Power Quality Improvement Technique
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Lecture – 05
Source of Poor Power Quality

Welcome to our Power Quality Improvement Technique. Today we are going to discuss the source of the power quality. I just left that portion while discussing, one or two slides may be a repetition like you know what are the Source of the Power Quality.

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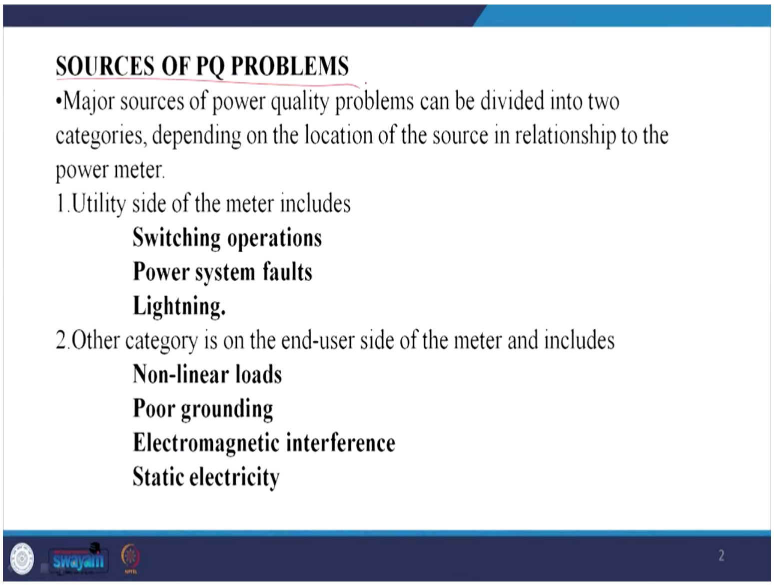

Major source of course, as I have discussed in a previous class that the switching operation. Maybe on a capacitor for rectifying the power factor and the power system fault and the lighting.

This is the utility side of the meter that includes these entities, that is problem of the power quality and that is mainly the reactive power and the active power problem. Thereafter, there is a harmonic problem mainly. This is the category of the end users includes non-linear load, poor grounding that is a oscillation of the neutral and the electromagnetic interference and the static electricity. We shall cover these entities in our subsequent discussion.

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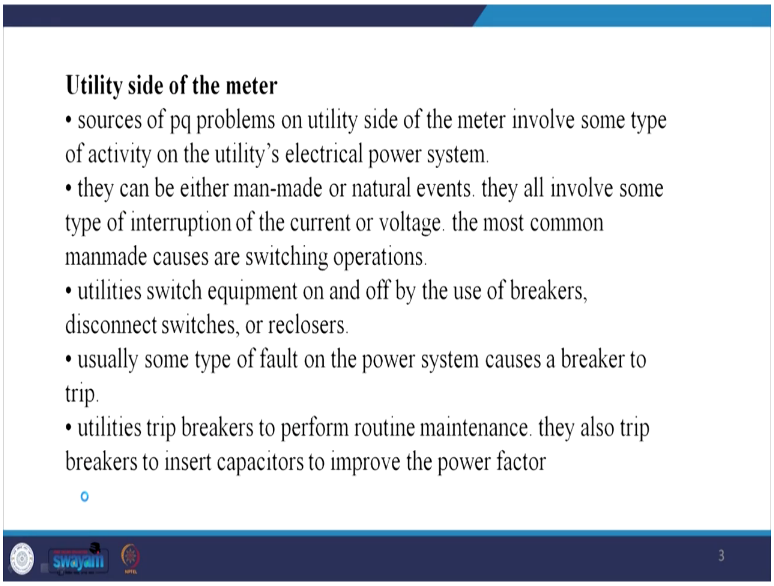

So, as we have discussed, we are just revisiting the sources of the power quality. Here please understand that this abbreviation is considered as power quality not a reactive power and active power. I am using it and this is not a standard notational also.

So, please do not use it for sake of our abbreviation I am making this abbreviation. A power quality problem on the utility side of the meter involve some type of activity on the utility's electrical power system. They can be either man-made or natural events and they all involve some type of interruption of the current or voltage.

The most common man-made causes are switching operations that we have seen in day to day life, like switching of the capacitor, switching of the facts devices, TCSC all those devices, then this is our part of the switching devices. Utilities switch equipment on and off by the breakers, if you have a fault then breaker will operate.

Usually some type of fault on the power system in this case breaker trips and there will be a problem of the web and thus may cause high voltage into a system. Utilities trips breakers to perform routine maintenance and they also trip breakers to insert capacitors to improve the power quality.

So, in all those cases we have a switching operation and if it is a transient then it is transient problem and sometime this oscillation may be sustained due to the undammed nature of the power system.

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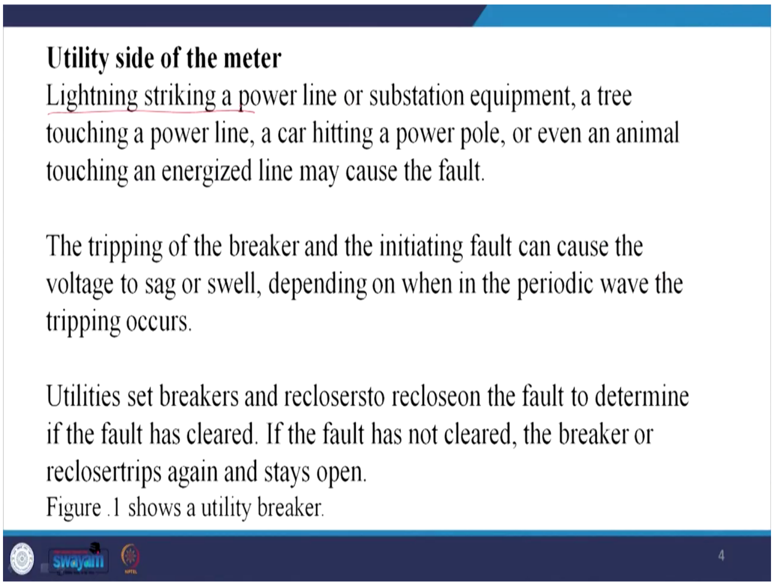

And there are lighting striking on the power line of the sub-system which we have discussed and let us see that.

