Power Quality Improvement Technique
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Lecture - 07
AC Power Quality Standard

Welcome to our NPTEL program on Power Quality Improvement Technique. Today we are going to discuss the Power Quality Standard. There is a research standard as well as a practical standard. We will discuss all the standards. So, we are going to describe the different power quality entities.

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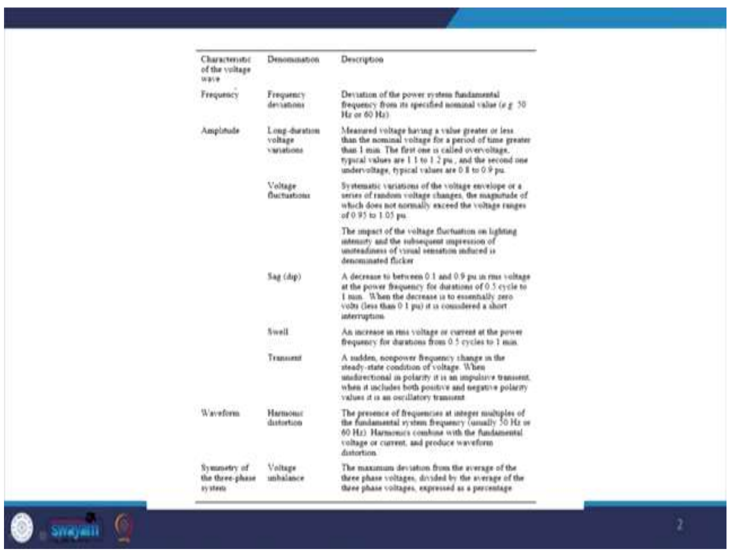

Characteristic of the voltage wave	Denomination	Description
Frequency	Frequency deviations	Deviation of the power system fundamental frequency from its specified nominal value (e.g. 50 Hz or 60 Hz)
Amplitude	Long-duration voltage variations	Measured voltage having a value greater or less than the nominal voltage for a period of time greater than 1 min. The first one is called overvoltage, typical values are 1.1 to 1.2 pu., and the second one undervoltage, typical values are 0.8 to 0.9 pu.
	Voltage fluctuations	Systematic variations of the voltage envelope or a series of random voltage changes, the magnitude of which does not normally exceed the voltage ranges of 0.95 to 1.05 pu.
		The impact of the voltage fluctuation on lighting intensity and the subsequent impression of unsteadiness of visual sensation induced is denominated flicker
	Sag (dip)	A decrease to between 0.1 and 0.9 pu in rms voltage at the power frequency for durations of 0.5 cycle to 1 min. When the decrease is to essentially zero volts (less than 0.1 pu) it is considered a short interruption
	Swell	An increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min.
	Transient	A sudden, nonpower frequency change in the steady-state condition of voltage. When unidirectional in polarity it is an impulsive transient, when it includes both positive and negative polarity values it is an oscillatory transient
Waveform	Harmonic distortion	The presence of frequencies at integer multiples of the fundamental system frequency (usually 50 Hz or 60 Hz). Harmonics combine with the fundamental voltage or current, and produce waveform distortion
Symmetry of the three-phase system	Voltage unbalance	The maximum deviation from the average of the three phase voltages, divided by the average of the three phase voltages, expressed as a percentage

So, first of all it is based on the characteristics of the voltage wave. We can have a power quality in voltage, current as well as the frequencies.

So, frequency. Deviation of the frequency that has to be considered as a case of the power quality. We utility, supposed to give quality power and the deviation of the power quality for the fundamental frequency should be 50 hertz or 60 hertz, have to be restricted within the specific limit. Thereafter amplitude. So, that is the peak value of the voltage or current. That is the long duration of the voltage variations.

So, what we say here is measured voltage having a value greater than or less than the nominal voltage for a period of time greater than 1 minute. So, that is something we consider as long duration of the voltage variation. The first one is called over voltage and it's typical values are 10% to 20% that is 1.1 to 1.2 per unit and the second one is under voltage and it's typical values are 0.8 to 0.9 per unit.

Voltage fluctuations. Systematic variations the voltage envelope, we shall see that in a waveform in later stage. Systematic variations of the voltage envelope or a series of random voltage changes, the magnitude of which does not normally exceed the voltage range 0.95 to 1.05pu. So, that is termed as voltage fluctuations. The impact of the voltage fluctuations on lighting intensity (if you have a lighting load and all those issues) and subsequent impression of the unsteadiness visual sensation induced is denominated as flicker.

So, it is something that will be constrained to your eyes. So, voltage fluctuations have a very detrimental effect on the productivity of the industrial houses. Thereafter voltage sag. So, that is quite important features. The decrease between 0.1 to 0.9pu; but if it is up to 0.9 or 0.8, we term it as a long-term voltage disturbance. It is not a sag. Then generally, we call it dip or sag if it is between 0.1 to 0.9 in rms voltage at the power frequency for the durations at least 0.5 cycle to 1 minute.

When the decrease is to essentially zero voltage that is less than 0.1 per unit it is considered as short interruption. Same way swell, it is a voltage. Increase in rms voltage or the current at the power frequency for the duration from 0.5 cycles to 1 minute, will fall into the category of the voltage swell.

Same way transient, you know that transient is a quite unpredicted phenomenon. It comes and goes for the very small duration of the time. A sudden non power frequency change in the steady state condition of the voltage. When unidirectional in the polarity it is an impulsive transient. All of a sudden, a spike comes and then goes in both positive and the negative polarity values and this can be a oscillatory transient.

Same way we can have the waveform. That is the problem with the harmonic contaminations which is called a harmonic distortion. The presence of the frequencies at integer multiples of the fundamental system frequency. Generally, if it is a 6-pulse converter then you have a harmonic contamination of $(6n \pm 1)$.

