Advance Power Electronics and Control
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Lecture - 01
Introduction

Welcome to the advance power electronics and control. Today, we will have introductory sessions on it. In the due course of time, we shall discuss about the application of the control in the power electronics and its utilities. So our course content we shall discuss today actually introduction of the course and what would be covered here in this content. Thereafter, power electronics concepts, why power electronics is one of the fundamental courses in electrical engineering.

And various finest applications and what is this future scope and advantages. Then, of course you know power electronics is it can be visualized as a few switches. So first of course we have to take it out the power electronic switches. You know the electronic switches and there will be a difference of the power electronic switches mainly based on the rating and the control.

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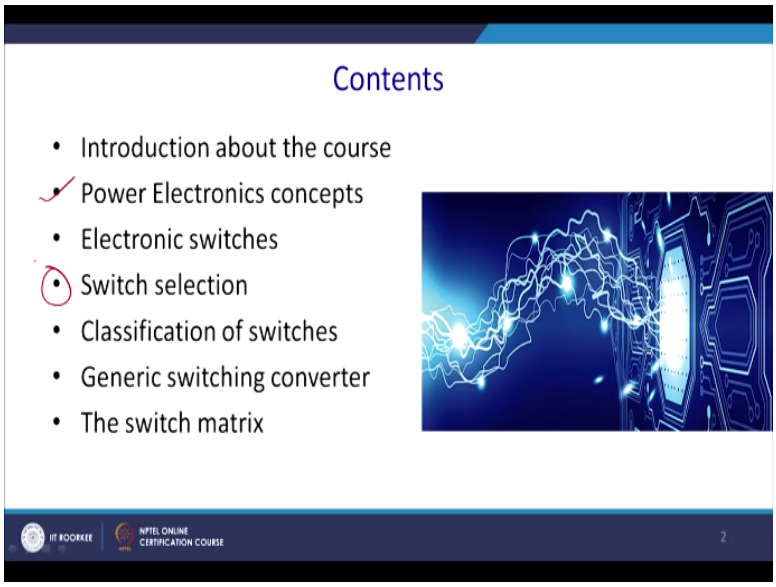

Then, accordingly we have to go for selection of the switches depending on the various considerations. In a particular applications or particular topology, we have to choose a particular switch, that selection of switching also will be learned here. There are classification

of the switching and generic switching converter and we will discuss different kind of switches followed by a matrix converter that will be a bi-directional AC to AC converter.

Now why power electronics? Problem of electrical engineering is that you require a variable voltage DC for various applications. Unfortunately, you do not have a DC transformer. Thus, to get a different voltage level from a fixed DC voltage, you require to have a power electronics utilities. Same way, when you are actually running a AC motor or drive, then it is a constant frequency operations.

So it will be run close to its synchronous speed depending on the pole and the frequency. As long as the frequency is constant, so machine will run near to this synchronous speed. So it is not possible to have a variable speed operation within a wide range with keeping the load torque constant and there also it finds a huge application.

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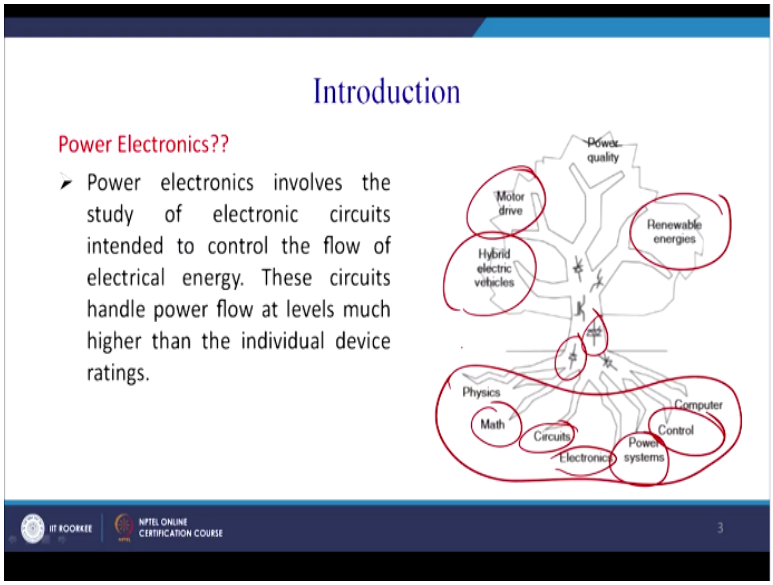

For this and you can see that actually it takes input for physics, so all the devices wide bandgap devices now it is coming we shall see. Of course, we require the input from the maths, we required inputs from the circuit theory, we required inputs from the basic electronics, we require to take inputs from the power system and control is a very important features of it.

