Welding Processes
Professor Murugaiyan Amirthalingam
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras
Arc welding power sources Part 03

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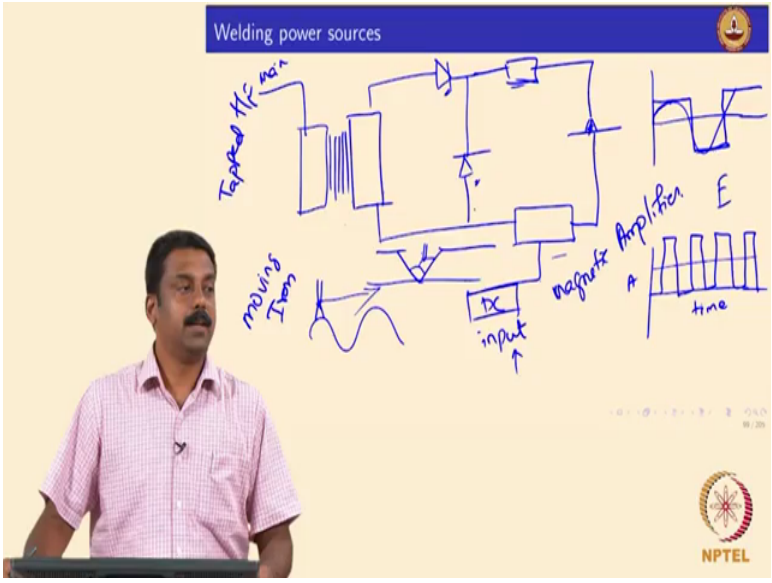

So we will see in this class the next generation power sources which are known as electronically regulated electronic controlled power sources. So there are again 4 or 5 types which are commonly used for GMAW, GTAW, SMAW we will look at it one by one.

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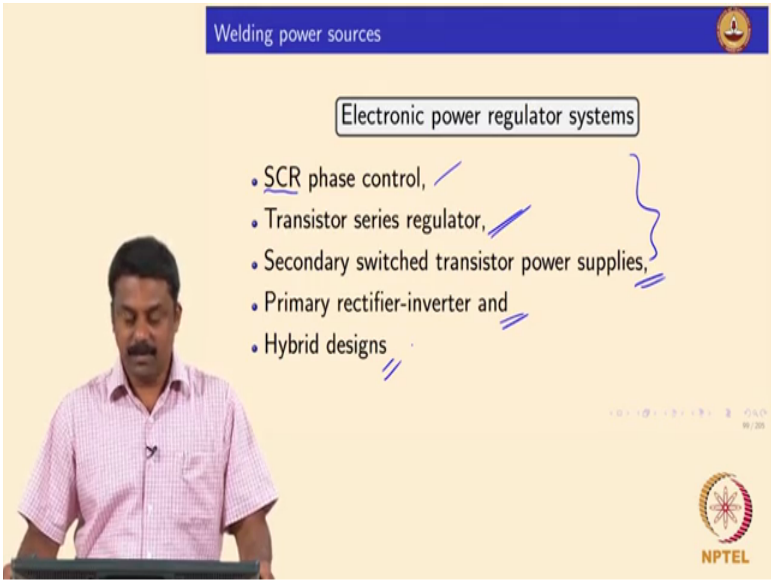

So the first development that actually happened is electronic power regulator system is SCR phase control system, so what are these SCRs? Is silicon control rectifier so these are semiconductor rectifiers ad by using these SCR's in sequence we can also increase the efficiency of the power transmission from the mains to the power source because if you remember in previous cases 3 phase power unless you have a proper rectifiers transformers as well we most likely will be wasting the other 2 phases we will be using single phase only out of 3 phases, if you do not have a proper transformer setup so you need to have a 3 phases 3 transformers and rectifier systems so that each phase can be regulated but even then you cannot really use those 3 phase outputs to on a single phase the arc voltage.

So we can change that by using a circuit where 3 phases that are coming from the main can be very effectively used by placing a silicon control rectifiers in series and these 3 phase main currents can be converted into (())(2:06) low voltage high current arc. So we will see one by one where this is the first development to happen from the conventional to the electronic power regulated systems after semiconductors arrived, the silicon control rectifier phase control power sources and then the lot of development happened in transistor technology, transistors they came into picture and then these transistors can be very effectively used to regulate the electric current.

So then we started using transistors as well so we will see some of the power sources which actually uses transistors to regulate the output current and you can also rectify, you can also invert the output current so they can be used if you are using it in a series number of transistors and then there are improvements in terms of the switching ON and OFF of a transistors, so then the transistor capacities are also increased in terms of ON and OFF the output characteristics.

So from the conventional transistor to we went to secondary switch transistor power supplies then finally the state of the art is the primary rectifier inverter systems and if you look at nowadays the welding power sources you can lift it is like very compact, very tiny sort of a small box but if you look at moving ion the power control power sources can you lift? It is not possible, it is so huge. Even this the SCR transistor the primary switch transformer supply they are also relatively big in size but if you look at the modern power sources which are rectify inverter based system is extremely compact.

So we did one trick very simple trick with that we could reduce the power source and the cooling requirement tremendously low, so we look at so what modification made in terms of the circuits so power source suddenly became very compact. So of course we also use the microprocessor semiconductor transistor inside by changing the circuit components we made the power sources into very compact systems by using the inverter based power sources and then we also have hybrid designs with the microprocessors we will also see end of the class so how we can use the microprocessor, computer programs, in built feedback control to regulate the current and voltage in the welding.

