Welding Processes
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Arc welding power sources Part 01

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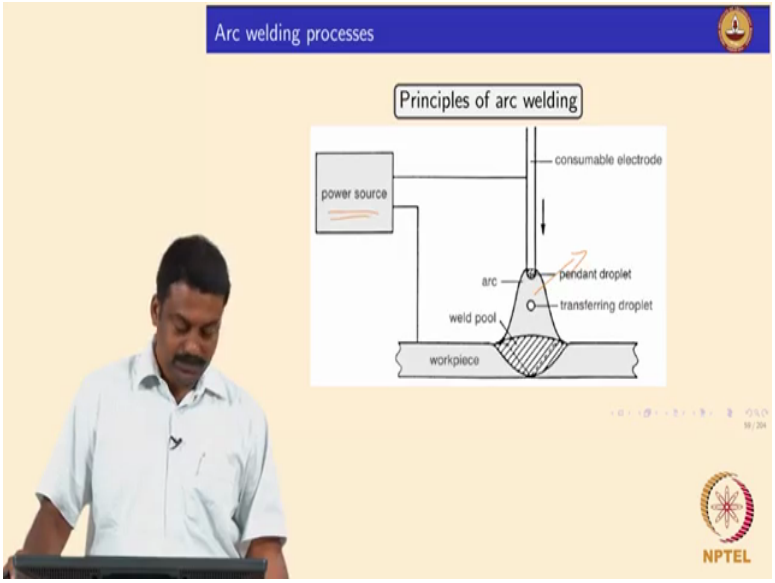

Okay, so in the components we looked at the arc, is it not? So we looked at entire physics of arc now we also looked at the shielding gases, it is second important parameter which can affect your welding process, okay so and then we looked at how shielding gas can be selected based on the material parameter, material behaviour, then we will move on to the next chapter which is the important guy here power source, right any questions?

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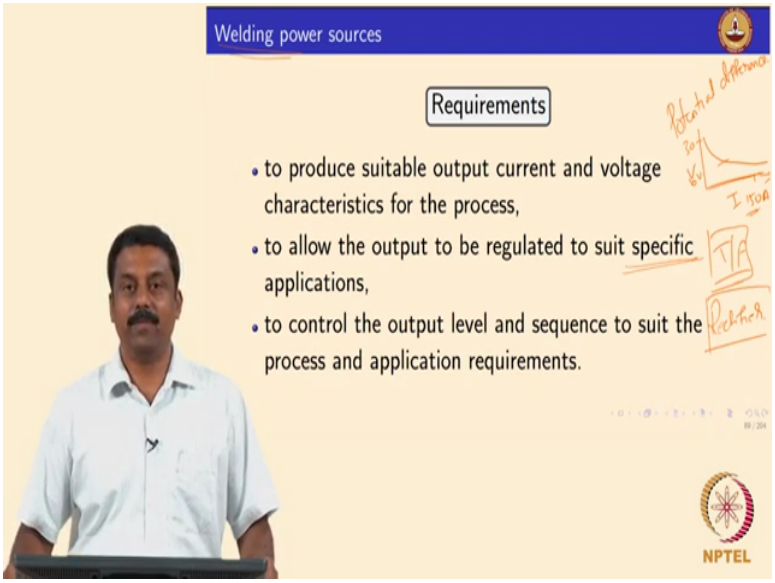

So far on the shielding gas yes so why do you need a power source? It is already there in the list, so what is the main criteria for welding welding arc striking arc? It is already there you can read.

Student is answering: Anode and cathode.

Yes, of course anode and cathode should be there, potential difference, okay. So potential difference how does it effect? So we have a problem, so if we look at the conventional all the wirings in and around us okay so it is all very high voltage, tube lights conventionally they work to 30 volts that is our socket voltage or high voltage systems and low current 4 amps, 2 amps, 5 amps, 15 amps with the maximum, maximum you can say 50 amps in industrial circuit but in welding we need opposite.

So we need low voltage and extremely high current. So we cannot straight away use the wall mount the socket start welding that is impossible because the characteristic the basic characteristic of arc it should be low voltage and high current, so we looked at the classical definition so voltage is a current, so voltage not more than 30 is a function of current. So how do we reduce the voltage from the valve it can be very high 10000 volts from the main it can come.

So if he has very industrial line conventionally it can be 4000 volts or 5000 volts very high voltage in 3 phases. So now suppose if you wanted to use a simple DC current for welding your voltage will be around 10 volts but your amperage will be say close to say 150 amperes or even higher it can go upto 1500 amperes. So this is the basic criteria in which power source operate.

So we cannot use directly from valve socket and start drying the power or current and voltage to start welding it is impossible because arc cannot be ignited even if we ignite the arc you cannot sustain that because voltage you will end up getting an enormously high amount then the basic the definition of sustained discharge in high amperage and low voltage cannot be attained.

