Chemical Process Control
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Lecture – 47
Programmable Logic Control

Welcome come back so let us now see how we can incorporate or draw these ladder logic diagram for a simple example like this a batch mixer so what will you are going to use? we are going to use the government program of this virtual lab which is funded by ministry of human resources development of India.

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And they have this program of virtual labs and we are going to use a lab which is created by College of Engineering Pune.

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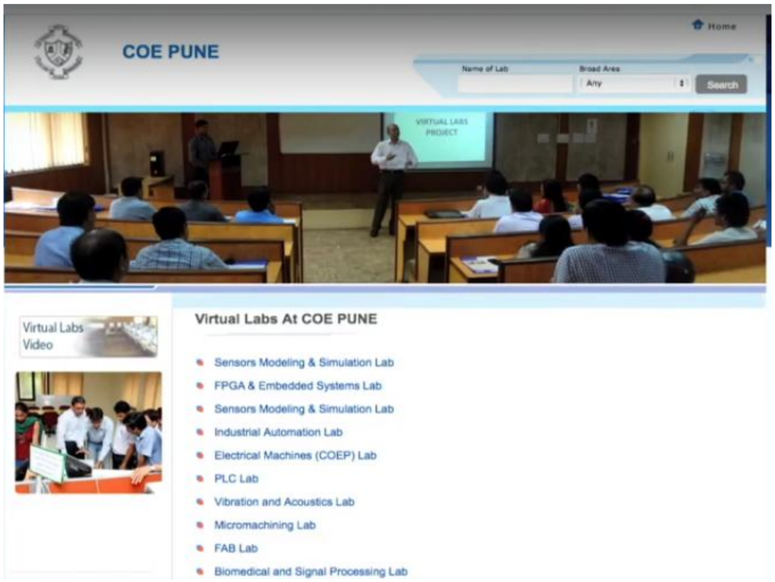

So, they have a simulator which we can use to incorporate this ladder logic so within that we can go to this PLC lab which is programmable logic control lab okay.

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We are not going to specifically go over any of these experiments we are just going to use their simulators so you can take any of these and then we will go to this simulator okay.

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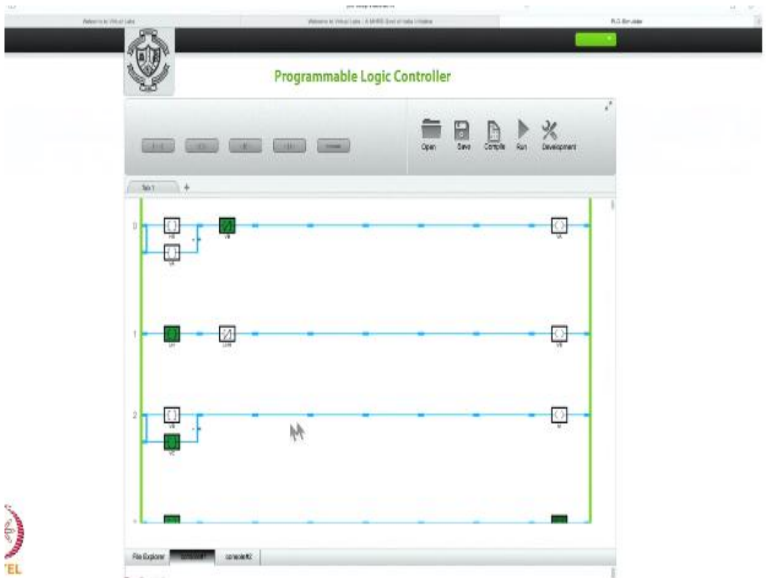

So, this is a simulator which is going to allow us to rung these ladder logic or construct a ladder logic for this particular system. So, let us start with how we want to operate this particular mixer. So, first we need to add rungs so you add different levels of actions which are going to be taking place. Let us say I have added rung 0 the first thing which you want to do is the operator has to switch on the hand switch.

So, this is the normally open contact, this is a normally closed contact, this is an output and this rung is very straight forward. So, we will just put in this here and we need to call it hand switch so in tag we will write it as hand switch and the output is going to be the valve has to open. So, when the hand switch is pressed you want the valve VA to open. Let me just save it and then compile it, if I say that its correct and then we can run it.

