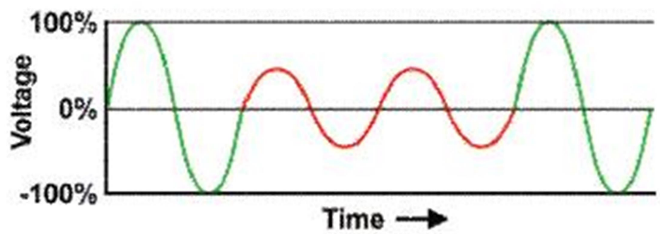
UNIT-I

Voltage Sag or **Voltage Dip** (**IEC International Electro technical Commission** term) is defined by the IEEE 1159 as the decrease in the RMS voltage level to 10% - 90% of nominal, at the power frequency for durations of ½ cycle to one (1) minute. Also, voltage sag is classified as a short duration voltage variation phenomena, which is one of the general categories of power quality problems.

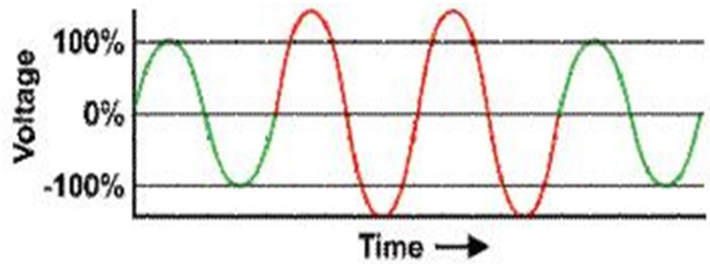


Common Causes of Voltage Sags or Dips:

Voltage sags are generally caused by weather and utility equipment problems, which normally lead to system faults on the transmission or distribution system. For example, a fault on a parallel feeder circuit will result in a voltage drop at the substation bus that affects all of the other feeders until the fault is cleared. The same concept would apply for a fault somewhere on the transmission system. Most of the faults on the utility transmission and distribution system are single-line-to-ground (SLG) faults.

Voltage sags can also be caused by the switching of heavy loads or the starting of large motors. To illustrate, an induction motor can draw six to ten times of its full load current during starting. If the current magnitude is relatively larger than the available fault current at that point in the system, the voltage sag can become significant.

Voltage Swell is defined by IEEE 1159 as the increase in the RMS voltage level to 110% - 180% of nominal, at the power frequency for durations of ½ cycle to one (1) minute. It is



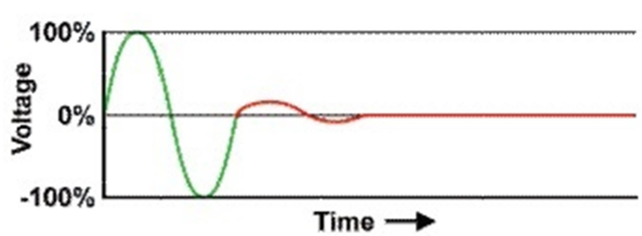
Voltage Swell	Magnitude	Duration
Instantaneous	1.1 to 1.8 pu	0.5 to 30 cycles
Momentary	1.1 to 1.4 pu	30 cycles to 3 sec
Temporary	1.1 to 1.2 pu	3 sec to 1 min

Causes and Effects of Voltage Swells:

Voltage swells are usually associated with system fault conditions - just like voltage sags but are much less common. This is particularly true for ungrounded or floating delta systems, where the sudden change in ground reference result in a voltage rise on the ungrounded phases. In the case of a voltage swell due to a single line-to-ground (SLG) fault on the system, the result is a temporary voltage rise on the unfaulted phases, which last for the duration of the fault.

Voltage swells can also be caused by the deenergization of a very large load. The abrupt interruption of current can generate a large voltage, per the formula: V = L di/dt, where L is the inductance of the line and di/dt is the change in current flow.

