Modelling and simulation of Dynamic Systems
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Lecture - 10
Methods of drawing bond models Electrical Systems

I welcome you all, in this lecture on methods of drawing bond graph models for electrical systems .So next half an hour we are going to see how we can we use bond graph in modeling and electrical system. So this was the example which we have seen at the beginning of lectures on the bond graph of modeling, say a simple RLC circuit a series RLC circuit if it take and if you we are asked to draw the bond graph model of this system then it is very simple.

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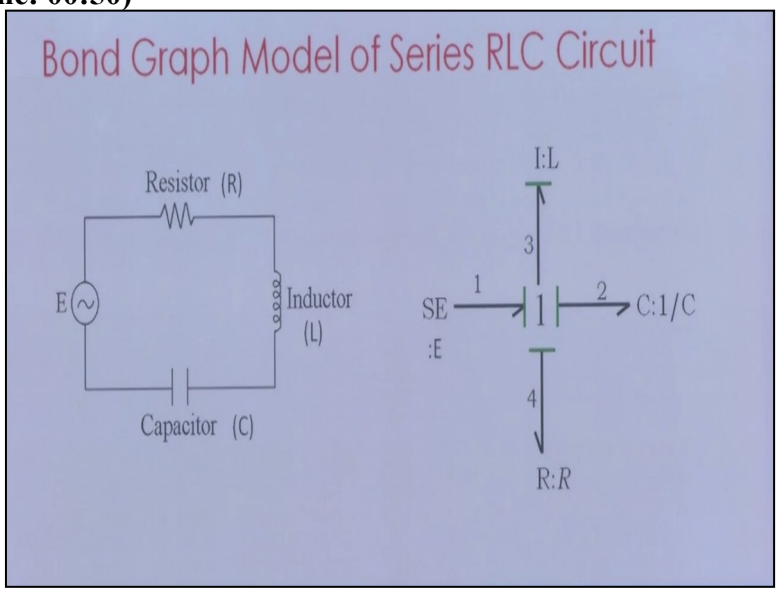

So in this series RLC circuit you can see that we have a voltage source in series with resistor inductor and capacitor. So as we have seen in the methods of drawing bond graph that first we identify what all are the different components, so here we have the source.

So, we identify the source here a resistor an inductor and a capacitor, so this way we identify the sources and we mark how the power flows through these elements and then we put the constraint and the constraint here is the same current through all the element so I put a one junction here and then I causal it the usual way so voltage source will given an effort resistor.

will take for current and return effort inductor will take an effort and return flow and capacitor will take flow and return the effort so this way we can draw the bond graph model

of this series RLC circuit. Next if, suppose we have a parallel RLC circuit as here again we have seen this

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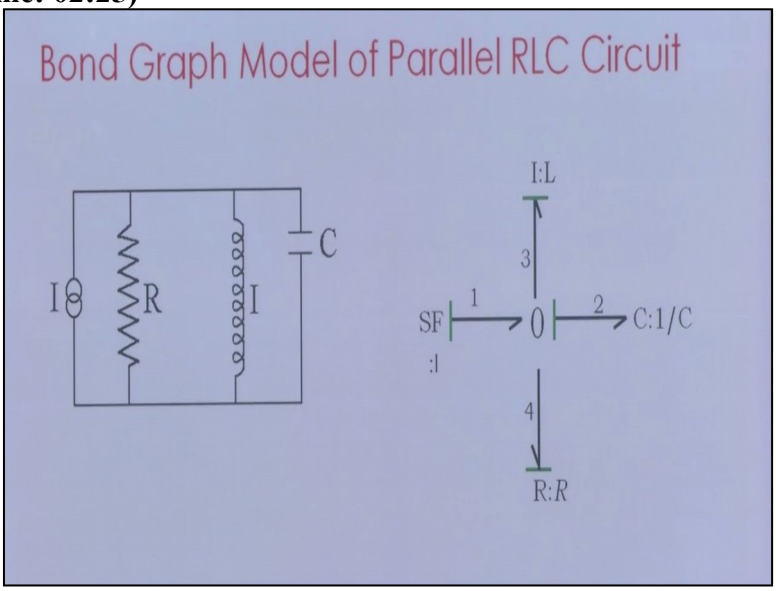

Example, at the introductory lectures of bond graph. So here are I c the circuit parallel and these are subject to a current source. So again we identify what are the source what are the elements here we have a source of current represented by source of flow we have a register represent by r inductor represented by I and the capacitor represented by c now the constraint here is that all the elements are in parallel so that we put here by putting a 0 junction,

Which essentially means that the voltage gross all the elements are going to be same. Then of course as we as done earlier we causal a bond graph the current source will be giving current. so effort so current the inductor will be talking a effort and r turning of flow capacitor will taking flow returning the effort and inductor here will be taking the effort and returning flow and here we can see that this 0 junction is determined by the capacitor here.

So, these are the two simple keys which we have just seen that is one series rlc circuit and another parallel rlc circuit what happens if we go for more complex cases or complex electrical system so certain methodology need to be devised to take care of the modeling of the complex electrical system so will be seeing those methodologies. So let us see so the bond graph of electrical circuit.