So, you can see that these two ends have been energized and now as this is a normally open contact unless this button is pressed this valve VA is not going to open. So, let us right click it and then when I say toggle it will make it from 0 to 1. So, when it becomes one the valve opens. Now when the operator switches on the button the valve VA opens that means it will start flowing material A but then the operator need not press the button all the time.

So, if the operator switch or remove the hand from the button the valve is closing which is not what we want we want to ensure that once the operator presses the button only once and then the valve keeps on valve keeps itself open the way you can do it is we will put some OR condition here, so we will again go to development we will add a parallel condition to this so we will say that either the operator has to switch on the button or the valve has to remain open.

So, I am putting a VA status here what it means is if the valve is open then this will become 1 so even if the operator switches or removes his hand from the button the valve will keep on open. So, again let us see whether this compiles, it compiles successfully let us run. Now let us say the operator switches on and then because of that we open and now even if the operator removes this but hand from the button

As VA is on it will keep the line going and therefore this entire path so now the path will be like this and as long as everything in that is green the output will remain green. So, by using this we have ensured that the valve VA will remain open and now as valve VA is open it will keep on making sure that the level inside of the tank will keep on filling. Now let us see what happens next so you have to add something about what happens to the level.

We will put a tag about LH. So as long as LH or level is below LH this will remain open. So, till that time VA will keep on running what we want is when the level goes above LH when this becomes 1 we want to ensure make sure that valve VB starts. So, our output for valve VB we will be here. Again save it, let us compile it and let us run it. Now again let us go from the beginning.

The operator switched on the button VA started the operator removed his hand the VA will keep on running and then after some time the level will become above LH and then VB started but now you notice that when the level became LH I have started VB but VA is also on. So, you have to ensure that when VB starts VA should not be running so that can be accomplished by putting a normally closed contact.

So, I can ensure this by putting this other type of contact here so I will put this as VB so now what this is going to ensure is that normally when VB is closed this will be complete, when VB opens this will become open because this is sort of a normally closed contact. So, let us see what this is going to do. Again we will save, if we will compile and run. So let us start from the beginning the operator switches on VA starts operator closes the button VA will still keep on running.

After some time, the level becomes 1 and the moment level becomes LH, above LH VB has started and as it was normally closed contact for VB this caused VA to stop. So, here ensured that when VB has switched on VA has become or VA has closed. Now this at this same time when VB is added we also have to add that the agitator has to start. So, we will need another rung for the agitator.

So, it will say that if my valve is open or when my VB is running if my VB is on I want my agitator be on. So, let us again trace back our activities. VA started after some time level is going to become a LH VB VA has stopped VB and motor has started. Now this VB addition has to take place till the level is below LHH. So, we will have to add that condition here that what happens when the level becomes LHH.

And that we can keep by putting this normally closed contact here. So, we will call it as LHH so what it means is VB will be on as long as level is above LH and below LHH. So, it will ensure that VB will keep on running and then what happens is that we will ensure that we have gotten all the mixing till LHH then we have to ensure that how do we remove the product.

So, we will need another rung for that and that rung what it will do is we have to see that the level has to first reach LHH. So, you will have a contact here based on LHH and when the level reaches LHH you will want your product valve to start. So, let us see now what happens and at the same time when the product valve opens that time also you want the agitation action to be going on.

So, we will have to have a parallel connection here so either VB or VC is on your agitator should be on. So, let us see what happens the operator has switched on operator removed his hand still the VA tank is filling and then after some time the level will become LH at that time VB started

VA is closed agitator also started and this will take place till the level is LHH. Now when the level becomes LHH at that time we will stop this and because of that VB has stopped.

We can see that VC has started and your product has also started. But now as the product starts this LH will go below the LHH will go below its value so it will go down and at that time what you see that as soon as it went below the level again VB has started which is not correct what we want is when level reaches LHH which it starts and it remains like that. So, in order to ensure that what we will have to do is we will have to make some additional corrections here.

So, what we will have to do is, we will have to put a condition here which says that when VB is on VC is not on. So, if I make this as VC it will ensure that the moment VC starts VB cannot start again and the other thing we have to ensure is that once VC has started it remains on. So, you will have to have a parallel branch here, which says that when VC is on I will want to keep it on.

And then this will take place till the level remains above LL. So you will also have a condition on LL. Okay so let us now see whether it accomplishes what we want, it is still correct in terms of syntax and let us run. So let us go from the beginning. The operator pushes the button VA starts operator removes his hand VA still works and then after some time the level reaches LH. So, this will toggle to 1 the moment level goes above LH you will have VB will start motor will start.