So that is how the welding power sources are very important, so welding power sources are important to produce suitable output with low voltage and high current, okay and these power sources should also be capable of giving what you want, you will not be using it for only one voltage power characteristic so today you will be welding say 3 mm thick so you can choose

current of 100 amperes and voltage generates say 10 volts or so and tomorrow if you want to weld 3 mm to 5 mm then you need to increase the current.

So that power source should be capable of generating the amperage based on your need and you can regulate it you need to regulate that based on your applications or if you change the shielding gas obviously voltage will change and you will need to the power source should be capable of either generating the voltage required or during the welding you may also maintain constant current.

So even if you change the voltages by the shielding gas the current should be maintained for example or inconstant current in other words or even if you change the arc length your voltage should be constant so if you change the constant if you want to change the arc length, so if you want to maintain the voltage obviously you need to have the power source adapted to your need.

So these are all the requirements of the welding power source, so the first basic requirement is to generate low voltage arc so that is the first requirement of the power source and with the low voltage arc we will have to get required amperage to generate heat in the arc, okay and during this process we should also be able to adjust the current based on our need, so output amperage can be adjusted, is it clear?

And then we can also make it adaptive so even if the process dynamics change even if your distance between the cathode, anode change you can still maintain if you want a constant current or if you want to maintain a constant voltage the power source should also be self-adjusting such a way that the arc length can be adjusted, so these are all the characteristics we like in the power source.

So there are various ways in which this can be achieved the power sources, so how many of you have seen the power source welding power source? No one? Have you seen any red boxes, blue boxes lying around the lab? What is inside have you ever wondered?

Student is answering: Stabilizer.

Stabilizer, what is stabilizer?

Student is answering: Regulate the current.

Regulate the currents, so the so one of the basic requirement in old days, nowadays transformer must be there so definitely the main component of conventional power source is transformer, okay the current has to be increased, but apart from transformer suppose if you want to have an direct current generator so what else do you need to have? Rectifier, exactly.

So in a conventional power source a transformer and rectifier would always be there, but in modern transformers where we have micro process controller, electronic regulated transformers the power source transformer is still there but the size can be different. So we look at in what are the types of power sources that are actually developed over the years and how the history changed from say First World War time until now? Because if we look at the power sources nowadays you can carry by hand, so you see someone welding outside there is a blue box he carry by himself that could generate similar current voltage waveform of and power source of this size of the room in fifties.

So with lot of advancement happened in electronics and nowadays with computers and of course now we are working on internet of things so we could also talk to power source when I am watching Asian games at my home because that is also nowadays responsible. So we looked at the development in the power source can be very interesting.

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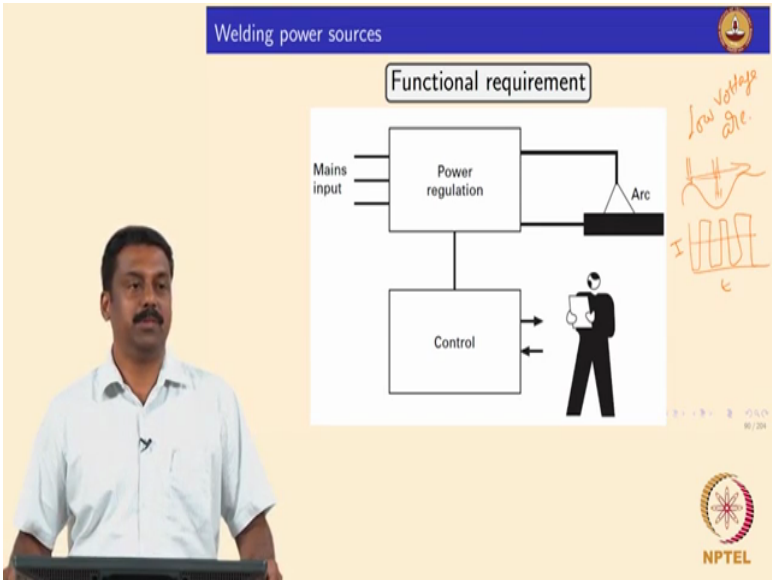

So the first one we will see so what are the functional requirements of the power source? Already explained, okay so the primary requirement is the only one the primary requirement is to generate low voltage arc that is the primary requirement, what are the other functional requirements? For example I want to keep the heat input arc energy constant doing my

welding, suppose if you are welding in a complex geometry something like this okay you are depositing something and you cannot maintain the constant arcs suppose if you are the electrode is fixed in height, suppose if you are moving along this direction so obviously compare to here and if electrode comes here the arc length will be different, so obviously if arc length is different your voltage will also be different.

But nowadays we can make it adaptive, so based on the feedback so we can also measure the voltage instantaneously so either power source can reduce the voltage by the microprocessor control mechanisms which I will explain in the next slides or if power source is also controlled or lined with a robot which is actually welding and robot can also move the electrode accordingly moment it recognize high voltage, okay.