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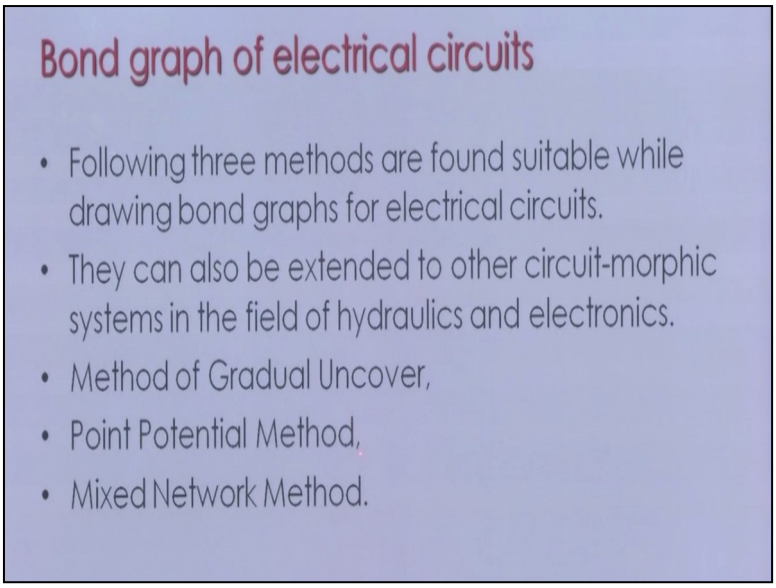

So, the 3 methods have been found to be suitable in modeling of the bond graph of complex electrical systems these methods are method of gradual uncover point potential method and the mix network method so method are gradual uncover basically here what we do is there whatever complex part is there complex series are parallel combinations are there those we combination we try to make some part of cover cover it and then draw the circuit and at the bladder part we try to uncover post part.

So, let us see and these methods can also be extended for circuit mark it system in the field of hydraulics system or in the field of electronic system I am not going to discuss this hydraulic and electronic systems here in this course those who are interested can read our book on modeling of macro electronic system. So let us begin with the methods of gradual uncover so as the name indicates method of gradual uncover means that we are going to uncover the complex parts gradually which has been covered earlier in order to simplify the problem.

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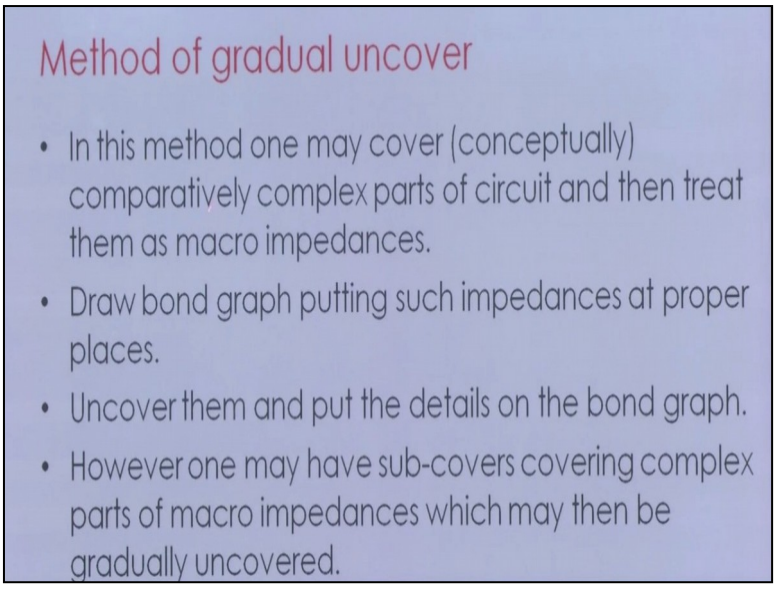

So, in this method one may cover conceptually comparatively complex part of the circuit and then treat them as micro impedances fine and then draw the bond graph putting such impedances at proper places then uncover them and put the details on the bond graph and however one may have uncovering complex part of macro impedance which may then be gradually uncover. So this is what is done. To explain this concept let us take an example here

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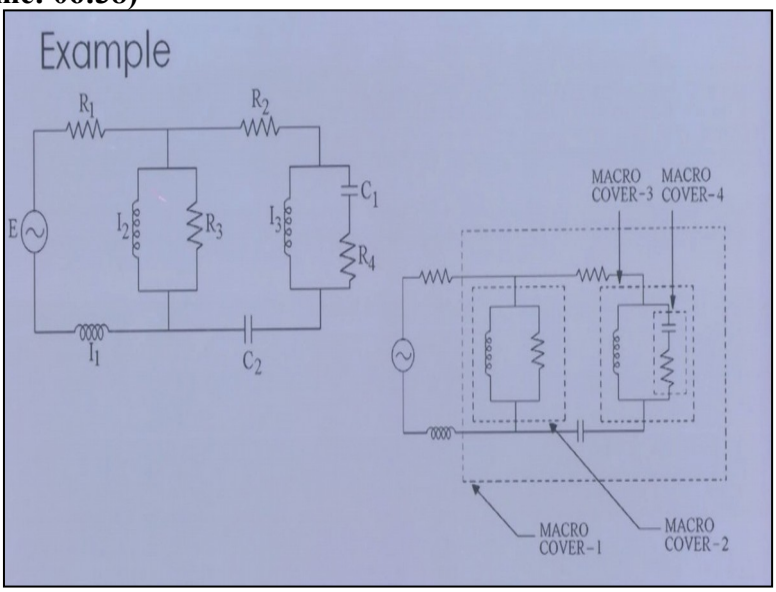

Now, here you can see that we have a voltage source a register r one then we have some part here say consisting of inductor I to resistor r three in parallel one.