And after some time LHH will also become 1 so when LHH becomes 1 you will have VB stopped VC has started motor is still running and have the level will start falling. So, as soon as the level starts falling these LHH will no longer be level will not be above LHH. So, this will go off. So what happens is in all the time your level was always above 1 or as long as the level is above LL this was 1.

So, product has started and after the products starts these LHH will go back but as long as the level is above LL, VC will continue, the motor will continue and only when the level falls below LL your machine will stop. And the reason why you are saying this is because automatically when level is below LL that means the level is below LH as well and because of that the entire machine will be off.

We can see that by using the simple ladder logic the computer or we will be able to accomplish this set of logic in order to ensure that the batch process the sequence and the logic inside the batch process is conducted. So, what we saw here is that even though I did not specifically mention logic inside it essentially what we have incorporated are different logic gates.

Whenever you have a connection where things are in series along a single rung this all means an AND condition. So, in order for this rung to be active this has to be satisfied and this has to be satisfied and this has to be satisfied. So, all the conditions which are AND would be along a single line of a rung whereas anything which is parallel here that indicates an OR condition that either this has to be satisfied or this has to be satisfied.

So, that the path goes like this or the path goes like this. So an OR condition AND condition is incorporated like that and by using a normally closed contact you incorporated NOT condition.

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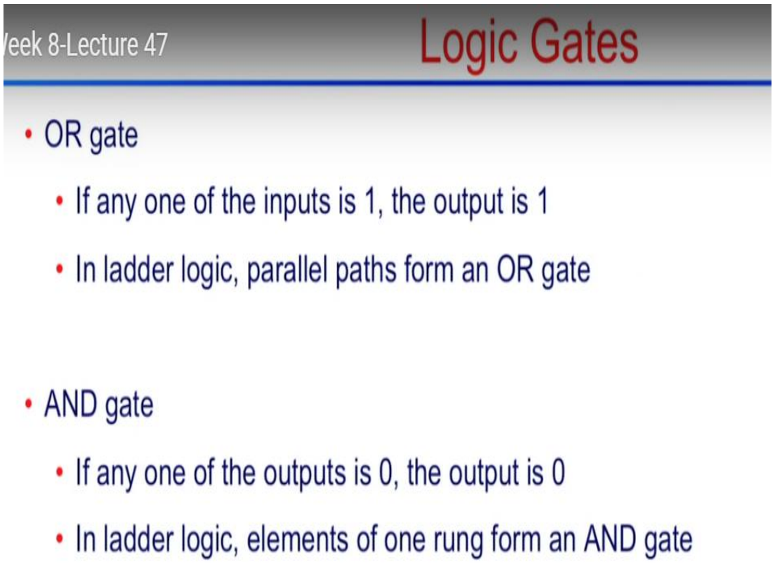

So, that is how these basic gates like OR gate AND gate and NOT gate can be implemented.

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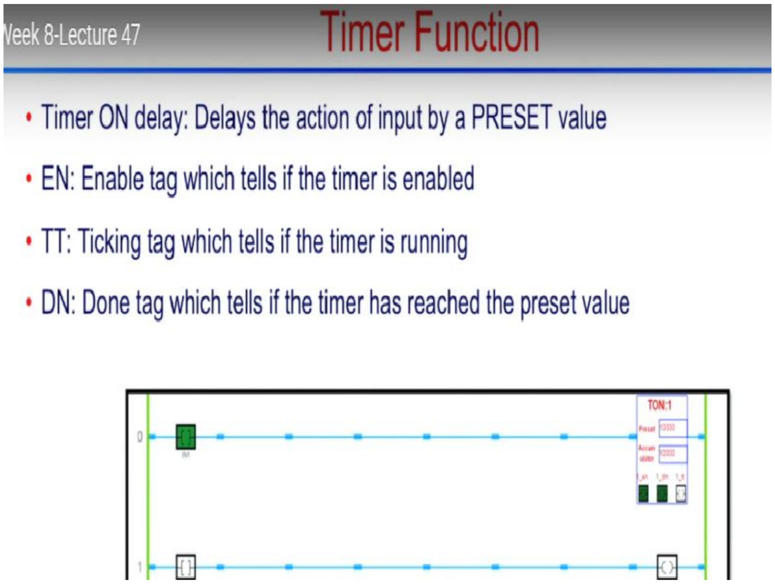

Along with that PLC programmable logic control allows you to add the timer function which tells you when a certain condition is satisfied it will start counting in real time and you can do some action when the counter is running so when it is TT it means some action has to be done during that much amount of time or you can have a separate action when the counter is done. The example for this is let us say a particular product purity goes beyond desired value.