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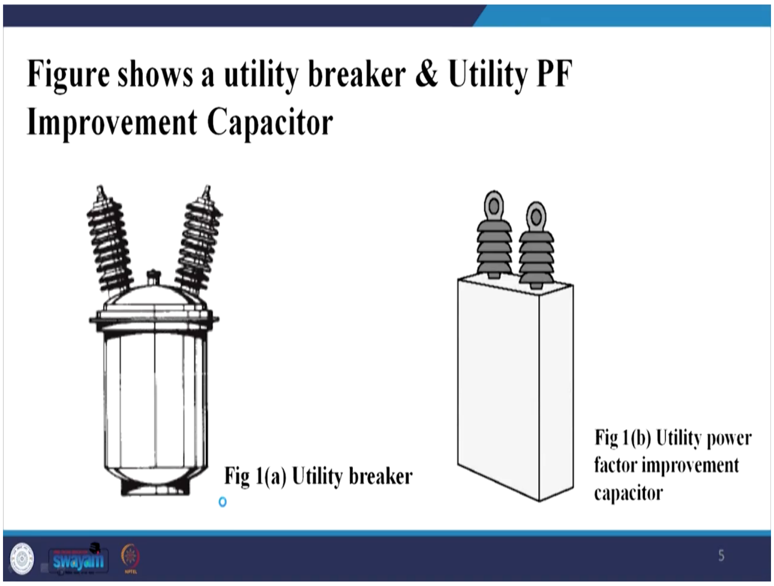

This is the utility circuit breaker and this is a utility power factor improvement capacitor. These two entities generally are the switching element and thus causes problem sometimes, but it is a necessary entity because power factor required to be improved.

But while inserting it you may call the ferroresonance and also while you are making or breaking these devices then also some problem of power quality may be present. So, we are talking about first the utility side then we will talk about the consumer side also.

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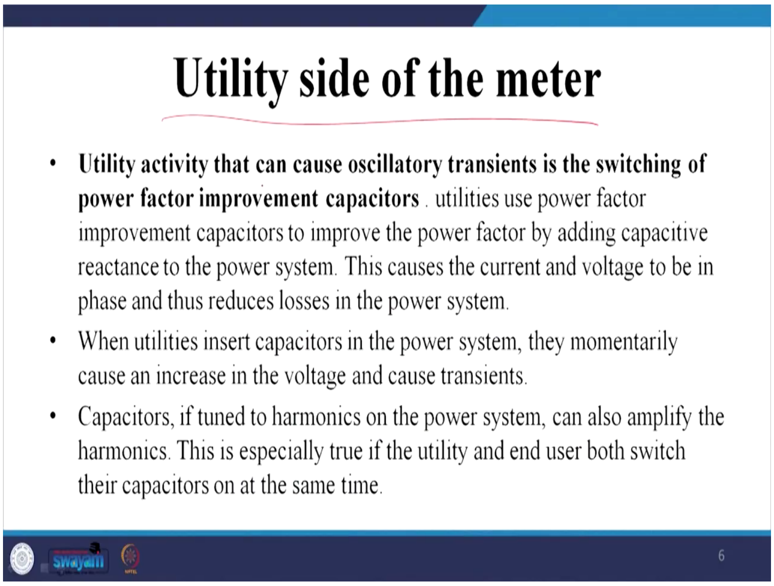

Utility activity that can cause oscillatory transients is the switching of the power factor improvement capacitors. So, that is one of the main demerits and that frequency will super impose your power supply and thus you will have a sag sometime and swell sometime, this kind of voltage may come. Utilities use power factor improvement capacitor to improve the power factor by adding capacitive reactance to the power system. This causes the current and voltage to be in phase and thus reduces losses in the power system.

When utilities insert capacitors in the power system, they momentarily cause an increase in voltage and causes transient. Capacitors, if tuned to harmonics on the power system, can also amplify the harmonics. That is also a problem. This is especially true if the utility and the end user both switch their capacitors on at the same time and thus have a quite detrimental effect on it. And let us see the end user side.

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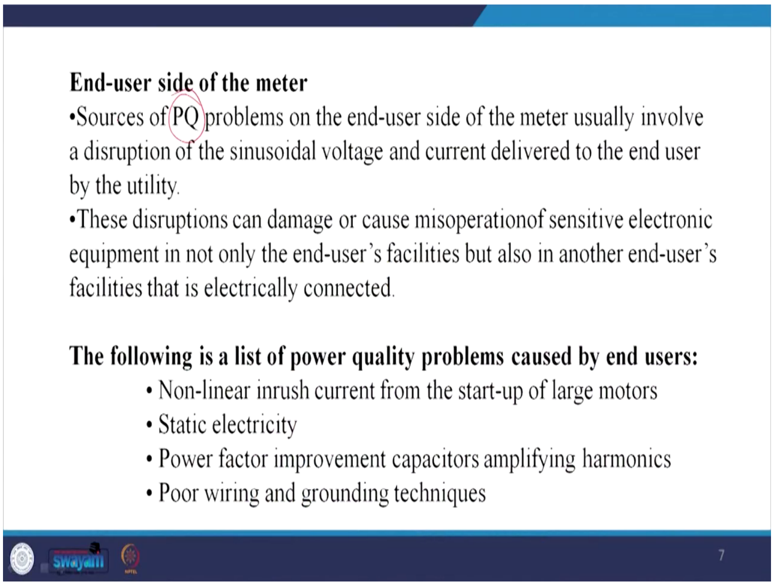
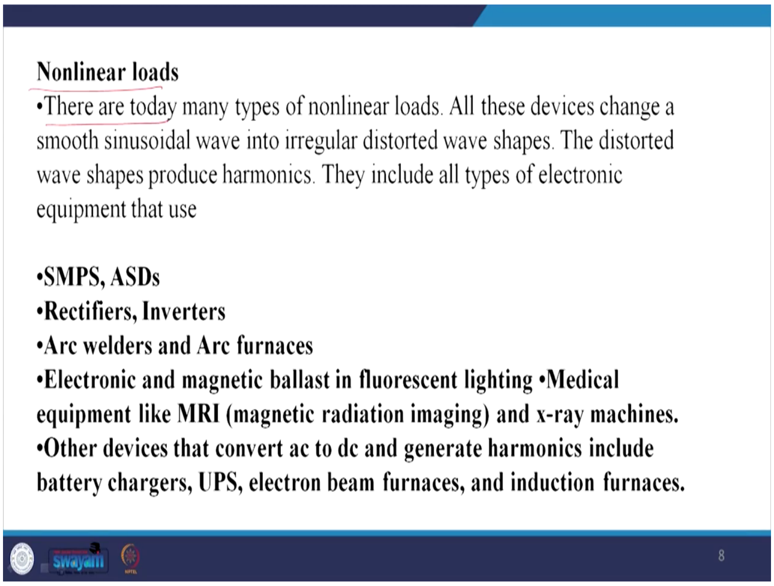