And harmonics combined with the fundamental voltage and current produces the voltage distortion. Similarly, symmetry of the 3-phase. That is basically unbalanced voltage. The maximum deviation from the average of the 3-phase voltages, divided by the average of the 3-phase voltages, expresses as a percentage. So, that is also comes under the power quality per view.

So, we required to mitigate all of these. Hence once it happens, we require to mitigate and furthermore we have a few more details.

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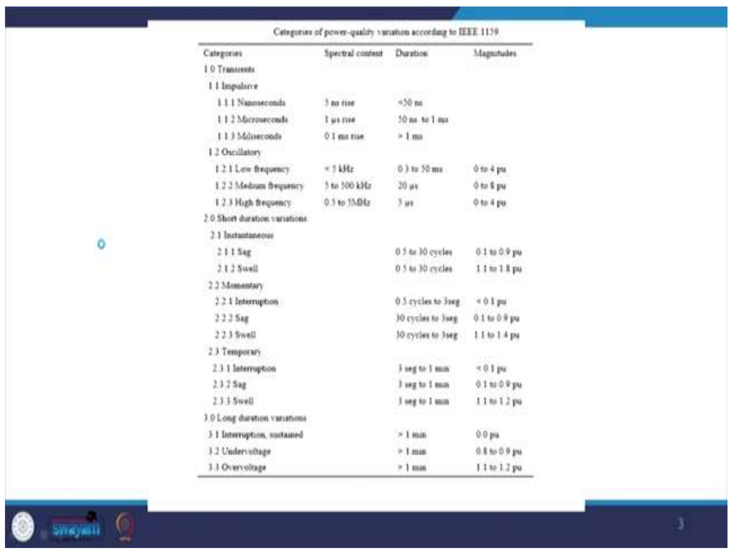

Categories of power-quality variation according to IEEE 1159

Categories	Spectral content	Duration	Magnitudes
1.0 Transients			
1.1 Impulsive			
1.1.1 Nanoseconds	5 ns rise	<50 ns	
1.1.2 Microseconds	1 μs rise	50 ns to 1 ms	
1.1.3 Milliseconds	0.1 ms rise	> 1 ms	
1.2 Oscillatory			
1.2.1 Low frequency	< 5 kHz	0.3 to 50 ms	0 to 4 pu
1.2.2 Medium frequency	5 to 500 kHz	20 μs	0 to 8 pu
1.2.3 High frequency	0.5 to 5MHz	5 μs	0 to 4 pu
2.0 Short duration variations			
2.1 Instantaneous			
2.1.1 Sag		0.5 to 30 cycles	0.1 to 0.9 pu
2.1.2 Swell		0.5 to 30 cycles	1.1 to 1.8 pu
2.2 Momentary			
2.2.1 Interruption		0.5 cycles to 3seg	< 0.1 pu
2.2.2 Sag		30 cycles to 3seg	0.1 to 0.9 pu
2.2.3 Swell		30 cycles to 3seg	1.1 to 1.4 pu
2.3 Temporary			
2.3.1 Interruption		3 seg to 1 min	< 0.1 pu
2.3.2 Sag		3 seg to 1 min	0.1 to 0.9 pu
2.3.3 Swell		3 seg to 1 min	1.1 to 1.2 pu
3.0 Long duration variations			
3.1 Interruption, sustained		> 1 min	0.0 pu
3.2 Undervoltage		> 1 min	0.8 to 0.9 pu
3.3 Overvoltage		> 1 min	1.1 to 1.2 pu

So, this is one important research standard. We have already defined those terms. We shall see the implications of it. First of all, we have defined transient in previous slide. Transient can be impulsive. Impulsive transient can be further classified according to nanosecond, microsecond, milliseconds. So, it is for nanosecond if it is for 5 nanosecond or less than 15 nanosecond and also microsecond, if 1 microsecond to 50 nanosecond and similarly it can be millisecond for 0.1 millisecond to 1 millisecond. There after it can be an oscillatory.

So, oscillatory that can be a low frequency. It can be a very low, in a kilo hertz level 5 kilo hertz and for the period of 0.3 to 50 microsecond and it's magnitude can be as high as 0 to 4 times and for medium frequency it can be ranges from 50 to 500 kilo hertz and duration will be little short around 20 microsecond, but it's magnitude can be further high. It can be 8 per unit that mean 800 percent higher. Similarly, for high frequency when it is in the range of 0.5 to 5 megahertz and duration will be very small as of the time 5 microsecond and magnitude is also generally up to 4 per unit.

Thereafter short variations, under that category we define the instantaneous. In that category we have defined sag for duration of 0.5 cycle to 30 cycles and if the magnitude is between 0.9 to 0.1pu we will consider it as sag. Similarly, for swell duration of 0.5 to 30 cycles and magnitude will be 1.1 to 1.8pu. And thereafter you may have a momentarily some phenomena, under that interruptions, when for 0.5 cycles to 3 seconds the power is off almost with a magnitude of less than 0.1pu.

Similarly, in case of sag it is for 30 cycle to the 3 segments. So, it is same as well in case of swells. For long duration, 30 cycle to the 3 seconds and to 1.1 to 1.4 per unit. Similarly, that is instantaneous. Thereafter you may have a temporary. You have an interruption, same way duration between 3 segments to the 1 minute with a magnitude of less than 0.1pu.

Sag same way between 3 segments to 1 minute. Swell is for less than 1 minute and this will be the magnitude and under long duration variations, generally power interruptions sustained for more than 1 minute, undervoltage for more than 1 minute and overvoltage for more than 1 minute, then in that case we do not say it is sag or swell. We call it undervoltage or overvoltage. While discussing later, this standard will be used frequently. So, please refer this standard because once we will correct, we will correct those entities.