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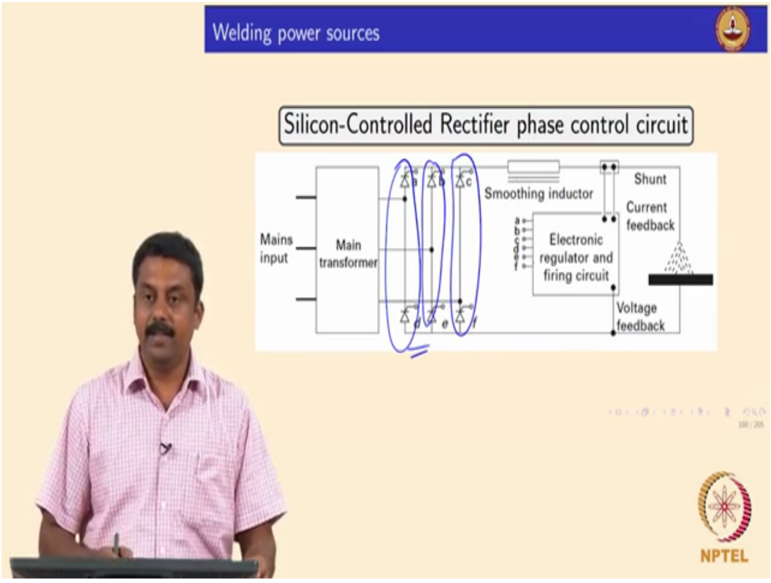

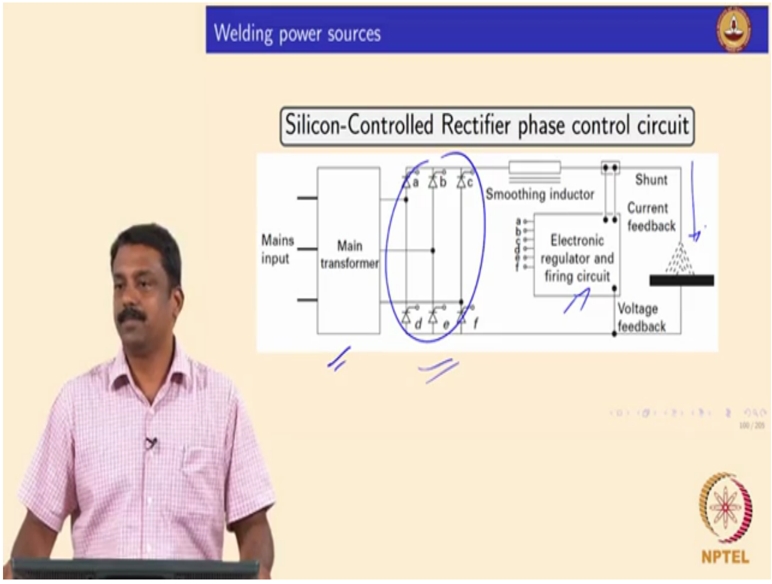

So first one SCR systems, so SCR systems as I said it uses silicon control rectifiers so these are a b c d e f these guys so if you look at the main inputs 3 phase main coming to main transformer so main transformer actually transforms from primary to secondary winding and secondary winding is connected to see in this case 6 SCR's so 3 in one phase and the other, if you look at each line is connected to one rectifier series SCR series, so the one phase and the second phase and third phase.

So advantage over here is so now by switching back and forth these rectifiers sequentially and we can regulate the output current (where) we can also convert into DC for example if you carefully control the output characteristics suppose if you want to have a DC current so you have an off cycle which are coming from a b c only going to output circuit then you will have a DC.

So if we have if you want to regulate if you want to reduce the amperage for example you can only turn ON a and b and you can turn OFF b and c and d and f (d and f). So based on the sequence of switching back and forth the rectifiers SCR's we can regulate and convert the whatever current comes in to either DC or AC with step down amperage. So these are possible because of these SCR's and diode based system so the response time of diode based is very very slow so we cannot regulate the diode based rectifiers as we need in this case because it has to happen much fast quickly.

So the a and b, c the rectifiers which are connected to mains by carefully switching back and forth we can either have a DC current going out of these SCR's or AC current whether it is the (high power or low) high amperage low amperage we can play around. So I am just giving an example if you have an SCR power source you will have thousands of SCR's in the circuit, okay.

So if you look at the circuit board which so these are simple circuit boards so you will have an SCR's embedded in circuit boards and which can regulate the output current whether it is AC or DC based on your need and the circuit the rectifiers will be turned ON, obviously then we can also have a smoothening inductors and then you have an additional regulators to regulate the current which is coming from these SCR guys which will be sent to the arc, is it clear?

So in this case you still have transformer but these SCR guys would regulate the output current from this main transformer it is efficient already so because so we have 3 mains, 3 phases all connected in series with these rectifiers and then we can convert the transformer high voltage current into low voltage high amperage currents which are needed for the welding applications, so we can make it as an AC current or DC current how you are switching back and forth to the rectifiers SCR's and you can also step down by turning these rectifiers based on the output need, is it clear? It is very simple right and if you look at the board it is also very simple, you will have an rectifier SCR's and inductors systems, how many of you have seen motherboard of computer? What are there inside? Do you have similar system? Capacitors for example, inductors then you will have diode sometimes and what are the use the same purpose regulate the output.

In some cases if you want to a USB port so then you need something to reduce the high voltage into low voltage, is it not? So how is it achieved? Same I am explaining here, it is the same way, so it is not complex it is used in everyday life regular life. So based on your needs you know computer motherboard also will have all these things it have rectifiers, diodes, inverters, inductors, capacitors because each input for example keyboard would need a certain voltage to be operating to receive the inputs USB port needs a defined voltage, how do you supply these voltages to the input modules of computer? By having all these things, okay.

So in this case we have a very high amperage in our computer system your voltage is low, amperage is also reasonably low. So that is what if you look at the motherboard you will see all these things SCR's will be there, diodes will be there, the inductors will be there, capacitors will be there to regulate the output. So processor may need a certain voltage to operate, how do you supply that voltage?