Sources of the power quality problems on the end user side of the meter usually involve the disruption of the sinusoidal voltage and current delivered to the end user by the utility. So, I as a consumer supposed to get sinusoidal voltage and current. I am not getting it. These disruptions can damage or cause misoperation of sensitive electronic equipments. You may be listening a very high clarity speakers from "Bose" and that may be distracted by the ill supply or contaminated power supply. Hence, these disruptions can occur in the sensitive electronic equipment, in not only the end user's facilities, but also in another end user's facilities that is electrically connected.

So, it will also affect the neighborhood. So, the following are the least of the power quality problem that can be caused by the users. Non-linear inrush current from the startup of the large motors, static electricity that is something we will see. After that static electricity may damage your sophisticated devices and then that may come for the any reason by fictions. So, for this you know when the power electronics engineers are soldering the sensitive electronic equipment, they are asked to wear the wristband.

So, that their body is fully discharged and lagging and required to sit with their legs that has to be put on the steel plate something like that. So, that he is totally discharged. Power factor improvement capacitors sometime amplifies harmonic. That we will see later because it may cause a resonance of a particular harmonic.

Poor wiring and grounding techniques also cause the oscillations of this neutral point and moreover impedance of one line is more, another line is less then there will be a voltage unbalance. So, from this unbalance also there is a issue of the power quality. (Refer Slide Time: 08:53)



Now, the non-linear load, there are today many types of non-linear loads. All these devices change a smooth sinusoidal wave into irregular distorted wave forms. The distorted wave forms produce harmonics. They include all type of electronic components. For example, SMPS and the adjustable speed drives, rectifiers, inverters, arc welders which we have discussed in detail in a our class.

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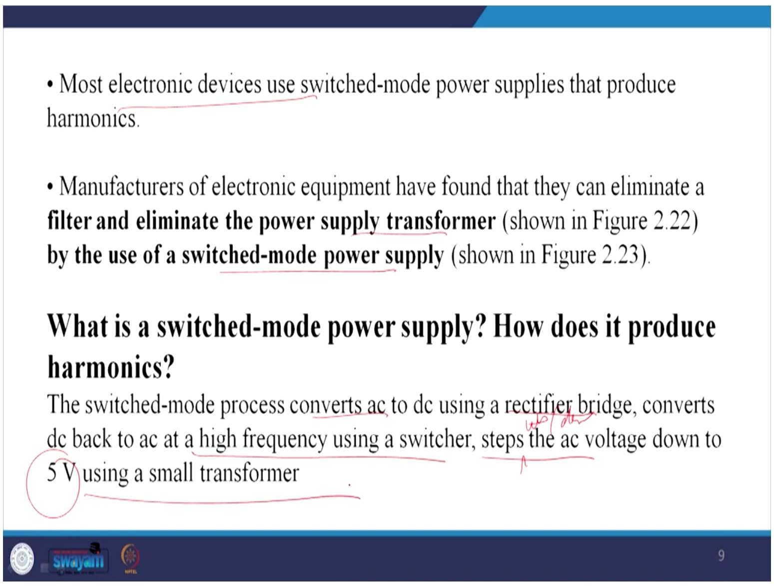

So, now we wanted to show something. Most of the electronic devices use switched mode power supplies that producer harmonics. The manufacturers of electronic component have found that they can eliminate filter and eliminate power supply transformer by the use of a switch mode power supply. And what is switch mode power supply and how does it produce harmonics?

The switch mode power supply process converters (because you have a laptop charger, desktop charger all are this quantity) AC to DC using a rectifier bridge, converts DC back to AC at a high frequency using switches and steps down generally steps ups or down the AC voltage down to the 5V using a small high-frequency transformer.

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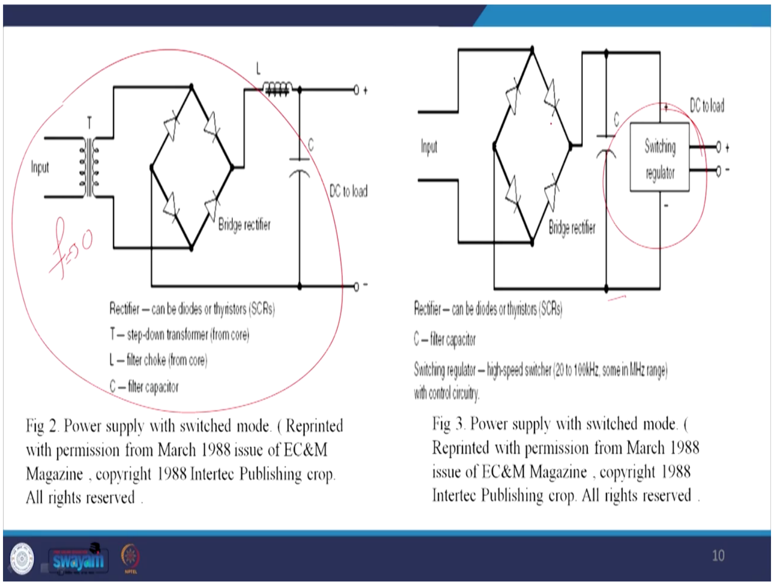

So, this is the case of the normal power supply where this transformer is at 50 Hertz, but generally inside it, there will be a DC to DC converter and that will be operated at high frequency and for this reason they are being used.

