Power Quality
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Lecture - 02
Power Quality Standards and Monitoring

Well, good morning to all of you. Now today we will start on this Power Quality, the 2nd lecture we did on Power Quality Standard and Monitoring.

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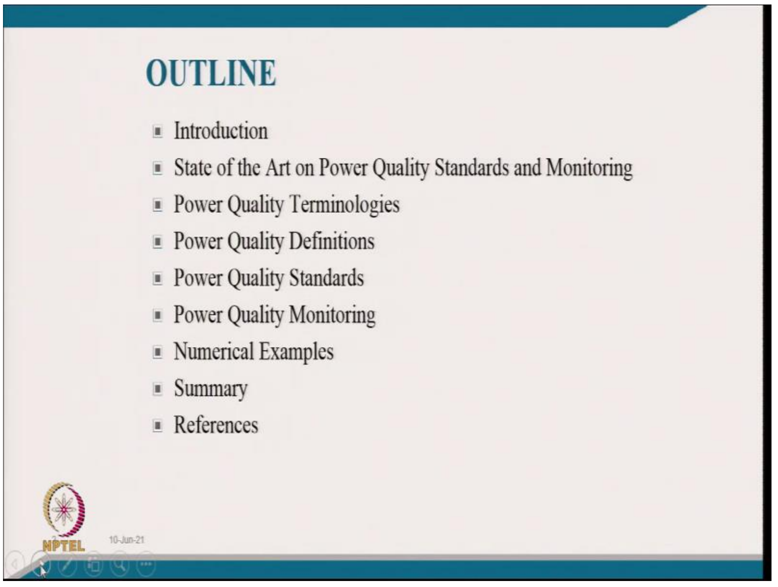

The outline of this lecture or this presentation is we will start from the introduction, and then we will go for the start of state of the art on power quality standards and monitoring. I like to cover power quality terminology, then power quality definition.

Then we will go to power quality standards talk about power quality monitoring and the instruments and equipment available from different manufacturers. Then we will give some numerical examples that will make this course interesting, followed by a summary and references.

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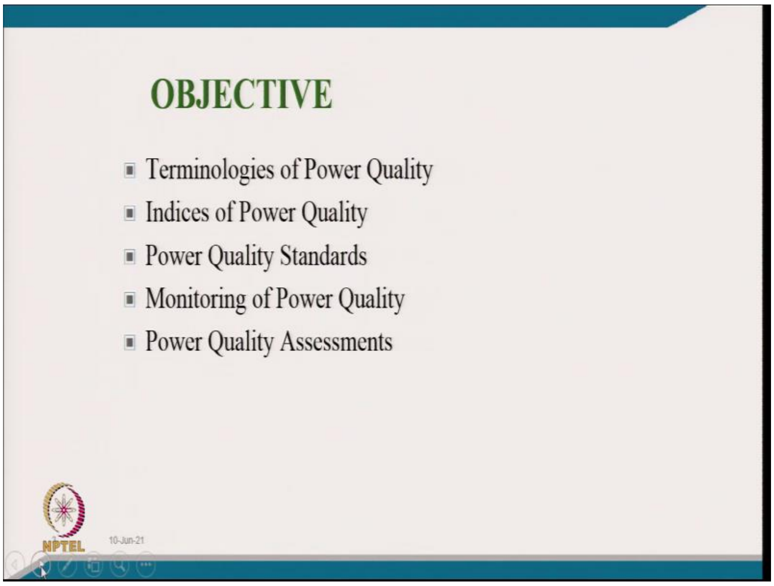

The objective we put it for is to explain the terminology of power quality because you have to quantify the power quality. Then we would like to talk about indices of power quality. Then the power quality standard, the monitoring of power quality, and the power quality assessment.

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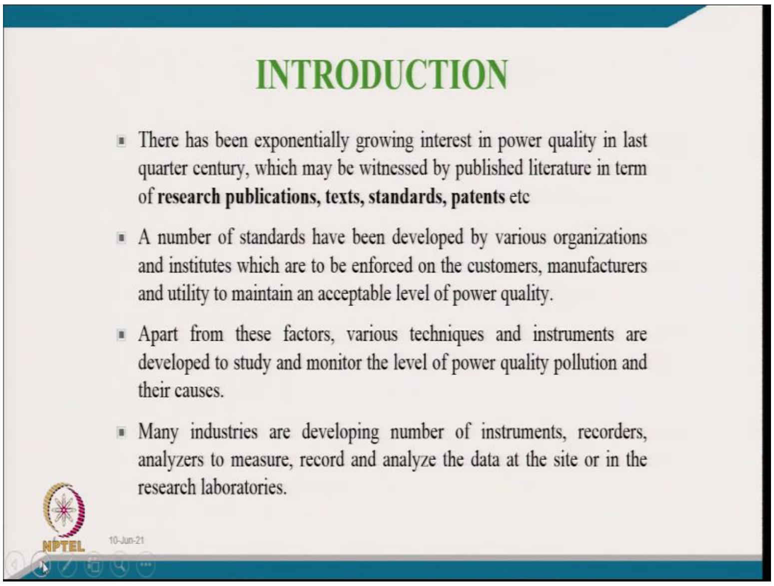

Well, to start with, there has been exponential growth in interest in power quality in the last quarter-century, which may be witnessed by published literature in terms of research publication, texts, standard, patents of application nodes from different manufacturer for different equipment of mitigating the power quality. A number of the standard have been developed by various organizations and institutes, which are to be enforced on the customer manufacture and utility to maintain the acceptable level of power quality.

Apart from these factors, various techniques and instruments are also developed to study and monitor the level of power quality pollution and their causes. And many industries are developing a number of instruments, recorders, analyzers to measure and record, and analyze the data at the site or in the research laboratory to quantify the kind of problems at different places.

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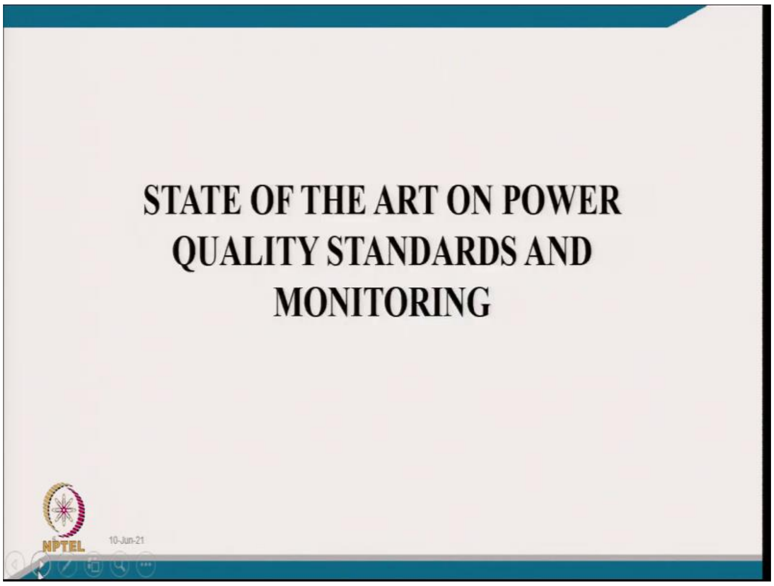

First, we would like to talk about state of the art on power quality standard and monitoring.

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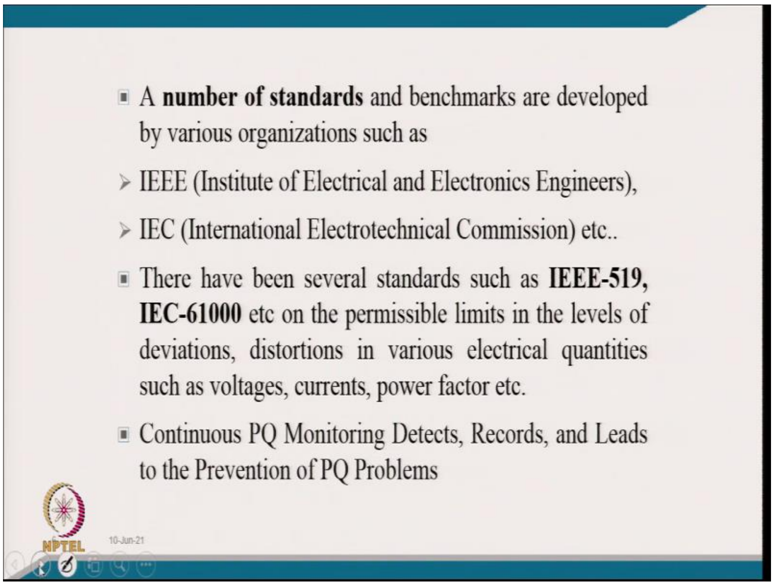

Well, a number of standards and benchmarks are developed by various organizations such as IEEE. I hope you are aware of the IEEE (Institute of Electrical and Electronics Engineers), which consists of more than 40 lakh documents. A lot of standards have been developed for different purposes. On power quality, also they have several standards. The main standard we like to introduce and talk about them what is important.

Another organization is a commercial organization called IEC (International Electrotechnical Commission). It is placed in Geneva, and they have typically developed many standards. Out of these two organizations, these two standards typically include IEEE- 519 from the IEEE site and IEC- 61000.

They give the permission limits on the deviation, distortion in various electrical quantities such as voltage, current, power factor, and continuous monitoring detecting, recording and leads to prevention for power quality problems. We have to quantify first, and then only you can think about it.

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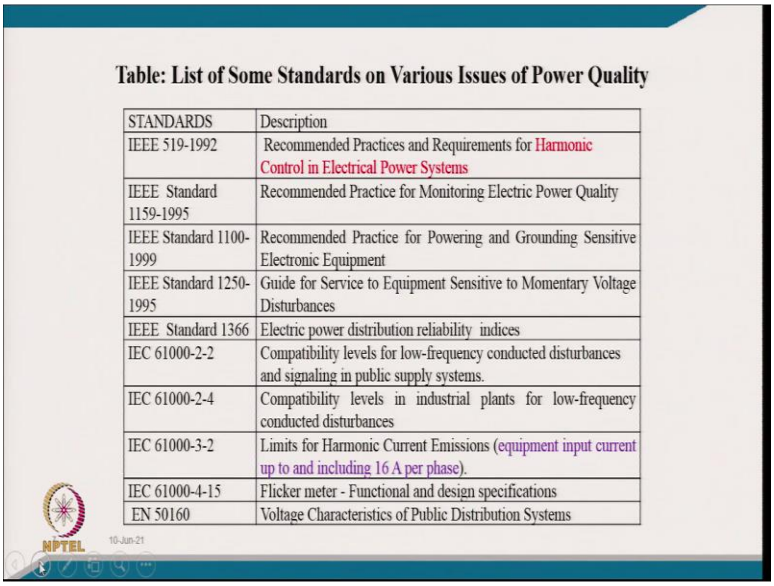

Table: List of Some Standards on Various Issues of Power Quality

STANDARDS	Description
IEEE 519-1992	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
IEEE Standard 1159-1995	Recommended Practice for Monitoring Electric Power Quality
IEEE Standard 1100-1999	Recommended Practice for Powering and Grounding Sensitive Electronic Equipment
IEEE Standard 1250-1995	Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances
IEEE Standard 1366	Electric power distribution reliability indices
IEC 61000-2-2	Compatibility levels for low-frequency conducted disturbances and signaling in public supply systems.
IEC 61000-2-4	Compatibility levels in industrial plants for low-frequency conducted disturbances
IEC 61000-3-2	Limits for Harmonic Current Emissions (equipment input current up to and including 16 A per phase).
IEC 61000-4-15	Flicker meter - Functional and design specifications
EN 50160	Voltage Characteristics of Public Distribution Systems

This is a typical list of some of the standards on various power quality issues. They are not all, and it is only a few standards, and we cannot cover all. A very popular standard is the IEEE- 519. It was initially developed in 1981 and modified in 1992.

It was recently also modified in 2014, and the standard title: recommended practice and requirement for harmonic control in electric power system. It is around a 100-page document.