So you need to have a defined circuit to supply required current power voltage power to this processor, same thing in power source as well, how you achieved, how efficient a circuit is? It is determined by what are the components are there in the circuit. So the power source is nothing different if you open the power source you will also have the boards in any equipment for that matter these boards contains all this to define to give defined current and voltage needed for the operations.

So in unfortunately in our case we also need a low voltage high current arc, so we need to define the circuit and the efficiency is determined by the what are the components what you have. So already compared to the moving ion power source the SCR phase control is much more efficient, so because the heat loss the efficiency is much higher by using the SCR's in the circuit.

So we also use all the 3 phases coming in the main to regulate the outputs, is it clear? It is nothing strange it is same what you have in computers. So this is clear, right the SCR phase control circuit? Good.

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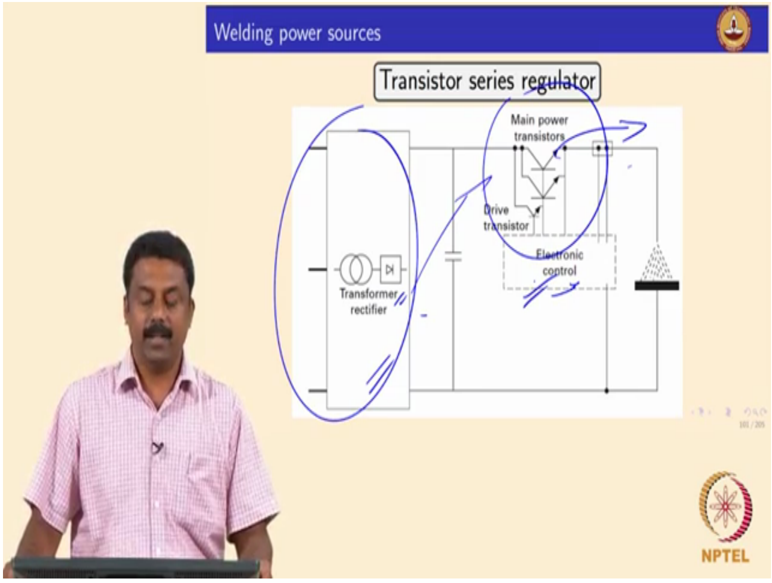

So the second one again so the other difficulty with SCR is the switching time, rectifier they have their own response time. Suppose if you want to do a rapid response so I want to generate current output with a pulse of 50 hertz so then you will have to the rectifiers would work by response sent time of SCR is also not as good as what you want so semiconductors they also own their own response time, diodes are even worst creating responses, even the semiconductor rectifiers also is not that efficient, so then transistors can be used.

So a transistor if you use it is very simple, circuit becomes extremely simple you do not need rectifiers, you do not need any inductors, transistor would do the job for you. So in this case so you will have primary transformer rectifier system so which would change convert from main to the circuit of the power source you will have transformer and you may have a rectifier to convert the same the current high voltage current coming from the secondary winding into high voltage DC.

So now we will have one transistor or transistors I am giving one example of transistor, so in this transistor can be made into operational by giving an input current, input voltage. Suppose again the same has the magnetic amplifier use, so this transistor has a defined power rating 0 to 10 volts for example, if you give 10 volts it shuts off and if you have 9.5 it would release the output current and voltage based on the transistor power rating.

So by carefully manipulating the input voltage to this transistor we can regulate the output that is it, is it clear? So we generally need, what you need is in simple electronic control which controls the transistor output characteristics now the system is already becoming smaller, in previous case you have rectifiers, semiconductors, inductors after the arrival of transistor you still have the big transformer part, rectifier part over here but the output circuit is all transistor based, the output from the transistor can be regulated and you give input from the rectifier or transformer directly and the output can be regulated by the electronic control of the transistor, is it clear?

So disadvantage of this is the transistor should be cooled efficiently, for example you send on a current of 100 amperes with a voltage of whatever so from the main 230 volts and you want a output of 10 volts and 50 amperes so remaining where does it go? So it has to be dissipated by the transistor so the transistor should be cooled very efficiently because transistor purest steps down the current and the voltages and sends the output that means remaining should be dissipated as heat.

So then the cooling the requirement of transistor is enormous especially your transformer the characteristics and such that so you need to have an efficient cooling for the transformer to cool so that this transformer can regulate the current outputs very effectively, is it clear? So this transistor based systems are efficient because it becomes lighter the compact and we can also regulate the output from the transistor using an input so that will control the transistors the output characteristics, main difficult main negative point is the cooling so you need a enormous amount of cooling to regulate the temperature of the transistors.

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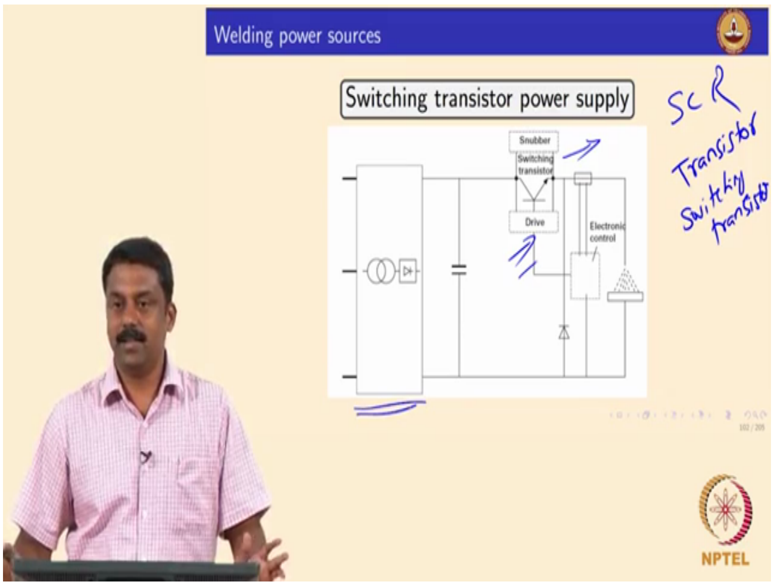

So in order to avoid this problem after development after we have the much more development in transistor based systems so we started using switching transistors. So in the switching transistors we do not need regulator input signal transistor to get the output. So in this case we switch ON and OFF the transistors an extremely fast rating. So transistor is continuously switched ON and OFF.