Interruptions are classified by IEEE 1159 into either a short-duration or long-duration variation. However, the term "interruption" is often used to refer to short-duration interruption, while the latter is preceded by the word "sustained" to indicate a long-duration. They are measured and described by their duration since the voltage magnitude is always less than 10% of nominal.



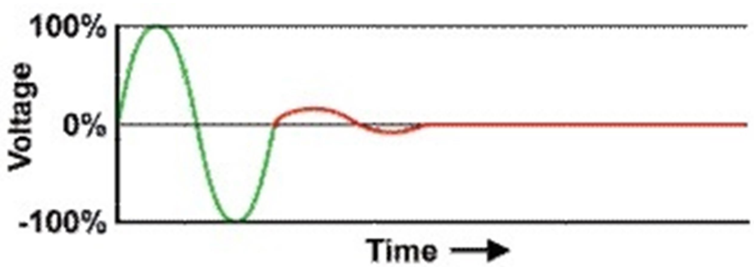
Short-duration Interruption:

Interruption is defined as the decrease in the voltage supply level to less than 10% of nominal for up to one (1) minute duration. They are further subdivided into: Instantaneous (1/2 to 30 cycles), Momentary (30 cycles to 3 seconds) and Temporary (3 seconds to 1 minute).

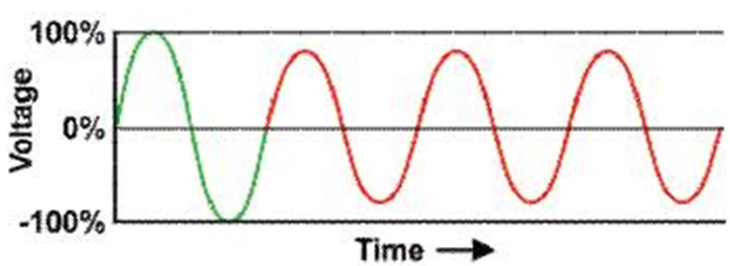
Interruptions mostly result from reclosing circuit breakers or reclosers attempting to clear non-permanent faults, first opening and then reclosing after a short time delay.

Aside from system faults, interruptions can also be due to control malfunctions and equipment failures.

Sustained Interruption is defined by IEEE 1159 as the decrease in the voltage supply level to zero for more than one (1) minute. It is classified as a long duration voltage variation phenomena. Sustained interruptions are often permanent in nature and require manual intervention for restoration.



Under voltage is classified as a Long-duration Voltage Variation phenomena. Long-duration voltage variation is commonly defined as the root-mean-square (RMS) value deviations at power frequencies for longer than one (1) minute.

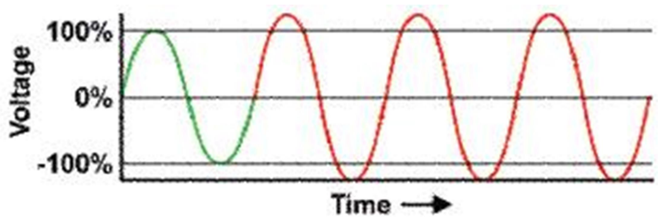


Undervoltage is described by IEEE 1159 as the decrease in the AC voltage (RMS), typically to 80% - 90% of nominal, at the power frequency for a period of time greater than 1 minute.

Undervoltage generally results from low distribution voltage because of heavily loaded circuits that lead to considerable voltage drop, switching on a large load or group of loads, or a capacitor bank switching off.

Overvoltage is classified as a Long-duration Voltage Variation phenomena. Long-duration voltage variation is commonly defined as the root-mean-square (RMS) value deviations at power frequencies for longer than one (1) minute.