They talk about not only the benchmark, but they also give some of the practices you can probably meet for different applications. Another standard of this IEEE-1159, typically developed in 1995 is the recommended practice for monitoring electric power quality. It defines the different parameters and methods for different kinds of instruments or equipment to record or monitor this power quality.

Another standard is IEEE – 1100, developed in 1999 is the recommended practice for powering and grounding sensitive equipment. If you do not ground properly, these electronics equipment will certainly have noise and disturbance. Grounding also became very important, and another standard of IEEE standard 1250 was developed in 1995. It is typically guide for service to equipment sensitive to momentary voltage disturbances. IEEE standard 1366 is for electric power distribution reliability.

So another organization which we already talked about IEC-61000 International Electrotechnical Commission from Geneva commercially standard. They have this standard name called 61000, and this standard has different parts, probably around 15-16 parts.

We have only talked about a few parts here, typically part 2-2 compatibility level of low-frequency conducted disturbances and signaling in the public supply system. And another standard IEC-61000-2-4, compatibility level in industrial plant and low frequency conducted disturbances, and IEC 61000-3-2, limits for harmonic current emission equipment input current up to and including 16 amperes per phase. It is related basically to all the equipment of single phase because of single phase supply. If you talk about either 220 or 230 volts, you might have seen the maximum socket of the 16-ampere socket there. This standard is made for that purpose only that the load you can have up to 16 amperes.

They give a different kind of limit for a very small rating, typically starting from a few watt like 20 less than 25 watt more than that. Another standard 61000-4-15, flicker meter functional and design specification. So different standards they go on introducing and based on the different instruments they start coming or meters coming recorder now ammeter they are coming. They go on to introduce different functionality, including that.

Another European standard of 5016 is the voltage characteristic of the public distribution system. These are very important if you want to go there may be more than 100 of standards in the power quality for quantifying and recording for different purposes like now.

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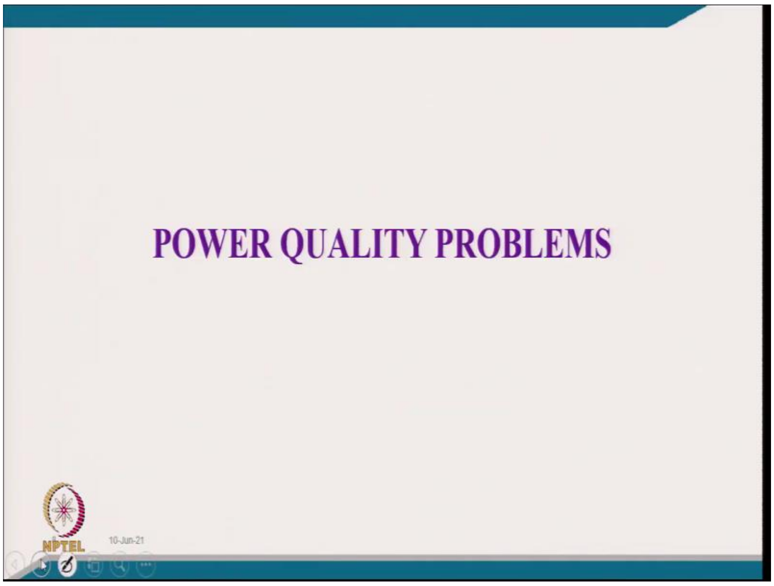

We like to discuss power quality problems again in a little bit in detail.

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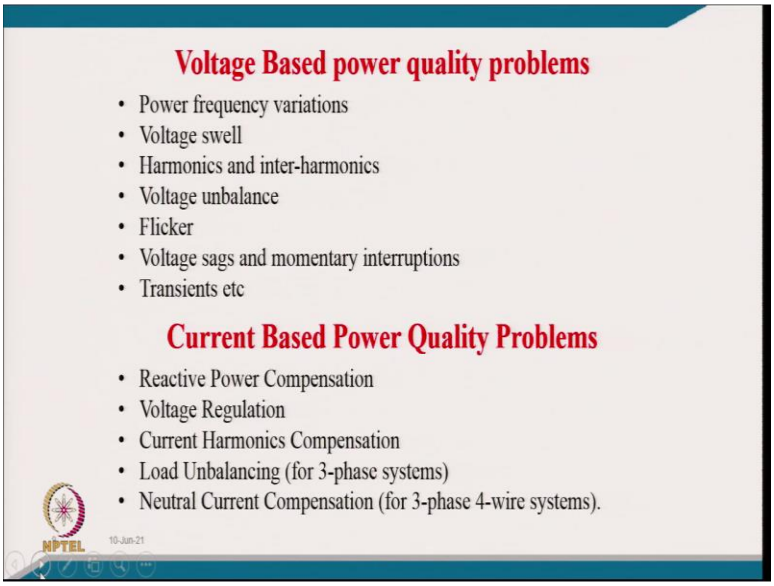

First, we have voltage-based power quality problems like power frequency variation—the voltage-based power quality problems in the sense of the power quality problems in the typically normal grid.

What problem can be there in the power supply? One is the power frequency variations. You might have observed the frequency variation in supply voltage, and it was earlier in India, and now it is a little less. Earlier could have been that we are not connected to any costs associated with power frequency variation. But now we have associated because there is a concept coming like of a smart grid and other features. You can think about frequency increasing means we have more generations connected to the network. You have more generation, more power, but certainly loads are less.

That is an indirect reflection on the frequency, and when frequency goes down, it means generation is less load is more. Now, it is related to the cost of generation, transmission, and distribution or utilization. If the frequency goes up, you make the electricity cheaper, and if the frequency goes down, you make the cost of electricity costlier.

Certainly, we do not have different electricity rates for consumers in India. Still, of course, there are different rates up to 200 units, and we have a different rate than more than that, and a bulky consumer-like IIT has around 10 rupees 25 paisa. These are the different rates, but these rates are not in India, depending upon the time variation for a distribution company.

I have talked about two both distribution companies in Delhi. They say that they will probably purchase electricity in the daytime in the summer peak around 9 rupees 50 paisa, and sell around 10 rupees 25 paisa. Still, in winter, they will sell-buy only typically 2 rupees 50 paisa or so.

The public does not reflect this cost variation, but it is typically there for the utility. Still, suppose you go to other countries. In that case, many countries like Australia, Europe, and America correlate this cost with the certainly with the frequency, and with that, you will be able to automatically.

Regulate the feed indirectly here also regulate when the regulatory commission came. They relate something with the generation transmission and going to be up to the distribution company, which regulates the frequency back. Now, we do not have a frequency variation hardly even 1 percent means 0.5 Hertz or some above or below earlier; otherwise, limit-wise standard says 3 percent while violating even the 3 percent.

But when this regulatory board came and introduced this with the financial standard, this frequency variation in India is also reduced. We are because the typical equipment in the different power generating stations is coming from abroad, and we have to bypass their protection. There was a danger and other issues related to the operating network and those generators.

Those problems were there, but after introducing this regulatory commission and these tariff-related to the frequency variation, this problem is also reduced, and frequency variation is not too much now, even less than 0.5 Hertz variation you will see.

This becomes very important the another is the voltage swell. We discussed it even in the previous lecture also that if you certainly throw the load or you make a commercial switching, voltage tied to go up for a very short period few for few cycles it goes. It we call it voltage swell.

I will show you discuss a little later in more detail and then the harmonics and inter-harmonics, voltage unbalance, flicker, voltage sags and momentary interruption, and of course, the transient line. These are voltage power quality problems, and we will talk about current-based power quality problems. We first related to the reactive power burden on the system.

We have to compensate for that or you have to generate the reactive possibility, and you have to generate the reactive power locally also. I do not know whether you are aware that we can generate the reactive power typically from capacitor banks and inductors. Still, we can generate reactive power by active devices without using many energy storage devices.

The Japanese group like a group is especially with pioneer in electric power quality. In 1984 they reported that you could generate reactive power without having energy storage devices with the switching devices.

Another problem is the voltage regulation problems like what is regulation means. When you draw a lagging power factor load, you might have seen that your voltage goes down, and when you have a leading power factor, the voltage tries to go up even in the distribution system.

With the help of a typical capacitor panel, you can improve the voltage profile or so, but you can understand the load nature is very difficult to control. Consumers are giving a different kind of load in terms of a maybe lagging power factor load, leading power factor load, in general, it is lagging, but now it becomes more complicated when you have a harmonic producing load like that.

The regulation problems also become severe, and then the current harmonics. It was discussed in the previous lecture also, you draw a lot of load with the current harmonics, and these loads are classified later as a non-linear load. Still, you cannot avoid those loads because of the many processes requiring such a solid-state controller.

And then you have a load unbalancing where we load on balance on 3- phase system. Even you might have a design or probably, let us say, plan it for balanced load on all 3-phases. Take a typical example in a hostel; you might be giving the three different wings of the hostel the 3- phase supply for one phase from one wing, another phase to another wing, and the 3rd phase another wing. You might have made the load balance by design, but you cannot force the consumers to keep all the time load equal to all 3- phases. And that certainly causes the load to unbalance because most of the domestic loads or you can see residential loads are single phase loads, and even commercial building loads are like single phase loads. That causes the reasonable unbalance in the typical 3- phase system called load unbalancing means all three phase currents are not equal all the time.

And their nature; nature in the sense they are perfect or they are harmonic level. That also causes the voltage power quality problem, and they also cause the increased losses in the typical distribution system and the transformer. And then the neutral current when you have a 3- phase 4- wire system. I usually mean what we said earlier: maybe one phase load may not be there, or you are only drawing a single phase load. The maximum current in the neutral can be equal to that phase current that can be more, not more than 33 percent, which means one-third of that typically. That is why the conductor earlier what design only typically rating of the 50 percent because we call it 50 percent core.

But now, when if you have all three currents equal in all three phases, there have been some times when there are the higher order of harmonics in line to neutral connection, which becomes a reason for the neutral conductor bursting. There has been a case study of neutral conductor bursting in the high rise building where there are many computer loads and lighting loads with even consist the magnetic ballast.

Of course, we may not have so many buildings in India, but look into a country like Singapore which is only vertical or you might have a 100 storey building. There might have a neutral conductance phase going in the building on different floors and that neutral conductor might put off only a 50 percent cross-section of the phase conductor. But the current in the neutral conductor goes to 150 percent of the phase conductor due to these higher order harmonics, busting the neutral conductor.

We classified current-based power quality problems with another classification. In a 2 wire system like a single phase, we have reactive power and harmonics. If it is a 3 wire system then along with the reactive power and harmonics, it can have unbalanced currents or negative sequence currents and neutral current problems.

What is this voltage sag? Voltage sag is a decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute.