So in this case suppose if you want to regulate the output control so we can change the frequency of switching ON and OFF so that these transistors output can be regulated and you can also generate AC waveform based on the frequency of the transistor operations and then you can also regulate the outputs by rapidly switching ON and OFF the transistor which is there in the output circuit and this is very efficient because now if you do not need it you switch it OFF, so you do not generate heat, whereas in previous case transistor is ON you always regulate the power by the input current input voltage is going to the transistor, in this case this is not, okay by rapidly turning ON and OFF you can regulate the output current and voltage.

So it is very efficient because the cooling it is needed in last case it is not there, in last case transistor is always operational it is dissipating whatever we do not want as a heat. In this case we are switching ON and OFF so by using a switching transistors the heat generated from the transistor is already used and we can achieve the very high frequency current as well by using the transistors switching ON and OFF extremely rapidly and we do not generate much heat because when you do not need it when you want to step it down you can also increase the frequency of switching ON and OFF so then we can regulate the output very nicely and then the previous disadvantage of generating heat and cooling requirement is reduced in this case by the use of switching transistors, is it clear? Yes or no? Any questions? So what are the systems we saw?

SCR, transistors, switching transistors, we can see so we can see these 3 types regularly so it is not so expensive power sources would be operating in one of these modes SCR is still older, transistor based power sources are still common but the advantage of these guys are you know we can regulate to some extent the output so if you want to have an pulse you can generate by changing the frequency of turning ON and OFF the transistors you can play around, we can play around the input current for example in previous case so that we can also change the output, we can also vary the input which is going to the transistor in such a way that you will also have a pulsing the output for the transistor can also be pulsed, same is here you can also change the frequency of switching ON and OFF the current can be pulsed.

But the disadvantage of having the transformer in the primary input output circuit it is still there until then until this switching transistor the power source size is huge because the transformer needs for transformer is still there. So the size of the power source is not compact because the transformer if still there.

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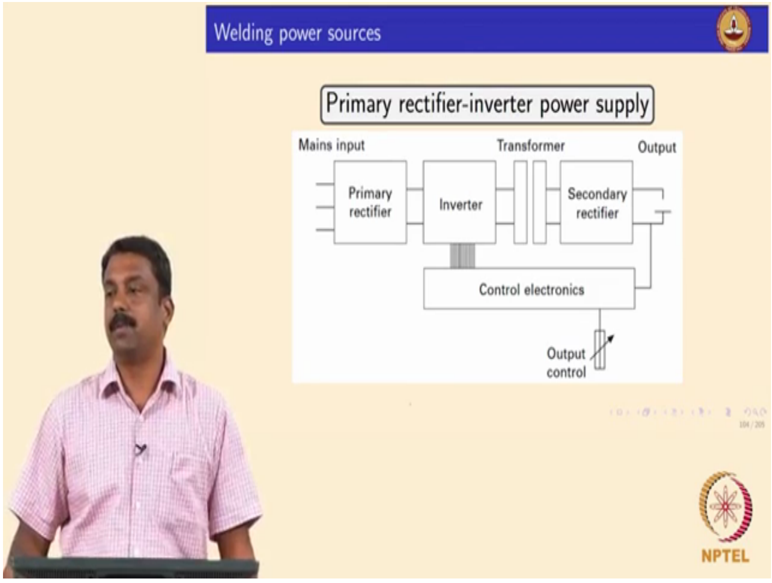

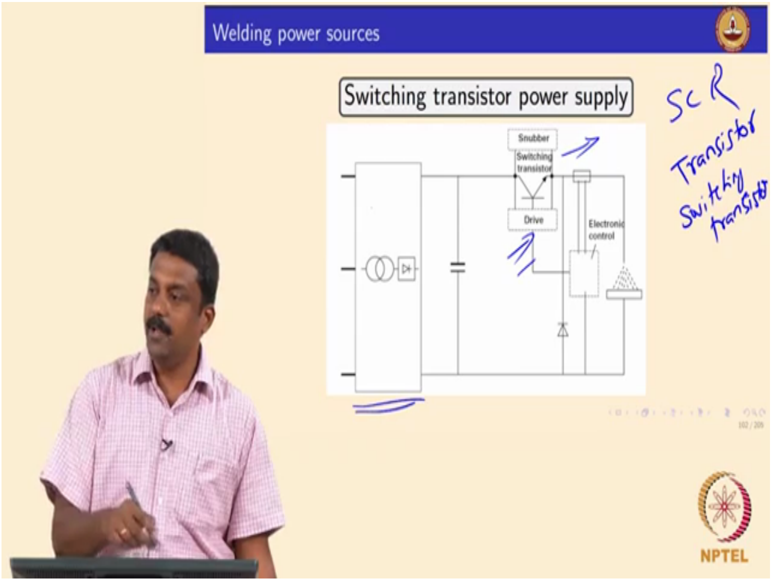

So after serious development in power source technology people came up with the modern power source which is the primary rectifier inverter power supply. So before going to that so by switching transistor so we can also change this frequency of switching and with that we can also have a pulsing with varying current IP and then so this is background tp either you can have high mean or reduced mean by increasing the switching time and you can also have a shorter switching time and longer switching of time.