And this root is quite strong and of course the computer applications and ultimately these are the symbols of the few power electronic switches and output of the applications will be the power quality. The power quality issues come because of the power electronics and

ultimately power quality deteriorated by use of the power electronics only. Thereafter, we will find solution in the power electronics that is the beauty of it.

And also nowadays actually we have a distributed generation of the solar and the wind and the other things, so renewable energy since you have a variable speed applications or a variable output voltage application. Renewable energy is one of the applications of the power electronics. Most of the energy consumed in the world around 70% of the energy consumed in the world is electrical energy in the motor drive.

So here also it finds its huge applications because we require variable speed motor drive for the different applications and also it is picking up and that is hybrid electric vehicles because of the pollution and all those things. Hybrid electric vehicle or normal electric vehicles both we would find a huge application of the power electronics. So these are the actually the basis or roots of the power electronics and these are the outcome of the power electronics and these are all advanced applications.

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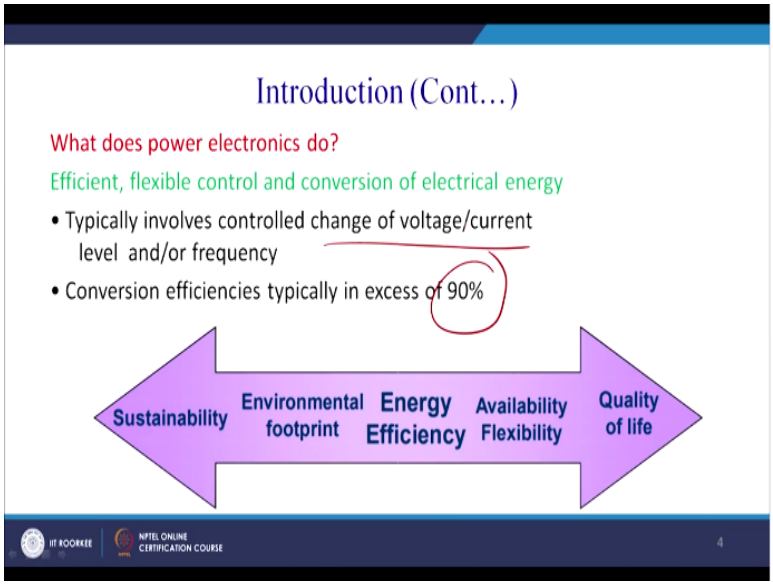

Now power electronic essentially processes the energy, it does the cooking. You have a raw power which your utility cannot take like raw vegetable you cannot take, we have a raw power which we cannot take, we require to process the power according to the order requirement and so that it can fit to the right kind of application and right kind of utility and gives us the desired results.

So what essentially it does, it does efficiently, it does flexibly, it gives a wide range of control and other variations. Typically, it involves change of voltage and current or frequency or power and generally conversion we wish to achieve in and around 90% that is one of the biggest challenge. We have a non-power electronic waste solutions, their efficiency is mechanical power system.

Their efficiency is quite low and it is quite slow in operation. For this reason, you know we required to see these aspects, sustainability, environmental footprint, so we should have actually all the pollution to be controlled, energy efficiency, energy saved is energy earned and available flexibility so that same machine can be operated in a different more different zone of operations.

You may not require multiple machines to do the different kind of job and the modern living that is we require modern living and we are getting shortage of the energy. So this is an quality of life comes into the picture that is greatly enhanced with the use of the power electronics.

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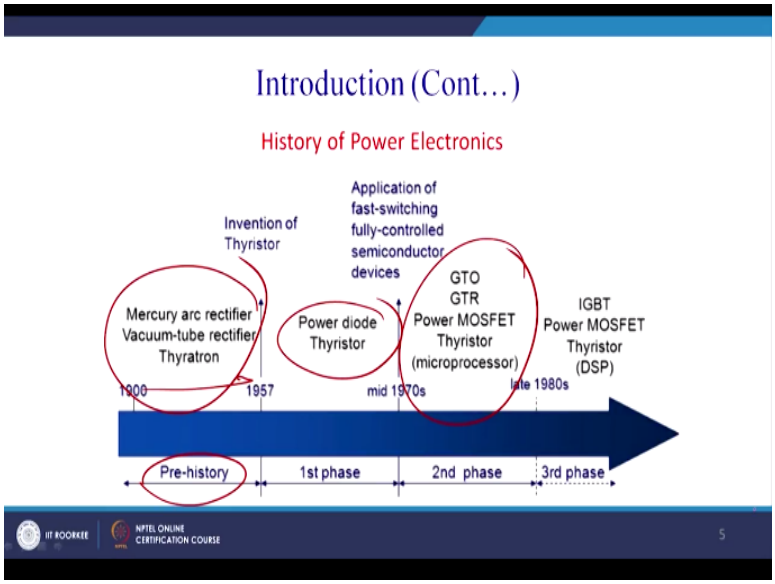