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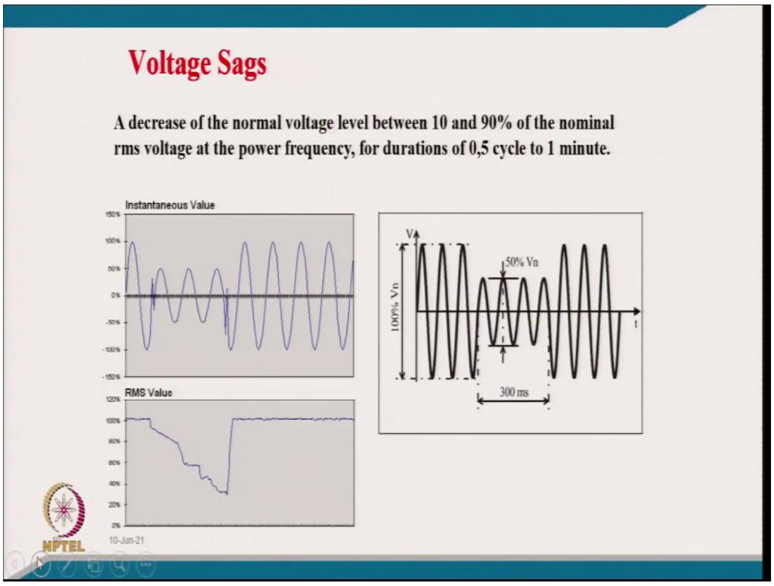

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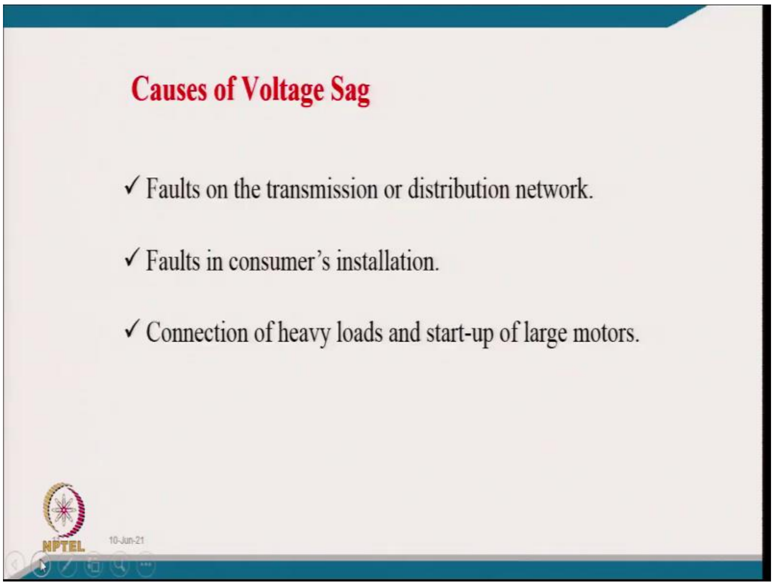

What are the causes of this voltage sag? The first cause typically is the faults on the transmission or distribution network, faults in the customer's installation and connection of heavy load, and start-up of large motors.

It can be seen when a high rating motor is started a large current is drawn from the distribution system. That large current can cause a substantial voltage drop at the point of common coupling even the grid impedance is a very small. It causes a voltage sag or voltage dip in the system.

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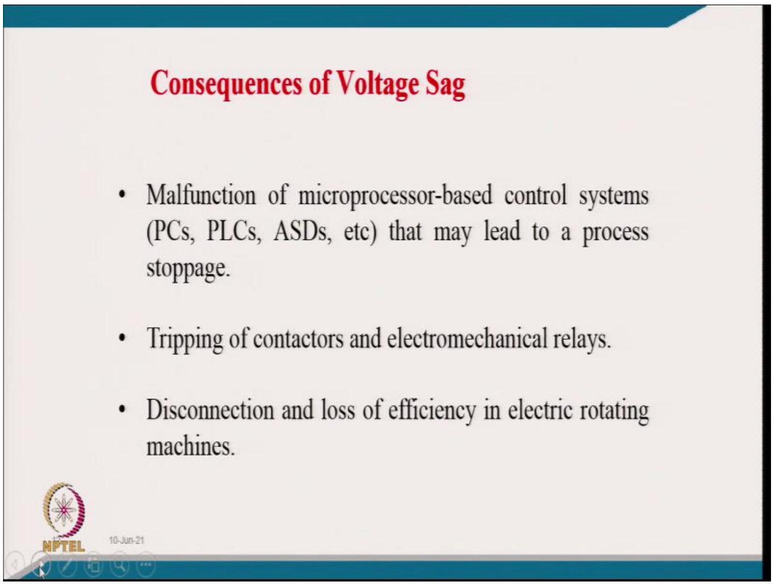

What are the consequences of the voltage sag?

- Malfunction of microprocessor-based control systems like programmable controllers, programmable logic computers or personal computers, programmable logic computers adjustably speed drive. And that is a reason that UPS is normally used with the PC so that voltage sag or dip do not affect the computer; otherwise computer may trip for a short period. Typically a sag for a few cycles or going for a minute may lead to a process to stop it.

- Interruption in the process like protection may operate or tripping of contactor and electromechanical relays in the process and disconnection and loss of efficiency in an electrical rotating machine.

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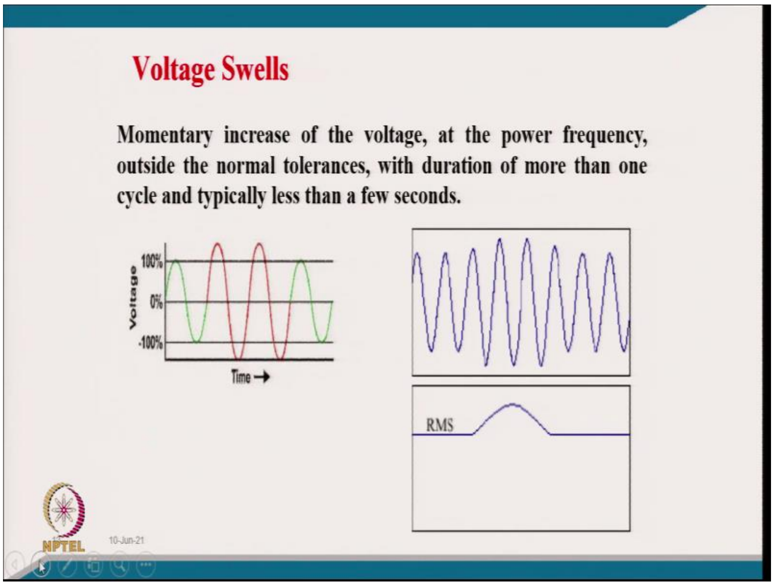

Voltage swell is just opposite to the voltage sag, the momentary increase of the voltage, at the power frequency, outside the normal tolerances, with a duration of more than one cycle and typically less than a few seconds.

It can be seen in the figure that for the red portion, a couple of cycle voltages are going beyond the 100 percent limit. Similarly, it can be seen the RMS voltage increases for only a few cycles like.

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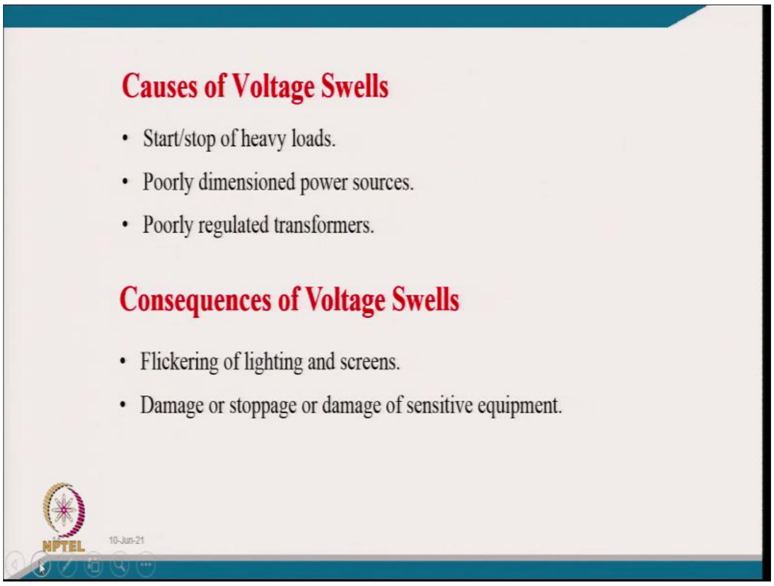

What are the causes of voltage swell?

Just like a start and stop of heavy load, the voltage try to go up or poor dimension power sources or poorly regulated transformer.

The consequences of this voltage sag are the flickering of lighting and screen and sometimes the damage or stoppage or damage of sensitive equipment.

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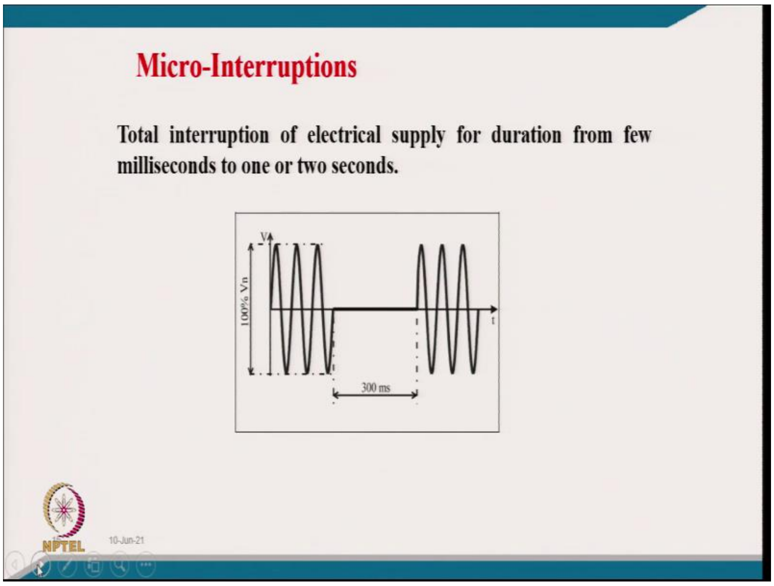

What is the micro interruption?

Total interruption of electrical supply for a few milliseconds to one or two seconds is called micro interruption. Such an interruption in the supply causes many processes to stop like I.

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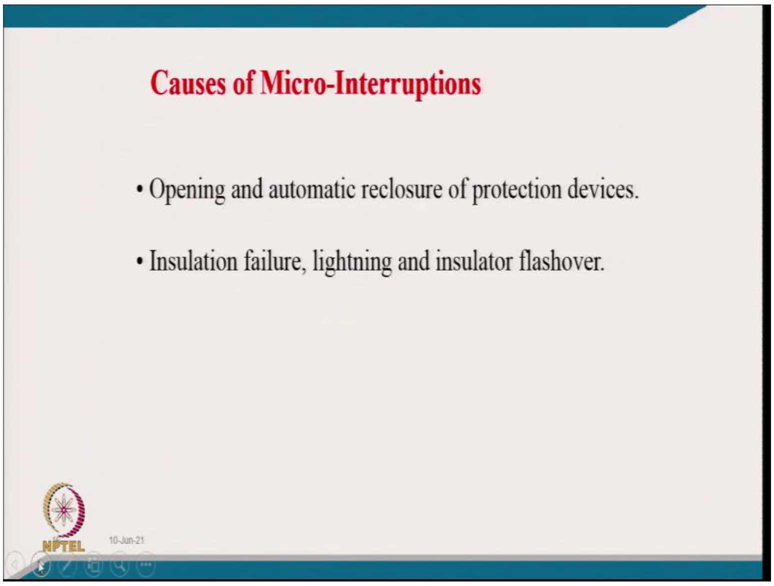

What is the causes of micro interruption?

Opening or automatic reclosure of protection devices, insulation failure, lightning and typically of insulator flashover.

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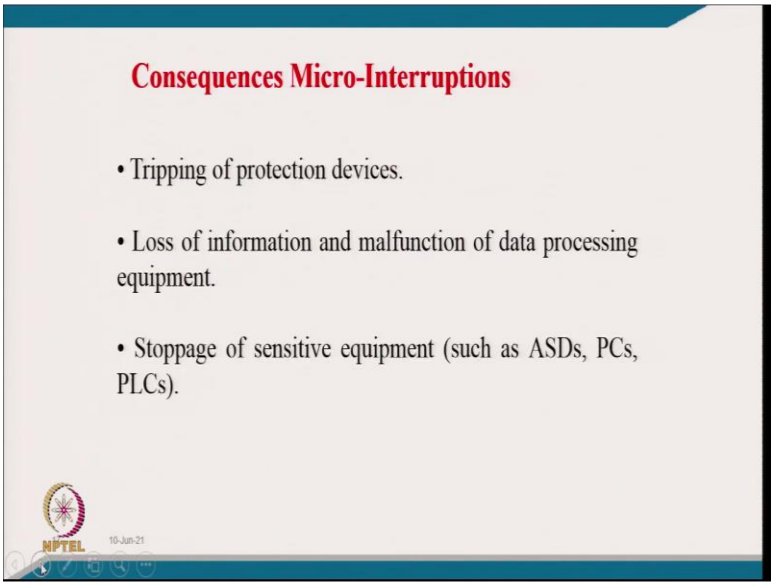

Consequences of these micro interruptions: Tripping of protection devices, loss of information and malfunction of data processing equipment, and stoppage of sensitive equipment such as adjustable speed drive, personal computers and programmable logic controllers.