Then it tells me that I have to take a certain action within the next 5 minutes so during those 5 minutes this TT will be on and some action will be done and when the timer is done after 5 minutes what sort of action has to be done that can be incorporated here. So, time based actions can also be incorporated using a PLC.

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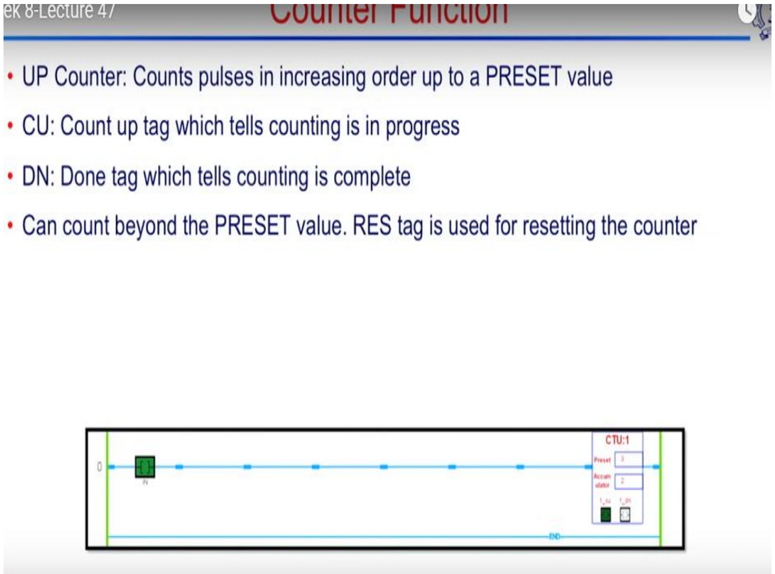

Some discrete events can also be captured this example of that would be sort of a breakthrough inside adsorption so if a certain product breakthroughs you do not want the multiple breakthrough through that adsorption column after a certain amount of breakthroughs we would want to take the column offline. So, those sort of discreet actions can also be done by using a counter function.

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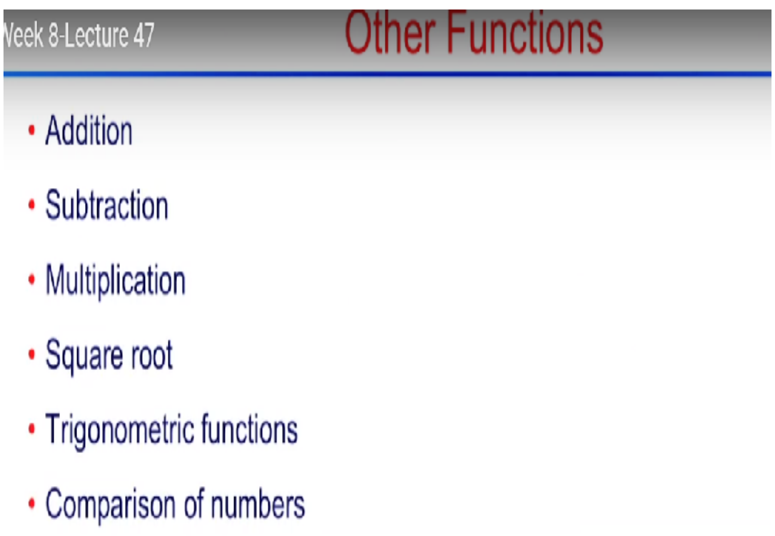

And then other simple mathematical functions like addition subtraction multiplication doing a square root trigonometric functions or comparison of numbers can also be incorporated using PLC's. So, now you can see that a lot of control logic and also be done using this kind of a scheme and that is why it is known as a programmable logic control. So, you can really program the sort of logic or control you want to do inside your process. So, let us now take a real example here.