So let us see the chronological advancement of the power electronics. So it is not new, Tesla and this actually famous debate on AC and DC transmissions and you know we unfortunately had our DC machines and we found that you know generations of AC is bettered and transmission distribution of AC is better because of this actually use of the transformer and thus we required to use.

Because we produce AC and we consume DC to mismatch to actually to fit the gap initially we had mercury arc rectifier. So we required to rectify it and feed it to the DC load or DC machines or DC light. So gradually it has deceivers been phased out but in older Calcutta days actually we had DC connections for quite long time. Now this has a prolonged life span you know.

Till actually 50 years this was the only sole process of converting AC to DC but efficiency level was quite low and required huge maintenance and thereafter so forth this is we are writing is a prehistory or it is a pre-historical age for power electronics, not of course for the human being. Though, thereafter power diode and thyristors were invented. That is a huge jump in the technology.

And it was invented around 1957 so and that continued to middle of this actually 1970 and power electronics finds its application most of the AC to DC conversion. Thereafter, we will finally discuss little later that thyristor based types are basically half controlled devices, you can control its turn on but turn off it is not actually very easy, we require an external circuit to turn it off.

So for this reason actually we are looking for a full controlled devices and thus from the middle of the 70s and this is an actual research starts in power electronics and its application and its devices, that was in middle of 70s. There we had a different devices like GTO, power MOSFET, thyristors and also digital control comes into the pictures and that actually reduces the basically the uncertainty issues of the analog control.

And so this is microprocessors, DSP, all those things gradually incorporated. Now we have IGBT, MOSFET, thyristors, IGCTs. Now we are going for the silicon carbide-based devices, so that will be the other fourth phase rather. So and here we are using a PGA, DSP and all those actually programming logic and thus control and the device go hand-in-hand to give a better quality of life.

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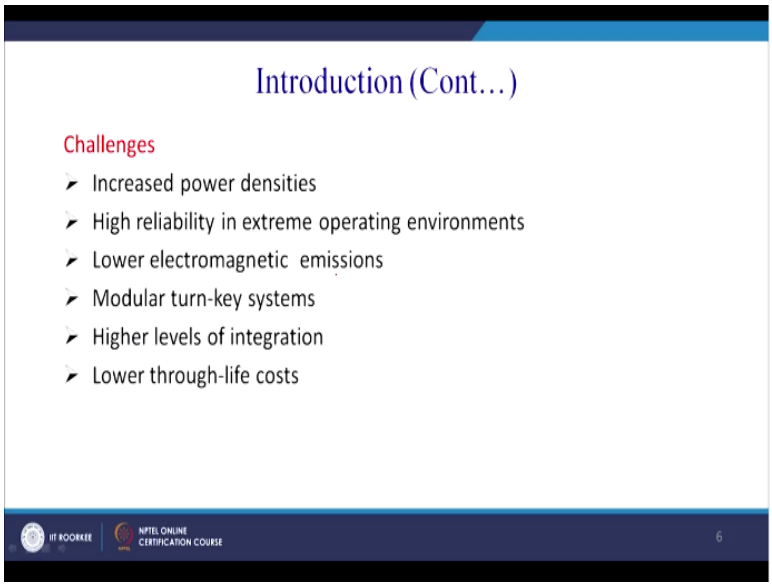

Now what are the challenges? Why we require to use? Challenge is we have to take a device which can handle more amount of the power in less volume. So we talk about the power densities. We want the megawatt level power handling capability for per CC something like that and also highly reliable in extreme environmental conditions. So we should see that you know it can be usable like you know we can use a power electronics device sub-Saharan actually in Siberia or sub-Saharan Africa.

So in Siberia it has to operate -50 degree centigrade and sub-Saharan Africa and also it will heat up and temperature can go as high as 20 degree centigrade. So within a whole range whether it is possible to operate, if it is a military application that require more stringent condition if it is a space application that require more stringent conditions. All those application power electronics finds its place suitably.