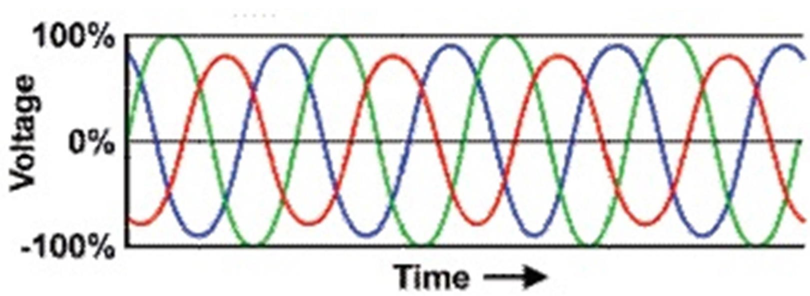
Overvoltage is defined by the IEEE as an increase in the AC voltage (RMS), typically to 110% - 120% of nominal, at the power frequency for duration longer than 1 minute. It is often the result of high distribution voltage due to incorrect tap settings on transformers, switching off a large load



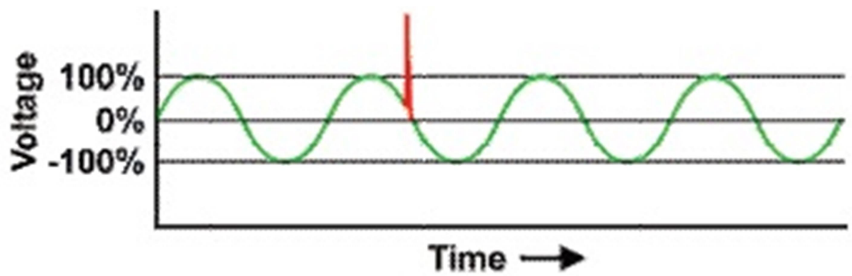
Voltage Unbalance (or Imbalance) is defined by IEEE as the ratio of the negative or zero sequence component to the positive sequence component. In simple terms, it is a voltage variation in a power system in which the voltage magnitudes or the phase angle differences between them are not equal. It follows that this power quality problem affects only polyphase systems (e.g. three-phase).

Voltages are rarely exactly balanced between phases. However, when voltage unbalance becomes excessive, it can create problems for polyphase motors and other loads. Moreover, adjustable speed drives (ASD) can be even more sensitive than standard motors.

Voltage unbalance is primarily due to unequal loads on distribution lines or within a facility.

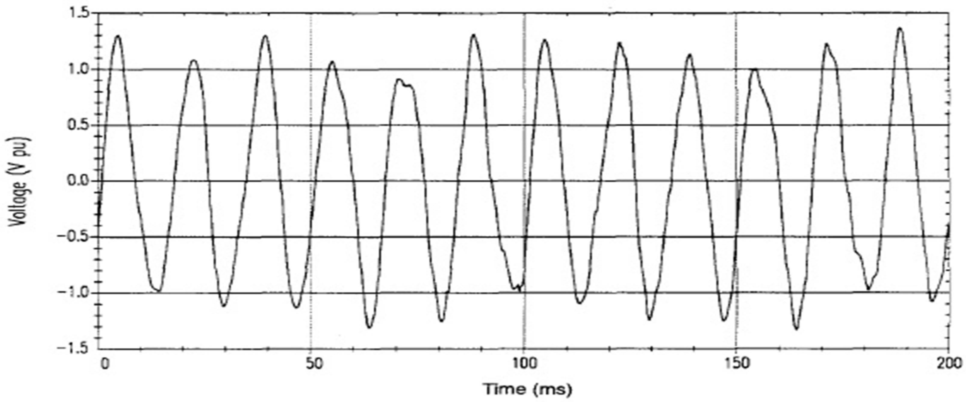


Transients are power quality disturbances that involve destructive high magnitudes of current and voltage or even both. It may reach thousands of volts and amps even in low voltage systems. However, such phenomena only exist in a very short duration from less than 50 nanoseconds to as long as 50 milliseconds. This is the shortest among PQ problems, hence, its name. Transients usually include abnormal frequencies, which could reach to as high as 5 MHz.