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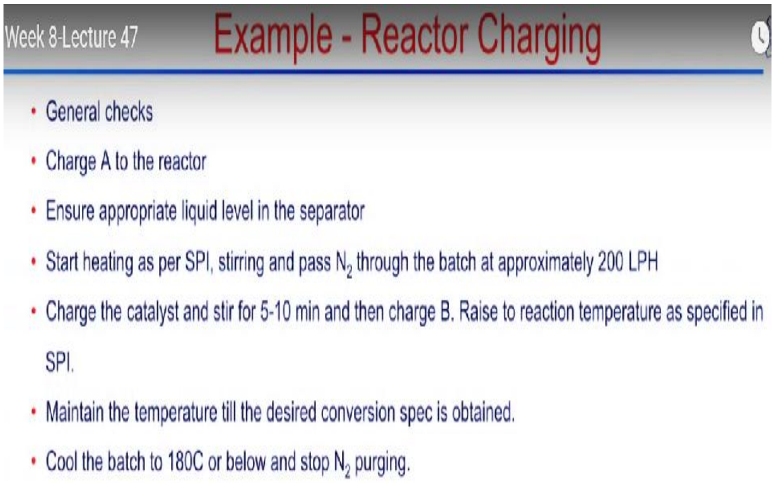

So, what I am going to show you now is a recipe for a real batch and in the interest of confidentiality I will not tell you what that process is but I have just copied the exact steps which are listed for that particular recipe which reads like this you have to do some general checks and then charge A into the reactor ensure appropriate liquid level in the separator then start heating as per the standard procedure while stirring.

And pass nitrogen through the batch for at approximately 200 litres per hour then charge the catalyst for 5-10 minutes and then charge B raise the reaction temperature to the value specified in SPI maintain the temperature till the desired conversion is reached and then later on cool the batch to 180 degrees or below and stop the nitrogen purging So, that is an actual extract from a batch recipe.

So, let us know see how does that relate to the sequential and logic control I will go through all of these steps one by one so when I say general checks it means you have to the operator manually checks whether things are in order. Let us say reactor is empty the pressure is a appropriate temperature is appropriates all those things can also be done via a sensor. So, all those general checks would be sort of a process and safety interlock which I talked about that.

In order to sometimes the before feeling a particular raw material you have to have some sort of nitrogen purging inside the reactor. So, all those general checks will be part of a process and safety interlock.

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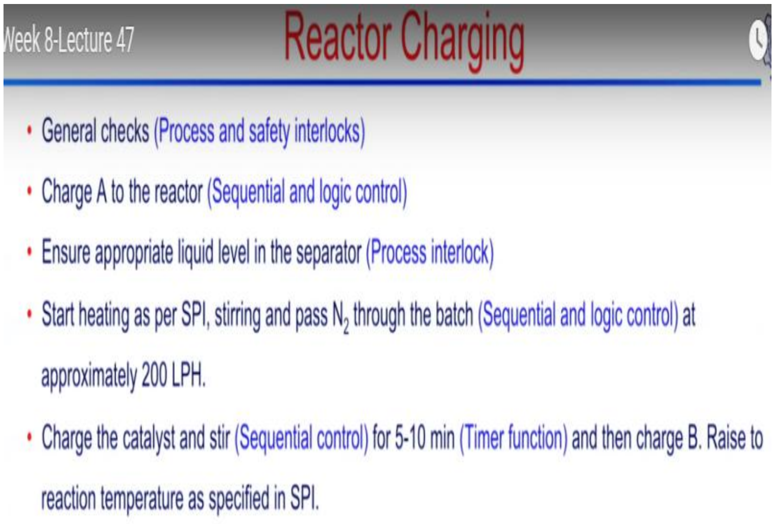

Then there is charge A to the reactors so that is a part of sequential and logic so you are introducing a sequence into a process like we did for the mixer. Then ensure appropriate level in the separator that is part of a process interlock then start heating and then you have pass nitrogens all these sequential steps would be part of this sequential and logic control then charging catalyst and stirring again we saw those are all sequences up to a certain time.

So, the timer function will come in here and then you want to maintain the temperature till a conversion is reached there is some process related specification so there is a process interlock there and then you cool it again and then stop nitrogen purging so again there is a sequence so all these actions which you have seen a lot of things you can see there is this process and safety interlock or sequential and logic control.

And some of the things I have skipped because those will be the part of the next part of batch control so that is how the first type of batch control would come in in terms of sequential and logic control. So, once things are up and running.

