate to regulate within the narrow bandwidth required by frequency-sensitive equipment



Power frequency trend and statistical distribution at 13-kV substation bus.

3. a) Voltage unbalance /Voltage Imbalance

Voltage imbalance (also called voltage unbalance) is sometimes defined as the maximum deviation from the average of the three-phase volt ages or currents, divided by the average of the three-phase voltages or currents, expressed in percent. Imbalance is more rigorously defined in the standards6,8,11,12 using symmetrical components. The ratio of either the negative- or zero sequence component to the positive-sequence component can be used to specify the percent unbalance. The most recent standards11 specify that the negative-sequence method be used. Figure 2.9 shows an example of these two ratios for a 1-week trend of imbalance on a residential feeder. The primary source of voltage unbalances of less than 2 percent is single-phase loads on a three-phase circuit. Voltage unbalance can also be the result of blown fuses in one phase of a three-phase capacitor bank. Severe voltage unbalance (greater than 5 percent) can result from single-phasing conditions.



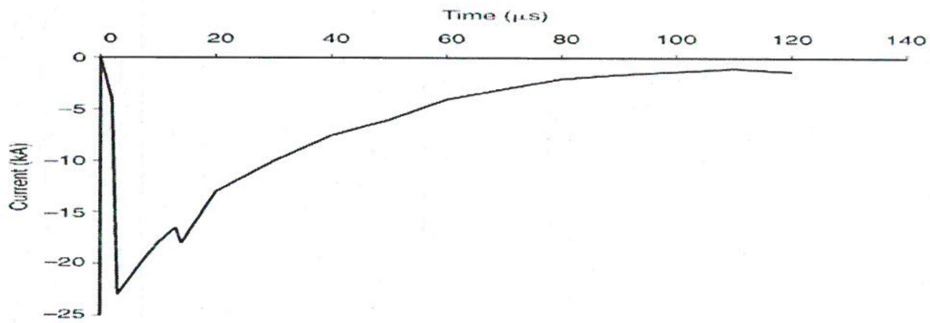
Voltage unbalance trend for a residential feeder.

3.b) Types of transients in power systems

Broadly speaking, transients can be classified into two categories, impulsive and oscillatory. These terms reflect the wave shape of a current or voltage transient.

1. Impulsive Transient 2. Oscillatory Transient

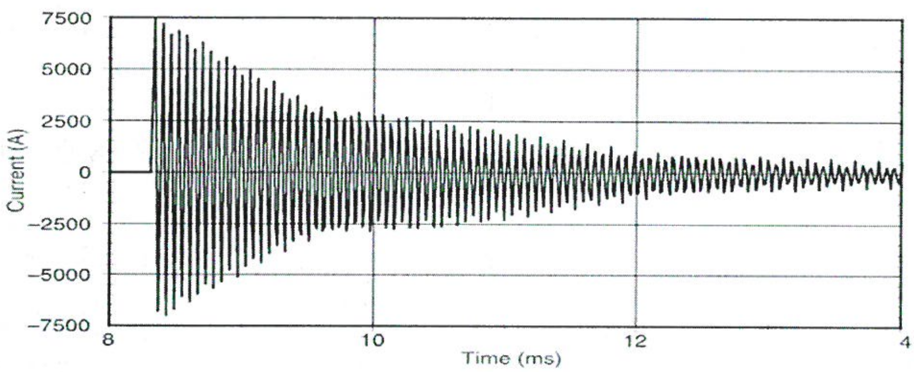
Impulsive transient: An impulsive transient is a sudden; non–power frequency change in the steady-state condition of voltage, current, or both that is unidirectional in polarity (primarily either positive or negative). Impulsive transients are normally characterized by their rise and decay times, which can also be revealed by their spectral content.



Lightning stroke current impulsive transient.

The above figure 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.

Oscillatory 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. 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.



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

A transient with a primary frequency component less than 5 kHz, and duration from 0.3 to 50 ms, is considered a low-frequency transient. This category of phenomena is frequently encountered on utility sub transmission and distribution systems and is caused by many types of events.

UNIT II

4. a) Different strategies in utilities that are to be used to decrease the impact of lightning.

Here are some strategies for utilities to use to decrease the impact of lightning.

1. Shielding: One of the strategies open to utilities for lines that are particularly susceptible to lightning strikes is to shield the line by installing a grounded neutral wire over the phase wires. This will intercept most lightning strokes before they strike the phase wires. This can help, but will not necessarily prevent line flashovers because of the possibility of back flashovers. 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.