Branching then we have the resistor r two and then again we have branching consisting of inductor i3 capacitor c one and r four again series and all of these are parallel with i3 that combination is parallel with i3 and of course then here we c 2 and finally here i1. So you

can see the complex nature of this circuit now to draw the bond graph model of this what we can do is that as I said here we can put a big cover here as you can see the macro cover1.

So such that we have the voltage source register this macro cover one and this inductor they are in series. Inside this macro cover again we can put a macro cover 2 here covering this inductor and register so that these entities can be treated as then one then I can also take macro cover 3 here consisting of this inductor and inductor and this combination as parallel and of course the is combination I can treated macro cover 4 t is way you can see that I have made many macro cover in order to simplify my problem now let as seen.

Now can I draw the bond graph model for such a system so as I was telling you if we look at this figure.

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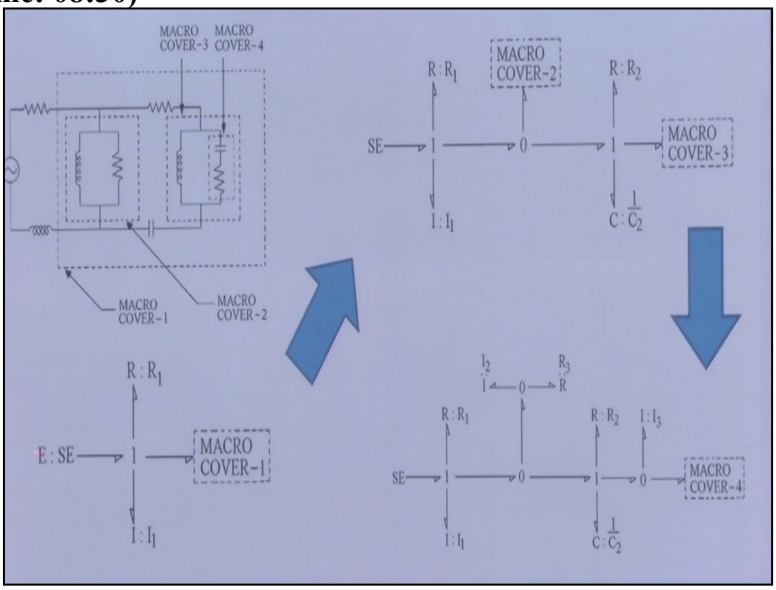

So we have a volt a source se then we have register r1 inductor i1 and whatever rest is there that is macro cover so all these elements are in series. So I put a 1 junction here representing Constant current to all of them and this macro cover one is there now what we do next, we uncover this macro cover 1.

Now for doing that we can see that if I uncover the macro cover one then we have a macro cover to their which is again this macro cover to is they are and then we have and this do is parallel the resistor capacitor and micro cover 3 and again this resistor and macro cover t reed and capacitor they are in series.

So what we do is that first, we put a 0 junction here and put macro cover two and whatever these components are there aright this component and then I open of t is macro I open of the here so we have a r two macro cover 3 and t is capacitor in series I put a 1 junction here find after t is I can uncover t is micro cover 3 and here micro cover 3 you can see that we are inductor and macro cover 4 in parallel.

So here I just add a 0 junction inductor and macro cover 4 are put over here and

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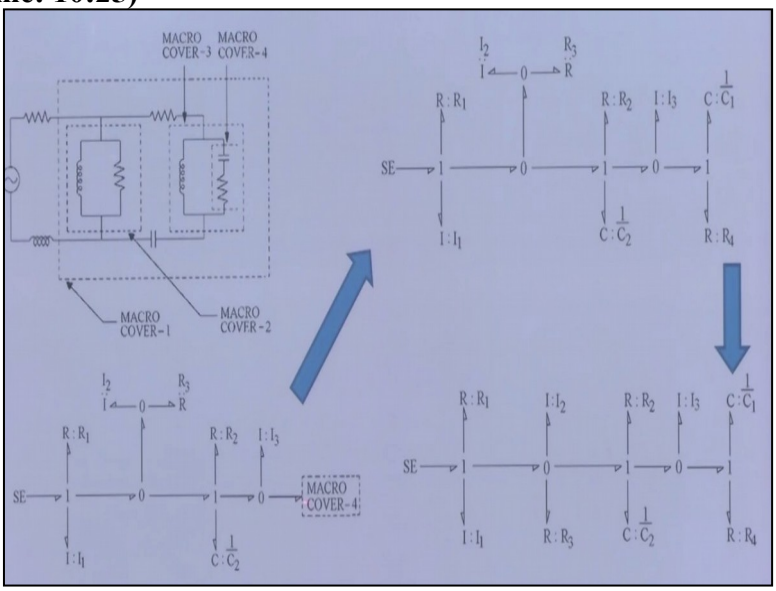

In next step we uncover then macro cover4 also so here you see that t is was the previous line and previous model now here macro cover four we are a capacitor and resistor in series. So, here again I put a 1 junction and a capacitor and resister I attach your there so the is way it completes a this one and further I can simplify by t is bond graph by the is 0 junction and 0 junction they are neighboring zero junction so I can models them these two neighboring 0 junction t is are 2 I to here and are t r ear.