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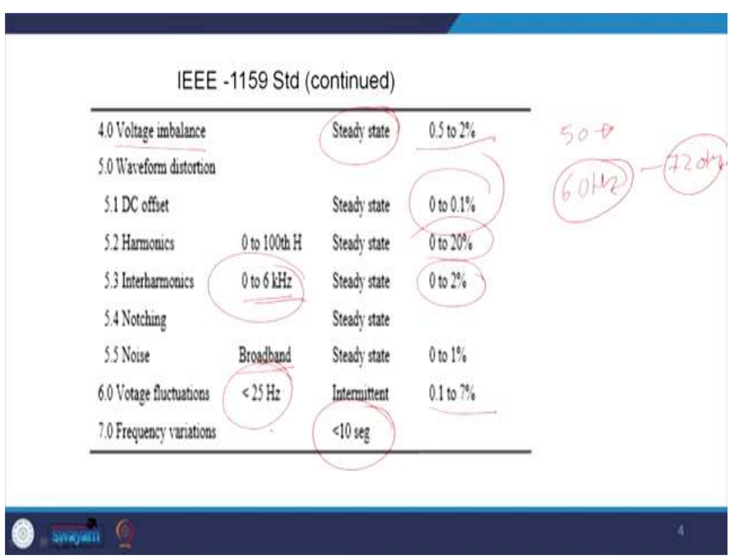

So, we will continue with the IEEE-519. So, voltage unbalance that is in steady state within 0.5 to 2 percent is acceptable in IEEE-1159 standard and waveform distortion there are different entities to it. DC offset can be as low as 0.1 percent, harmonics can be within zero to 20 percent. There is an inter harmonic. So, for example, if you have a 50 hertz supply as in case of India and you have a 60 hertz supply in USA and maybe you have chosen a devices that has a switching frequency of the 720 hertz, but if you put this device in India 720 will be a inter harmonic.

So, inter-harmonics it should be in between 0.5 to 2. So, this will be the inter-harmonics and it should be less than 2 percent. Notch should be zero and the noise on the broadband should be limited to 1 percent. Voltage fluctuations should be less than 25 hertz and intermittent and also should be within 0.1 to 7 percent and frequency variations should be less than 10 segment.

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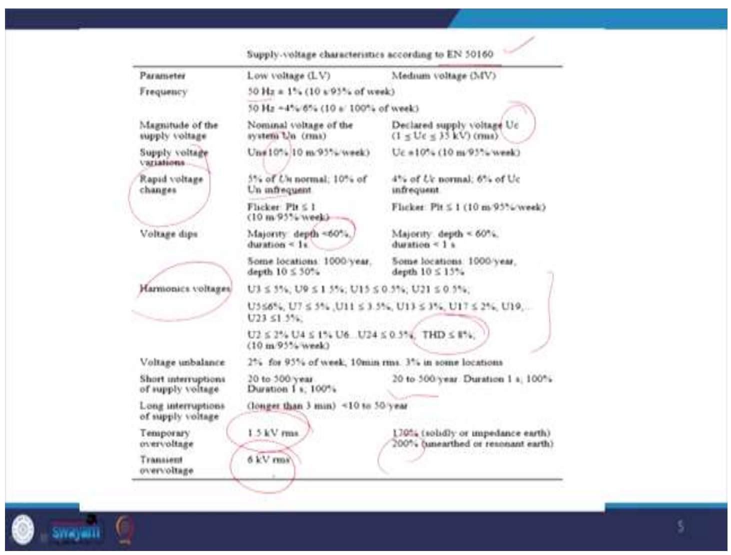

Supply-voltage characteristics according to EN 50160

Parameter	Low voltage (LV)	Medium voltage (MV)
Frequency	50 Hz ± 1% (10 s/95% of week)	
	50 Hz +4%/6% (10 s/ 100% of week)	
Magnitude of the supply voltage	Nominal voltage of the system Un (rms)	Declared supply voltage Uc (1 ≤ Uc ≤ 35 kV) (rms)
Supply voltage variations	Un±10% 10 m/95%/week)	Uc ±10% (10 m/95%/week)
Rapid voltage changes	5% of Un normal; 10% of Un infrequent	4% of Uc normal; 6% of Uc infrequent
	Flicker: Plt ≤ 1 (10 m/95%/week)	Flicker: Plt ≤ 1 (10 m/95%/week)
Voltage dips	Majority: depth <60%, duration < 1s	Majority: depth < 60%, duration < 1 s
	Some locations: 1000/year, depth 10 ≤ 50%	Some locations: 1000/year, depth 10 ≤ 15%
Harmonics voltages	U3 ≤ 5%; U9 ≤ 1.5%; U15 ≤ 0.5%; U21 ≤ 0.5%;	
	U5≤6%, U7 ≤ 5% ,U11 ≤ 3.5%, U13 ≤ 3%, U17 ≤ 2%, U19,.. U23 ≤1.5%;	
	U2 ≤ 2% U4 ≤ 1% U6...U24 ≤ 0.5%, THD ≤ 8%; (10 m/95%/week)	
Voltage unbalance	2% for 95% of week, 10min rms. 3% in some locations	
Short interruptions of supply voltage	20 to 500/year Duration 1 s; 100%	20 to 500/year. Duration 1 s; 100%
Long interruptions of supply voltage	(longer than 3 min) <10 to 50/year	
Temporary overvoltage	1.5 kV rms	170% (solidly or impedance earth) 200% (unearthed or resonant earth)
Transient overvoltage	6 kV rms	

So, now let us discuss this IEEE standard and this is a distribution standard which has been followed in the European union and it is called EN 50160 and you see that for this reason we almost follow the same kind of standard mostly in Indian grid court. It is almost synonymous. So, the parameter it is low voltage and the medium voltage. The frequency will be 50 hertz and should be plus minus 1 percent and for 10 second it should be 95 percent of the week grid and we can have 4 percent or 6 percent for 100 percent of the week grid.