So we can also change the average mean current coming out of this the switching (transformers) transistors by playing around with the time at which you switch OFF and ON then your I mean current can be selected it is very simple transistor switch ON and OFF and that would regulate the output mean current. So as I said I mean you still have the need of transformer here so system is not reducing in size.

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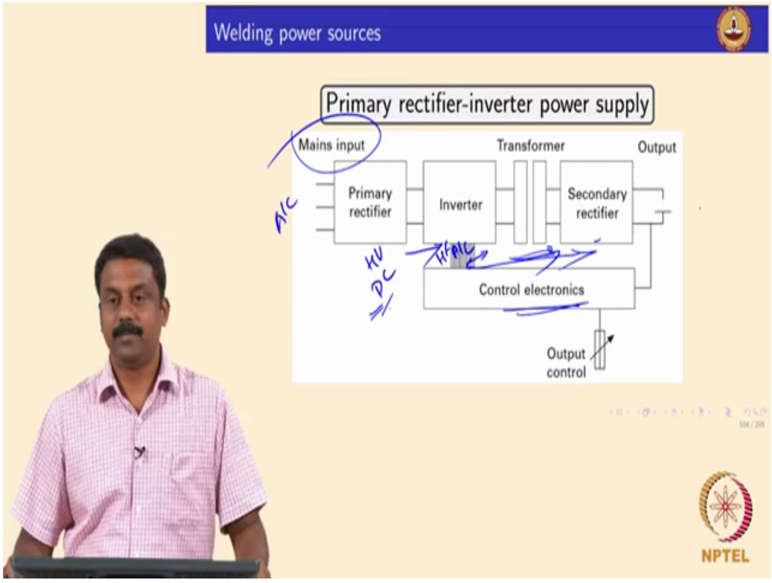

So the modern development which led to the compact power sources and with very efficient power sources is due to the invention of the primary rectifier inverter power supply and in this case so what we do is the main input current high voltage and low amperage current is first rectified so first we rectify the AC high voltage and then low current which converted into high voltage DC by using a rectifier and this can be select and control rectifier whatever you can use it.

So the AC from the main converter into high voltage DC and then subsequently using an inverter it is again converted into high frequency AC. So this in this case system has already became very efficient because we have a primary rectifier which converts the 3 mains input into single phase high voltage DC and this high voltage DC is converted by the inverter into high frequency AC single phase and in this case your voltage already reduced. So you have a high frequency AC with low voltage and that can be now easily transformed by using a simple very smaller transformer to your secondary system.

In previous case the transformer is so big and we play around output in this case we play around the input itself, so the high voltage AC current from the main is rectified into high voltage DC and subsequently it is converted into high frequency AC with low voltage and then you can use a simple transformer to transferring current from this input into the output circuit and output circuit we can have all these controls, you can have a secondary rectifier to convert back this AC into DC or you can also send the AC the required voltage and then you have all the control electronics, inductors, transistors whatever you want to have to regulate the output can be used.

So by changing the primary circuits the components we can already reduce the size of the power source significantly because the transformer is not here the huge transformer you need to convert the high voltage AC into our power source circuit. So we do not need the need of the big transformer which is needed to convert or to transfer the current from the mains to the power source so we use the primary rectifier to change or to convert high voltage AC into high voltage DC and then even inverter it will convert the high voltage DC into high frequency alternating current and subsequently this can be transformed using a simple transformer small size to your welding circuit.

So advantage of this is we reduce the size of the power source, power source has become very compact, you still have the controls electronics to regulate the outputs you may have transistors, you may have SCR so all these things would now regulate to step up, step down the currents but the primary function of converting high voltage low current into low voltage high current system is taken care of by modifying switching back the positions of the rectifiers inverters, is it clear?

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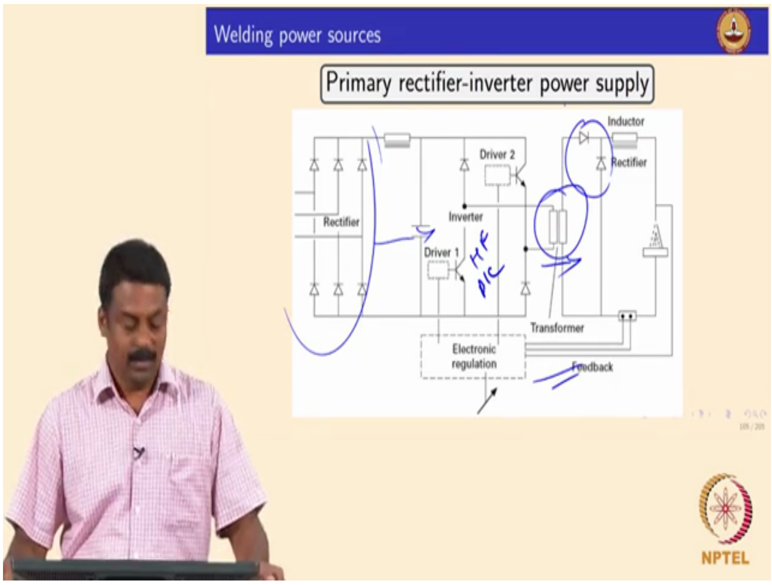