2. 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

3. Low-side surges: Some utility and end-user problems with lightning impulses are closely related. One of the most significant ones is called the "low-side surge" problem by many utility engineers. The name was coined by distribution transformer designers because it appears from the transformer's perspective that a current surge is suddenly injected into the low-volt age side terminals.

4. Protecting the transformer. There are two common ways for the utility to protect the transformer: 1. Use transformers with interlaced secondary windings. 2. Apply surge arresters at the X terminals. Of course, the former is a design characteristic of the transformer and cannot be changed once the transformer has been made.

   If the transformer is a non-interlaced design, the only option is to apply arresters to the low-voltage side. Note that arresters at the load service entrance will not protect the transformer. In fact, they will virtually guarantee that there will be a surge current path and thereby cause additional stress on the transformer.

4.b) The issues of Ferroresonance and switching transient problems

Ferroresonance in a distribution system occurs mainly when a lightly loaded, three-phase transformer becomes isolated on a cable with one or two open phases. This can happen both accidentally and intentionally. Most ferroresonance is a result of blown fuses in one or two of the phases in response to faults, or some type of single-pole switching in the primary circuit. A logical effective measure to guard against ferroresonance would be to use three-phase switching devices. For exam ple, a three-phase recloser or sectionalizer could be used at the riser pole instead of fused cutouts. The main drawback is cost. Utilities could not afford to do this at every riser pole, but this could be done in special cases where there are particularly sensitive end users and frequent fuse blowings.

Another strategy on troublesome cable drops is to simply replace the fused cutouts with solid blades. This forces the upline recloser or breaker to operate to clear faults on the cable. Of course, this subjects many other utility customers to sustained interruptions when they would have normally seen only a brief voltage sag. However, it is an inexpensive way to handle the problem until a more permanent solution is implemented.

Manual, single-phase cable switching by pulling cutouts or cable elbows is also a major source of ferroresonance. This is a particular problem during new construction when there is a lot of activity and the transformers are not yet loaded.

Ferroresonance can generally be damped out by a relatively small amount of resistive load, although there are exceptions. For the typical case with one phase open, a resistive load of 1 to 4 percent of the transformer capacity can greatly reduce the effects of ferroresonance. The amount of load required is dependent on the length of cable and the design of the transformers. Also, the two-phase open case is sometimes more difficult to dampen with load.

Switching transient problems with loads:

(i) Nuisance tripping of ASDs: Most adjustable-speed drives typically use a voltage source inverter (VSI) design with a capacitor in the dc link. The controls are sensitive to dc overvoltages and may trip the drive at a level as low as 117 per cent. Since transient voltages due to utility capacitor switching typically exceed 130 percent, the probability of nuisance tripping of the drive is high.

(ii) Transients from load switching: Reenergizing inductive circuits with air-gap switches, such as relays and contactors, can generate bursts of high-frequency impulses. There is very little energy in these types of transient due to the short duration, but they can interfere with the operation of electronic loads. Such electrical fast transient (EFT) activity, producing spikes up to 1 kV, is frequently due to cycling motors, such as air conditioners and elevators. Transients as high as 3 kV can be caused by operation of arc welders and motor starters.

(iii) Transformer energizing: Energizing a transformer produces inrush currents that are rich in harmonic components for a period lasting up to 1 s. If the system has a parallel resonance near one of the harmonic frequencies, a dynamic overvoltage condition results that can cause failure of arresters and problems with sensitive equipment.

5. **a)** Over voltage protection devices:

Surge arresters and transient voltage surge suppressors: Arresters and TVSS devices protect equipment from transient over voltages by limiting the maximum voltage, and the terms are sometimes used interchangeably. However, TVSSs are generally associated with devices used at the load equipment. A TVSS will sometimes have more surge-limiting elements than an arrester, which most commonly consists solely of MOV blocks. An arrester may have more energy handling capability; however, the distinction between the two is blurred by common language usage. The elements that make up these devices can be classified by two different modes of operation, crowbar and clamping. Clamping devices for ac circuits are commonly nonlinear resistors (varistors) that conduct very low amounts of current until an overvoltage occurs. Then they start to conduct heavily, and their impedance drops rapidly with increasing voltage.