So, this way we are able to draw the bond graph model of this complex system as this one and this as we done using meter do of gradual uncover

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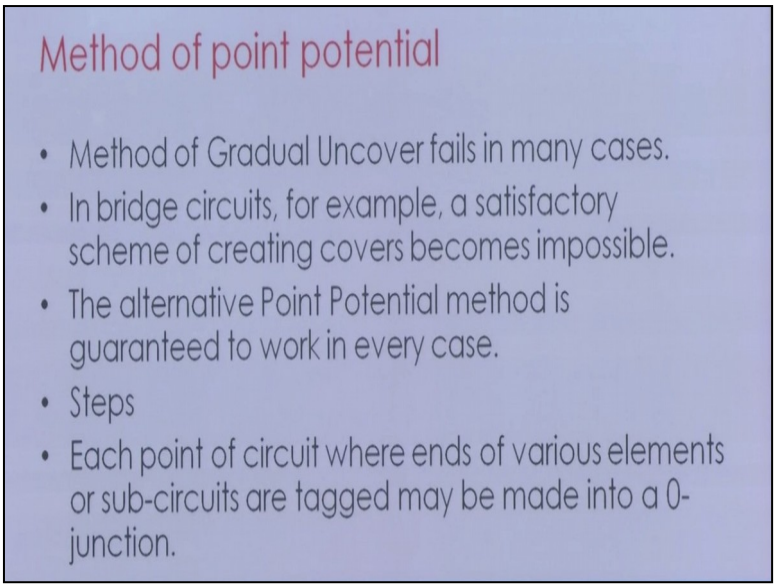

Next, let see the methods of point potential method of gradual uncover fails in many cases find for example in situation like bridge type of circuits in bridge circuits for example is satisfactory sc of creating covers becomes almost impossible.

So, we need to find out some under net way of drawing the bond graph model for such a system. So the alternative point potential method can we use to draw the bond graph model for t is type of system. Now in t is system what is done is that each point of circuit where ends of various elements are sub circuit are tagged may be made into a 0 junction so each end are of various elements are sub circuits h t hose can be tagged as are made into a 0 junction t is what is done is case point potential meter do.

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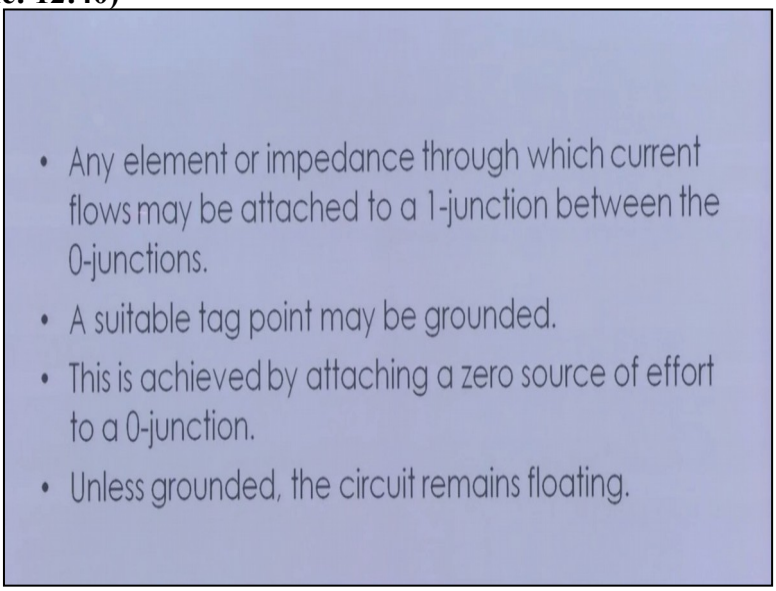

So, then any element or impedance through which current flows may be attached to a 1 junction between the 0 junctions. So t is can be done align t and a suitable tag point may be

grounded t is ac receive by attach thing a 0 source of effort to a 0 junction t is means that grounded point is subject in to a 0 volt and unless grounded the circuit remains floating is should not forget to ground and electrical circuit is otherwise now the circuit floating now each individual circuit may be separately grounded if there are many circuits then these each individual circuit may be separately grounded for example in case of transformer.

We have the primary winding and we have the secondary winding so these primary and secondary windings may be separately grounded on the both sides

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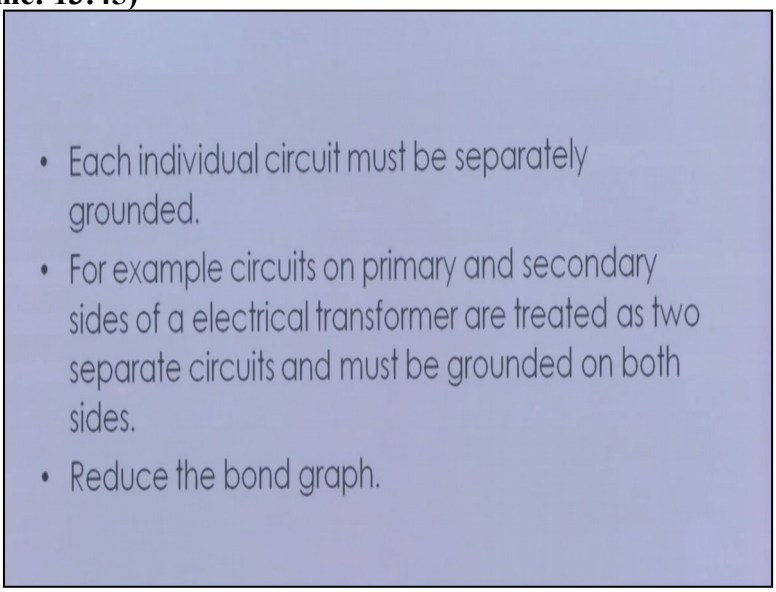

And then we reduce the bond graph. So, the is the general method for drawing bond graph using point potential method now let us taken example and see how this is done.