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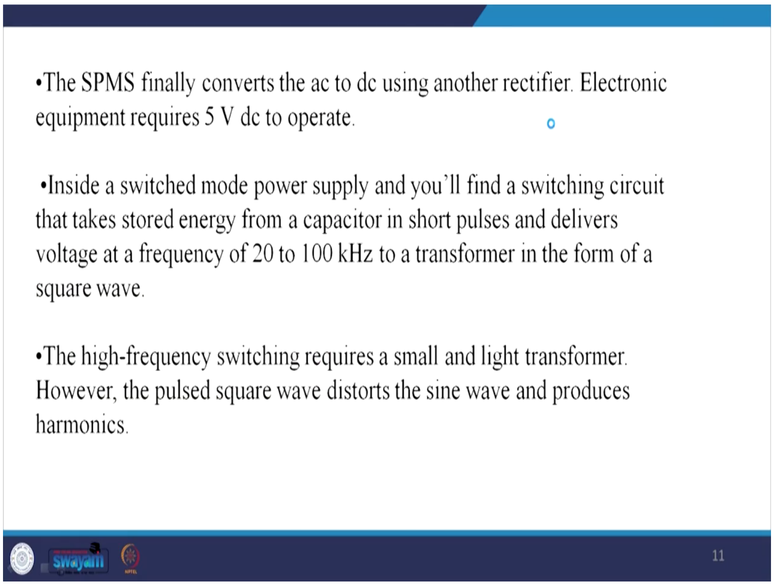

So, the SMPS finally, converts the AC to DC using another rectifier and generally it has to be synchronous rectifier because diode gives you 0.7 volt drop. So, to reduce the drop there is a mechanism.

The electronic equipment requires 5V DC to operate it. Inside a switched mode power supply you will find a switching circuit that takes stored energy from a capacitor in short pulses and delivers voltage at a frequency of generally quite high as 20kHz to 100kHz so that the compactness of the transformer can be a addressed. This high frequency switching requires small and light transformer.

However, the pulsed square wave distorts the sine wave and produces harmonic in that way. So, for this reason all your laptop charger and all those entities, unless they are put into the power factor rectification technique, they will have those problem.

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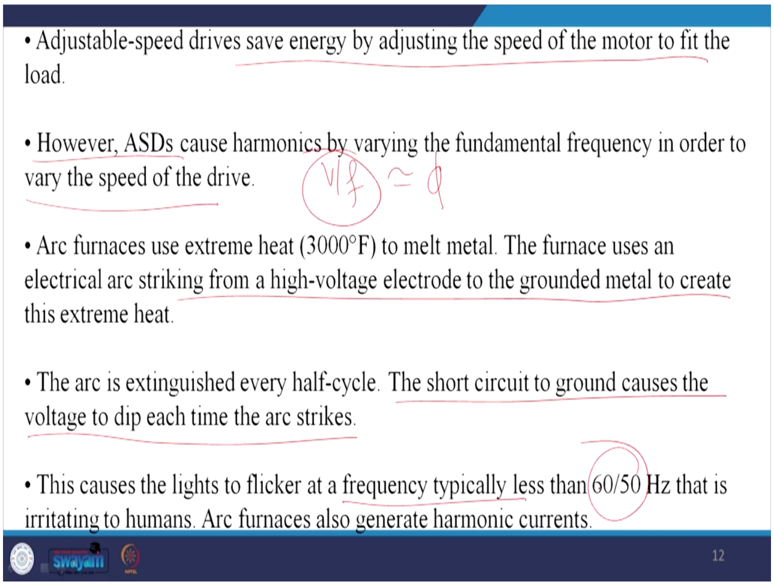

And apart from that, adjustable speed drive save energy by adjusting the speed of the motor to fit the load. However, the adjustable speed drives cause harmonics by varying the fundamental frequency in order to vary the speed, it may have a V/f control. Once we have V/f control this ratio require to be maintained constant. So, that flux almost remains constant and thus you can have a variable frequency operation.

Arc furnaces use extreme heat to melt the metal. The farness uses the electrical arc striking from the high voltage electrode to the ground metal to create this extreme heat. The arc is extinguished every half cycle. The short circuit to ground causes the voltage to dip each of the cycle it is strikes.

And moreover, this causes the lights to flicker at a frequency less than 50 to 60 Hertz in case of India it is 50 Hertz and that is irritating to the human beings. Arc furnaces also generate harmonic currents.

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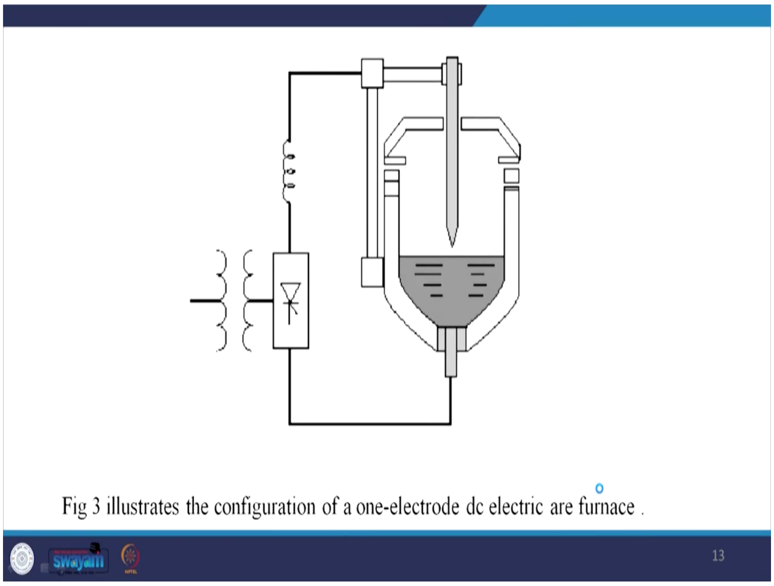

So, that is also a problem. This is an example of the arc furnace.

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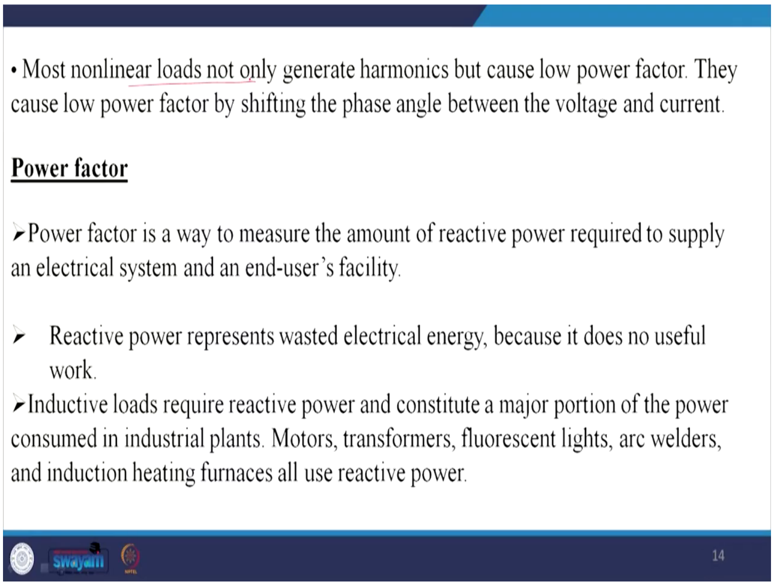

Now, most popular non-linear loads not only generate harmonics but can cause low power factor and they cause low power factor by shifting the phase angle between voltage and current. So, what is power factor? You know very well just for the sake of recap. The power factor is a way to measure the amount of the reactive power required to supply to an electrical system at the end user's facility, active and reactive both.