- Lightning Strikes
- Switching activities
  - Opening and closing of disconnects on energized lines
  - Capacitor bank switching
  - Reclosing operations
  - Tap changing on transformers

Voltage Fluctuations are described by IEEE as systematic variations of the voltage waveform envelope, or a series of random voltage changes, the magnitude of which falls between the voltage limits. Generally, the variations range from 0.1% to 7% of nominal voltage with frequencies less than 25 Hz.



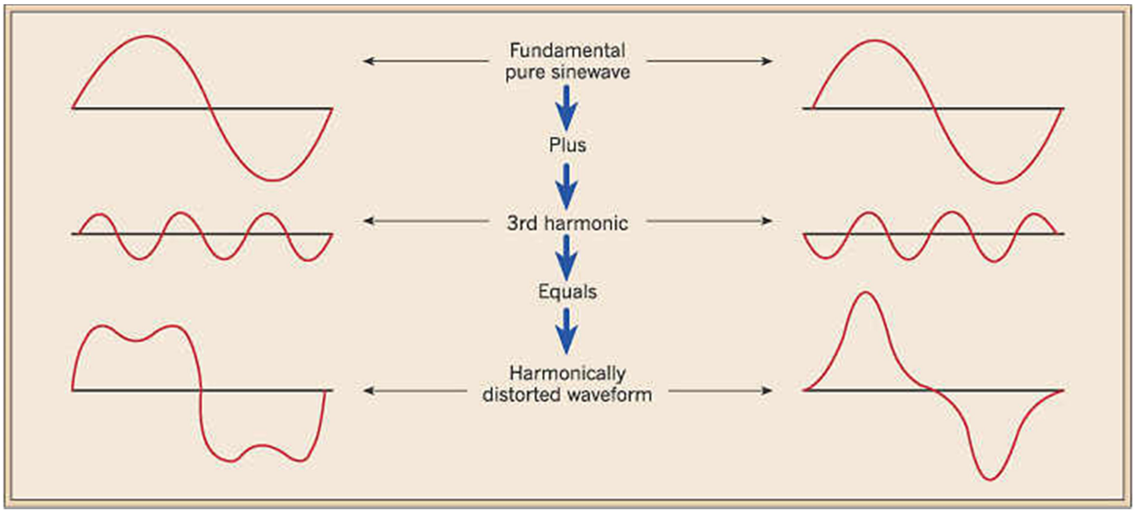
Voltage fluctuation and light flicker are technically two distinct terms, but have been erroneously referred to the same meaning.

Sources and Causes

Equipment or devices that exhibit continuous, rapid load current variations (mainly in the reactive component) can cause voltage fluctuations and light flicker. Normally, these loads have a high rate of change of power with respect to the short-circuit capacity at the point of common coupling. Examples of these loads include:

- Electric arc furnaces
- Static frequency converters
- Cycloconverters
- Rolling mill drives
- Main winders
- Large motors (starting)

Harmonics are described by IEEE as sinusoidal voltages or currents having frequencies that are integer multiples of the fundamental frequency at which the power system is designed to operate. This means that for a 60-Hz system, the harmonic frequencies are 120 Hz (2nd harmonic), 180 Hz (3rd harmonic) and so on. Harmonics combine with the fundamental voltage or current producing a non-sinusoidal shape, thus, a waveform distortion power quality problem. The non-sinusoidal shape corresponds to the sum of different sine waves with different magnitudes and phase angles, having frequencies that are multiples of the system frequency.



Harmonics exists due to the nonlinear characteristics loads and devices on the electrical power system. These devices can be modeled as current sources that inject harmonic currents into the electrical system.

DC offset: The presence of a dc voltage or current in an ac power system is termed dc offset.

Effects: It may saturate the transformer core causing additional heating and loss of transformer life.

- Even a small amount of DC offset current is undesirable as it can result in corrosion of the network and customer's earthing system.

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.