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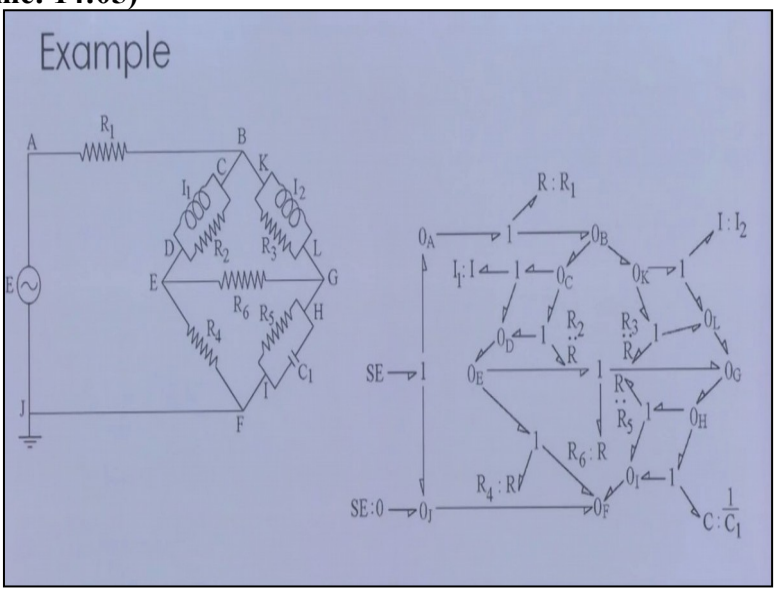

So, this our circuit say here the volt a source there is the resistor ends of the resistor r k and b and then we have a bridge here and then with various ends b e f g and here of course other ends for a b c d e f g I and. So one j the point is grounded now to draw the bond graph model for t is system I just first we identify the ends of the elements so say that resistor r is end is I mark a 0 a here 0 at other ended b so I mark 0 b then here t is end is c I

Mark 0c this end is 0 d this end is mark 0 e this f 0 f g here so 0 g here so 0 and I here so 0 I similarly here the k .so 0 k and l so 0 l so this way it is mark there end is j here. So 0 j and of course yak now you see that after marking of these in a cross these in between these 0 point we have resistor r 1 so we put ever 1 junction and attach the register r1 here. So this own it is done now you see here between c and d there is inductor I want so c and d I put a 1 junction and at this 1 junction I attach the inductor I 1 line wise I attach the resistor or two.

So I put a 1 junction here attach the r 2 here are resistor 4 is there so between e f 1 junction is put are 4 is put here between and I 1 junction is a capacitor put t is side and resistor r 5 put that side similarly between k and l inductor I 2 is put here and similarly other side between k and l resistor r 3 is put after inside in the 1 junction and here c between j and a bold a source.

So I put a 1 junction and put the sc element now put what we can do is that we can apply the ground here sc equal to 0 I am applying here and let see bond graph gets reduced.

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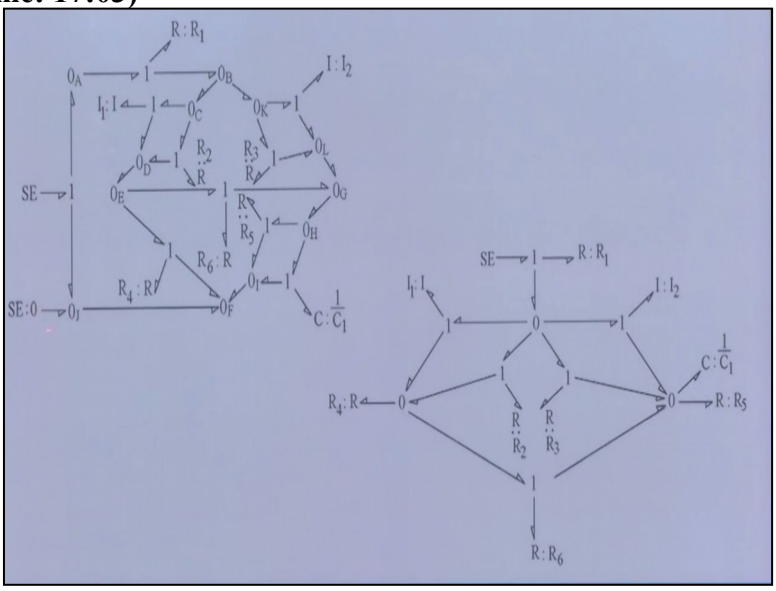

In next line am applying c equal to zero here s. Now see that w en t is subject to the 0 bold so effort in t is one is zero similarly this is a 0 junction of effort t is will be. So t is bond will be vanish again this is 0 junction so this bond vanish and t is bond also vanish and again t is 0 junction so t is bond is vanish as well t is one vanish let see we have c here 0 same power coming and going so I can remove t is 0 a see I have one or r one is here then vanish t is 0 b and form zero e or 0 b and 0 c I can merge.