Reactive power represents waste of electrical energy, because it is not useful for work. Inductive loads require reactive power and constitute a major portion of the power consumed in industrial plants. Motor, transformer, fluorescent light, arc welding etcetera and induction heating furnaces all use this reactive power.

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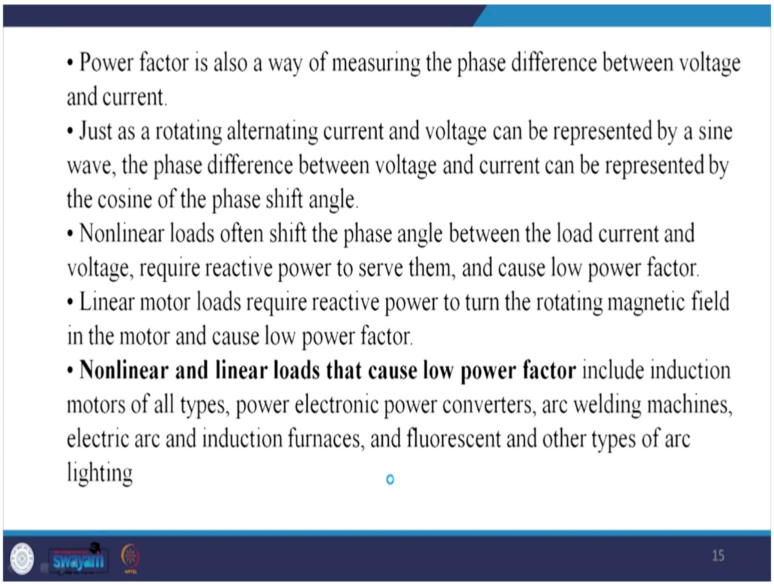

The power factor is also a way of measuring the phase difference between the voltage and current. Just as a rotating alternating current and voltage can be represented by a sine wave, the phase difference between voltage and current can be represented by the cosine of the phase shift angle.

So, we can represent it as a phasor. Non-linear loads, what does it do? These often shift the phase angle between the load current and the load voltage, because you know you change the firing angle of the alpha of a full control converter and you see that there is a displacement power factor and thus what happened your power factor get deteriorated and these loads also require reactive power to serve them and causes low-power factor.

Moreover, linear motor loads require reactive power to turn the rotating magnetic field in the motor and cause low power factor. Non-linear and the linear load that cause low power factor includes induction motor of all types, power electronic power converters, arc welding machines, electric arc and induction furnaces and fluorescent and other type of arc lighting.

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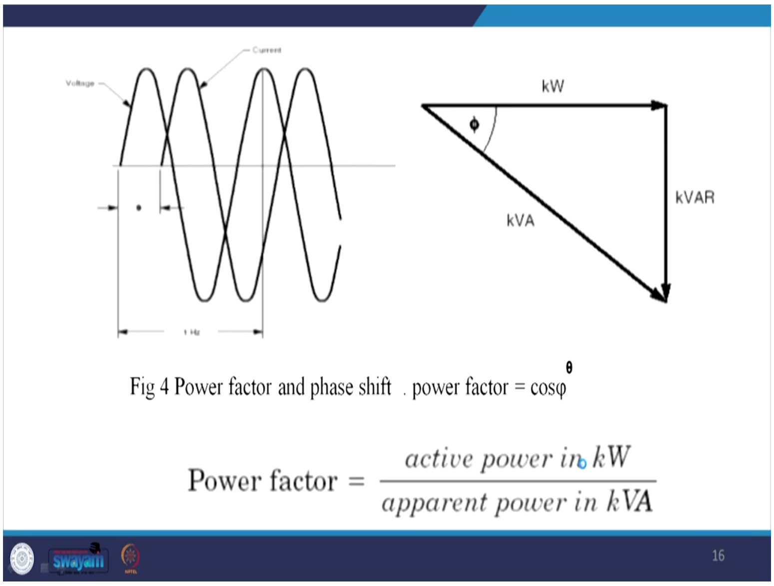

So, this is the example of the voltage and current, they have a phase of ϕ. Thus, what happen? So, this angle ϕ and cos of it is a power factor. Power factor is essentially the ratio of active power in watt and apparent power in kVA.

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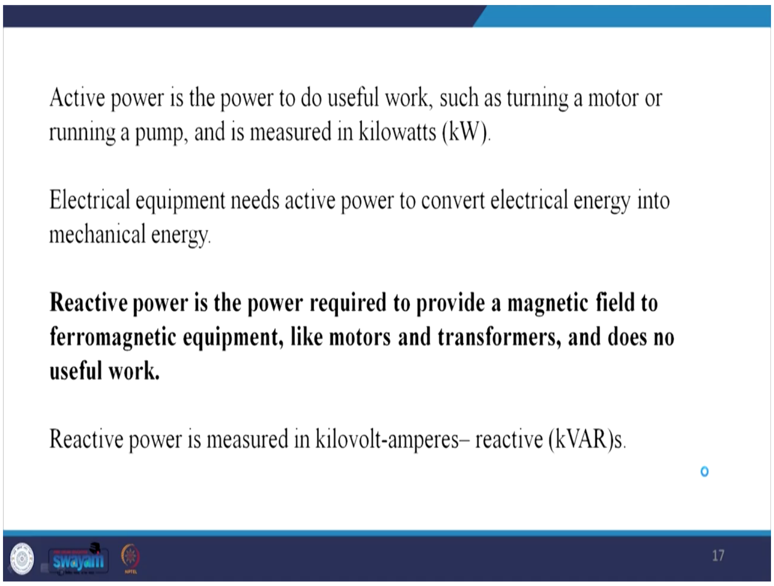

Active power is the power to do useful work, such as turning a motor or running pump and is measures in kilowatts or megawatt whatever may be. The electrical equipment needs active power to convert electrical energy into mechanical energy.