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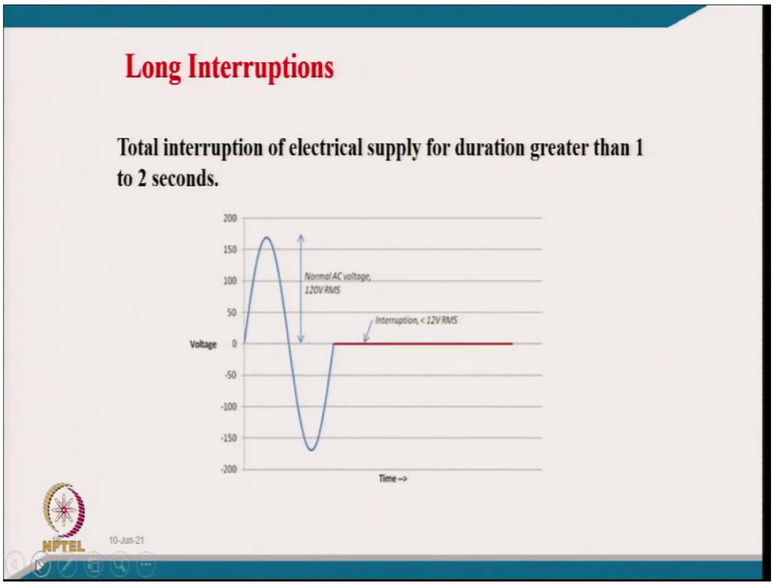

Long interruption is very common in a country like India. It is a total interruption of electric supply for greater than 1 to 2 seconds. It is very common and that's why most people typically keep UPS or inverters with their sensitive equipment.

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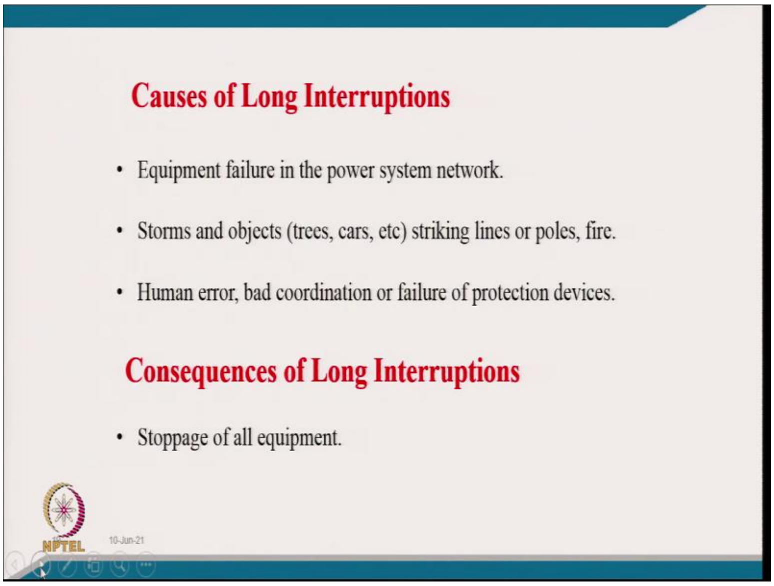

What are the causes of long interruption?

- Equipment failure in the power system network.
- Storms and objects (trees, cars, etc) striking lines or poles, fire.
- Human error, bad coordination or failure of protection devices.

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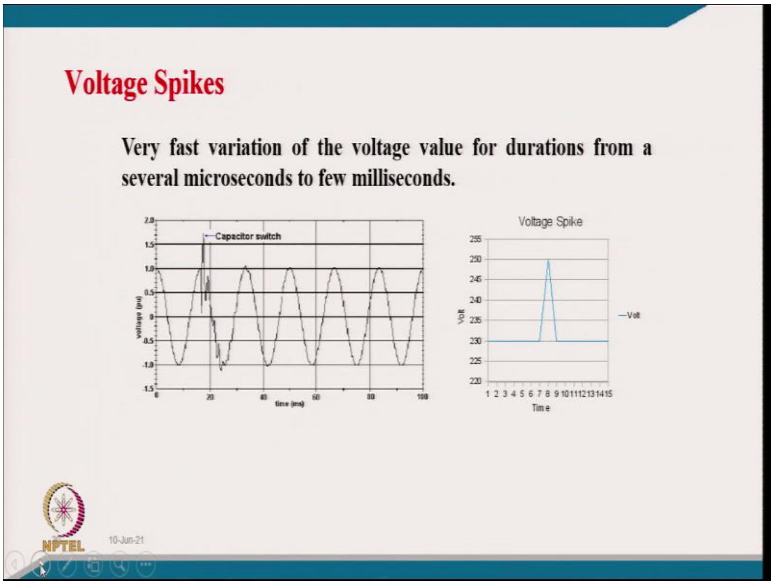

Voltage spikes are the very fast variation of the voltage value for durations from several microseconds to a few milliseconds.

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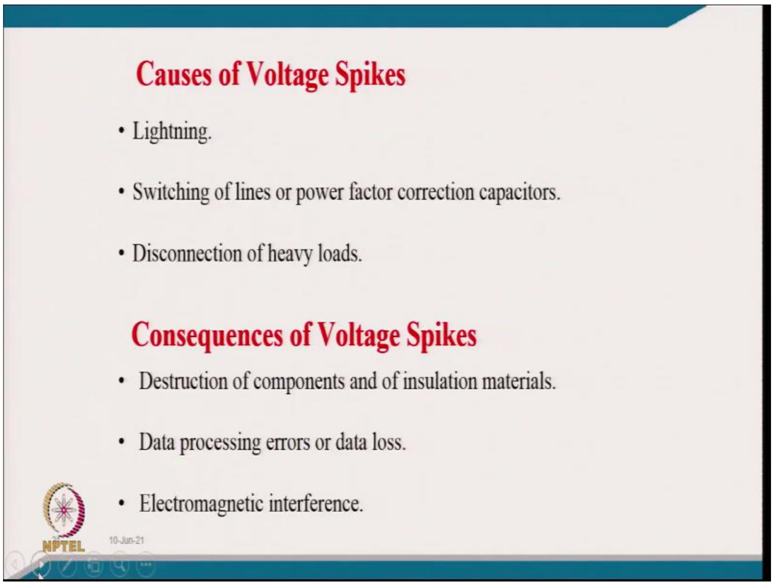

Causes of Voltage Spikes:

- Lightning.
- Switching of lines or power factor correction capacitors.
- Disconnection of heavy loads.

Consequences of Voltage Spikes:

- Destruction of components and of insulation materials.
- Data processing errors or data loss.
- Electromagnetic interference.

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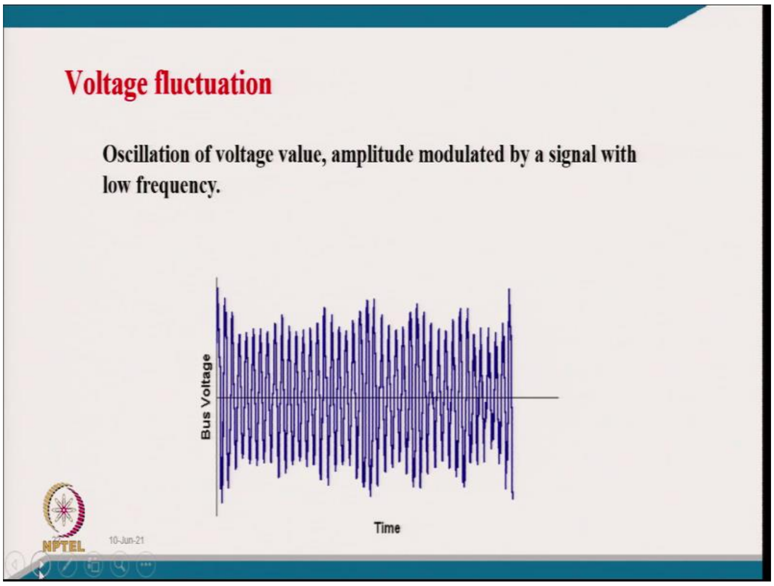

Voltage fluctuation is the oscillation of voltage value, amplitude modulated by a signal with low frequency. If the load is varying at a very low frequency then that frequency is certainly reflected into the current that flows into the distribution system. It causes the low-frequency voltage drop in the distribution system, which reflects the same frequency component in the supply voltage.

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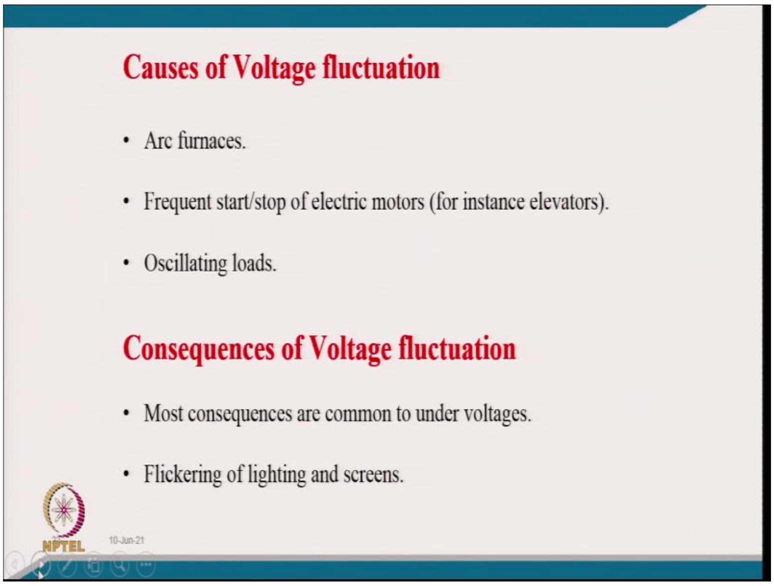

Causes of Voltage fluctuation:

- Arc furnaces.
- Frequent start/stop of electric motors (for instance elevators).
- Oscillating loads.

Consequences of Voltage fluctuation:

- Most consequences are common to under voltages.
- Flickering of lighting and screens

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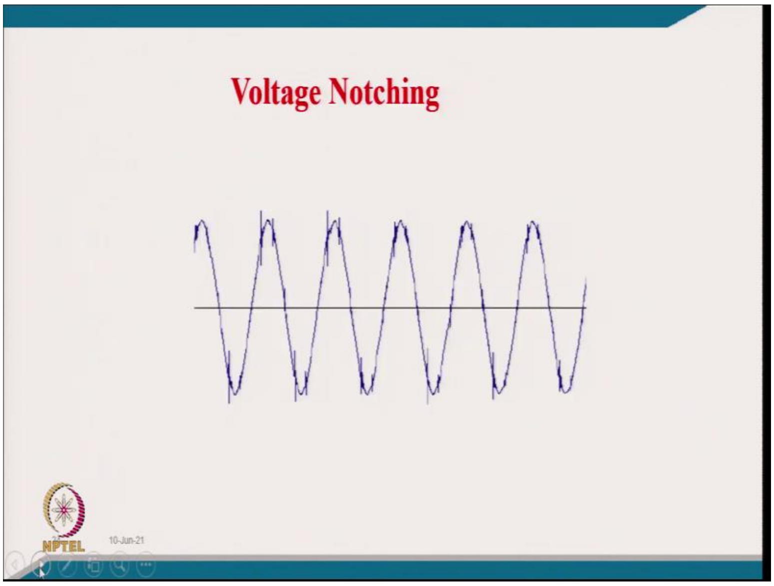

Voltage notching is nothing but a higher-order harmonic along with the fundamental voltage.