Isolation transformers: Isolation transformers are used to attenuate high-frequency noise and transients as they attempt to pass from one side to the other. However, some common-mode and normal-mode noise can still reach the load.

5.b) There are two main sources of transient overvoltages on utility systems: capacitor switching and lightning. These are also sources of transient overvoltages as well as a myriad of other switching phenomena within end-user facilities.

Capacitor switching: 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. Thus, the use of capacitors on power systems is quite common and will continue to be. Some capacitors are energized all the time (a fixed bank), while others are switched according to load levels. Various control means, including time, temperature, voltage, current, and reactive power, are used to determine when the capacitors are switched. It is common for controls to combine two or more of these functions, such as temperature with voltage override.

One of the common symptoms of power quality problems related to utility capacitor switching overvoltage's is that the problems appear at nearly the same time each day. On distribution feeders with industrial loads, capacitors are frequently switched by time clock in anticipation of an increase in load with the beginning of the working day. Common problems are adjustable-speed-drive trips and malfunctions of other electronically controlled load equipment that occur without a notice able blinking of the lights or impact on other, more conventional loads.

UNIT III

6. a) Role of end-user application in power quality improvement

- The reasons that an end user might decide to apply power factor correction capacitors are to
- Reduce electric utility bill
- Reduce I2R losses and, therefore, heating in lines and transformers
- Increase the voltage at the load, increasing production and/or the efficiency of the operation
- Reduce current in the lines and transformers, allowing additional load to be served without building new circuits

The primary motivation is generally economics to eliminate utility power factor penalties, but there are technical benefits related to power quality as well.

(i) Location for power factor correction capacitors: The benefits realized by installing power factor correction capacitors include the reduction of reactive power flow on the system. Often, capacitors will be installed with large induction motors. This allows the capacitor and motor to be switched as a unit. Large plants with extensive distribution systems often install capacitors at the primary voltage bus (C1) when utility billing encourages power factor correction. Many times, however, power factor correction and harmonic distortion reduction must be accomplished with the same capacitors. Location of larger harmonic filters on the main distribution bus (C2) provides the required compensation and a low-impedance path for harmonic currents to flow, keeping the harmonic currents off the utility system.

(ii) Voltage rise The voltage rise from placing capacitors on an inductive circuit is a two-edged sword from the power quality standpoint. If the voltage is low, then the capacitors provide an increase to bring the voltage back into tolerable limits. However, if the capacitors are left energized when the load is turned off, the voltage can rise too high, resulting in a sustained overvoltage.

6.b) Causes of Voltage Flicker

Although voltage flicker is not technically a long-term voltage variation, it is included in this chapter because the root cause of problems is the same: The system is too weak to support the load. Also, some of the solutions are the same as for the slow-changing voltage regulation problems. The voltage variations resulting from flicker are often within the normal service voltage range, but the changes are sufficiently rapid to be irritating to certain end users.

Flicker occurs on systems that are weak relative to the amount of power required by the load, resulting in a low short-circuit ratio. This, in combination with considerable variations in current over a short period of time, results in flicker. As the load increases, the cur rent in the line increases, thus increasing the voltage drop across the line. This phenomenon results in a sudden reduction in bus voltage. Depending upon the change in magnitude of voltage and frequency of occurrence, this could result in observable amounts of flicker. If a light ing load were connected to the system in relatively close proximity to the fluctuating load, observers could see this as a dimming of the lights. A common situation, which could result in flicker, would be a large industrial plant located at the end of a weak distribution feeder.

Whether the resulting voltage fluctuations cause observable or objectionable flicker is dependent upon the following parameters: Size (VA) of potential flicker-producing source, System impedance (stiffness of utility), Frequency of resulting voltage fluctuations A common load that can often cause flicker is an electric arc furnace (EAF). EAFs are nonlinear, time-varying loads that often cause large voltage fluctuations and harmonic distortion. Most of the large current fluctuations occur at the beginning of the melting cycle.

7. a) Utilities generally try to maintain the service voltage supplied to an end user within ±5 percent of nominal. Under emergency conditions, for short periods, ANSI Standard C84.1 permits the utilization voltage to be in the range of 6 to 13 percent of the nominal voltage. Some sensitive loads have more stringent voltage limits for proper operation and, of course, equipment generally operates more efficiently at near nominal voltage.