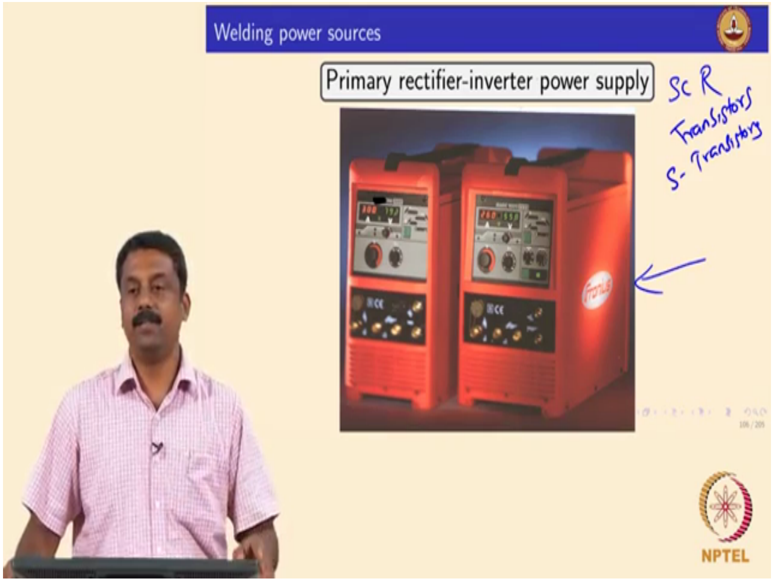

The circuit looks very simple so you will have primary rectifier from 3 phase main you will have a single phase high voltage DC and that is sent to an inverter so inverter converts high voltage DC into high frequency AC and thus can be transferred to the our welding circuit using in a simple transformer because it is already in high frequency high current AC so you just need to have a simple transformer very simple transformer to transfer the current and then you will have a rectifier you may have to convert this AC into DC again and you will have inductor circuit and then electronic regulation to control the output.

So this is extremely now efficient process because you do not waste much so whatever you are getting 3 phase line it is all converted so the efficiency of the power source increases tremendously using the rectifier primary rectifier inverter systems. So the modern power source right now if you go and buy you can buy such power source rectifier inverter power source for 5 Lacs and it will have a power rating of 500 amperes or 500, 600 amperes easily something like this so we can carry.

So if we have a big transformer in the primary circuit they will be huge recall the picture I showed you in last class in the tapped transformer you need 2 percent to push so we also have in our laboratories the SCR controlled or transistor controlled power sources they are still huge they make lot of noise, so now we have taken out by using rectifier inverter systems, so rectifier inverter would reduce the need of the big transformer and then we will have a much more compact systems like what you see over here and we can carry very simply and we can also regulate the all the functions of regulations are still there using in the transistors or SCR’s you can use them to achieve the waveforms what you need, you need a pulsed waveforms or square waveforms or you want square wave DC or square wave AC so all of them can be achieved by using the transistors and the SCR's in the output circuits, is it clear?

So this is state of the art the primary rectifier inverter systems so generally it is known as inverter power sources, so inverter power sources are general terminology we have to use to denote these kind of power sources. So more DC inverter power sources, then the transformer is not there in the primary circuit, transformer is not there so use rectifier inverter to convert the mains into an high frequency AC and subsequently it is sent to the welding circuit and then you have a (secondary inverter) secondary rectifier if you want DC power source DC waveform and then subsequent control will be there using transistors or SCR's is it clear guys? Yes or no?

So the major electronic control power sources are SCR's phase control power sources and then transistor, switched transistor and then these guys so primary rectifier inverter power supply, good. So in the advancement still are they are happening because we are always greedy so we will have to maximize the efficiency of the process and we also need to control the stability of the process as well, so we also need to make it more adaptive you will have to make it more of to modify based on what is happening in real life in situ. So the power source should be made capable of doing these feedback controls.

Suppose one example you are welding with a consumable wire the moment the consumable makes a short circuiting with the weld pool and you want to turn the current OFF so then you need to device feedback mechanism the power source should be capable of measuring voltages the moment short circuiting happens then voltage decrease, the moment it decreases the power source should identify okay switch OFF the current and this will happen extremely rapid pace, it should happen with frequency of save for example 100 hertz.

So then the power sources the semiconductors the electronics what we use to control the output should be regulated so quickly unless we have microprocessor we cannot do that. so we put microprocessors inside the power source to regulate the complex waveforms what we want to generate so this rectifier inverter system nowadays are adaptive with the microprocessors inside.

So it is like you put a computer inside with the feedback control, so feedback the power source get the information from the welding circuit and then the microprocessor can calculate when to send input so one transistor turn ON because you are sending current stop, it should tell the inductors to activate so these are all now regulated using a microprocessor based systems we make life complex.

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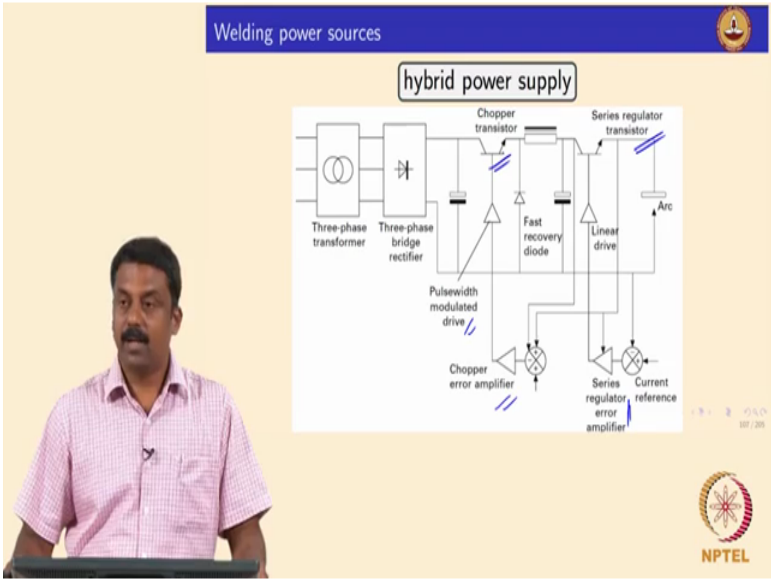