And thereafter, lower magnetic emissions, this is one of the challenges, nowadays actually what happened we have a EMI, EMC problems that is called electromagnetic interference and electromagnetic compatibility. We will see that we will use actually huge, we use find lot of application of the electromagnetism and that will generate a considerable amount of electromagnetic noises that require to suppress because it will otherwise interface with the communication and also it is hazardous for the human being a life.

So we require to find it out that lower magnetic emission and we require to something like modular turn-key system, it will be a compact, you fit into them before a motor something a box of small size and that will do everything, that is the concept. So for this, modular turn-

key systems we are looking for and higher level of integration, many devices can be compacted in a single entity.

And also lower costs throughout the life and we will have a large mean breakdown time. These are the actually the challenges that power electronic devices required to achieve and that will be effectively controlled by a control system.

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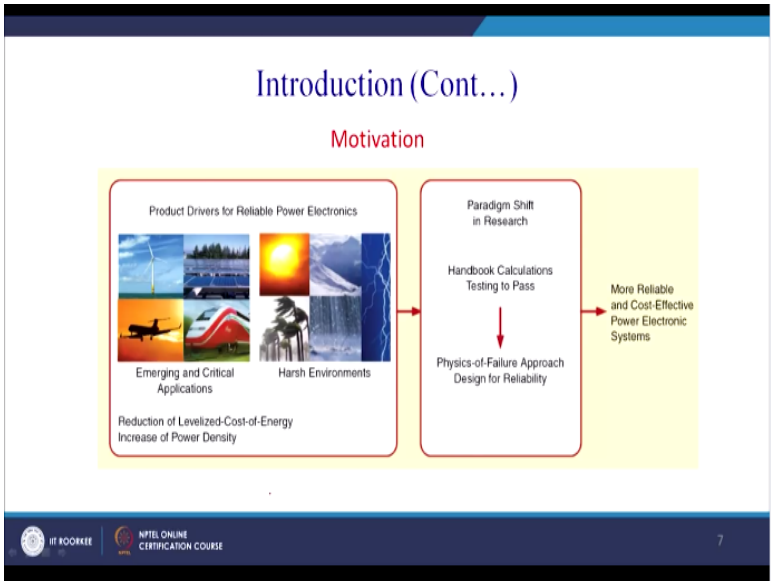

So see that this is a motivation of the power electronic for the future researcher. So this is the renewable energies, avionics and high speed train like bullet trains and there actually we have critical issues, we have to harvest most of the power from renewable energy sources and also you require to have very effective ways and nowadays actually the people flies, we expect that every 10 years the number of passenger is going to be doubled.

So we require to make our sky more safer, cheaper for added value to the system and power electronics required to do that and there lies a challenge. Same way we require to have fast transport system and the modern transport system. There we will find a lot of applications of the power electronics and also we have an environmental harshness. So you may have actually thunderstorm, we may have something one line has been collapsed.

So power require to submit so we can use the flexible AC transmission system to deal with that thing even if there is a damage with undamaged line we can have for time being we can handle a huge amount of power. So these are the actually the motivations where you can

work and power electronics can give a very effective solution to this problem. So from there we are gradually looking to the paradigm shift of the research.

So you have to do the since we are engineer we require to do the application specific research. We will take a problem, gradually we will have a top-down approach and we will go to the devices. So we will see that in a courses, will see that how we design actually power electronics converter or inverter and so paradigms shift in research, handbook of calculations. Thereafter, it has to qualify different testing conditions.

Then only we have to find it logic behind it and apart from that physics of failure and design and reliability, this is something we require to test, we require to design a system that is quite reliable. So we require to take the main breakdown time to some level that is also a challenge. It is not that it is working today, it required to work another 10 years at least because if you talk about let us say solid state transformer.

One lifespan of the transformer is 40 years, so same way we can expect when we talk about the solid state transformer that transformer also lasts for during this period that is a huge challenge and the huge scope of research for the future researcher. For more reliable cost-effective power electronic system can deliver those conditions.