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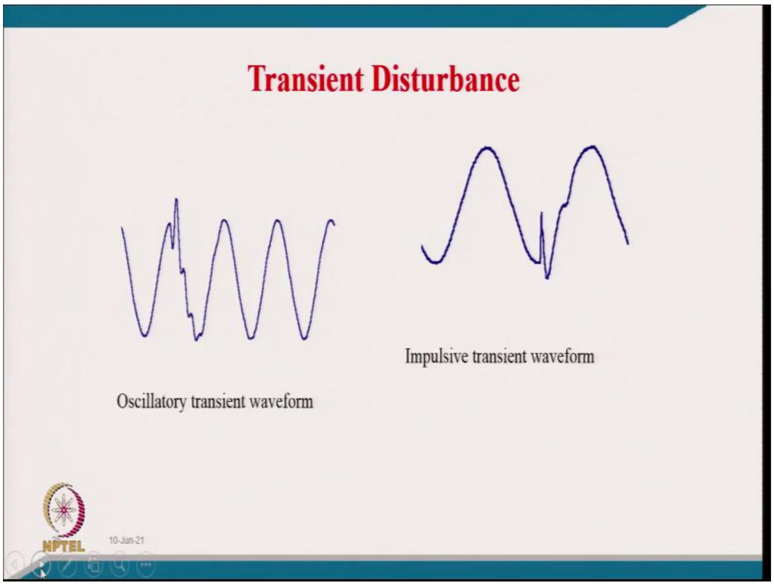

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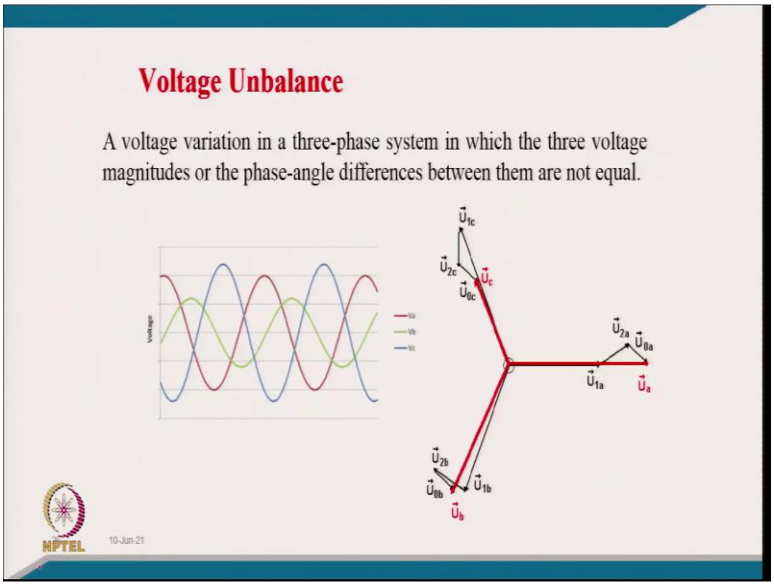

Voltage unbalance is a voltage variation in a three-phase system in which the three voltage magnitudes or the phase-angle differences between them are not equal.

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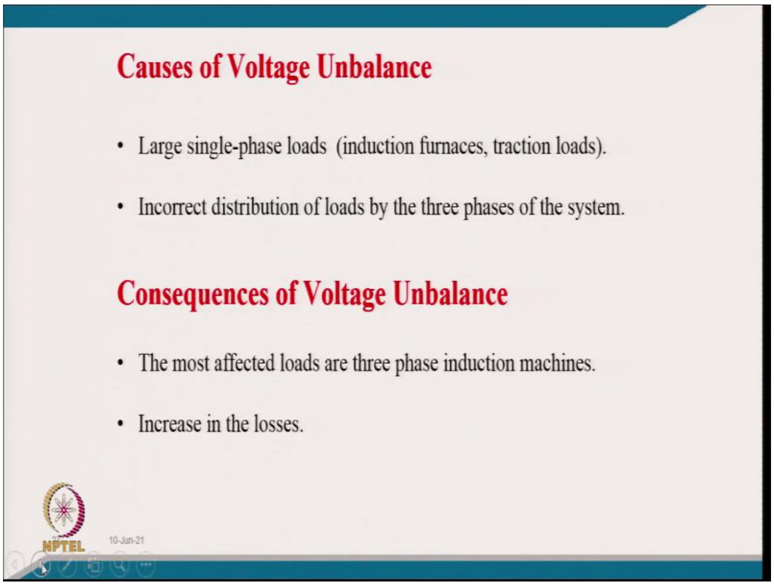

Causes of Voltage Unbalance:

- Large single-phase loads (induction furnaces, traction loads).
- Incorrect distribution of loads by the three phases of the system.

Consequences of Voltage Unbalance:

- The most affected loads are three phase induction machines.
- Increase in the losses.

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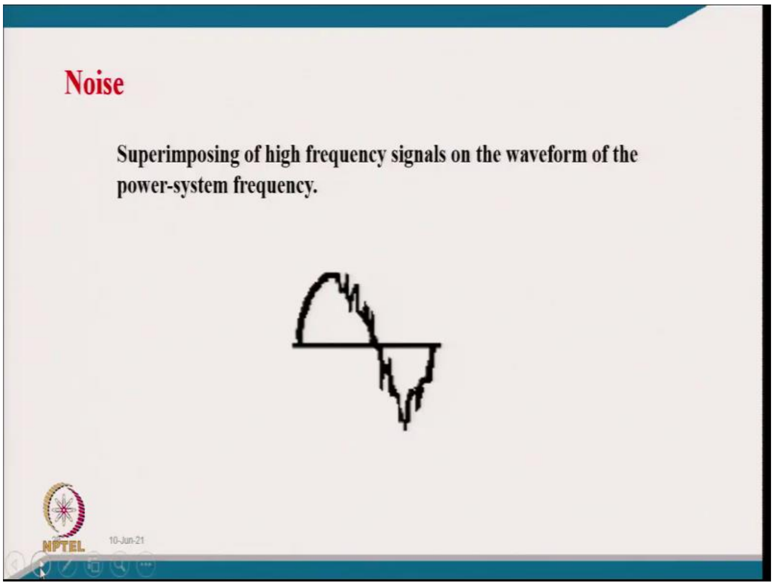

Noise is the superimposing of high-frequency signals on the waveform of the power-system frequency.

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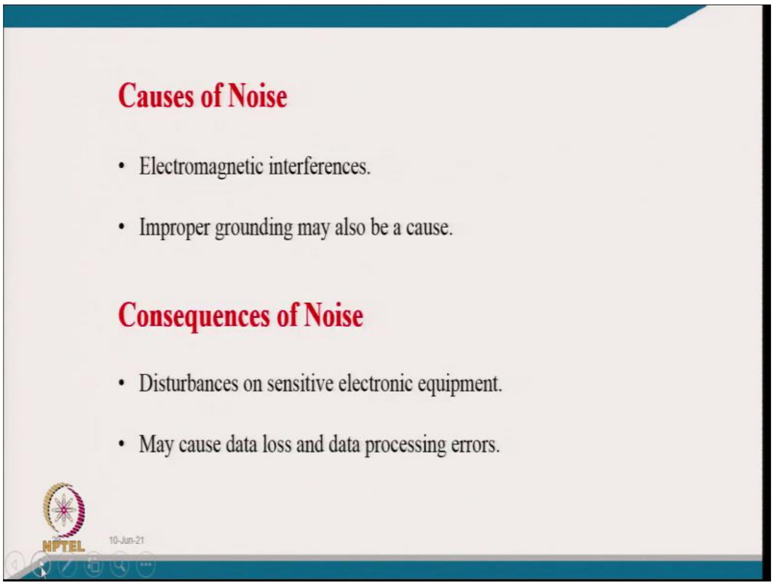

Causes of Noise:

- Electromagnetic interferences.
- Improper grounding may also be a cause.

Consequences of Noise:

- ➢ Disturbances on sensitive electronic equipment.
- ➢ May cause data loss and data processing errors.

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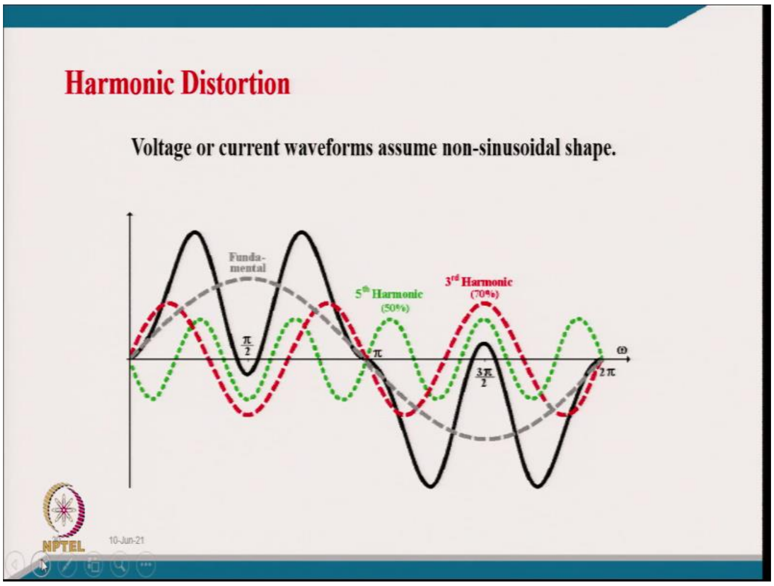

Harmonic distortion is when voltage or current waveforms assume non-sinusoidal shape.

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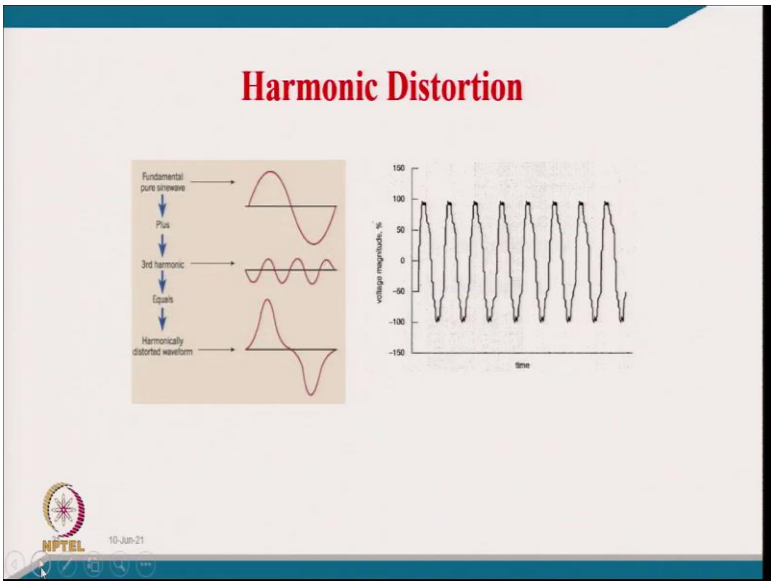

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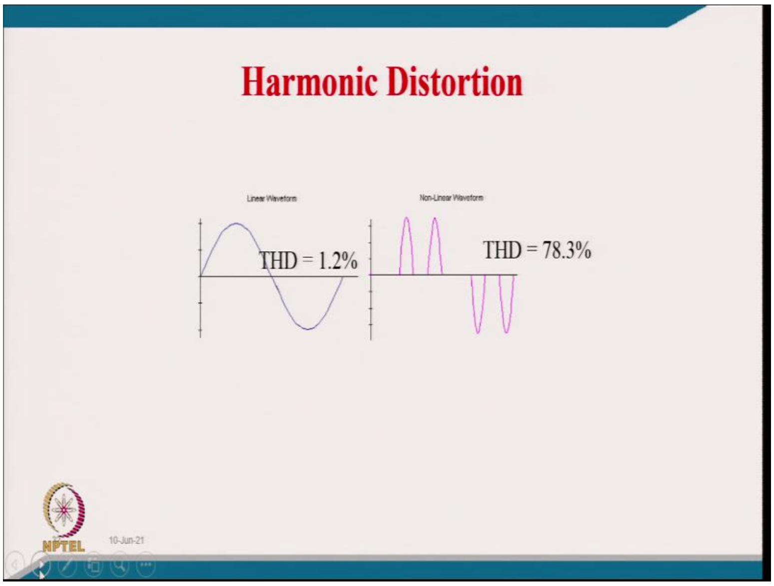

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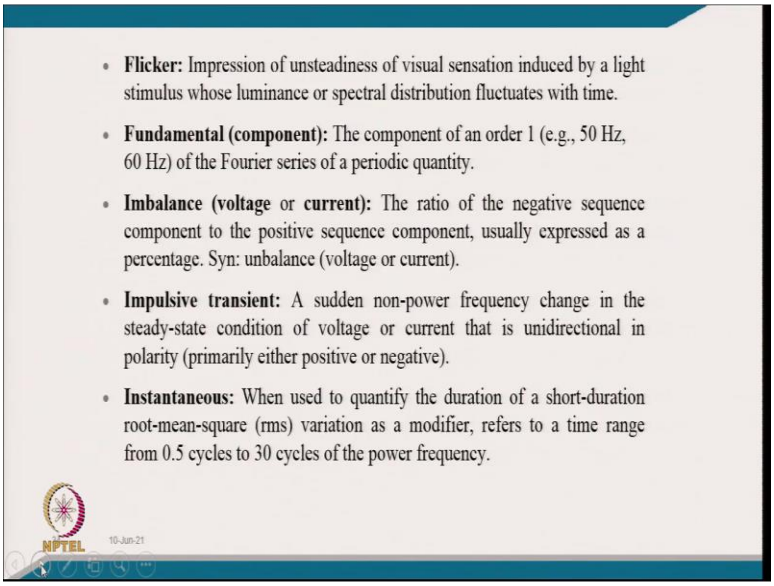

Flicker: Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.