The root cause of most voltage regulation problems is that there is too much impedance in the power system to properly supply the load (Fig. 7.1). Another way of describing this is to say that the power system is too weak for the load. Therefore, the voltage drops too low under heavy load. Conversely, when the source voltage is boosted to overcome the impedance, there can be an overvoltage condition when the load drops too low. The corrective measures usually involve either compensating for the impedance Z or compensating for the voltage drop IR jIX caused by the impedance.

Utilities must keep voltage within statutory limits (e.g., ±5% or ±6%).Good voltage regulation prevents voltage collapse, enhances reactive power balance, and improves overall grid stability.

Proper voltage levels minimize I^2R losses in lines.High voltage drop means the utility must push more current, increasing losses and reducing system efficiency.

For end user Proper voltage levels minimize I^2R losses in lines. High voltage drop means the utility must push more current, increasing losses and reducing system efficiency.

Reducing Energy Wastage : Poor voltage can lead to inefficient operation of motors and heaters, increasing electricity bills.

7.b) There are a variety of voltage regulation devices in use on utility and industrial power systems. These are divided into three major classes: 1. Tap-changing transformers 2. Isolation devices with separate voltage regulators 3. Impedance compensation devices, such as capacitor.

Utility step-voltage regulators: The typical utility tap-changing regulator can regulate from 10 to 10 percent of the incoming line voltage in 32 steps of 5/8 percent. There are some variations, but the majority are of this type. Distribution substation transformers commonly have three-phase load tap changers (LTCs) while line regulators installed out on the feeders are typically single-phase in North America.

Ferroresonant transformers On the end-user side, ferroresonant transformers are not only useful in protecting equipment from voltage sags (see Chap. 3), but they can also be used to attain very good voltage regulation.

Electronic tap-switching regulators : Electronic tap-switching regulators can also be used to regulate voltage. They are more efficient than ferroresonant transformers and use SCRs or triacs to quickly change taps, and hence voltage. Tap switching regulators have a very fast response time of a half cycle and are popular for medium-power applications.

Magnetic synthesizers : Magnetic synthesizers, although intended for short-duration voltage sags (see Chap. 3), can also be used for steady-state voltage regula tion. One manufacturer, for example, states that for input voltages of ±40 percent, the output voltage will remain within ±5 percent at full load.

UNIT-IV

8. a) There are a number of devices available to control harmonic distortion. They can be as simple as a capacitor bank or a line reactor, or as complex as an active filter.

In-line reactors or chokes: A simple, but often successful, method to control harmonic distortion generated by adjustable-speed drives involves a relatively small reactor, or choke, inserted at the line input side of the drive. This is particularly effective for PWM-type drives. The inductance slows the rate at which the capacitor on the dc bus can be charged and forces the drive to draw current over a longer time period. The net effect is a lower-magnitude current with much less harmonic content while still delivering the same energy.

Zigzag transformers: Zigzag transformers are often applied in commercial facilities to control zero-sequence harmonic components. A zigzag transformer acts like a filter to the zero-sequence current by offering a low-impedance path to neutral. This reduces the amount of current that flows in the neutral back toward the supply by providing a shorter path for the current. To be effective, the transformer must be located near the load on the circuit that is being protected.

Passive filters: Passive filters are inductance, capacitance, and resistance elements configured and tuned to control harmonics. They are commonly used and are relatively inexpensive compared with other means for eliminating harmonic distortion.

Active filters: 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.

8.b) Evaluations of harmonic distortion are usually performed at a point between the end user or customer and the utility system where another customer can be served. This point is known as the point of common coupling.

The PCC can be located at either the primary side or the secondary side of the service transformer depending on whether or not multiple customers are supplied from the transformer. In other words, if multiple customers are served from the primary of the transformer, the PCC is then located at the primary. On the other hand, if multiple customers are served from the secondary of the transformer, the PCC is located at the secondary.

When the primary of the transformer is the PCC, current measurements for verification can still be performed at the trans former secondary. The measurement results should be referred to the transformer high side by the turns ratio of the transformer, and the effect of transformer connection on the zero-sequence components must be taken into account. For instance, a delta-wye connected transformer will not allow zero-sequence current components to flow from the secondary to the primary system. These secondary components will be trapped in the primary delta winding.

9. a) The harmonic voltages are too great (the voltage too distorted) for the control to properly determine firing angles. The harmonic currents are too great for the capacity of some device in the power supply system such as a transformer, and the machine must be operated at a lower than rated power. Harmonic voltages are too great because the harmonic currents produced by the device are too great for the given system condition. Nonlinear loads appear to be sources of harmonic current in shunt with and injecting harmonic currents into the power system. For nearly all analyses, it is sufficient to treat these harmonic-producing loads simply as current sources.