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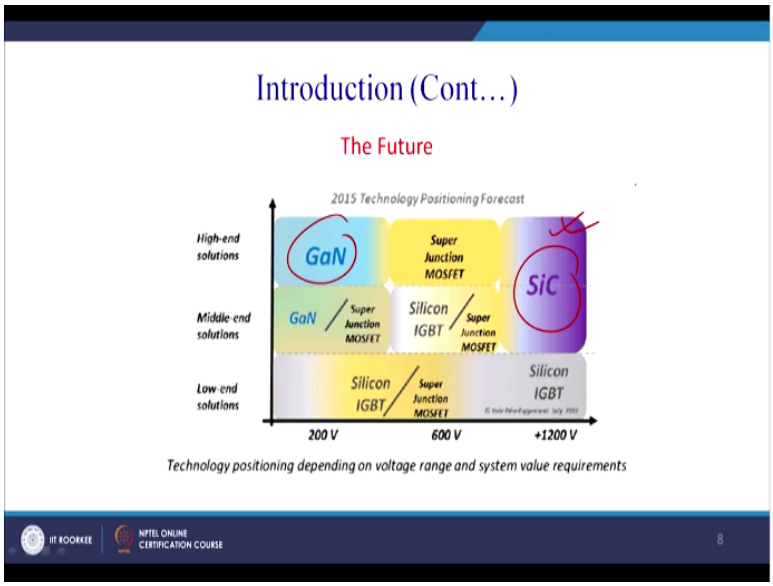

Now these are actually the devices, of course today is 2018 and this data has been taken on 2015. So these are called high bandgap devices. High bandgap devices can handle huge voltages and power. So for this you can see that now actually all the research is shifted to the

silicon carbide waste devices. Gradually, may be after 10 years we will be frequently using those devices.

And thus take a look of this matrix, you know silicon IGBT is a solutions of the lower end solutions and we have a super junction MOSFET and these are the actually the voltage ranges that is still available now and you know these are the high end solution, ultimately this is actually the current can be put into the y-axis that should become power. So you can see that the silicon carbide you know actually it taking our whole shot up actually sets for high end solutions and which can handle which amount of the voltage.

Thus, future lies on this silicon carbide based device, GaN based device for high switching frequencies, for low voltage applications and also super junction MOSFETs so which can be suitably preferred on the lower or middle level voltages. Now we have find that power electronics finds its application. We already discussed, let us put into the perspectives.

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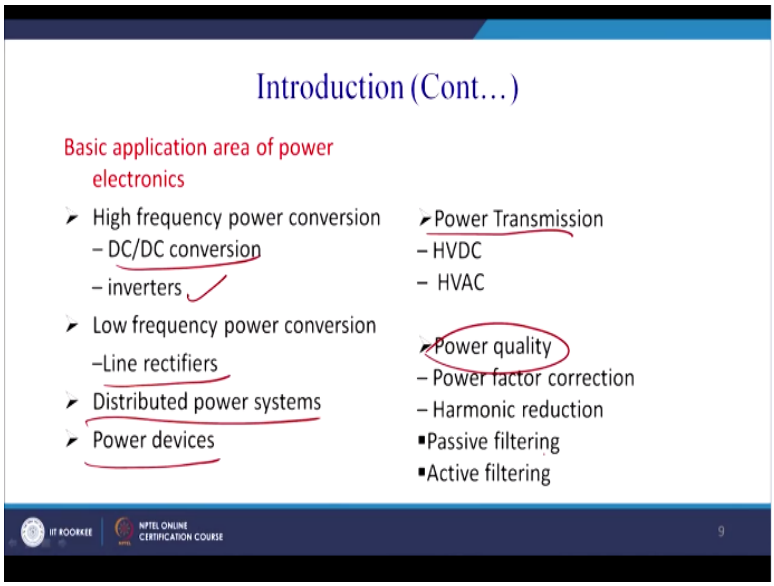

Power electronics since why I required power electronics because you know we do not have a DC transformer. So for this reason high frequency power conversion DC to DC conversion, there is a transformer but that is high frequency transformer for this reason it will be quite compact and there are inverters. Since you have a solar panel or you have a DC source, from there adjustable speed AC drive, so for this reason you require inverter.

Thereafter, low frequency power conversion mostly basically the line rectifiers and there we still use a mostly the thyristors because till now power rating of the thyristor is quite highest

and it will be naturally commuted it with that but problem lies the power quality is a greatest casualty when you use actually line rectifiers, for this reason we are gradually looking for the active filters.

Distributed power system nowadays actually with advent of the distributed generations, we have a high penetration of the solar in different rooftops or different solar cells been placed in different locations as well as wind. So distributed power system is one of the area and where we require to handle and monitor power to it and so there is a huge application of the power electronics.

And power devices also one of the area of power electronics so which suitable use of the power electronics devices and research on it because we are not researching on. We are basically using from the application point of view but someone required to do this research otherwise our requirement will not be fulfilled because they will do their design from their fundamentals but our requirement is something else, so we have to match that bridge.