Fundamental component: Fundamental component is nothing but component of first harmonics 50 Hertz or 60 Hertz of the Fourier series of a periodic quantity.

Imbalance (voltage or **current):** It can be a imbalance in voltage and current of a 3-phase system. It is defined as the ratio of the negative sequence component to the positive sequence component, usually expressed as a percentage.

Impulsive transient: A sudden non-power frequency change in the steady-state condition of voltage or current that is unidirectional in polarity (primarily either positive or negative).

Instantaneous: When used to quantify the duration of a short-duration root-mean-square (rms) variation as a modifier, refers to a time range from 0.5 cycles to 30 cycles of the power frequency.

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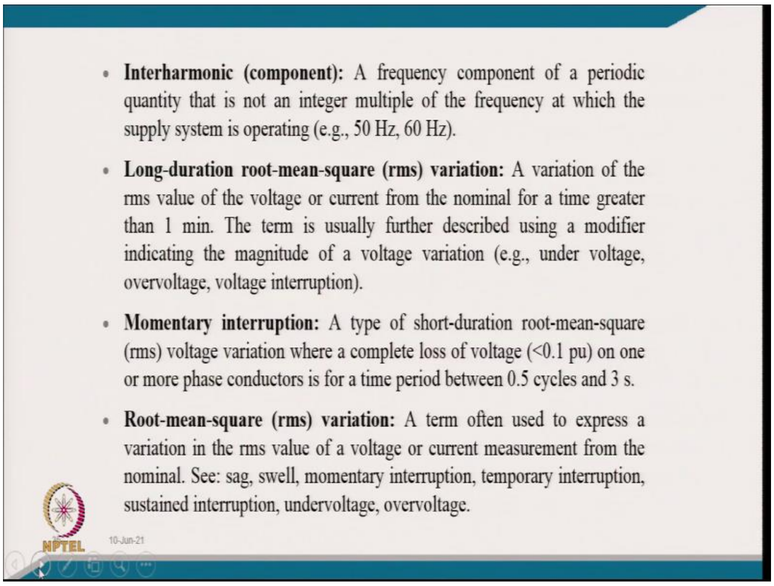

Interharmonic (component): A frequency component of a periodic quantity that is not an integer multiple of the frequency at which the supply system is operating (e.g., 50 Hz, 60 Hz).

Long-duration root-mean-square (rms) variation: A variation of the rms value of the voltage or current from the nominal for a time greater than 1 min. The term is usually further described using a modifier indicating the magnitude of a voltage variation (e.g., under voltage, overvoltage, voltage interruption).

Momentary interruption: A type of short-duration root-mean-square (rms) voltage variation where a complete loss of voltage (<0.1 pu) on one or more phase conductors is for a time period between 0.5 cycles and 3 s.

Root-mean-square (rms) variation: A term often used to express a variation in the rms value of a voltage or current measurement from the nominal. See: sag, swell, momentary interruption, temporary interruption, sustained interruption, undervoltage, overvoltage.

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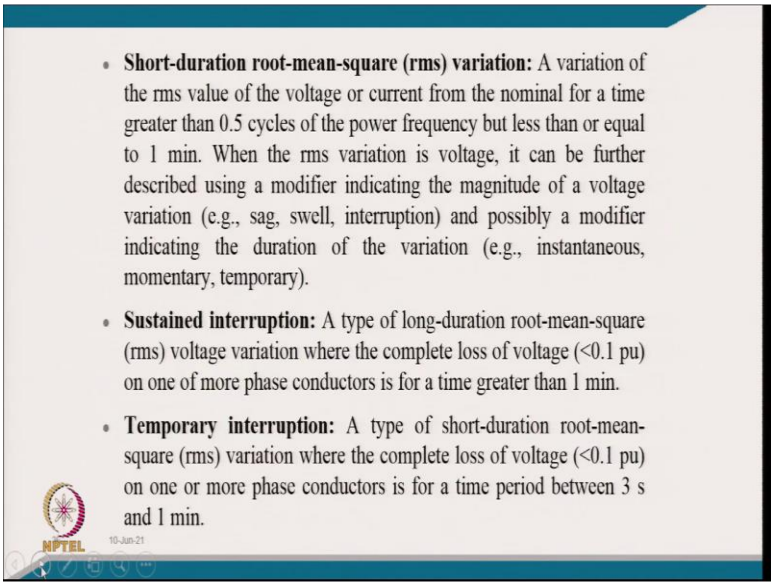

- **Short-duration root-mean-square (rms) variation:** A variation of the rms value of the voltage or current from the nominal for a time greater than 0.5 cycles of the power frequency but less than or equal to 1 min. When the rms variation is voltage, it can be further described using a modifier indicating the magnitude of a voltage variation (e.g., sag, swell, interruption) and possibly a modifier indicating the duration of the variation (e.g., instantaneous, momentary, temporary).

- **Sustained interruption:** A type of long-duration root-mean-square (rms) voltage variation where the complete loss of voltage (<0.1 pu) on one of more phase conductors is for a time greater than 1 min.

- **Temporary interruption:** A type of short-duration root-mean-square (rms) variation where the complete loss of voltage (<0.1 pu) on one or more phase conductors is for a time period between 3 s and 1 min.

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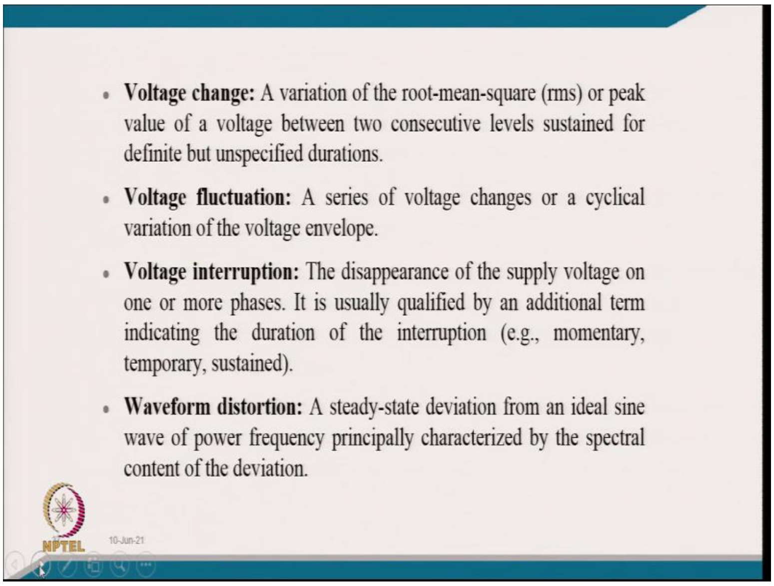

- **Voltage change:** A variation of the root-mean-square (rms) or peak value of a voltage between two consecutive levels sustained for definite but unspecified durations.

- **Voltage fluctuation:** A series of voltage changes or a cyclical variation of the voltage envelope.

- **Voltage interruption:** The disappearance of the supply voltage on one or more phases. It is usually qualified by an additional term indicating the duration of the interruption (e.g., momentary, temporary, sustained).

- **Waveform distortion:** A steady-state deviation from an ideal sine wave of power frequency principally characterized by the spectral content of the deviation.

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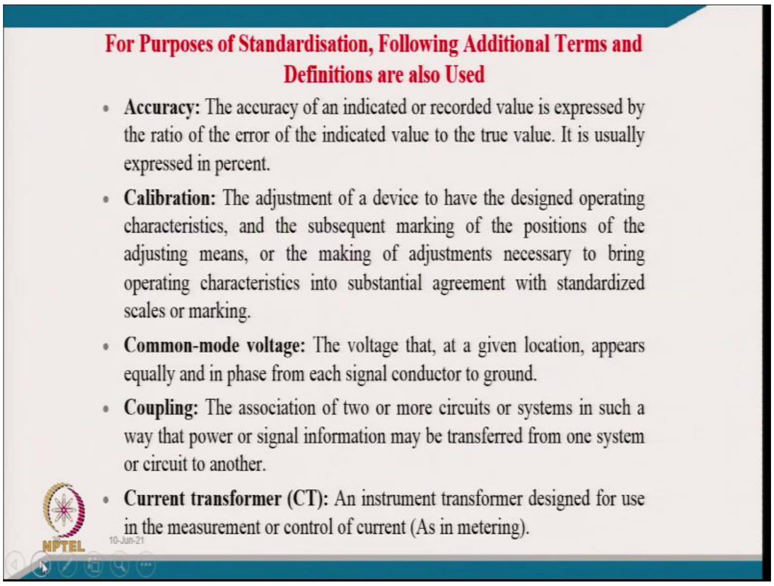

For the purposes of standardisation, the following additional terms and definitions are also used.

- **Accuracy:** The quality of freedom from mistake or error, that is of conformity to truth or to a rule (As in instrumentation and measurement). The accuracy of an indicated or recorded value is expressed by the ratio of the error of the indicated value to the true value. It is usually expressed in percent. See: accuracy rating of an instrument (As indicated or recorded value).

- **Calibration:** The adjustment of a device to have the designed operating characteristics, and the subsequent marking of the positions of the adjusting means, or the making of adjustments necessary to bring operating characteristics into substantial agreement with standardized scales or marking. Comparison of the indication of the instrument under test, or registration of the meter under test, with an appropriate standard (As in metering).

- **Common-mode voltage:** The voltage that, at a given location, appears equally and in phase from each signal conductor to ground.

- **Coupling:** The association of two or more circuits or systems in such a way that power or signal information may be transferred from one system or circuit to another.

- **Current transformer (CT):** An instrument transformer designed for use in the measurement or control of current (As in metering).

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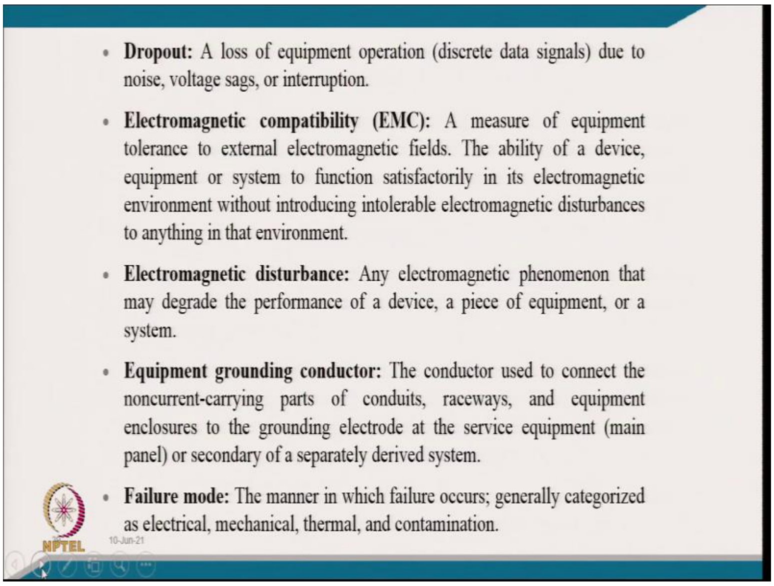

- **Dropout:** A loss of equipment operation (discrete data signals) due to noise, voltage sags, or interruption.