So these are all functional requirements of the power source, okay similarly you want an pulsed DC, okay so suppose this is your current and time so generally I do not want like this, there are various reasons why we do not need constant current suppose if you want pulsed current so instead of doing this I want the current something like this going like that and this is beneficial in GMAW when you use a pulsed DC to promote the metal transfer in spray mode, so we will see in subsequent classes.

Now these are all pulse requirements so I do not want constant DC current I want the pulsed DC, so then my power source should be capable of generating such waveforms so there are lot of modifications we have done in science of power source which could make these things possible which are not possible 30 years before, right. So these functional requirements can vary in a various ways suppose if you want to control the wire melting rates for example then you need to play around with the wire feed rate and instantaneous measurement of the arc length or voltage and then the microprocessor or computer inside the power source immediately calculate the rate of wire melting and if you want to maintain in a constant wire feed rate or wire melting rate then the power source should also be capable of generating the current and voltage characteristics, okay so these are functional requirements, right.

So by keeping all this in mind so we have done lot of work in the power source fabrication so again so this all done in academic research plus people who are developing these power sources, okay.

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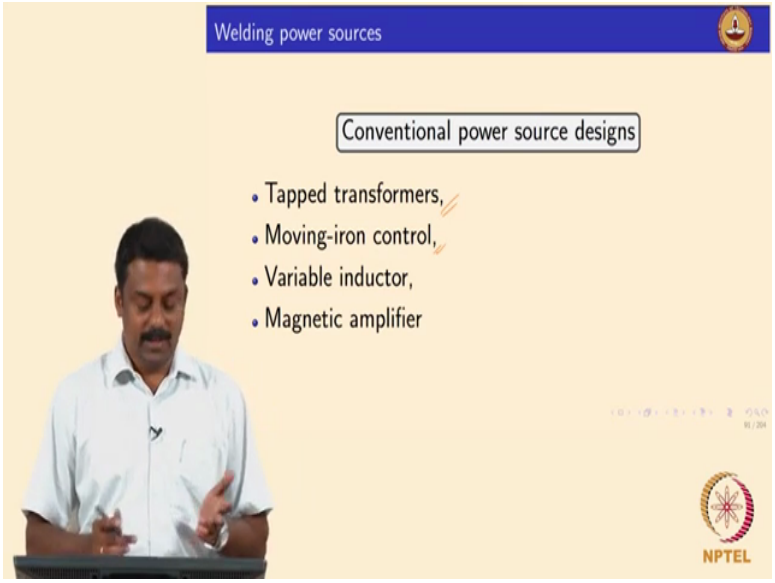

So in conventional power source designs if you look at in old days I do not know how many of you explored in your childhood going to on a welding shop or a mechanic shop, no? So I used to go there are very good welders even though they did not know what they were doing but they were highly skilful. So in my home when I was studying there used to be one very good mechanic because my area is known for power looms so lot of metal powers involved in looms.

So there are lot of welding shops would repair the damaged the parts for the looms and they had fantastic power sources which I did not know they were fantastic until I was doing my PhD. So the moment I started learning about these things I wondered these guys had these for example the tapped transformer power source and I saw in my childhood. So it is still working that guy's son is now operating mechanic shop the transformer still working it is extremely simple power source but it is huge almost as tall as me, okay that guy would go and it is like a monster consuming lot of power but it works like a charm, okay.

So these are all conventional designs of the welding power sources like for example I put 4 major classification of conventional power source tapped transformer is one of the primitive welding power source used for GMAW or in manual metal arc welding it is commonly used and then there are some advancement there are some inherent problem with tapped transformers so we (used) moved on to moving ion control and then variable inductor and then magnetic amplifiers because these are all conventional power source because it is very simple so they do not have any semiconductors inside there are no complex modes which can

burst when you are welding so these are all within a simple transformer rectifier systems. So at most we would use mechanic amplifier it is a variable inductor, okay.

So we will see this and we will enjoy this beauty of these power sources and then we will move on to the silicon controlled rectifier or microprocessor control power sources, okay.

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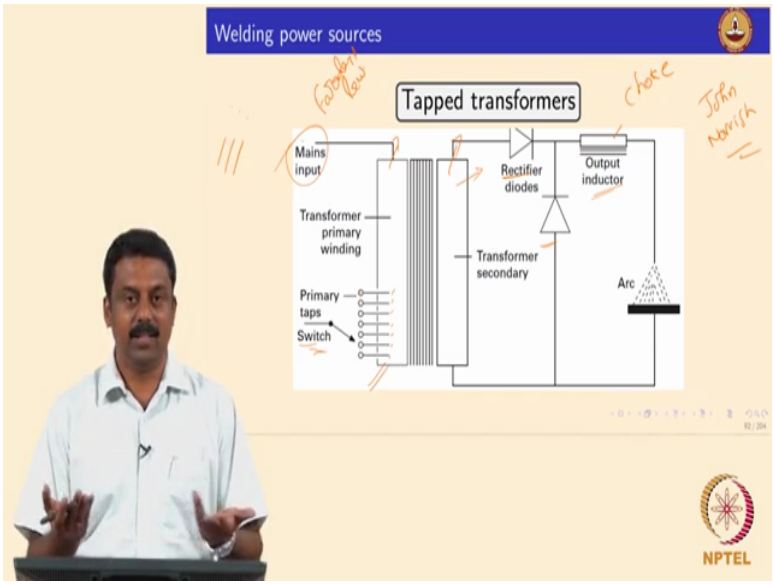