Again, we require HVDC transmissions, high voltage or extra high voltage DC transmissions, there also we find lot of power electronics application, also HVAC applications where we use high voltage, high power rated inverters and one aspect is the power quality because of we require to have adjustable speed drive and other issues that will corrupt the power for this power quality problem has pops in and that required to be actually modified or mitigated.

And thus power quality problem also actually solution lies with the power electronics. Even though cause of this power quality is power electronics and solution of the power quality is also the power electronics and definitely the power factor connections, harmonic reductions and it can be done in active and passive filtering and passive filtering is done by the combination of LC filters.

And there are lot of disadvantages of it, it may actually interact with the lines frequency and may cause a resonance and also actually direct itself with the time because of the capacitor value gradually decreases. Due to that actually nowadays actually trend towards is through the active filtering with STATCOM, so that solution also provided by the power electronics. So power electronics has a huge scope and applications for the modern days and for giving a better quality of life to the human being.

We have seen that power electronics takes input from the maths; power electronics takes input from the physics. If you combine maths and physics, its control, ultimately device required to be control and there all the control techniques which you have studied will be applied. One of the greatest applications of the control system is the power electronics. So power electronics researcher or the practitioner has to have a very sound knowledge in control.

And for this we club these two entities together, we do not want to teach power electronics and the control in other entity, it is basically application of the control system in power electronics.

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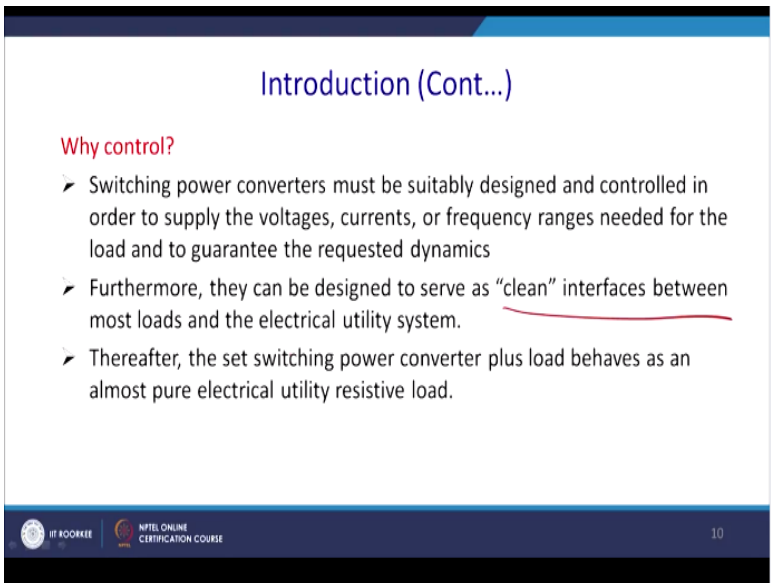

So switching power converter must be suitably designed and controlled in order to supply the required voltage current and other requirement and for this reason we require to be effectively control it and it is a feedback control and different kind of control technique is possible and we will find that actually. They can be design and serve as a clean interface between the load and the electrical utility.

Therefore, there must be a switching power converter pulse behaves almost as a pure electrical utility for the resistive load and is one of the application of it. Control is required to smoothening the (()) (23:06) because you may have some kind of problem, environmental problem, any hazards that has to come into it and power electronics devices has to overcome it, ultimately brain will be the control to mitigate that problem.

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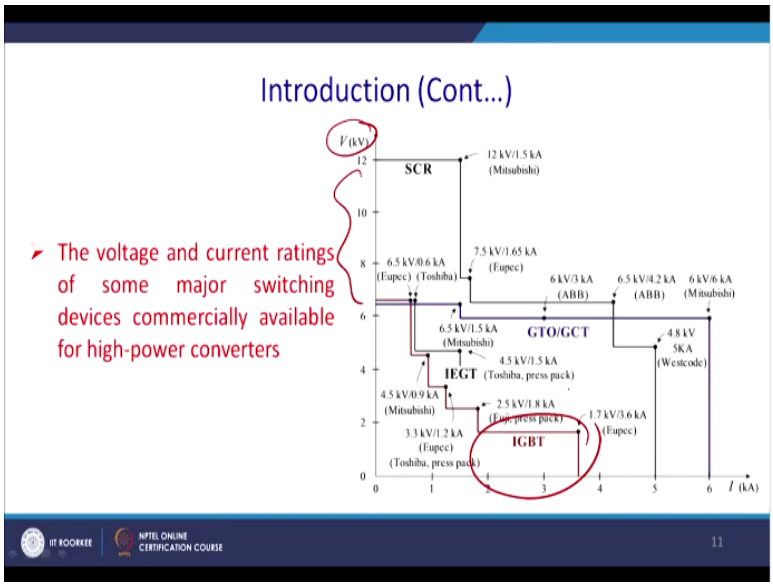

So this is actually the device rating that we can talk about today. You can see that SCR has huge voltage rating and it is available and it can operate actually 12 kV and 1.5 kilo ampere of current. Thus, you multiply this power rating goes as high as actually MVA or mega volt rating. So you can see gradually you know so thereafter but it is a half controlled device, you can turn it on or turn off, has to have a complicated process.