Magnitude of the voltage, nominal voltage of the system in rms which is generally 440 volt and declared supply voltage generally Germanys instead of the U they write V. So, it should be around 35 kV rms. Then the supply voltage can have a variation of 10 percent for the week grid. Similarly, it can also have a 10 percent variation. A rapid voltage change can be up to 5 percent of under normal condition, 10 percents under week frequency control. Flickers, it should be less than 1 percent and here also should be less than 1 percent. Voltage dip should be less than 60 percent for the duration of less than 1 second.

Majority of dip should be less than 60 percent for up to 1 second in some location. So, we can have this kind of entities. So, third harmonic voltage should be less than 5 percent. The ninth harmonic should be less than 1.5 percent. Fifteenth harmonic should be less than 0.5 percent. 21th harmonic should be less than 0.5 percent and accordingly the total THD also should be less than 8 percent.

And voltage unbalance can be of 2 percent for 90 percent week grid for 10 minutes and 3 percent in some location and the short interruptions for 1 second for 100 percent and for the durations of the span of 20 to 500 years and the long interruptions will be for longer than 3 minutes and temporary over voltage is limited up to 1.5 kV rms and it can be as high as 35 kV for 170 percent for solidly or impedance earth and 200 percent for the unearth or resonant earth. Transient over voltage can go as high as 6 kV.

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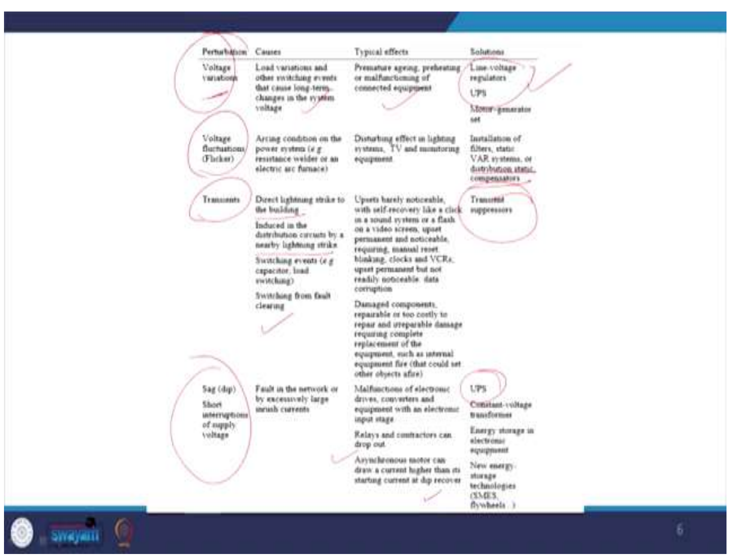

Perturbation	Causes	Typical effects	Solutions
Voltage variations	Load variations and other switching events that cause long-term changes in the system voltage	Premature ageing, preheating or malfunctioning of connected equipment	Line-voltage regulators UPS Motor-generator set
Voltage fluctuations (Flicker)	Arcing condition on the power system (e.g. resistance welder or an electric arc furnace)	Disturbing effect in lighting systems, TV and monitoring equipment	Installation of filters, static VAR systems, or distribution static compensators
Transients	Direct lightning strike to the building Induced in the distribution circuits by a nearby lightning strike Switching events (e.g. capacitor, load switching) Switching from fault clearing	Upsets barely noticeable, with self-recovery like a click in a sound system or a flash on a video screen; upset permanent and noticeable, requiring manual reset blinking, clocks and VCRs; upset permanent but not readily noticeable: data corruption Damaged components, repairable or too costly to repair and irreparable damage requiring complete replacement of the equipment, such as internal equipment fire (that could set other objects afire)	Transient suppressors
Sag (dip) Short interruptions of supply voltage	Fault in the network or by excessively large inrush currents	Malfunctions of electronic drives, converters and equipment with an electronic input stage Relays and contractors can drop out Asynchronous motor can draw a current higher than its starting current at dip recover	UPS Constant-voltage transformer Energy storage in electronic equipment New energy-storage technologies (SMES, flywheels ...)

So, now what is the implication of it. So, let us understand that these are the disturbances, these are the cause, these will be the effected entities and this is the solution.

So, voltage variation. So, you may have a voltage disturbance. We have seen sag swell, lot of entities. Mainly it is caused by load variation and the other switching events that cause long term change in the system voltage. All of a sudden you overthrow a big line or a sudden fault and due to that the variation of the voltage occur. Premature ageing of your machines, preheating and the malfunctioning of the connected equipment are the effect.

To overcome that we look at the sensitive instrument to be provided with the line voltage regulator, UPS, motor generator set so that it can give you the clean power to the motors. Voltage fluctuations or flickers, arcing condition on the power system resistance wielding or the electrical arc furnace are the cause. They are making some wielding somewhere.

Then what will happen? The disturbing effect in lighting system like if you are projecting then there will be flickers. TV and the monitor equipment can be damaged permanently especially CRT and other devices. Nowadays CRT is over. Then how can you recover from it? Solution is installations of filters, static VAR systems or the distribution static compensator.

Now, transients. So, it may be from the many sources like direct lighting strike to the building or the transmission line or may be induced in the distribution circuit by nearby the lightning strike. Switching events such as capacitor, load switching from the fault clearing can also be the cause. So, it may damage many entities, like upset barely noticeable, with the self recovery like click in a sound system or a flash of the video screen, upset or burn permanent and the noticeable, requiring reset of the VCR TV or other sensitive equipment even fans.

So, you required to have a transient suppressor. Thereafter you have voltage sag. Fault in the network or the excessive large inrush of the current and that is what it will do. It will cause malfunction of electronics devices converted equipment with the electronic input relays and the contractor can drop out. Asynchronous motor can also draw a current higher than it’s starting current and dips and recovers.

And here also you require uninterrupted power supply, constant voltage transformer, energy storage in electronic equipment, or may be ultra capacitor. A new leased energy storage system such as SMES and the flywheel can also be the solution for the intermediate sag control. Now similarly there can be a swell. It can be effect of single line to the ground failure, upstream failures, switching off the large load or the switching of the large capacitor.