Voltage distortion is the result of distorted cur rents passing through the linear, series impedance of the power delivery system, although, assuming that the source bus is ultimately a pure sinusoid, there is a nonlinear load that draws a distorted current. The harmonic currents passing through the impedance of the system cause a voltage drop for each harmonic. This results in voltage harmonics appearing at the load bus. The amount of voltage distortion depends on the impedance and the current. Assuming the load bus distortion stays within reasonable limits (e.g., less than 5 percent), the amount of harmonic current produced by the load is generally constant. While the load current harmonics ultimately cause the voltage distortion, it should be noted that load has no control over the voltage distortion. The same load put in two different locations on the power system will result in two different voltage distortion values.

9.b) 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.

Characteristics of typical nonlinear commercial loads are detailed in the following sections:

Single-phase power supplies: Electronic power converter loads with their capacity for producing harmonic currents now constitute the most important class of nonlinear loads in the power system. Advances in semiconductor device technology have fueled a revolution in power electronics over the past decade, and there is every indication that this trend will continue. Equipment includes adjustable-speed motor drives, electronic power supplies, dc motor drives, battery chargers, electronic ballasts, and many other rectifier and inverter applications.

Fluorescent lighting: Lighting typically accounts for 40 to 60 percent of a commercial building load. According to the 1995 Commercial Buildings Energy Consumption study conducted by the U.S. Energy Information Administration, fluorescent lighting was used on 77 percent of commercial floor spaces, while only 14 percent of the spaces used incandescent lighting. Fluorescent lights are a popular choice for energy savings. Fluorescent lights are discharge lamps; thus they require a ballast to provide a high initial voltage to initiate the discharge for the electric current to flow between two electrodes in the fluorescent tube. Once the discharge is established, the voltage decreases as the arc current increases. It is essentially a short circuit between the two electrodes, and the ballast has to quickly reduce the current to a level to maintain the specified lumen output. Thus, ballast is also a current-limiting device in lighting applications.

UNIT V

10. a) The main power quality issues affected by DG are:

1. Sustained interruptions. This is the traditional reliability area. Many generators are designed to provide backup power to the load in case of power interruption. However, DG has the potential to increase the number of interruptions in some cases. Much of the DG that is already in place was installed as backup generation. The most common technology used for backup generation is diesel gensets. The bulk of the capacity of this form of DG can be realized simply by transferring the load to the backup system. However, there will

be additional power that can be extracted by paralleling with the power system. Many DG installations will operate with better power quality while paralleled with the utility system because of its large capacity. However, not all backup DG can be paralleled without great expense. Not all DG technologies are capable of significant improvements in reliability. To achieve improvement, the DG must be capable of serving the load when the utility system cannot.

2. Voltage regulation: This is often the most limiting factor for how much DG can be accommodated on a distribution feeder without making changes. Generator controls are much faster and smoother than conventional tap-changing transformers and switched capacitor banks. With careful engineering, this can be accomplished with sufficiently large DG. However, there are many problems associated with voltage regulation. In cases where the DG is located relatively far from the substation for the size of DG, voltage regulation issues are often the most limiting for being able to accommodate the DG without changes to the utility system. It should first be recognized that some technologies are unsuitable for regulating voltages. This is the case for simple induction machines and for most utility interactive inverters that produce no reactive power. Secondly, most utilities do not want the DG to attempt to regulate the voltage because that would interfere with utility voltage regulation equipment and increase the chances of supporting an island. Multiple DG would interfere with each other

3. Harmonics: There are harmonics concerns with both rotating machines and inverters, although concern with inverters is less with modern technologies. Harmonics from rotating machines are not always negligible, particularly in grid parallel operation. The utility power system acts as a short circuit to zero-sequence triplen harmonics in the voltage, which can result in surprisingly high currents. For grounded wye-wye or delta-wye service transformers, only synchronous machines with 2/3 pitch can be paralleled without special provisions to limit neutral current.