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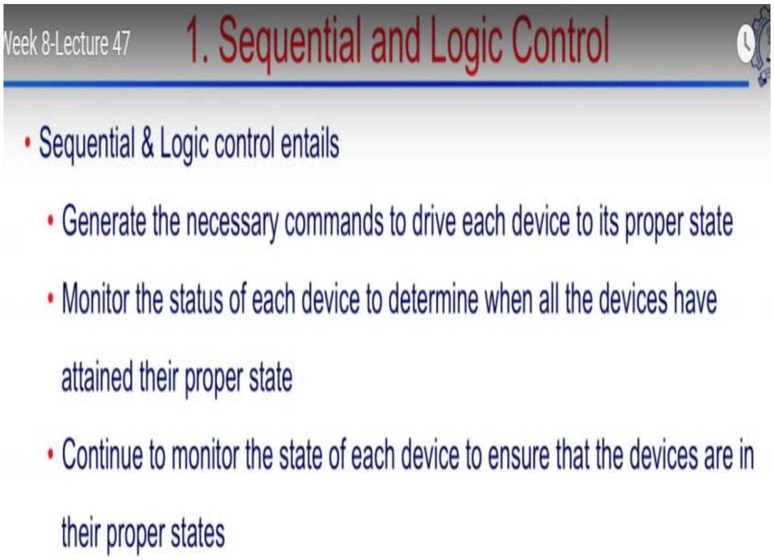

Then you will, so within that what this sequential and logic control does is it will generate the necessary commands to drive each piece of equipment from one state to the other it will ensure that it remains there and it will also monitor the status of the process.

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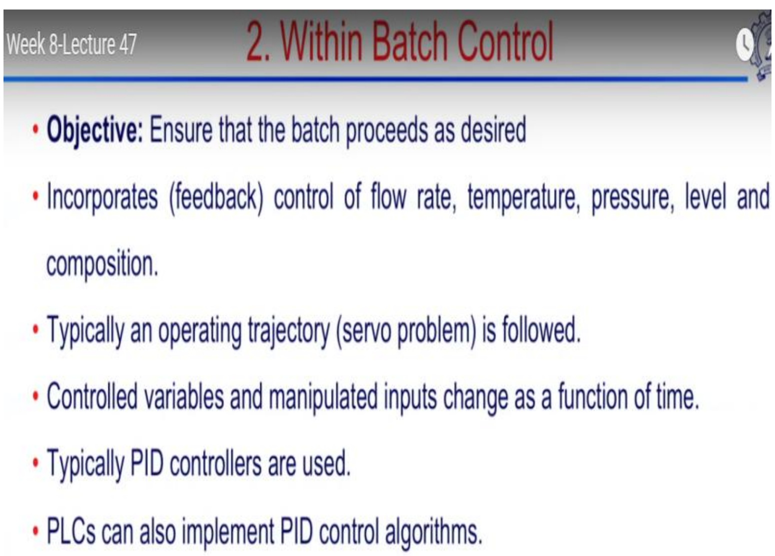

So, once that step is done then what? then we reach the next part which is known as within batch control. So, what it does is, so now if you go back to the figure which I had shown you earlier in terms of start-up operational phase and shut down so now we have finished the start-up and then we will reach a phase inside a batch where things are more or less steady you have to maintain a certain set of condition.

So, that portion will be taken care of by this fiction of within batch control if you want to do an analogy with the continuous process that is exactly this is this part is very similar to how a continuous process control works that things are more or less steady in terms of the process variables or you are just maintaining things there. So, this this part of the controller or batch control.

We will incorporate these feedback controllers for flow temperature pressure level and sometimes composition here again a difference between a batch process and a continuous process is that in a continuous process most of the times you would be dealing with a regulatory control where you would want to reject a disturbance and maintain steady conditions in batch process a lot of times servo control also plays a key role.

That you want to increase the reactor temperature from current value to the final value a lot of times a batch recipe has a different segments that you increase the temperature within a certain step. So, all those would be part of a servo control so a lot of times Servo controllers are also present this will be accomplished by using PID controllers which we have already seen and all this is incorporated within a programmable logic controls like we saw earlier.

So, there are no different controllers for sequential logic control and within batch control all of those are incorporated in a PLC.