The first primitive power source is known as tapped transformer, I will show the simple circuit of the power sources so I borrowed from John Norrish who is actually as I said is my academic grandfather, so the simple basic power source which you can also build is if you have a transformer and rectifier. So what is C over here in a simple circuit? So this is main inputs generally it is 3 phase, okay so just for clarity we show a single phase here but we have a 3 phase.

Suppose if you have 3 phase line you will have to make it a single phase so in a conventional way if you want to make it basically you need 3 transformers. Each line would transform into a single phase by using a 3 transformer but that is extremely energy inefficient, so commonly what we use is we use rectifier system, 3 rectifiers so first we convert into DC from each phase and then we can manipulate whether you can use it for 3 arcs or you can also make it alternatively by turning the rectifiers ON and OFF.

So in simple tapped transformer we have a transformer, so what is the role of transformer? So it is to use to transfer or transform current from one circuit from other circuit, so that is the

main role of transformer for transferring the alternative current from one circuit to other circuit. So what is the principle of transformer operation? Which law governs transformer operations?

Faraday's law, yes good so in a typical transformer you have a primary winding and secondary winding, right. So based on the windings so magnetic flux which is goes into the primary, secondary winding is the same if you change the number of windings you also change the voltage, so by carefully manipulating the winding characteristics we can change the voltage which is coming out of this secondary winding.

So what we do is in the tapped transformer, so we will have taps in the primary winding and these taps can be selected based on a switch. Suppose if you want to have voltage maintained you select a switch at certain direct you know the input voltage is coming out as now for voltage in the secondary circuit. But if you carefully select the number of windings you want to use in a transformer we can also change the voltage based on the number of switches which is activated, number of windings that are activated in the primary circuit, is it clear?

So if you want to have with entire voltage transferred the voltage is maintained obviously you select all the windings or you can also choose the windings number of windings what you want to use based on the windings you are actually selecting within the switch it will also either change the voltage. So once you are changing the voltage obviously from the high voltage based on the number of windings you choose you will also change the output voltage, right is it clear?

So by simply having a switch enabled in a primary winding we can choose we can step down the high voltage into low voltage, is it clear? But we have serious problem here because these switches cannot give a continuous varying voltage. For example this would give you say 50 volt and other switch can give only the defined volt from the nature of the winding, okay so we can go 30, 40 or say 40, 30, 20, 10, say 5, 2, 1.

So voltage can be one to be selected. So if you want to change the continuous variation voltage has to be varied continuously it is not possible in this process, so that is a disadvantage but this kind of transformers are widely used in conventional way because it is very simple. In the transformer that is it and then based on the number of windings you select from a switch so you must have seen the old transformer, I will show you the picture of this

and you can just activate the switches in the winding and you can choose the voltage accordingly and then current characteristics can be changed.

And then obviously if you want to convert AC into DC you need to have rectifiers, so generally you have rectifiers in this output system so that the entire the alternating current waves can be transferred into full wave DC, so that we do not waste anything. Similarly we also have 3 phase converter into single phase by having a three series rectifier systems so that you know the all three can be operated so that this 3 phase AC can be transferred into 3 DC lines, is it clear?

So we can have an output inductor so what is inductor? To regulate the current which is flowing out, do you have a inductor in your home? No, why do you use inductor? Fan, AC is there so this is commonly used so choke is inductor which regulates the current based on the windings in the inductor so that is why you need to have a choke in a tube light if you do not have choke then bulb life goes down because it regulates the output current.

Similarly to regulate the output current so we also have a inductor in output circuit and if you do not want DC current if you want AC current you can take out the you can switch OFF the rectifiers, is it clear? So obviously so if you want to strike an arc you need a DC voltage, voltage is reduced by the switches we are selecting these primary winds because number of winding determines the voltage in the primary and the secondary circuit, so the moment you stepped down the voltage I can use rectifiers to convert AC into DC and use an output inductor to regulate the current to increase or decrease like a simple as a choke and then you can strike an arc.