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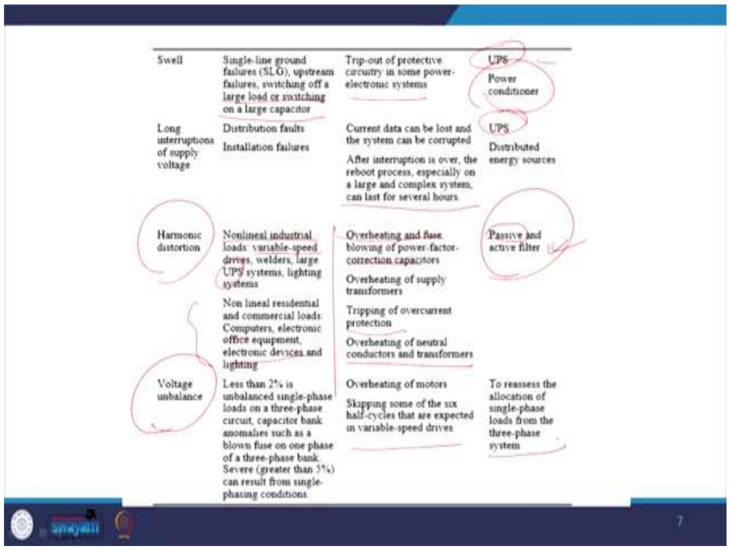

Swell	Single-line ground failures (SLG), upstream failures, switching off a large load or switching on a large capacitor	Trip-out of protective circuitry in some power-electronic systems	UPS Power conditioner
Long interruptions of supply voltage	Distribution faults Installation failures	Current data can be lost and the system can be corrupted After interruption is over, the reboot process, especially on a large and complex system, can last for several hours.	UPS Distributed energy sources
Harmonic distortion	Nonlineal industrial loads: variable-speed drives, welders, large UPS systems, lighting systems Non lineal residential and commercial loads: Computers, electronic office equipment, electronic devices and lighting	Overheating and fuse blowing of power-factor-correction capacitors Overheating of supply transformers Tripping of overcurrent protection Overheating of neutral conductors and transformers	Passive and active filter
Voltage unbalance	Less than 2% is unbalanced single-phase loads on a three-phase circuit, capacitor bank anomalies such as a blown fuse on one phase of a three-phase bank. Severe (greater than 5%) can result from single-phasing conditions.	Overheating of motors Skipping some of the six half-cycles that are expected in variable-speed drives	To reassess the allocation of single-phase loads from the three-phase system

So, what happens? It can trip the protective circuitry in some power electronic systems, which may cause damage to it and overvoltage always cause lot of damage to the installations. Solution is definitely uninterrupted power supply and the power conditioners. Long interruptions of the power supply, can happen due to distribution fault and installation failures. As a result, current data can be lost for the system. Even after interruption is over, the reboot process, specially on the large and the complex system can last for several hours.

You are habituated with it because if your UPS is not working, all of a sudden power gone and you are working in important data that all are lost. So, for this reason you require a power back up UPS or distributed power sources. And another important entity, I shall cover a lot of discussions on it. There is harmonic distortion. The non-linear industrial loads, variable speed drives, welders, large UPS system are the reason this. We are seeing that UPS here, but UPS itself causes the distortion in harmonics and non-linear residential load and the commercial load, computers electronics equipments in offices all are adding the harmonic problem.

So, what is the problem of this harmonics? Overheating and because ultimately does not contribute to the real power. For harmonic power if you are taking the average it is zero but since current flows to the resistive network it will be unnecessarily hitting the elements. So, blowing of the power factor correction capacitors, overheating of the supply transformer. We shall see in detail why it is so. Tripping of the over current protection because peak may increase because of the presence of the harmonic. Overheating of the neutral of the conductor.

And the solution is provided by active power filter or passive power filter. We have to short our discussion because we require to complete it in 20 hours. We shall put more emphasis now on the active power filter. Similarly, voltage unbalance. Less than 2 percent unbalance is allowed in single-phase loads for a 3-phase circuit, capacitor banks and anomalies such as a blown fuse on one of the phases or due to any other reason load unbalance may cause.

So, ultimately if there is an unbalance more than 2 percent then the effect can be overeating of the motor, skipping some of the 6 cycles that is expected from the variables speed drive and thus torque rating of the motor will be reduced. To remove it we require a UPQC to release the allocation of the single-phase load from the 3-phase system.

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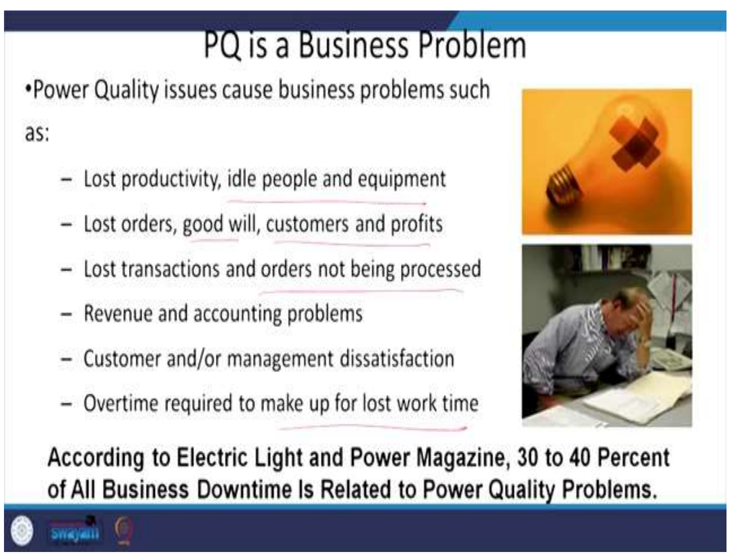

Now, as I have pointed out, let us see the power quality as a business problem. Why? As ultimately someone has to pay. So, what does happen? Loss of productivity, idle people and equipment, because of the power loss, lost order, loss of goodwill, loss of customers and profit. Lost transactions if data is lost, orders is not been processed. Revenue and the counting problem. Customers and the management dissatisfaction. Overtime required to make up for lost work time.