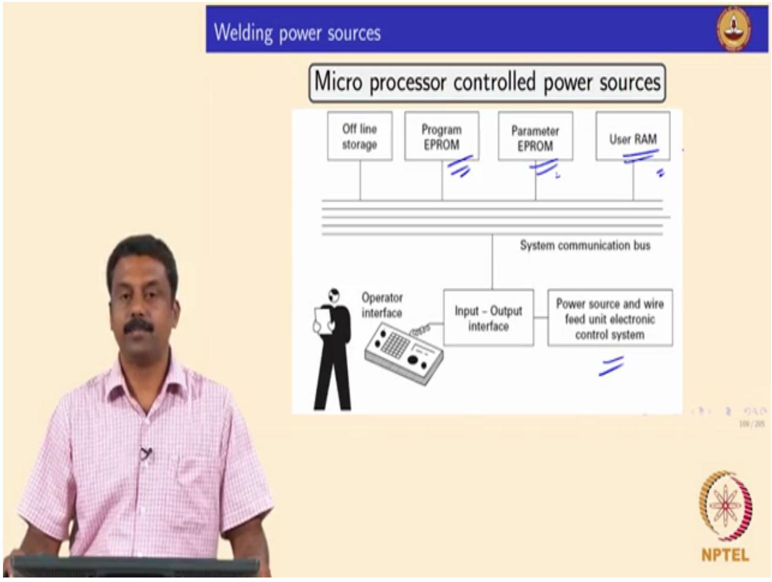

So we will introduce the various systems so transistors to chopper transistor to that means chop chop some of the waveforms, regulated transistors, or diodes phased with modulated drives, chopper error amplifiers, serial regulators and then current control and also feedback to control the wire feed rate so for a given composition so the microprocessor should also contain information about the melting rate of the composition so you choose one composition then it will immediately the program which already there database should calculate what will be the ideal wire feed rate for a given current, you set the current 90 amperes and then immediately the moment you set the current the power source should identify what feed rate it should give for the wire, first it has to make itself comfortable sending 90 amperes of waveform you want.

So then if you also want to control the waveforms during this process then it will also adapt quickly using a microprocessor and you do the calculations and then it will tell okay so over there SCR has sent so and so current so in this case you have a transistor so the square waveform should be sent so then the transistors would activate to send the square waveforms instead of conventional waveforms.

Similarly pulsing so switching transistors should be activated such a way that you will have a current pulsing so these are all controlled by the hybrid systems and then these hybrid systems are all regulated using a microprocessor control so you will have the various database ROM's program ROM's, parameter ROM okay program use your welding programs parameters based on the waveforms what you want to generate and then you will also have database store for each compositions for example and then they are all regulated using so power source you need and wire feed (())(35:30) they are all integrated, it is like having on a computer, it also sent out in input module.

So in the front screen so it all regulated using a microprocessor and the moment you take the nob and then turn it ON immediately the microprocessor through the calculations based on the program what you have and then parameter what should set and then you can also have a database of the compositions for example I want to weld 1.2 mm millimetre (())(35:57) wire a simple C3 wire and immediately the microprocessor should arrive at the parameters and database what it should use for a given applications.

So it regulates the waveforms the current voltage waveforms using that technique in whatever explained and then database you give or you develop for a given composition and diameter for example, is it clear?

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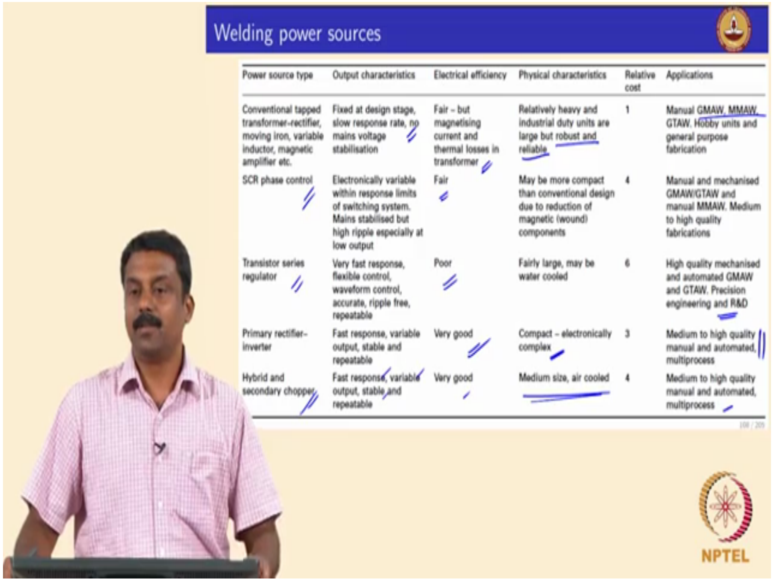
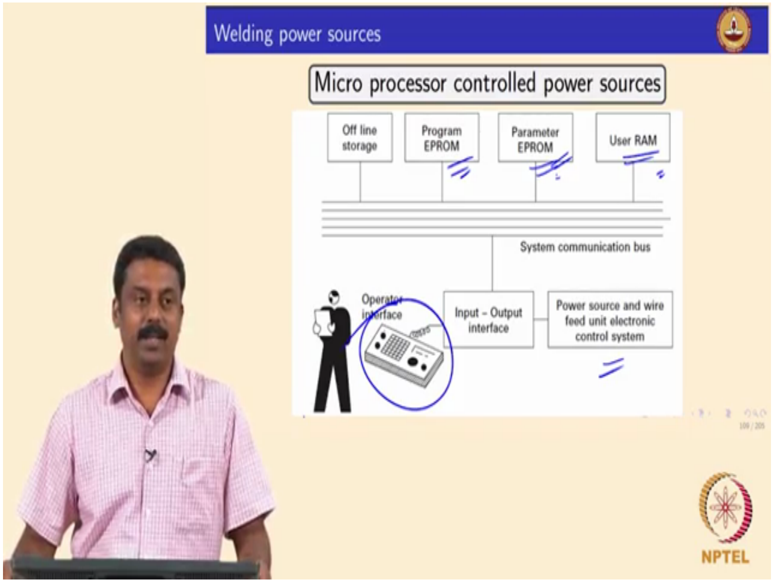