So this 0 then I can put 1 junction and attained so I am doing it here similarly I can put r 2 here so for here I put and junction r 2 here and also this done and then what we have I here d and d I can this g and this 0 this gone so at the e n I can just attach what r 4 so here I can attach the r 4 attach here these two can be I have at 1 in other in r 3 and I reach here.

So this to can be must and this one I here attach again I can just attach see is 1 by c here and similarly r by r 5 I can a put it here and here in between this g and e these to I have r is equal to this are reduce to this bond graph into this form

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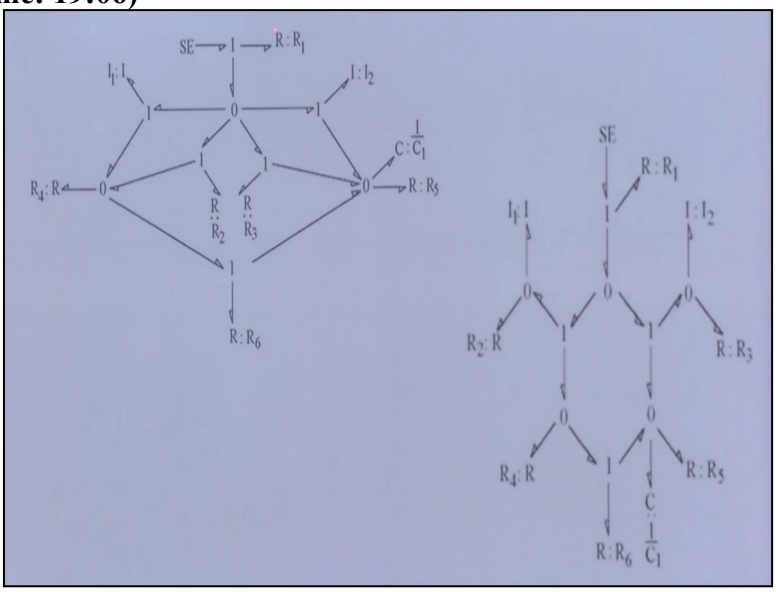

next t is bond graph further by reduces so you can see we have see and then r is r1 here and then 0 junction here and t is 1 here is a and then I have I and other r 2 I can find out find out the Voltas difference cross these to I can put to and then r here.

So, t is what doing that I putting me and r bother for going too subjected to same voltage different to find putting a zero. E here so this part is the likewise I can do force this part here I and r this gone then I can r four here form here I can come to r 6 at this 0 I have and see r

5 we Are this is what between this end 0 r 3 already I same to you so this way reduce the bond graph of into this one.

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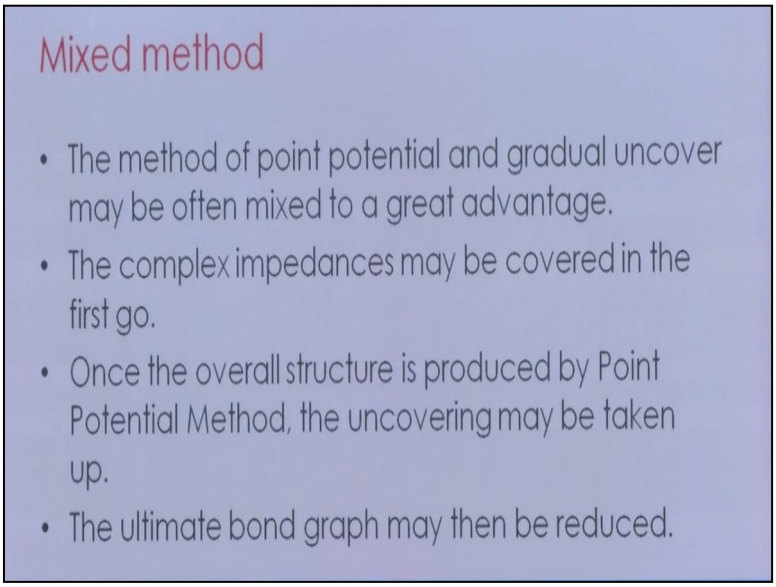

Next method is the mixed method now in this mixed met do what we do utilize more the concept that is met do of gradual uncover and method of the point potentially so the met do of point potential and gradual uncover may be often mixed to a great advantage and the complex impedances may be covered in the first go and once the overall structure is produced by point potential method then uncovering may be taken up and the ultimate bond graph may then be reduced using the consensual reduction principal.

So lets take again the same Problem and now this same problem and going to do with the help of combination of gradual uncover and method of point potential .so here you can see that whatever I do is that t is complex part I can put under macro cover on likewise this complex I can put under macro cover to and t is part I can put under macro cover three. So here what are doing is I am Appling the method gradual uncovers by cover these components and let us sees.

Now, we can go for the method of point potential so I identify the potential at point a here 0 a b here zero b and here c 0 c e and here e0 e d here 0 d and now across the elements a cross the 0 junction I attach in between one junction And attach the element they are.

So this r 1 and put as one junction attached the two r1 securely b and c b and c I attached put the macro cover 1 and b and d I attach 1 junction put macro cover 2 and between d and d and

I attach 1 junction an put macro cover 3 over here and respect of what are the thinks of the same a putting of r 6 and r 4 align t and here this f is subject to 0 grounded we have put a 0 voltage cross here .now you see that I can apply the method of gradual uncover in order to uncover the part 1 and 2 here part 1 and 3 here.