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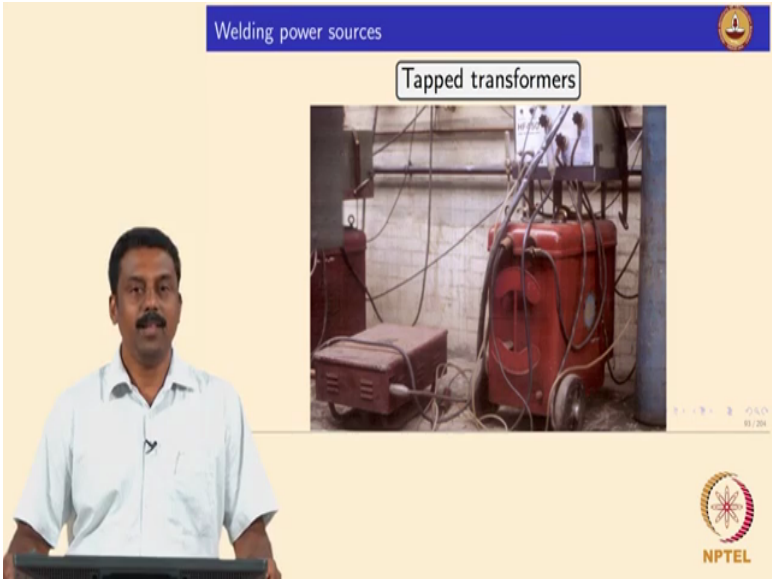

So this guy is a tapped transformer and it also needs enormous amount of cooling because transformer needs cooling. So you see that it is wonderful guy, so this is output terminals okay so this all cooled cooling guys and this guys is the switches and then it will give the directly connected signals to the transformers so you can just rotate so that you can choose the number of windings you want to select in the primary winding that will determine the voltage selections.

And then the control inductor in the output circuit would select would control the amount of current which is going to the in the arc so this is still operational so I took this picture again from John Norrish, okay good. And you must have seen I am not sure I mean how many of you have seen but I have seen such a system as I said it is still operational, it is extremely robust because it does not have any motherboard or board which could burst over time, a simple transformer and a winding and winding can be choose based on the switch on the rectifier we can use it to generate basic output and a choke to vary the output current that is what we need and a water cooling for transformer and 3 phase main you can plug it in and you get a single phase DC or AC current, right.

So the main disadvantage I told you already is we cannot vary the voltage continuously because switch determines the voltage in the primary winding.

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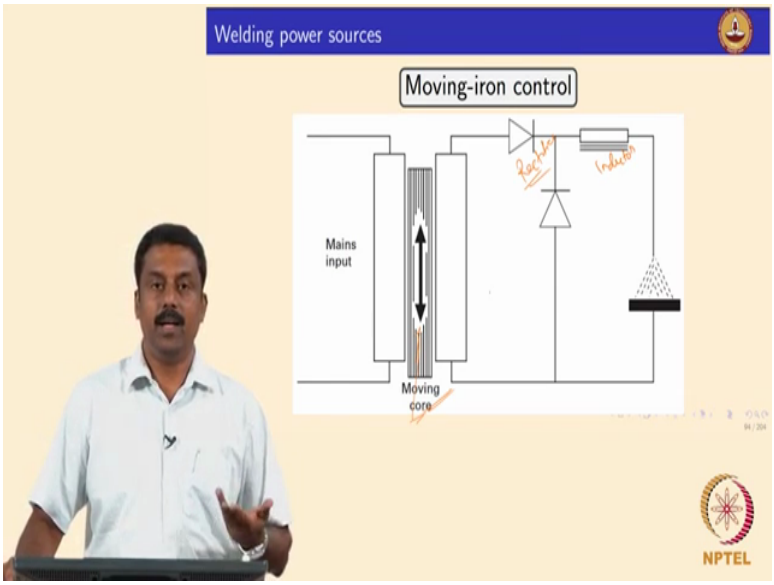

So people thought about it and then they developed another version of this to have a shunt which can change the magnetic flux which is actually induced from primary to secondary winding. So advantage over here is so we can gradually move these ions core, so based on the position of these moving core we can now control gradually because in switch it is defined one switch to another switch the voltage will be changed by the different distance of the windings, whereas in this case if you are moving ion core we can gradually change not (distinctive) discretive values of voltages, here you can change gradually because you can basically you will have an rotating pulley so we can just slowly move so the ion core goes inside the primary between the primary and secondary winding and based on the position of these primary the moving ion core the voltage can also be changed the transformer, okay.

So if the same as the previous tapped transformer here instead of having the switches to select the primary taps we have a moving ion core between the primary and secondary windings to gradually change the voltages in the power source, is it clear? So other things are the same so you will have rectifier and inductor to convert the alternating current to direct current in full wave direct current and the inductor to choose or to regulate the output current so again this is also it was also commonly used.

In this the power source the important negative point is cooling because the ion core has to be cooled sufficiently otherwise so even if you use a very soft ion magnets or soft ion core it is heated up significantly, so the cooling requirement is enormous when you use in a moving ion core the power source. So you will have to continuously cool the transformer core to keep it in operation otherwise if the temperature increases obviously you will have sagging or even

melting of the core soft ion core, is it clear? And this is commonly used even for even now some of the power sources some people may use it for GMAW or MMAW or SMAW shielded metal arc welding, good.