- **Electromagnetic compatibility (EMC):** A measure of equipment tolerance to external electromagnetic fields. The ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

- **Electromagnetic disturbance:** An electromagnetic phenomenon that may be superimposed on a wanted signal. Any electromagnetic phenomenon that may degrade the performance of a device, a piece of equipment, or a system.

- **Equipment grounding conductor:** The conductor used to connect the noncurrent-carrying parts of conduits, raceways, and equipment enclosures to the grounding electrode at the service equipment (main panel) or secondary of a separately derived system.

- **Failure mode:** The manner in which failure occurs; generally categorized as electrical, mechanical, thermal, and contamination.

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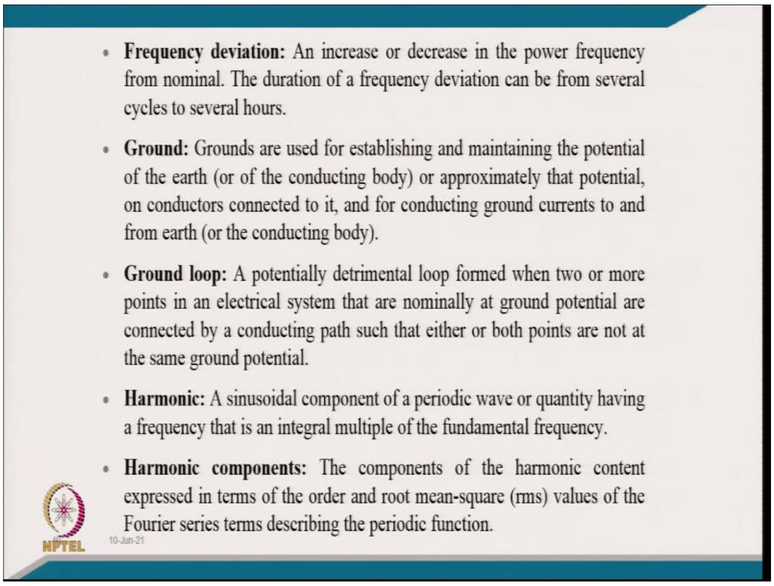

- **Frequency deviation:** An increase or decrease in the power frequency from nominal. The duration of a frequency deviation can be from several cycles to several hours.

- **Ground:** A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth, or to some conducting body of relatively large extent that serves in place of the earth. Grounds are used for establishing and maintaining the potential of the earth (or of the conducting body) or approximately that potential, on conductors connected to it, and for conducting ground currents to and from earth (or the conducting body).

- **Ground loop:** A potentially detrimental loop formed when two or more points in an electrical system that are nominally at ground potential are connected by a conducting path such that either or both points are not at the same ground potential.

- **Harmonic:** A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency. For example, a component, the frequency of which is twice the fundamental frequency, is called a second harmonic.

- **Harmonic components:** The components of the harmonic content expressed in terms of the order and root mean-square (rms) values of the Fourier series terms describing the periodic function.

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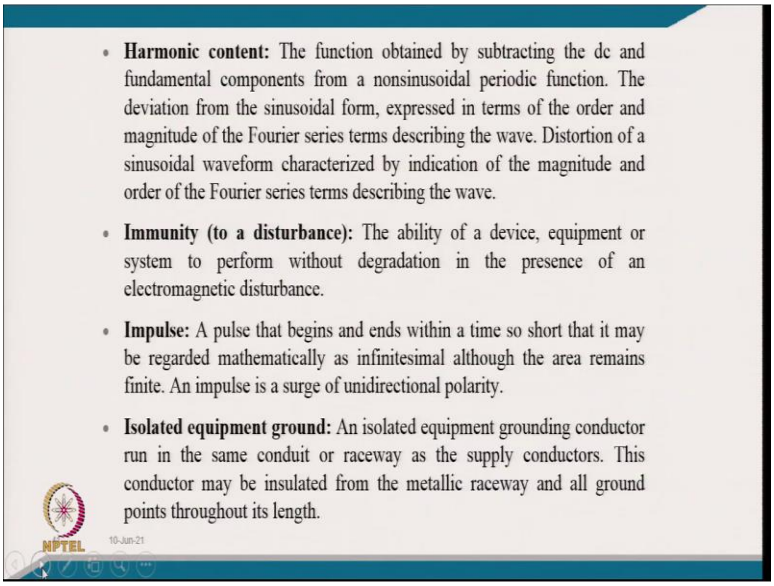

- **Harmonic content:** The function obtained by subtracting the dc and fundamental components from a nonsinusoidal periodic function. The deviation from the sinusoidal form, expressed in terms of the order and magnitude of the Fourier series terms describing the wave. Distortion of a sinusoidal waveform characterized by indication of the magnitude and order of the Fourier series terms describing the wave.

- **Immunity (to a disturbance):** The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

- **Impulse:** A pulse that begins and ends within a time so short that it may be regarded mathematically as infinitesimal although the area remains finite. An impulse is a surge of unidirectional polarity.

- **Isolated equipment ground:** An isolated equipment grounding conductor run in the same conduit or raceway as the supply conductors. This conductor may be insulated from the metallic raceway and all ground points throughout its length. It originates at an isolated ground-type receptacle or equipment input terminal block and terminates at the point where neutral and ground are bonded at the power source.

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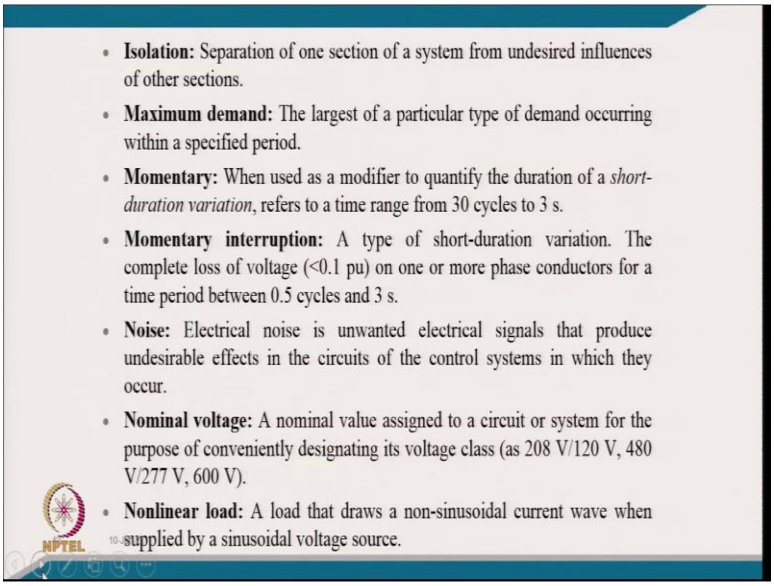

- **Isolation:** Separation of one section of a system from undesired influences of other sections.

- **Maximum demand:** The largest of a particular type of demand occurring within a specified period.

- **Momentary:** When used as a modifier to quantify the duration of a *short-duration variation*, refers to a time range from 30 cycles to 3 s.

- **Momentary interruption:** A type of short-duration variation. The complete loss of voltage (<0.1 pu) on one or more phase conductors for a time period between 0.5 cycles and 3 s.

- **Noise:** Electrical noise is unwanted electrical signals that produce undesirable effects in the circuits of the control systems in which they occur.

- **Nominal voltage:** A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (as 208 V/120 V, 480 V/277 V, 600 V).

- **Nonlinear load:** A load that draws a nonsinusoidal current wave when supplied by a sinusoidal voltage source.

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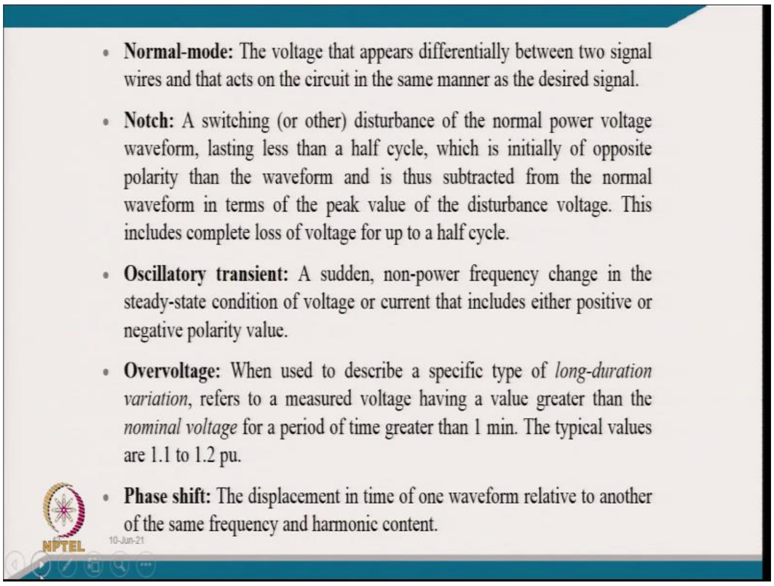

- **Normal-mode:** The voltage that appears differentially between two signal wires and that acts on the circuit in the same manner as the desired signal.

- **Notch:** A switching (or other) disturbance of the normal power voltage waveform, lasting less than a half cycle, which is initially of opposite polarity than the waveform and is thus subtracted from the normal waveform in terms of the peak value of the disturbance voltage. This includes complete loss of voltage for up to a half cycle.

- **Oscillatory transient:** A sudden, non-power frequency change in the steady-state condition of voltage or current that includes either positive or negative polarity value.

- **Overvoltage:** When used to describe a specific type of *long-duration variation*, refers to a measured voltage having a value greater than the *nominal voltage* for a period of time greater than 1 min. The typical values are 1.1 to 1.2 pu.

- **Phase shift:** The displacement in time of one waveform relative to another of the same frequency and harmonic content.

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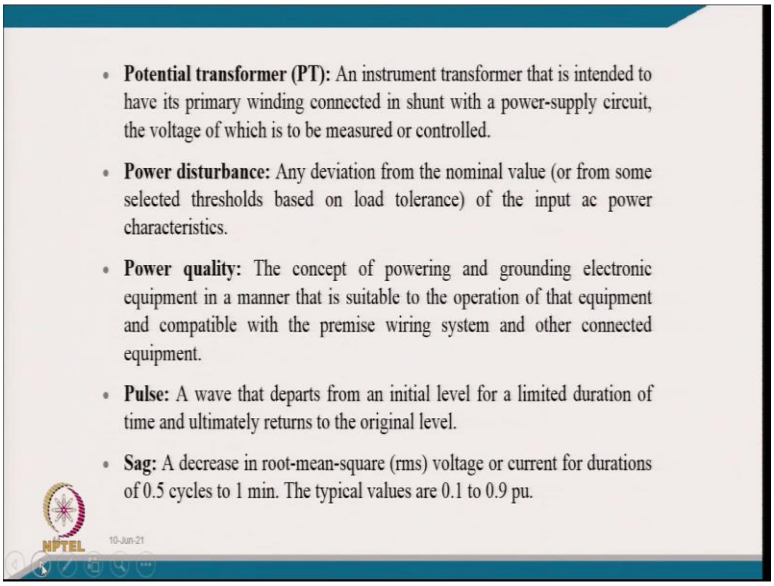

- **Potential transformer (PT):** An instrument transformer that is intended to have its primary winding connected in shunt with a power-supply circuit, the voltage of which is to be measured or controlled.

- **Power disturbance:** Any deviation from the nominal value (or from some selected thresholds based on load tolerance) of the input ac power characteristics.

- **Power quality:** The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment.