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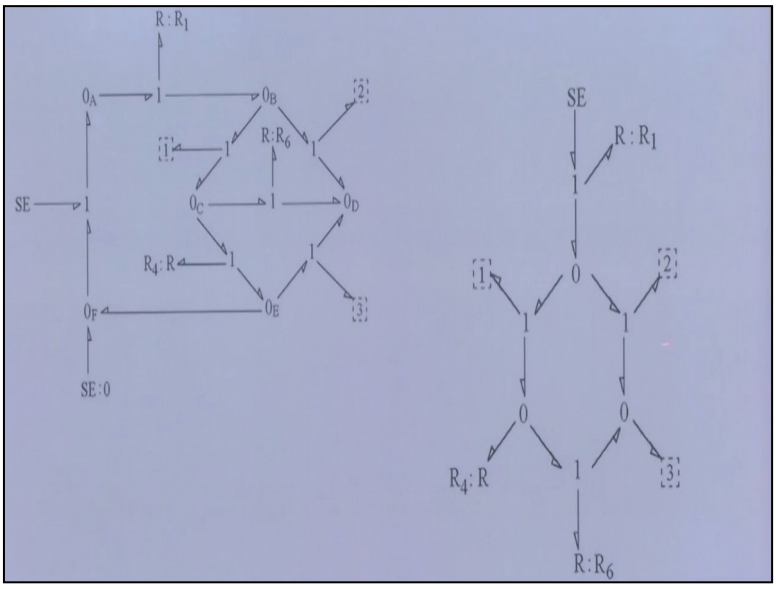

So, what I ad is two 2s simplification bond graph also so let us start from here sc one is 0 a can be eliminated because same whatever power in same is are how I remove this 0 so I have r is r 1 then I reach here 0 b and then between b and c say this 0 b and c I put 1 then c and e I put and c and e I put r 4 and e and d I put r 3 and between say c and b and I put 2. So t is what I do here fine and then after doing t is what we can do is that we can apply what we can apply the uncover met do here to uncover the is 1 2 and three.

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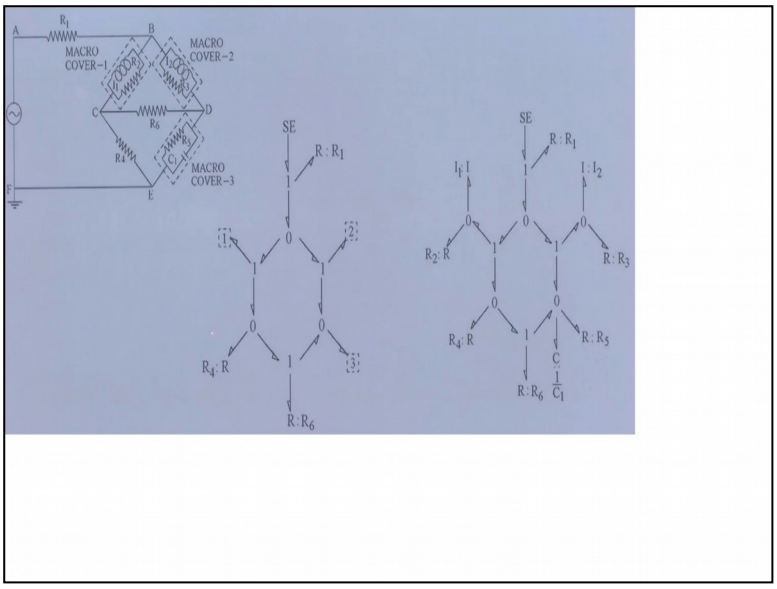

So, it is part 1 uncover to I uncover and 3 uncover and here so t is what I can do it here uncover in means is parallel put the in 0 junction attach I 1 and r2 here likewise a I can put a 0 junction and attach I 2 and r 3.

Likewise, here I can put capacitor on capacitor 0 one and r 5 and t is way I am able to draw the bond graph model for the same system using the method of the using the mix method. So this can be done then let us take an example for say modeling of an electrical motor all rig t so this is again in modeling of electrical system which we of from a cross.

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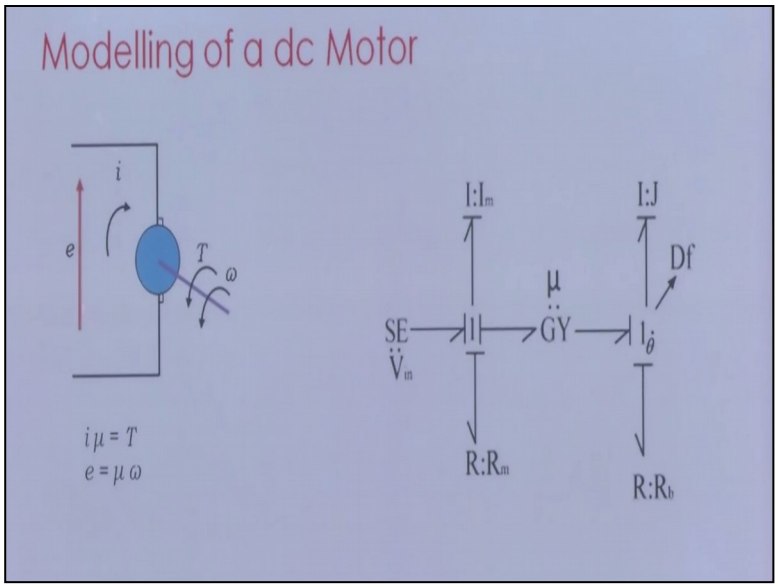

So, suppose the here this is a motor which is subjected to volte's to e all say we in and say current to this I and we have shaft here from we are getting t angular speed omega so these are the constitute relations imp the which we see toques t is I in too much this a volt as will be mu in to the blue in to w all rig t if we look at same the bond graph model of t is one. So are armature I can take it as inductor resistor in series with the volt as source so I draw I r and s e here and this relations imp basically the torque and current are related by it constant the motor so this muse I model white help character.