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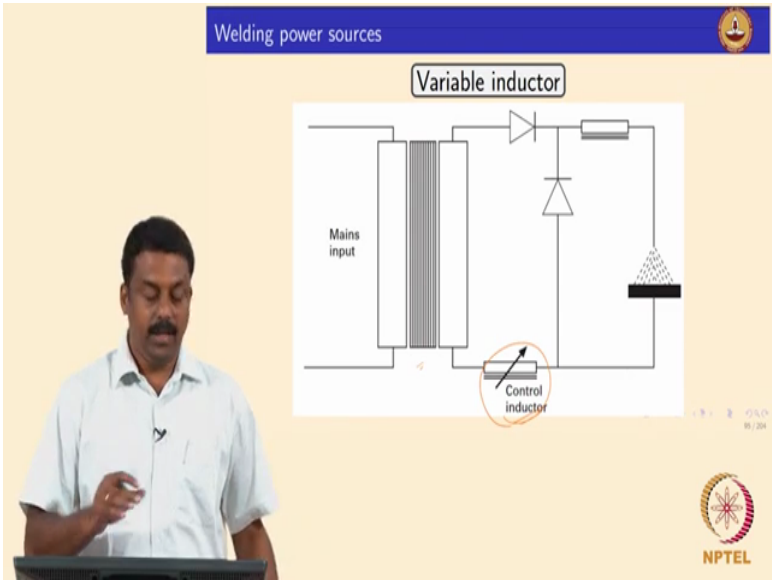

So the people thought about this disadvantage of tapped transformer and moving ion control, so developed alternative for these systems so third alternative is a variable inductor. So basically variable inductor how it actually works is you need to have additional control inductor in the output circuit, okay and this guy takes care of the output voltage and current, right so you can control the output current and voltages actually going out in the output circuit because transformer takes care I mean it actually transverse but you can have a number of inductors control inductors to step up the current and then reduce the voltage, okay.

So control inductor you know the job is efficient because we do not have an SH transformer or the moving ion core so we can have inductor in the output circuit to select the known amount of voltage and current. Again the disadvantage is the system cannot give maximum current the current rating of the system is quite low because you need to increase the current significantly, so we can play around with the transformer windings and cores to increase the amperage and as well as to reduce the voltage but the inductor what you use in the circuit determines the input which is determined through the transformer, is it clear?

So the control inductor can be used the output circuit to regulate the current which is going out, but this process you cannot control the output remotely so you will have to be there and

adjusting the control inductor when you are welding, so you need to manually do it every time and then try to control it. So remote operation is not really possible using this process because we need to adjust the (())(30:03) inductor all the time in your welding.

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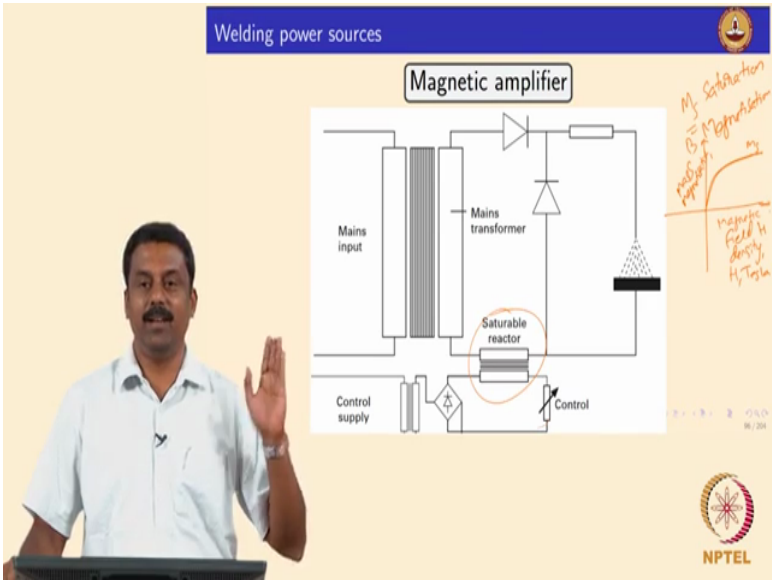