Power source type	Output characteristics	Electrical efficiency	Physical characteristics	Relative cost	Applications
Conventional tapped transformer-rectifier, moving iron, variable inductor, magnetic amplifier etc.	Fixed at design stage, slow response rate, no mains voltage stabilisation	Fair – but magnetising current and thermal losses in transformer	Relatively heavy and industrial duty units are large but robust and reliable	1	Manual GMAW, MMAW, GTAW. Hobby units and general purpose fabrication
SCR phase control	Electronically variable within response limits of switching system. Mains stabilised but high ripple especially at low output	Fair	May be more compact than conventional design due to reduction of magnetic (wound) components	4	Manual and mechanised GMAW/GTAW and manual MMAW. Medium to high quality fabrications
Transistor series regulator	Very fast response, flexible control, waveform control, accurate, ripple free, repeatable	Poor	Fairly large, may be water cooled	6	High quality mechanised and automated GMAW and GTAW. Precision engineering and R&D
Primary rectifier-inverter	Fast response, variable output, stable and repeatable	Very good	Compact – electronically complex	3	Medium to high quality manual and automated, multiprocess
Hybrid and secondary chopper	Fast response, variable output, stable and repeatable	Very good	Medium size, air cooled	4	Medium to high quality manual and automated, multiprocess



So I just plug this table from John Norrish book the use of the conventional power sources have been what applications are commonly used for example the hybrid power sources the characteristic of power sources fast response, variable outputs, stable, repeatable very good efficiency because again you took the transformer out and you do not need air cooled sorry it is an air cooled systems because you still use some of the chopped transistors for chopped applications and you can automate it for example.

The conventional process like for tapped transformer, rectifier moving ion, variable inductor, magnetic amplifiers it is fixed at design especially the tapped transformer it can give one output for a switch so it can be used for welding of a given waveform. So you will have efficiency it is not that good so it is huge maybe and industrial duty units you see this point what John Norrish mentioned robust and reliable because it runs you will not see even diode busting because there are no diodes.

So in our case for example one capacitor goes away in primary rectifier inverter system and you will have to replace the capacitor that will be close to one third of the cost of the power source itself, whereas in the conventional tapped transformer what could go round? It will work, transformer is there, rectifier that is it. So it will work like a robot it is extremely robust and reliable but it cannot be used for complex waveforms generation so can be simple GMAW, manual metal arc welding, GTAW and some simple fabrication purpose you can use.

And SCR phase control again so we can make it electronic regulated yeah efficiency again goes down because of the SCR’s we use so it is not really compared compared to the others and transistor regulated system efficiency is very poor, why? Because you waste lot of current the transistor based on the operating voltage it will not yeah so you lose lot of input current so the efficiency is very poor and all the power goes into transistor if it is not sent to output then it is wasted as a heat, efficiency is very poor.

So we can still use it for high precision jobs because the output can be regulated extremely nicely from by the transistors, okay so you will not have a very rebel in the waveforms so again the best so far is a primary rectifier systems or hybrid systems it is very complex compact and then but it can be electronic complex and it is regularly used nowadays for the production purposes because the waveforms we get it is to the point you do not see any ripples in the waveforms or change in frequencies, if you want some frequency you can achieve with the use of microprocessor, is it clear? Any questions so far in the power source?

So it is clear right how the conventional power source and the electronic regulated power source work. So how it has become compact in a rectifier inverter systems because we are taking transformer out from the primary circuit so just have a small transformer to send current voltage from the primary circuit to secondary circuit, any questions so far? CMD comes under yeah that is a good question so the power source technology itself is a primary rectifier inverter system, but you need a microprocessor control and also in CMD case you also needs energy.

So that means that everything is regulated, so you need to have a synergy between all these parameters so that is again so what is known as synergy control power sources. In synergy control power source what we do using a microprocessor control you have a material database you know melting rates for example so you feed for a given material the welding parameters so you know that it is going to melt so and so length for a given time. So we can calculate from that the wire feed rate.

Suppose if you have a 70 millimetre arc length you know how much it is going to melt in a given time so by knowing so by knowing preciously the melting rate we can also control the time at which it is going to short circuit, but then the moment short circuiting happens the power source should sense whether short circuiting happening or not? So that has to come from the feedback voltage feedback, the moment short circuiting obviously there will be the voltage difference.

So then the moment short circuiting happens the power source should turn the current OFF otherwise you will have a (())(42:37) force generated at the tip when short circuiting happens you will have explosion of the weld pool, then you lose pattern. So that is why we use synergy control that means that the wire feed rate, the current, the voltage waveforms the other thing is controlled synergistically.

So the box you have this guy synergic box so you set you cannot set all the parameters independently, you set a current so obviously everything is taken care off for a given composition become independently vary if you want to achieve a metal transfer by short circuiting, okay so if you want to independently vary then you cannot use synergy so then you will have to play around each and every parameter to optimize it.

So that is how now the power sources modern power sources they do because they already have this synergy developed in the database, is it clear? I do not want to go in much detail, it is too much for you to handle, as of now we need to know the types of power sources when you open the box you should identify so get yourself comfortable so what sort of power source you are welding with, is it clear?

Okay, good. So any questions in power source? So already given analogy so it is same as any system which are electronic regulated computer for example so you also regulate the current and voltage and the motherboards will have all these parts the purpose is different so the output is like a voltage means you need to reduce from the high voltage high current into low voltage low current, a USB point for example so you may have such a system that is what we call it as a board same as here no difference. So how efficient you make that that is important.