This is a data I have captured with the courtesy to the electric light and power magazine, 30 to 40 percent of all business downtime is related to the power quality problem.

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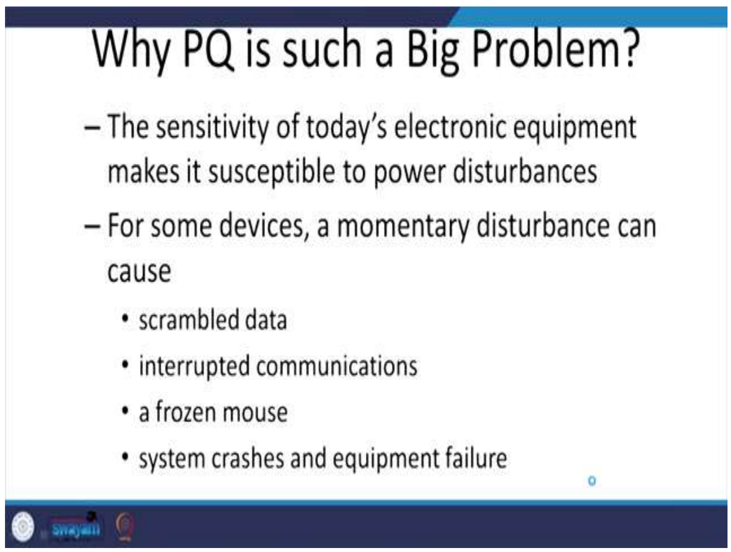

Now, why it is so? Because of scrambled data, uninterrupted communications, frozen mouse that is your mouse is not operating, system crashes with the system failure as a result disturbance in memory. Nowadays we say that data is the new fuel, if you have data then you can do lot of data mining and thus this data can be affected by the power quality.

For this reason, we have to give the utmost importance to the power quality when you are dealing with data.

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Now, who have been affected? Of course, say there is a very smooth process control for example, and the quality is a biggest challenge. For example, this semiconductor plant which is making let us say processor. You have to give a very accurate power supply to the manufacturing processes. Pharmaceutical, data center that is why I am telling, you know data centers are most vulnerable and they are the new fuel of the economy. For this reason, power quality has to support the data centers.

And in case of medium cost facilities that is automotive manufacturer, glass plant, plastic plant, textile and many other plants cement plant, paper pulp, lost of production, there will be a lots of scrap, cost to restart, there is extra labor cost, equipment damage, repair and other costs.

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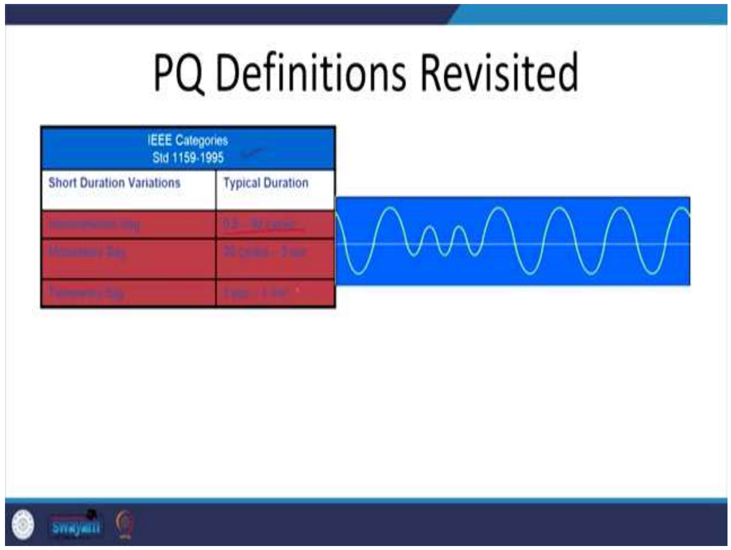

Now, let us see. We shall define this IEEE standard briefly. We will see that instantaneous sag moment. What does it mean by instantaneous sag? We have defined already. That is 0.5 to 30 cycles. Momentary sag is for 30 cycle to 3 second and the temporary sag is for 3 second to 1 minute. Let us see.

So, this is your short duration sag.

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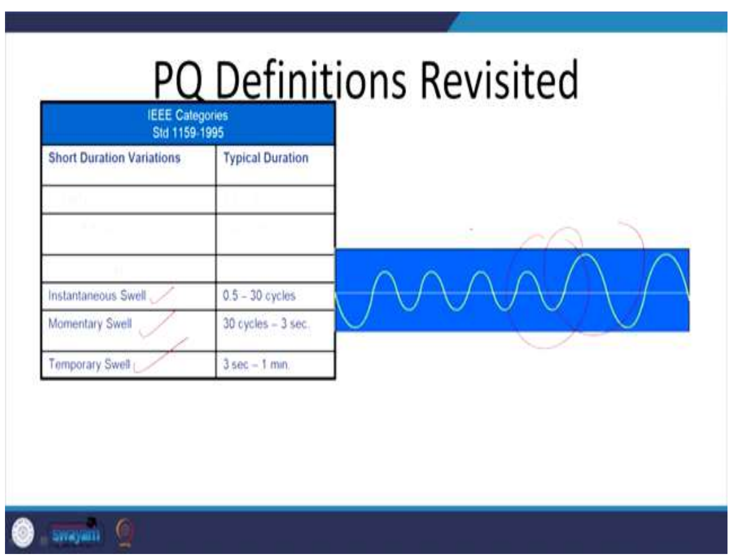

Similarly, we can have instantaneous swell and the momentary swell and a temporary swell of 0.5 to 30 cycle, 30 cycle to 3 second and 3 second to 1 minutes respectively. So, this is it and all of a sudden there is a swell. So, this is the instantaneous swell on that momentary swell. If this comes into the waveform, we will say that.