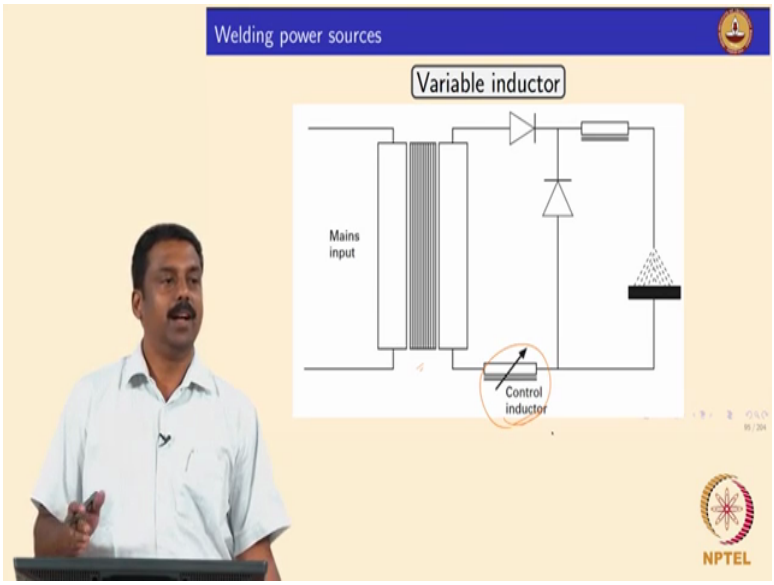

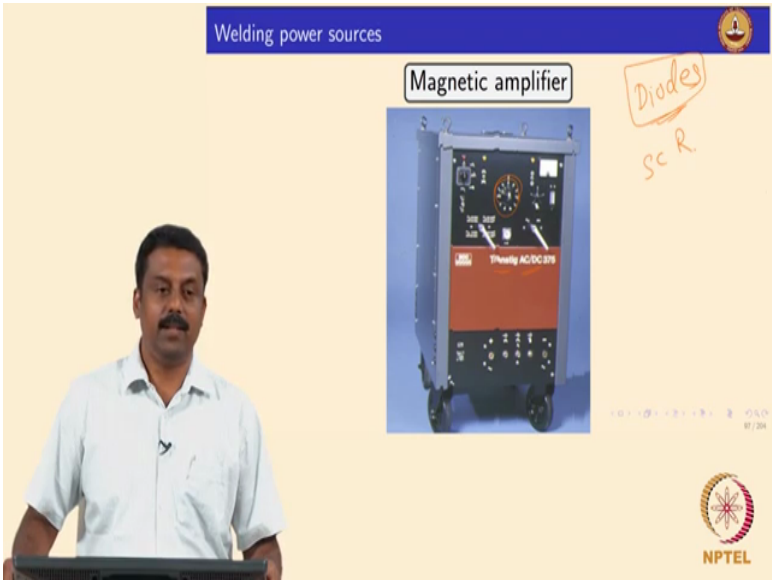

Now to overcome this advantage so again people thought this is very efficient process because we do not have the heat loss, or heat generation in transformer so you can use a simple inductor now you can control the regulate the output, but we cannot select the output from remote place or we cannot regulate it by some means. So what they have done is they added one simple thing with magnetic amplifier so the magnetic amplifier is nothing but you have a magnetic core built into the similar to what you have it in the transformer but the magnetic saturation of this core can be changed because these are electromagnets.

So if you increase the input DC current to this the magnetic core so we can also change the magnetic saturation okay so if the core magnetize to until its saturation you will not have any output, okay by carefully controlling the input current for this magnetic amplifier we can regulate the output current remotely, is it clear? So what you need to have is? You need to have a simple programmable not programmable meets not within C code or G code or computers so with simple DC supply, okay.

So you will have a simple control mechanism which can supply a DC current from again so this is a DC power source and this DC power source can give a DC input say for example 0 to 10 volts or 20 volts if it is 20 volts it saturates completely the magnetic core what you use then it is shuts OFF the current. So that depending on it is a saturation magnetization MS, so what is MS? Material scientist? Saturation magnetization, so what is saturation magnetization? What is it? Magnetic stresses, what is the axis generally we plot when you want to describe the magnetic stresses?

Student is answering: BH.

BH, where is B? x axis what is x axis? Horizontal axis of course x axis is horizontal axis, what goes in the x axis?

Student is answering: H.

What is H?

Student is answering: Magnetic field density.

Yeah, it is magnetic field density in this unit? Come on you cannot say just name, what is the unit of magnetic field density? Yes someone said, common guys this is very famous, tesla and this is y axis something there we have, it is a plot. So you are applying the field and what are you measuring? Strength of what? Material?

Student is answering: Mass magnetization of the material.

Yeah, it is mass magnetization of the material, okay so it is a function of the weight the mass so this H versus B and it approaches saturation upon applying in a field, okay. So this magnetic saturation MS can be changed or this mass magnetization can be changed in a thermal magnetic material yeah (())(34:16), okay so that is how. So we need to control the input DC in such a way that we can change the saturation mass magnetization of the circuit and that would determine the output, okay.

So in this case we can now regulate the output current remotely, okay so I can select the DC current these reactor the saturation reactor magnetic amplifier and in previous case we do not have this option, we will have a defined the inductor which will give you one output current or output voltage whatever. So if you want to have a variable current and voltage output you need to have a lot of inductors in the circuit so we can choose the one inductor for your given voltage and current.