So for this reason we have GTO and that is basically that both turn on and turn off can be controlled but problem lies you know rating till GTO is half of the rating of the thyristors. Thereafter, same way we have IGBT, if you wish to choose a higher voltage rating then current rating required to be low, so either we requite for the higher application we require to paralleling of the IGBTs or we require to use IGBT with high current rating, we have to put it to the multi-level inverter format.

So this is the power diagram of this devices till now available. Of course, we expect that this situation will change drastically once we will have a silicon carbide-based devices. Now let us very briefly tell you that what I am going to cover in this course. So this is the introduction classes.

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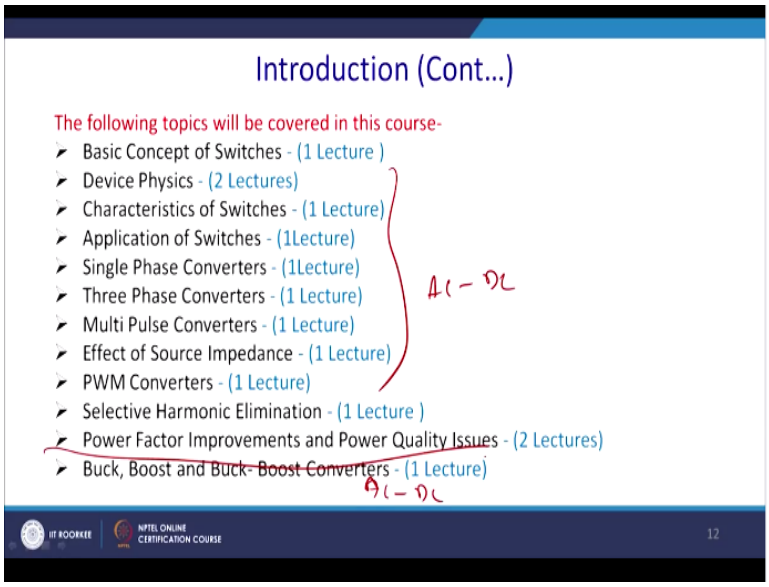

Next class, actually I will take it out the basic concept of the switches. Thereafter, I will devote some time on the device physics, those who have done the basic power electronics courses, they have already done this course but we require to little actually brush up of this courses and characteristics of the switches and switch application. Then, we will go to the single phase converter, three phase converter and thereafter we will go to the multiple converter, effect of the source impedance.

And then we will see that this is all are AC to DC conversion mainly. So PWM converter, thereafter we will see that selective harmonic eliminations, power factor improvement and the power quality issues and then from this point onward we shall go for the DC to DC converter. Till now, it was AC to DC. Now from this onward, it will be DC to DC converter.

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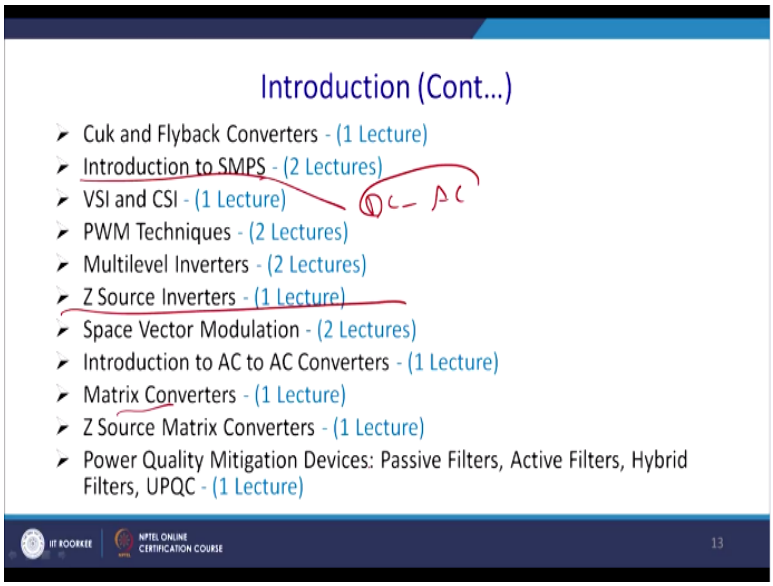

So we will have a different kind of isolated and non-isolated DC to DC converter, Cuk converter, Flyback converter. Thereafter, we will give an introduction to the SMPS according to its application. So we will find that what kind of topologies will be suitable for what kind of applications. Then, we shall go for the inverter application, that is basically DC to AC application from this point onward.