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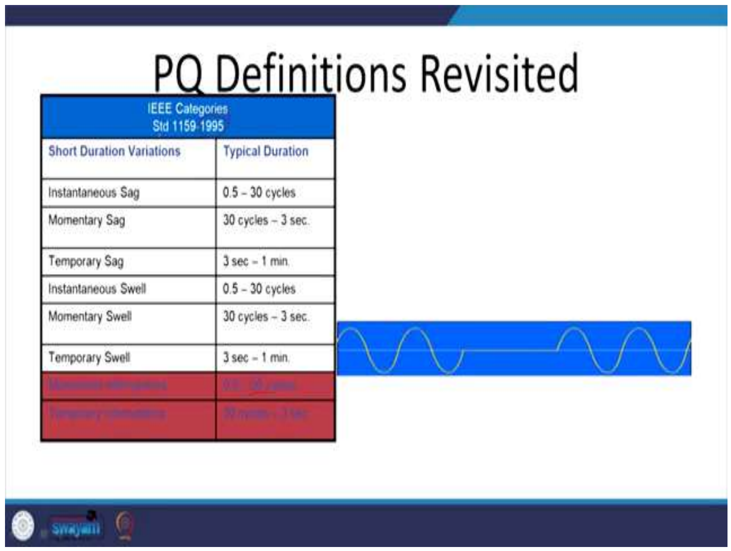

Similarly, momentarily interruption. It can be 0.5 to 30 cycles and it can be also 30 cycle to the 3 second. See that there is a momentary interruption for I hear I have made for the 2 cycles.

If it happens then it will be categorized as per the IEEE 1159 or 1995. This is actually the 1995 standard; hence it will be categorized as a momentary interruptions and the temporary interruption.

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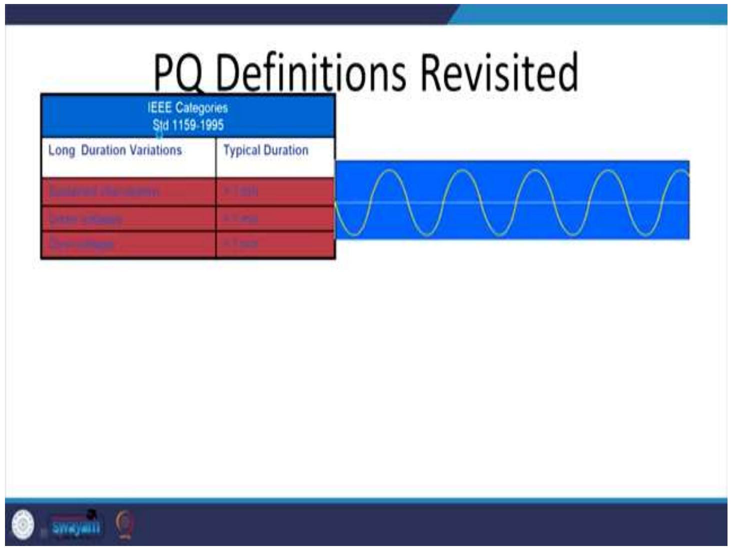

Now, long duration variations. Under that sustained interruptions for more than 1 minute, under voltages for more than 1 minute. So, this will be a sustained interruption that is for more than 1 minute and we can have under voltage for more than 1 minute and the over voltage also for over a minute.

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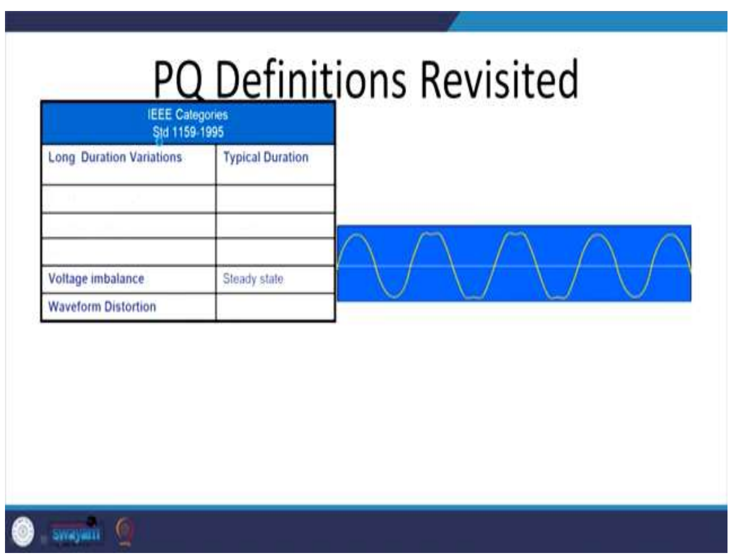

Now, we shall talk about voltage unbalance in a steady state and the voltage distortion. You can see that all of a sudden, the voltage distortion comes. So, this is a problem. So, this also comes under the power quality per view. We required to remove it.