Reactive power is the power required to provide a magnetic field to ferromagnetic equipment, like motors and transformers and does not do any useful work, but you require to feed it that is the issue and it comes once you convert and re-convert. Reactive power is measured in generally kilovolt-amperes-reactive or (kVAR)s.

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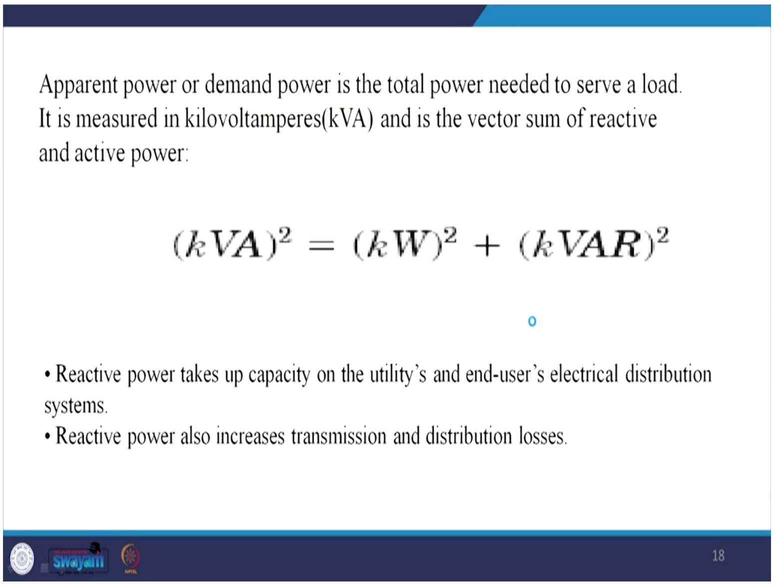

So, apparent power or demand power is the total power needed to serve a load. It measured in kilovolt-amperes (kVA) and is the vector sum of this kVA square equal to kilowatt square plus kVA square. Reactive power takes up capacity on the utility's and end user's electrical distribution systems. Reactive power also increases the transmission and the distribution loss. Why? Because you know we required to feed more if your kVA rating is generally same. Generally, we will find that transformer and all those entities are written in the kVA rating.

If the power factor is less, you require to feed more current to meet that demand. Thus, what happens? Thus, since you required to feed more current, all the losses related with the current will increase.

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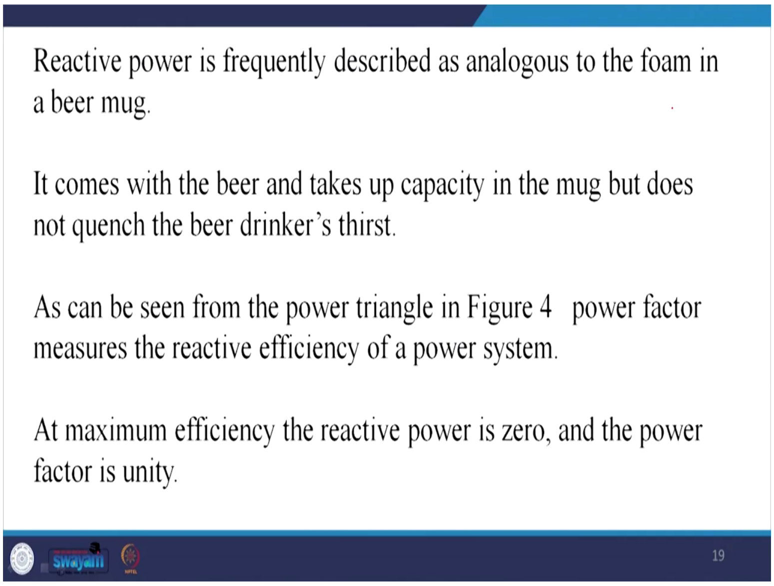

The reactive power is frequently described analogs to foam in the beer mug or a coffee mug. So, this foam part is something that is not liquid rather foam, that is the example of it.

It comes with the beer and takes up the capacity of the mug or coffee and does not quench thirst of the beer drinker. As can be seen from the power triangle in figure 4 power factor measures the reactive efficiency of a power system. At maximum efficiency the reactive power is zero, and the power factor becomes unity.

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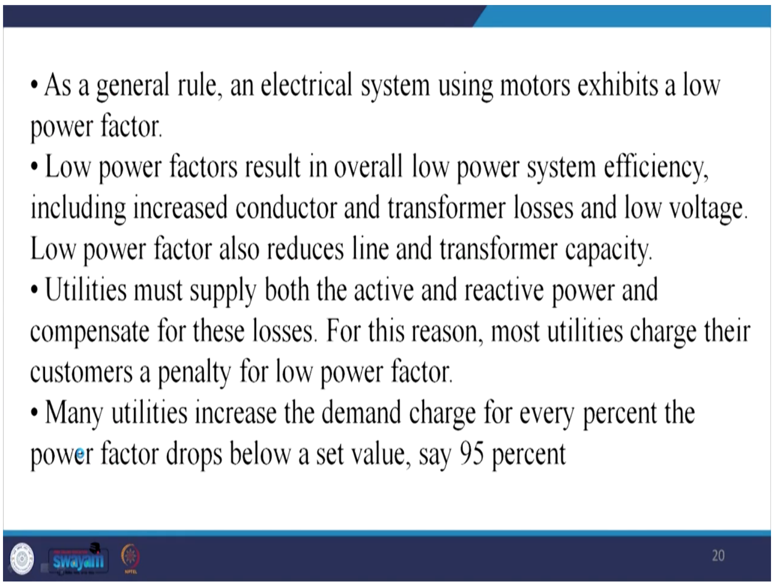

As a general rule, the electrical system using motors exhibits a low-power factor. The low power factor results in overall low-power system efficiency, including increasing conductor and transformer losses and low voltage. Low power factor also reduces the line and the transformer capacity. For this reason, we required to put that power factor correcting capacitor, but that itself has many problem and we have already discussed few. Utilities must supply both the active and reactive power and compensate for these losses. For this reason, most utilities charge their consumers a penalty for low power factor.