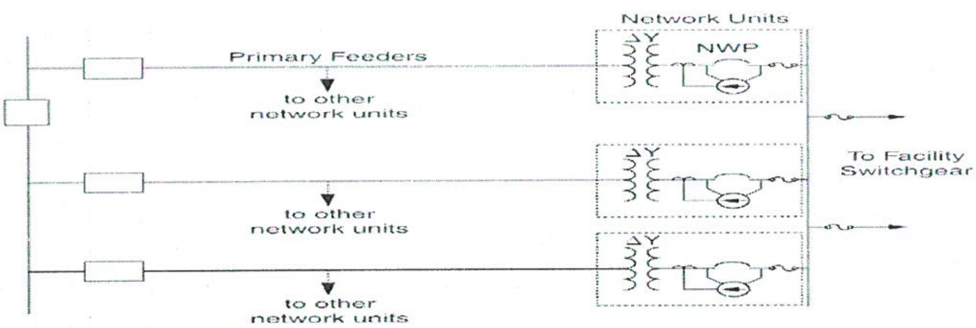
4. Voltage sags: This is a special case because DG may or may not help. During voltage sag, DG might act to counter the sag. Large rotating machines can help support the voltage magnitudes and phase relationships. Although not a normal feature, it is conceivable to control an inverter to counteract voltage excursions.

10. b) A Power Quality Measurement System (PQMS) is essential for monitoring, recording, and analyzing disturbances in the electrical network such as voltage sags, swells, harmonics, flicker, transients, interruptions, and frequency variations. PQMS plays a critical role for utilities, industries, and sensitive electronic loads.

Power quality measuring experience gained some of the difficulties in managing a large system of power quality monitors. 1. Managing the large volume of raw measurement data that must be collected, analyzed, and archived becomes a serious challenge as the number of monitoring points grows. 2. The data volume collected at each monitoring point can strain communication mechanisms employed to move that data from monitor to analysis point. 3. As understanding of system performance grows through the feedback provided by the monitoring data, detailed views of certain events, such as normal capacitor switching, become less valuable and would be of more use in a summary or condensed form. 4. The real value of any monitoring system lies in its ability to generate information rather than in collecting and storing volumes of detailed raw data. Based on the experience gained from the EPRI DPQ project, it was realized that the information system aspect of a power monitoring program plays a very important role in tracking power quality performance. Thus, the development of the most recent generation of power quality monitors was geared toward meeting the new information system demand, i.e., to be able to discover knowledge or information from the collected data as they are captured and to disseminate the information rapidly. This type of instrument employs expert system and advanced communication technologies.

11. a) For more than 7 decades, the norm for the electric power industry in developed nations has been to generate power in large, centralized generating stations and to distribute the power to end users through transformers, transmission lines, and distribution lines.
The original electrical power systems, consisting of relatively small generators configured in isolated islands used DG.
That model gave way to the present centralized system largely because of economies of scale. Also, there was the desire to sequester electricity generation facilities away from population centers for environmental reasons and to locate them closer to the source of fuel and water. New technologies would allow the generation to be as widely dispersed as the load and interconnected power grids could be small (i.e.,microgrids). The generation would be powered by renew able resources or clean-burning, high-efficiency technologies. Energy distribution will be shifted from wires to pipes containing some type of fuel, which many think will ultimately be hydrogen. Recent efforts to deregulate electric power have been aimed not only at achieving better prices for power but at enabling new technologies. However, it is by no means certain that the power industry will evolve into DG sources. Despite the difficulties in wire-based delivery described in this book, wires are very robust compared to generation technologies. Once installed, they remain silently in service for decades with remarkably little maintenance.

11.b) In large cities a number of utilities use a low-voltage network method of distribution.
These low-voltage network systems are of two major subtypes, the secondary network (also referred to as an area network, grid network, or street network) and the spot network. Secondary networks serve numerous sites, usually several city blocks, from a grid of low-voltage mains at 120/208 V, three-phase. Spot networks serve a single site, usually a large building or even a portion of a large building. The secondary voltage of spot networks is often 277/480 V, three-phase, but 120/208-V spot networks are also used.
Street networks and spot networks are supplied from two or more primary distribution feeders through integrated transformer/breaker/protection combinations called network units. These network units are often located in transformer vaults within the building or in underground vaults in the street. The objective of the network distribution design is to achieve high service reliability with high power quality. To accomplish this, the primary feeders are often chosen so that they originate at different substations or, at least at different bus sections of the same substation.



Spot network arrangement.

High power quality is achieved by having full service capability with any feeder out of service and rapidly removing any faulted feeder from connection to the low-voltage network.