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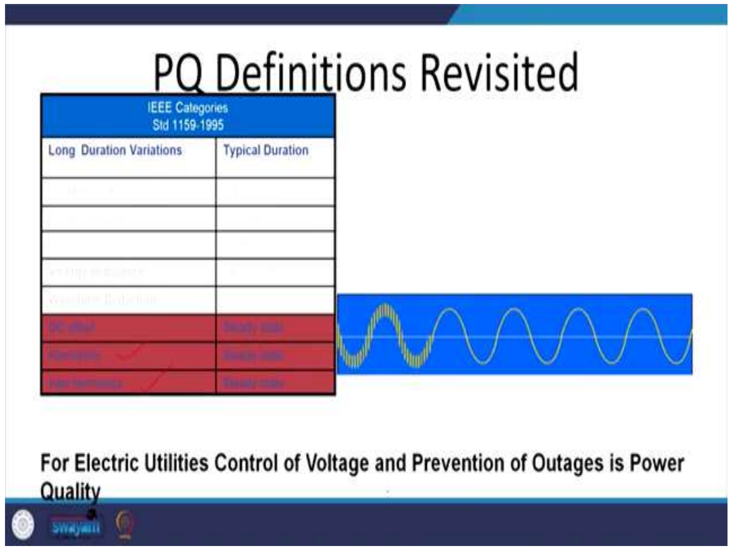

Similarly, we can have a DC offset. We can have a harmonic at steady state and the inter harmonic, that is something quite interesting. So, this is the harmonic at a steady state and you can have a DC offset (that is your AC and DC does not match) and sometime it is not, except multiple of it then we say that it is the inter harmonic.

So, for the electric utilities control of the voltage and prevention of outages is power quality. We required to mitigate all the issues that has been explained here.

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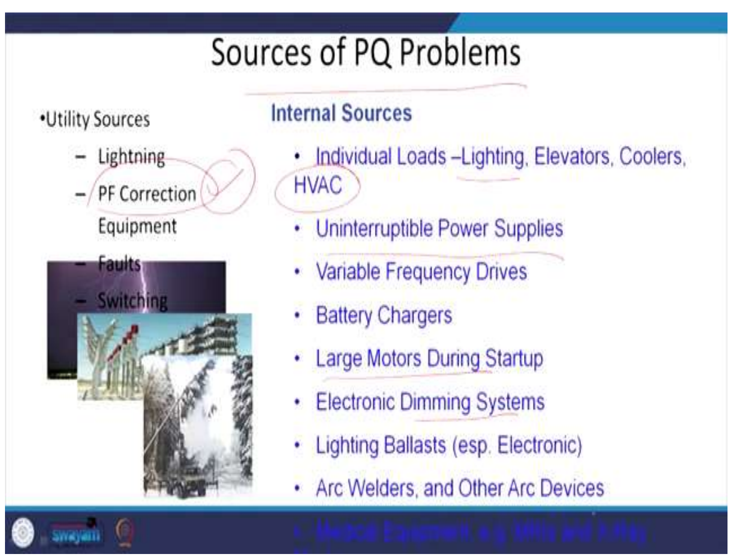

So, we have just discussed it. Just a recap. So, we can have sources of the PQ problems as lightning, power factor connection. We shall see in the next lecture in may be. And the correction equipment, fault switching all of these are the cause of the power quality problem. Power factor correction keeps the power factor corrected, but it is detrimental. See that pressing of the capacitor that for corrections of the power factor and what is its effect on the overall power quality.

And so, these are the few issues regarding power quality. The internal sources of these can be individual loads such as lighting (nowadays we have LED light), elevators, coolers, HVAC, thereafter uninterruptable power supply, thereafter variable frequency drive, battery charger, large motor during start, electronic dimming system, lightning electronic ballast, arc furnace, medical equipment (e.g. MRI) etcetera.

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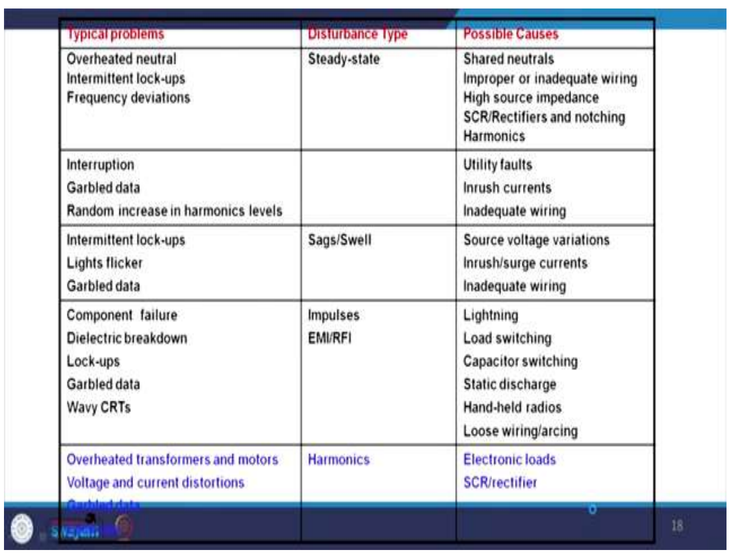

Typical problems	Disturbance Type	Possible Causes
Overheated neutral Intermittent lock-ups Frequency deviations	Steady-state	Shared neutrals Improper or inadequate wiring High source impedance SCR/Rectifiers and notching Harmonics
Interruption Garbled data Random increase in harmonics levels		Utility faults Inrush currents Inadequate wiring
Intermittent lock-ups Lights flicker Garbled data	Sags/Swell	Source voltage variations Inrush/surge currents Inadequate wiring
Component failure Dielectric breakdown Lock-ups Garbled data Wavy CRTs	Impulses EMI/RFI	Lightning Load switching Capacitor switching Static discharge Hand-held radios Loose wiring/arcing
Overheated transformers and motors Voltage and current distortions	Harmonics	Electronic loads SCR/rectifier

So, these are few categorized problems. Overheated neutral, intermittent lock up, frequency deviations. Disturbance type is steady state. Possible causes are shared neutral, improper or inadequate wiring, high source impedance SCRs or rectifier and notching harmonics. Another issue interruption, possibly caused due to utility faults, inrush currents. The problem can be intermittent lock ups, lights flicker that is for the sags or swell. Then component failure, dielectric breakdown, lock up and other things that introduces the EMI or EMC. Thereafter overheated transformer and motor’s voltage current distortions and that is causing the harmonics ultimately. Possible cause maybe electronic load SCRs or rectifier.

Thank you for your attention. We shall discuss power quality issues and problem in our next class.