- **Pulse:** A wave that departs from an initial level for a limited duration of time and ultimately returns to the original level.

- **Sag:** A decrease in root-mean-square (rms) voltage or current for durations of 0.5 cycles to 1 min. The typical values are 0.1 to 0.9 pu.

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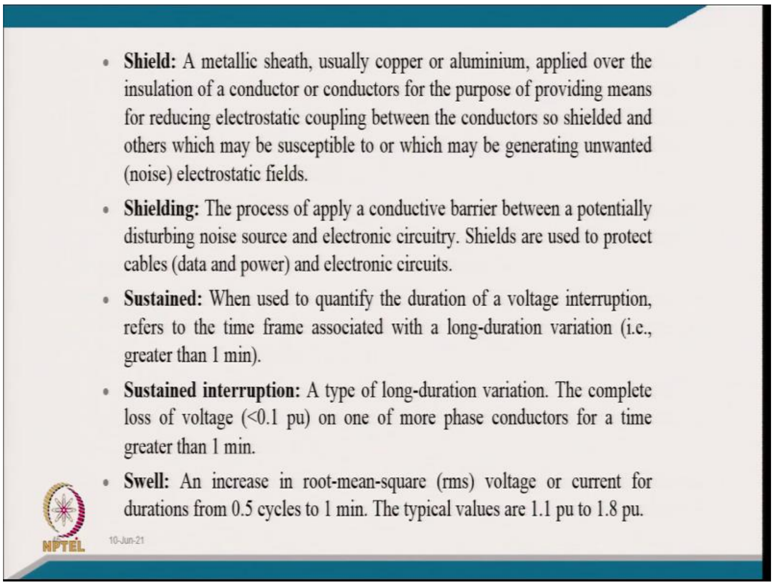

- **Shield:** A metallic sheath, usually copper or aluminium, applied over the insulation of a conductor or conductors for the purpose of providing means for reducing electrostatic coupling between the conductors so shielded and others which may be susceptible to or which may be generating unwanted (noise) electrostatic fields.

- **Shielding:** The process of apply a conductive barrier between a potentially disturbing noise source and electronic circuitry. Shields are used to protect cables (data and power) and electronic circuits. Shielding may be accomplished by the use of metal barriers, enclosures, or wrappings around source circuits and receiving circuits.

- **Sustained:** When used to quantify the duration of a voltage interruption, refers to the time frame associated with a long-duration variation (i.e., greater than 1 min).

- **Sustained interruption:** A type of long-duration variation. The complete loss of voltage (<0.1 pu) on one of more phase conductors for a time greater than 1 min.

- **Swell:** An increase in root-mean-square (rms) voltage or current for durations from 0.5 cycles to 1 min. The typical values are 1.1 pu to 1.8 pu.

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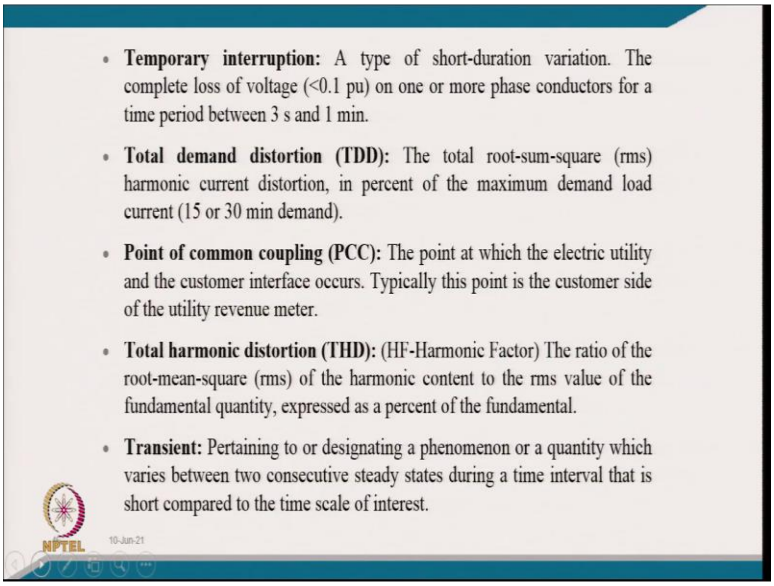

- **Temporary interruption:** A type of short-duration variation. The complete loss of voltage (<0.1 pu) on one or more phase conductors for a time period between 3 s and 1 min.

- **Total demand distortion (TDD):** The total root-sum-square (rms) harmonic current distortion, in percent of the maximum demand load current (15 or 30 min demand).

- **Point of common coupling (PCC):** The point at which the electric utility and the customer interface occurs. Typically this point is the customer side of the utility revenue meter.

- **Total harmonic distortion (THD):** (HF-Harmonic Factor) The ratio of the root-mean-square (rms) of the harmonic content to the rms value of the fundamental quantity, expressed as a percent of the fundamental.

- **Transient:** Pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval that is short compared to the time scale of interest. A transient can be a unidirectional impulse of either polarity or a damped oscillatory wave with the first peak occurring in either polarity.

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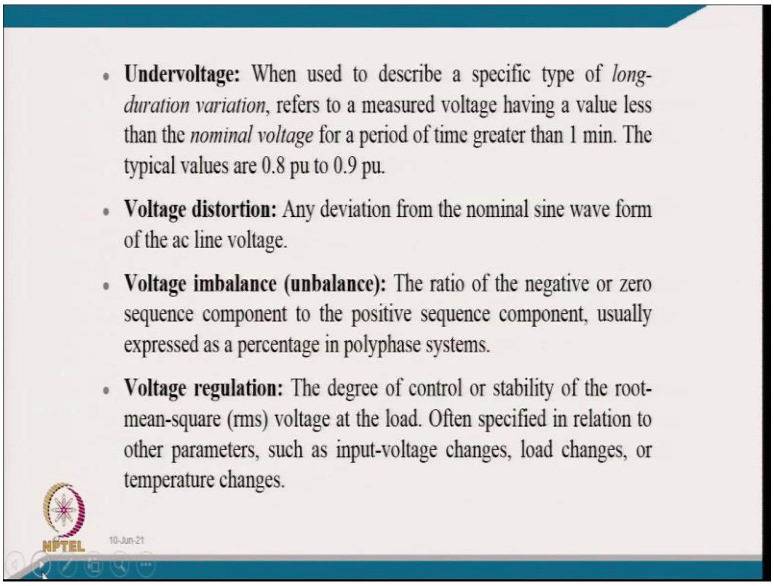

- **Undervoltage:** When used to describe a specific type of *long-duration variation*, refers to a measured voltage having a value less than the *nominal voltage* for a period of time greater than 1 min. The typical values are 0.8 pu to 0.9 pu.

- **Voltage distortion:** Any deviation from the nominal sine wave form of the ac line voltage.

- **Voltage imbalance (unbalance):** The ratio of the negative or zero sequence component to the positive sequence component, usually expressed as a percentage in polyphase systems.

- **Voltage regulation:** The degree of control or stability of the root-mean-square (rms) voltage at the load. Often specified in relation to other parameters, such as input-voltage changes, load changes, or temperature changes.

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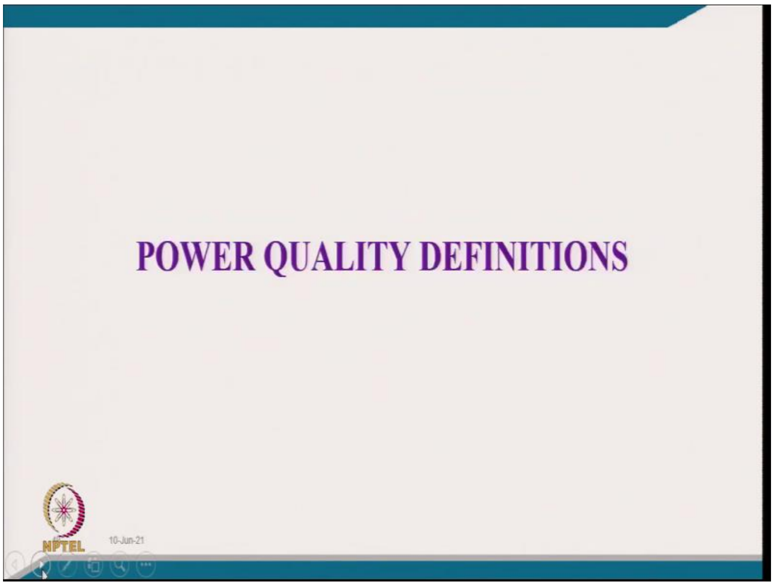

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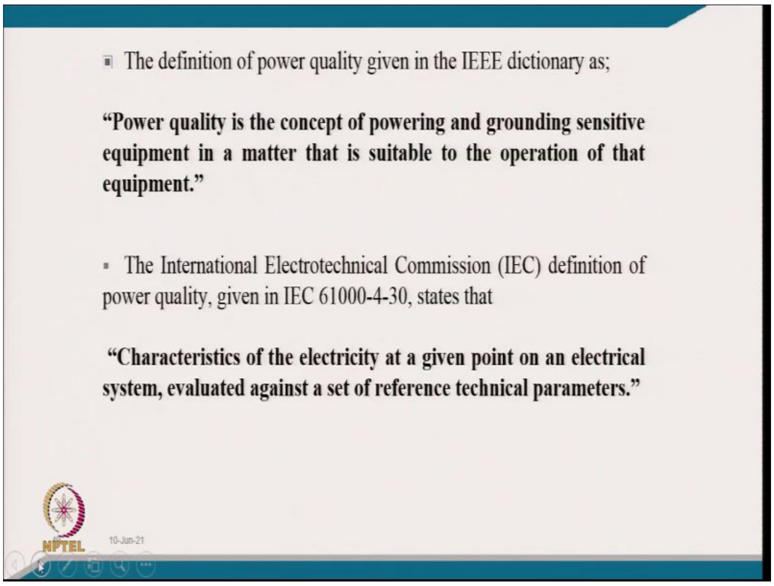

Different people have given a different definition for power quality. The definition of power quality given in IEEE dictionary is "power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable for the operation of that equipment."

The International Electrotechnical Commission (IEC) definition of power quality, given in IEC 61000-4-30, states that "power quality is the characteristic of electricity at a given point or a electrical system evaluated against a set of reference technical parameter,"

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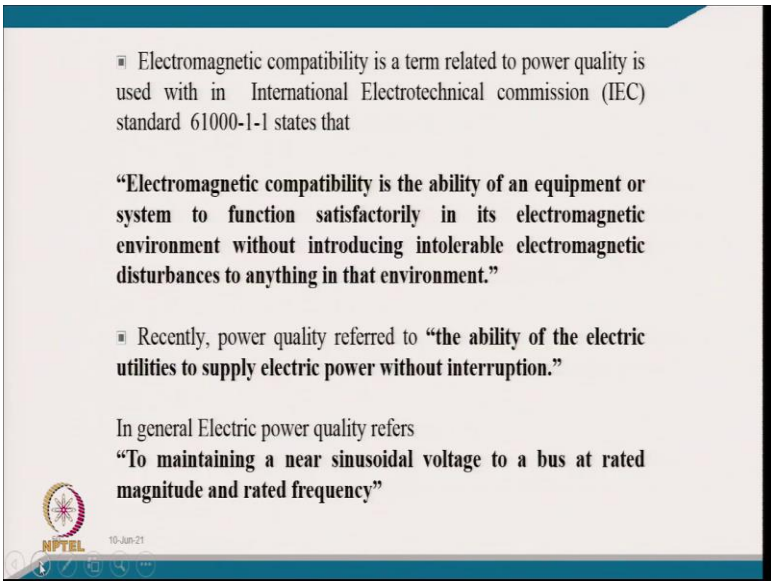

[Electromagnetic compatibility is a term related to power quality is used with in International Electrotechnical commission (IEC) standard 61000-1-1 states that: "Electromagnetic compatibility is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment."

Recently power quality referred to "the ability of the electric utilities to supply electric power without interruption." And in general, an electric power quality refers to maintaining a nearly sinusoidal voltage to a bus at rated magnitude and rated frequency.