Element and here basically my at this torque and is here is my omega. So that is there and of course here at the and i put say of the inertia of the rooter and here i attach riser representing bearing risers and here i can put since here to since sames the say rotation now in this bond graph you see this is my say I this is my r and this is my se and here is my gig and here is one and this is your I and this your r.

So, this part is what we call basically mechanical part and is your electrical part t is muse this will be actually torque and here this is e and I in the electrical side and torque angular velocity at the mechanical side. So, from, here you can see the two will be equal to muse I and here will be the back en basically that will be mute time omega. So, t is what going to b and then we can generate the system equation for this system.

We can a right the system equation another example here is a basically since and equation both an can be model here are this explain with the help of concept what we called at is activation that is by activation what do is that we make a power bond at the signal bond.

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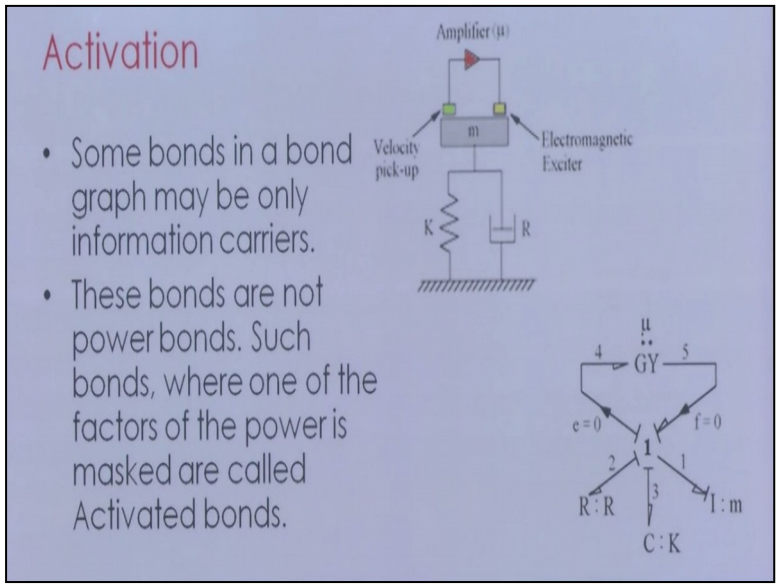

We do super one of the I the effort flow in order to making signal bond and such signal bonds can be used senses in your modeling.So, these bond are not power bonds and such bonds when we are one of the masked are call activated bonds so suppose we have spring system I want to say put this mass certain then position out it well saving a velocity pickup and amplify the velocity and then I apply the force on this mass using an electrometric exited.

So, that I able say keep I that certain position so two model this under system what we can do is this take a 1 junction are represent the velocity of the mass other 1 of the spring and her temper six will be aging jovial velocity here I put I inside then spring and then here these whatever seeing here basically velocity are flow is converted into effort we can used it generator to this model element this type of system.

So, here you can see the effort is 0 this bond so that is this is the flow only and then we amplify and that amplification the represented by modeling the putting the modal of director is mule and then it is a plane force a here. So again here we activate it effort activation for effort goes 0 here and these then we can model using the activation of the serrate element t is velocity put up and the electromagnetic exited at the same concept we can use to use to make to c element as a displace the sensor and by flow activating it and by effect activating.

I element then make it a since at the force so that solve here you this was the example which we see at the beginning of lectures on the bond graph of modeling s ape simple relic circuit is series relic circuit if it take and if you we are ask to say the draw the bond graph model of this system then it is very simple so in this series relic circuit you can see that we have old as source in series with resistor inductor and capacitor so as we as seen in the methods of drawing bond graph that first we identify what, are all the different components so here we are the source.

So, we identify the source a resistor and inductor and a capacitor .so this way be identify the sources and we s ape mark the own the power flows to this element all rig t and then we put the constant and the constant here is the same current true all the element .

So I put a one junction here and Then I case litter usual way source older source will given effort resistor will take for current and return effort inductor will take a effort and return flow and capacitor will take flow and return the effort so this way we kind draw the bond graph model of this series relic circuit next if suppose we have a parallel relic circuit is see a again seen this example at the inductor lectures and bond graph.

So here are I see or I see are the circuit parallel and these are subject to a current source so again we identify what are the source what are the elements here we have a source current of represented by source of flow we have a register represent by r inductor represented by I and the capacity represent by see now the constant here is that all the elements are in parallel so that we put here by put in the 0 junction.

Which sincerely means that the voltage a gross all the elements are going to be same and then of course as we as done all awe as a bond graph the current source will be given current effort.

So current the inductor will be talking a effort and returning of electrical part this muse this will be actually torque and here this e and I in the electrical side and torque angular velocity at the me handicap side so form here yam can see the two will be equal to muse I and here which will be the back en basically that will be mute time omega so this what going to b and then we can generate the system equation for this system. We can a right the system equation another example here is a basically since and equation both

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