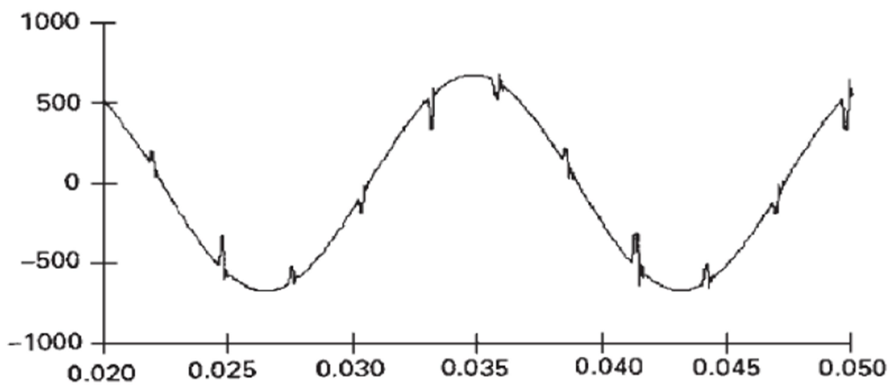
- Can cause problems such as light flicker, audible noise in TV sets, radios and audio equipment, and vibration in rotating induction machines.

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.

The following figure shows an example of voltage notching from a three-phase converter that

Produces continuous dc current.



[Fig.Voltage notching caused by a three-phase converter]

- The notches occur when the current commutates from one phase to another. During this period, there is a momentary short circuit between two phases, pulling the voltage as close to zero as permitted by system impedances.

Power frequency variations: are defined as the deviation of the power system fundamental frequency from it specified nominal value (50 or 60 Hz).

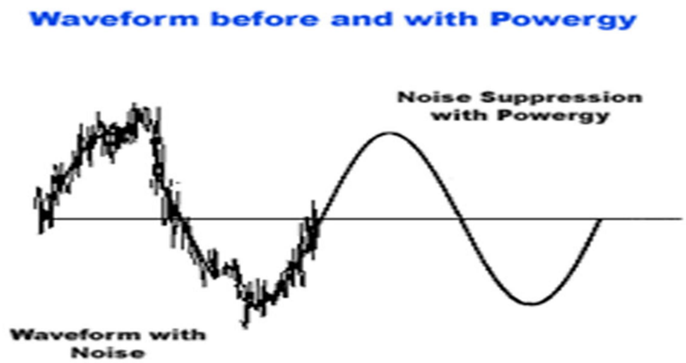
Power system frequency is directly related to generator rotating speed. There are slight variations in frequency as dynamic balance between load and generation changes. The size of frequency shift and its duration depends on load characteristics and response of generation control system.

Sources: Due to 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 system, frequency variations are rare.

Noise:

Defined as any unwanted signals that cannot be classified as harmonic distortion or transients and have broadband sprectral content lower than 200KHz



- Caused by power electronic devices, control circuits, arcing equipment, switching power supplies. Improper grounding can exacerbate the problem.

Remedies to Improve power quality problems:

Common Methods Available for Correcting Power Quality Problems

Equipment	*Application*
UPS	Voltage variations Supply interruptions Frequency variations
Earthing practices	Harmonics
Filters (Active/Passive)	Harmonics
Energy storage devices	Voltage variations Supply interruptions

Power Quality Monitoring

- Power quality monitoring is the process of gathering, analysing, and interpreting raw measurement data into useful information.
- The process of **gathering** data is usually carried out by continuous measurement of voltage and current over an extended period.
- The process of **analysis** and **interpretation** has been traditionally performed manually, but recent advances in signal processing and artificial intelligence fields have made it possible to design and implement intelligent systems to automatically analyze and interpret raw data into useful information with minimum human intervention.
- Power quality monitoring programs are often driven by the demand for improving the system wide power quality performance. Many industrial and commercial customers have equipment that is sensitive to power disturbances, and, therefore, it is more important to understand the quality of power being provided.