So suppose if you are welding in one constant material for ages, so in this case you can choose one control inductor so that will give you defined current and voltage, okay or you can have a series of circuits from the transformer connected and you can choose the current and voltage that you want, whereas in this case we change that by introducing a magnetic amplifier. So this amplifier will take care of the variable functions, so by changing the input DC for this amplifier you can also change the mass magnetization, if you change that then obviously you will also change how much flux is transferring from one coil to the one

winding to the other winding in this inductor that will determine the output current an output voltage, okay.

So this is the in 80s you know the state of art power source, okay so when you look at the 80's movies when you are welding in the movies you must have seen this power source, okay so I think in one of the star wars movies also somewhere I saw this sort of in a power source. So this guy this works like a magnetic amplifier power source so it is a brand name Transtig AC/DC. So AC/ DC so that means that it can give both AC and DC so it calls as a rectifier and then you see these guys? That is a DC source.

Similarly you must have seen in our labs also you will have one vessel like source and you can move the top nob to choose the required voltage. Similarly we can this guy selects the voltage input to the magnetic amplifier which would in term determines the output current, okay is it clear? So based on that you would choose the voltage and current and circuit.

So these power sources again you need to have a transformer and these are very simple systems, so you will have a transformer, rectifier at max and inductor that is it the inductor can be programmable or not. So you would change the output either by taps by selecting the taps in tapped transformers or by using an ion core which can move so that now based on the position of the end core you would choose the current voltage in the secondary windings or you can take away that and you keep the transformer intact you change the current and voltage in the output circuit by having inductor and you can have a number of inductor to choose yeah required current and voltage, you can also have a programme of inductor using an magnetic amplifier and that magnetic amplifier can give based the current and voltage outputs based on the input which is actually given to the amplifier itself, is it clear?

So these 4 are commonly used conventional power sources which are like 80's kids so no complexities, no microprocessor, no semiconductors so when we were going up we were playing marbles so we did not have cell phones something like this, we did not have any microprocessor in our hand. So these will the power sources are very simple they add their fantastic life and still they are surviving (so but again).

So we want to increase improve our functional requirements, so the functional requirements you know what we have nowadays are also very demanding so we will have to now introduce semiconductors. So semiconductors to the power source or computer related electronic related power source came up in 70's by introducing transistors also invertors. For example

various silicon control rectifiers because rectifiers in old days they were using how did the old rectifiers work? What did they have inside? No one? No, those are diode based diodes, right so diode based rectifiers.

Nowadays? Nowadays we have semiconductor rectifiers and those are all called SCR silicon control rectifiers SCR or transistors, so the transistors when they came into picture and the welding power also got advanced by replacing the highly inefficient diode based rectifiers into semiconductor based rectifiers, good.

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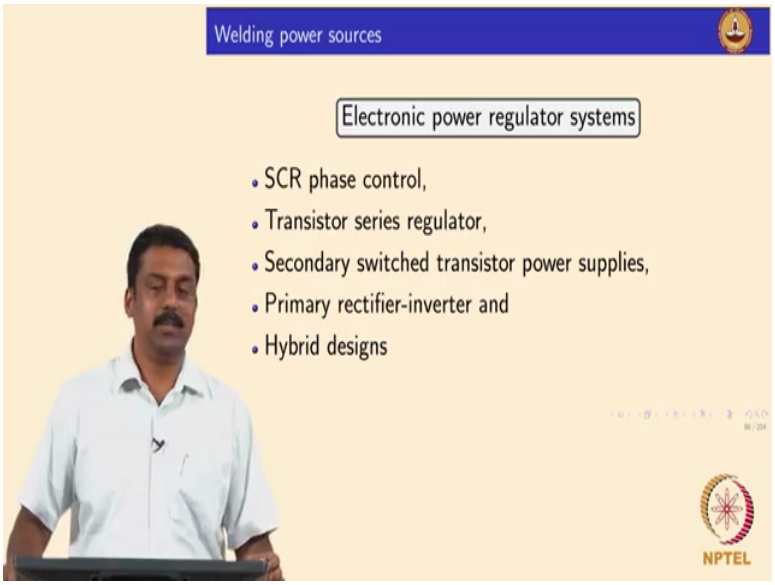

So we will stop by this and then we will move on to the next class in the electronic power regulators so we will move on to the 90's kids, okay. So we will look at the all the advancement that we have made in power sources by introducing semiconductors, transistors and invertors, okay good. So far what we have seen in this class? So we looked at in detail about the shielding gas, how the nature composition of shielding gas can change your weld bead geometry, micro structure, mechanical properties can be influenced by these selection of shielding gases.

So we looked at individually like we commonly used engineering alloys, steels, copper, nickel, aluminium alloys, what shielding gas we commonly use because the material properties can also thermophysical properties can also change the shielding gas selection and then we moved on to the next unit on power sources so we looked at the conventional power sources 4 of them, can you recall? Tapped transformers, moving ion core, variable inductor,

magnetic amplifier, okay good again the primary function of the power source is to generate sustainable low voltage arc that is very important.