And nowadays metering has been done for the industrial houses with kVA apparent power. Many utilities increase the demand charge for every percent the power factor drops below a set value, say 95 percent. This is the part of the standard we have taken and discussed at different class on standard. So, if it is not validated standard then utility can punish the consumers and if the utility does not provide the quality power then the consumer can take legal action against them.

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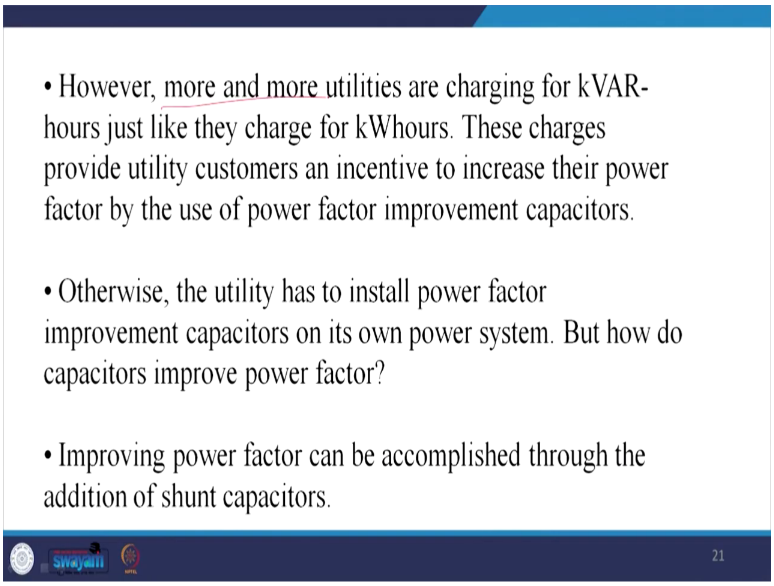

However, more and more utilities are charging for kVAR-hours just like they charge for kW-hours. That is what I was saying. These charges provide utility customers an incentive to increase their power factor by the use of the power factor improvement capacitors or by any other means. Otherwise, the utility has to install power factor improvement capacitors at its own power system. But how do capacitors improve power factor? That is also you know.

Improving power factor can be accomplished through the addition of shunt capacitors. Now, I will be coming later on what is the problem of having a shunt capacitor into the system.

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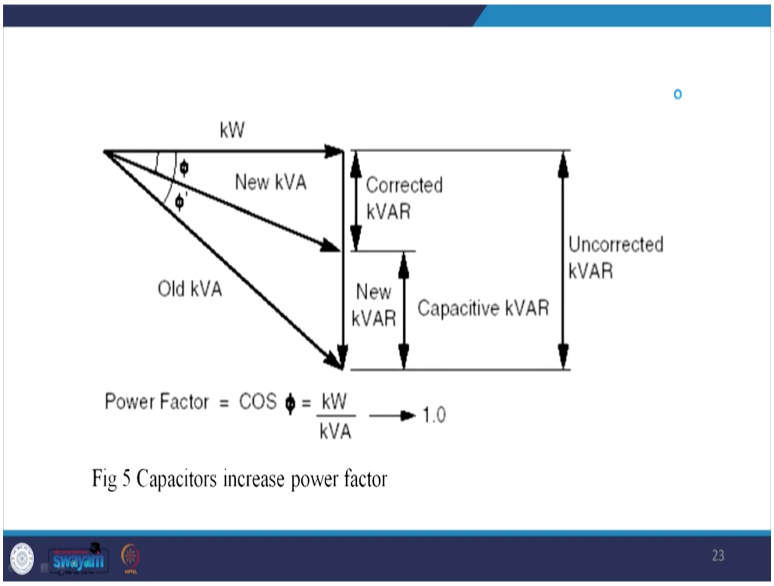

Fig 5 Capacitors increase power factor

So, see that. This is the example. This is the kW and you have a old kVA and ultimately due to this capacitor bank you have injected this much of kVA. So, new corrected kVA is this much and uncorrected kVAR is this much. So, new power factor can be made close to zero by properly tuning this reactive VAR and the capacitive VAR.

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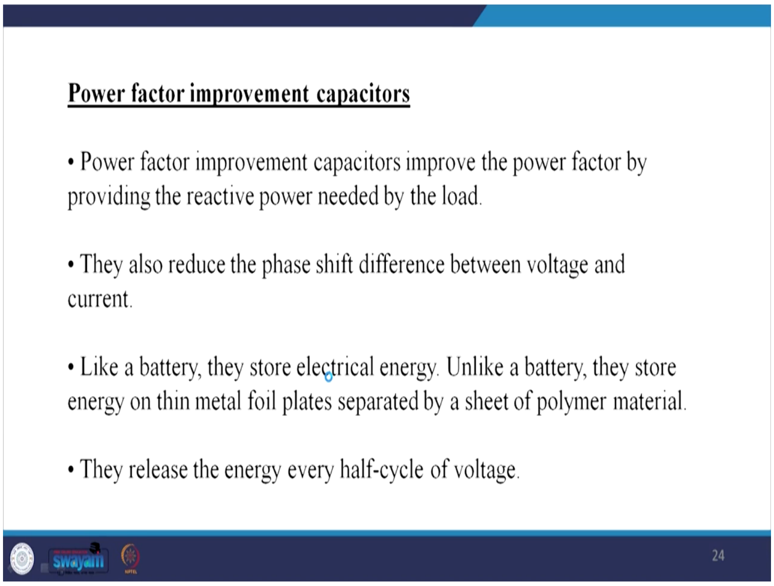

Power factor improvement capacitors improve the power factor by providing the reactive power needed by the load. They also reduce the phase shift difference between voltage and current. Like a battery, this also stores electrical energy. Unlike a battery, they store energy on thin metal foil separated by a sheet of the polymer material.

And what happens? They release the energy in every half cycle. So, this store the energy and discharges energy and in that way it compensates. Just opposite of what happened with the inductor and ultimately gives you the better power factor.