So they will have a voltage source inverter, credit source inverter. Then, PWM technique and we will have different topologies of the inverter that is multi-level inverter, jet source inverter. Now we will come to the control aspect of it that is space vector-based modulation technique, introduction to the AC to AC converter. Then, we will see that matrix converter, Z-source converter.

And then at last, we will discuss about the power quality mitigation device, passive filter, active filter, hybrid filter, UPQC.

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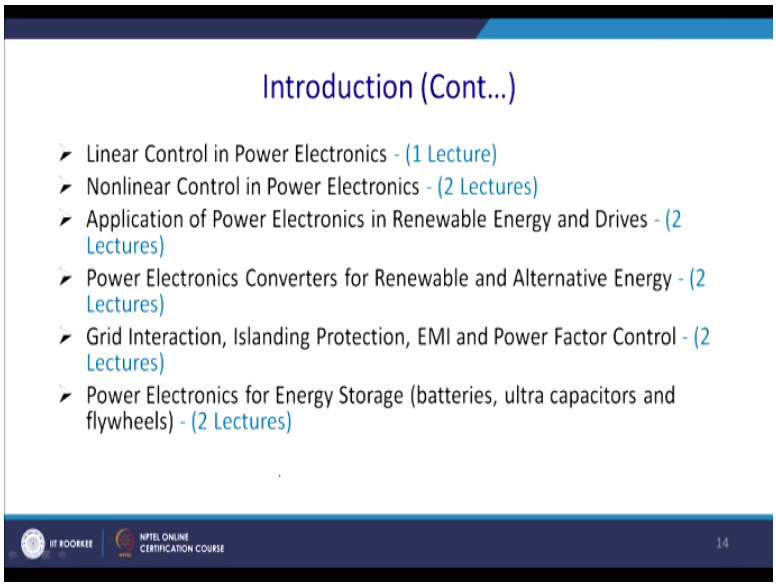

And then actually we shall discuss about the control part of it. So linear control of the power electronics that will be introduction of it. You know thereafter we will devote much time on the nonlinear control of the power electronics, application of the power electronics in renewable energy and drive, power electronics converter for the renewable and alternative energy, grid interaction, islanding protection, EMI and power control, power electronics for the energy storage for ultra capacitors, flywheels, batteries these will be discussed.

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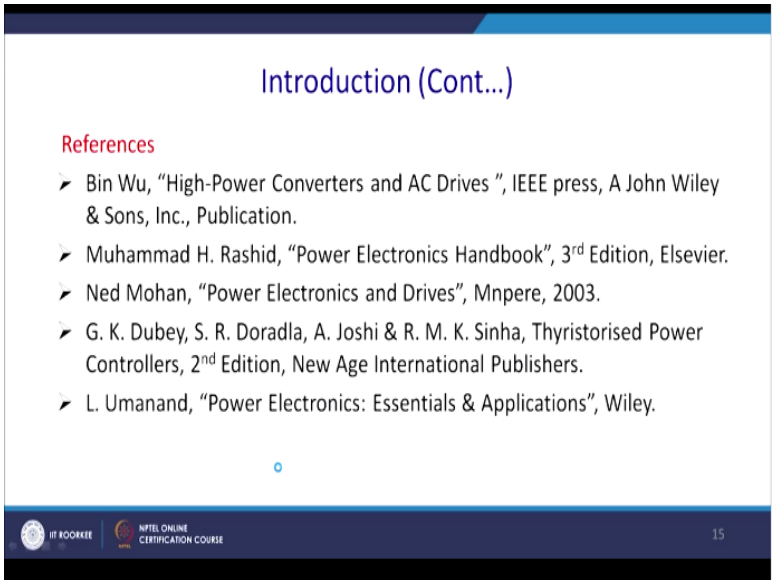

Now these are actually the books that you can refer, student may be allowed to contact me for any further discussions or any further queries. We shall continue with the next class with the devices and from the next class onwards, we shall go to deep into the power electronics control and its devices. Thank you so much for your kind attention.