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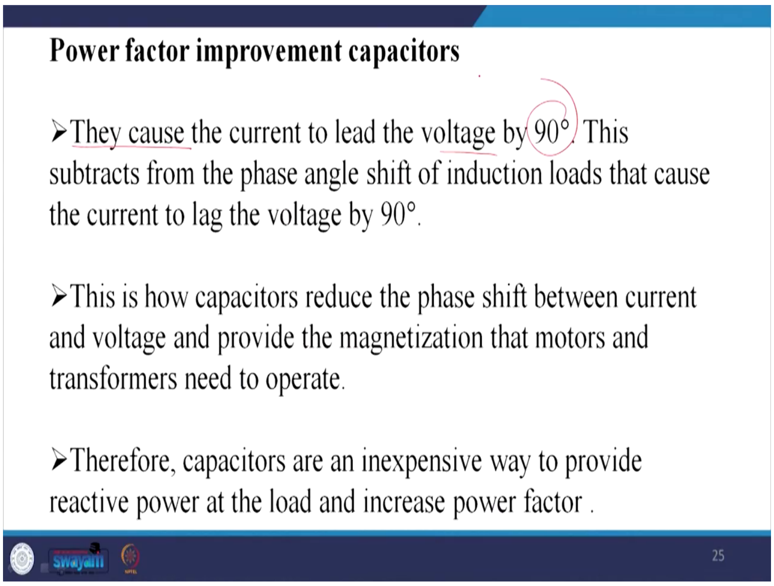

They cause the current to lead the voltage by 90 degree. This subtracts from the phase angle shift of induction loads that cause the current to lag the voltage by 90 degree, you know that.

This is how capacitors reduce the phase shift between current and voltage and provide the magnetization that motors and transformers need to operate. So, these required to be placed. Therefore, capacitors are an inexpensive way to provide reactive power at the load and gives you a better power factor of the system.

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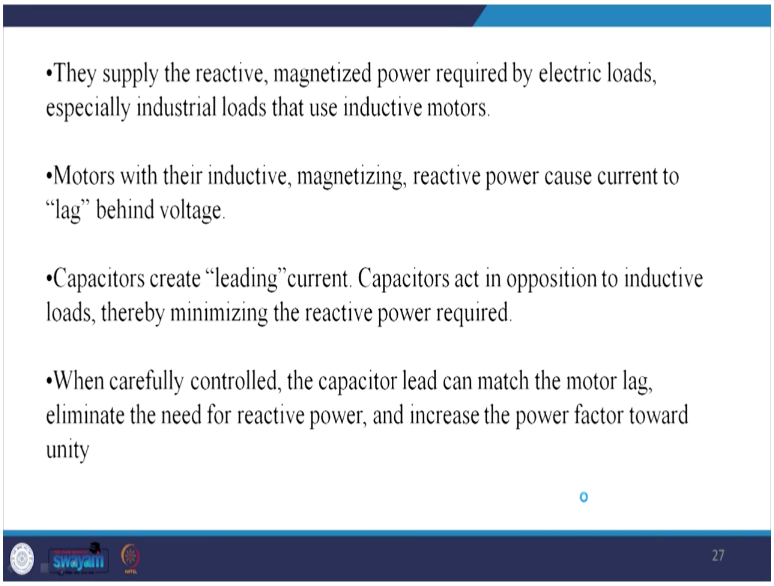

Moreover, what they do? They supply the reactive, magnetized power required by electric loads, especially industrial loads that use the inductive motors or the induction machines. Motors with their inductive, magnetizing, reactive power cause current to lag behind voltage. Capacitor creates "leading" current. Capacitor act in opposition to inductive loads, thereby minimizing the reactive power required by this industrial load.

When carefully controlled, the capacitor lead can match the motor lag and eliminate the need for reactive power and increase the power factor towards unity. That is something we are aspiring too.

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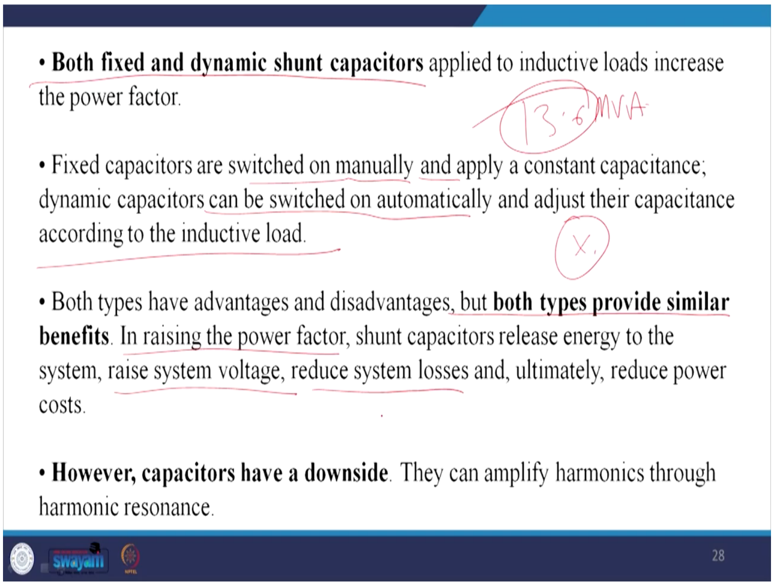

Now, there is a case of fixing. Both fixed and the dynamic shunt capacitors, generally it comes into the module as we have shown in the pictures. So, once you turn on the capacitor bang, it can give you the 100 kVAR or 500 kVAR something like that.

So, based on that you should have a historical data. So, how much power factor generally dips in evening or the peak demands when occurs, accordingly you will be switching on and switching off your capacitor bank. The application of the inductive loads increases the power factor. Fixed capacitors are switched on manually. In the facts devices classes, we have discussed in detail about the insertion of capacitor.

So, you are requested to go through those facts devices classes. Now by manually switching the fixed capacitors a constant capacitance is applied. Dynamic capacitors can be switched on automatically and adjust their capacitance according to the inductive load. So, generally if you require let us say 13.6 MVA and this quantity will change almost every half an hour.

So, generally 13 will come from the static devices and there may be a 20 percent variation of it. That 20 percent variation of this value maybe coming from this automated switching capacitor bank. Both types have advantages and disadvantages. We have discussed in detail in our facts devices class. So, please go through that lecture, it is available in YouTube.

But both provides similar benefits. In raising the power factor, shunt capacitors release energy to the system, raises the system voltage, reduces system losses and ultimately, reduce power costs and the cost of the power to the utility. However, there is a many downside of this capacitor. They can amplify harmonics through harmonic resonance. This is one of it. There is a plenty of disadvantage of this capacitor.

Thank you for your attention. I shall continue our discussions on the sources and its effect on the power quality in next class.