Now in terms of challenges how does this within batch control which looks very similar to a continuous process differ from a continuous process? so one thing is that in a batch process things are never steady things are always changing even though I am saying that with the

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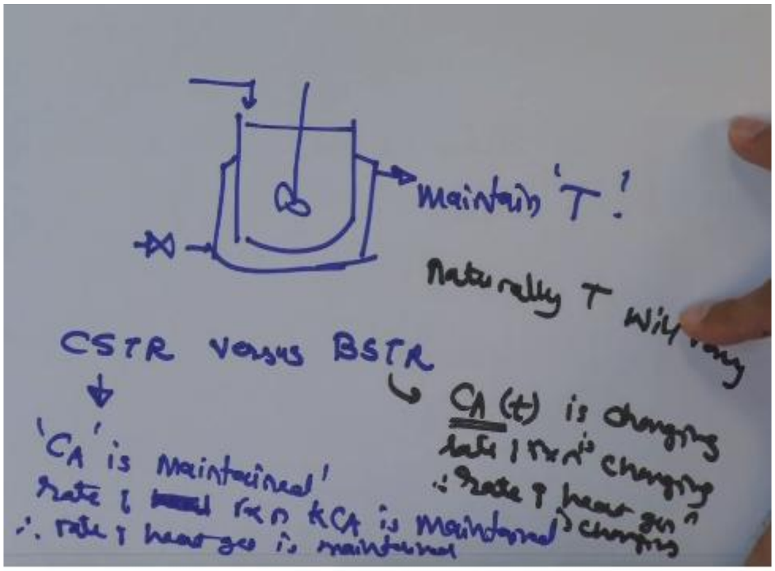

Let us take an example that there is a reactor and now it is a batch reactor and it has reached the within batch control part and you have to maintain temperature. You have to maintain the temperature by passing the coolant or cooling water and we will be comparing how a CSTR control and the batch stirred tank reactor control will differ. For a CSTR when you want to ensure the temperature what you also know is that CA is constant CA is also maintained.

So, rate of heat generation, so rate of reaction which is let us say kCA for a first order reaction is maintained and therefore rate of heat generation is maintained. So, what I mean is in a CSTR when you want to maintain the temperature all you have to do is unless there is some sort of a disturbance which is affecting the process this temperature naturally would remain or would be maintained and only those disturbance will have to be rejected by the controller. But same is not the case for a batch reactor.

So, in a similar batch reactor what is going to happen is as a function of time CA is changing. Even though there is no external disturbance as the batch is a dynamic process you are not adding anything continuously. So, the as the reaction proceeds CA will keep on changing and therefore rate of reaction is changing and therefore rate of heat generation is also changing and therefore naturally T will vary irrespective of an external disturbance.

So, this disturbance is sort of an internal disturbance because of composition or reaction. So, the controller will continuously have to work in order to maintain the temperature so that is the major difference between a continuous process and the batch process that in a batch process things are not steady and even a simple looking regulatory control would also be a little tricky or for a batch process.

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Lot of times in a batch process you move from a starting point which is far different from the final point and if the process is nonlinear the assumption of linearity or the approximation of linearity does not work and therefore the application of linear controls theory would be very limited when it comes to a batch process. So, if you are going from to 1 operating point to the other operating point which are far away.

Then even the PID controller will not the tuning for the PID controller will also have to be change during the course of the batch process. The other thing is a lot of times in a batch process when you mix things there is not much you can measure or you can do as the batch is progressing. An example would be if you have the similar reactor then the reaction will be going on and only when the reaction is over then the product will be withdrawn.

So, in order to measure the composition the sample will be taken either at the end of the batch or sometimes in the middle of the batch so you do not have continuous monitoring of the process and that also reduces the effectiveness of the control unless you get a feedback from the process you cannot take any action. So, limited feedback in a batch process is also one of the concern or one of the challenge for a control system.

And lastly a lot of things these batch processes the behaviour is irreversible that whatever action has happened you cannot reverse that most of the time you have to just discard the batch and start with a new one an example would be let us say a crystal size distribution in crystallizer or molecular weight distribution in a crystallizer. So, what a in a polymerization reactor so what is going to happen is the moment you have some measurement at the middle of the batch.

And you see that there are lots of crystals which are big there is no way for them and for you to break those crystals and then have smaller crystals. So, lot of times these behaviours in the batch are irreversible and you end up having very limited amount of manipulation available or possible within a particular batch. So, even though it looks like this particular phase of a batch process is similar to a continuous process.

There are additional challenges when it comes to within batch control for a batch process. So, let us now go back to our example of a real life example I said about a batch process and try to see how within batch control objectives are part of that same recipe.

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Reactor Charging

- General checks (Process and safety interlocks)
- Charge A to the reactor (Sequential and logic control (flow or level-based))
- Ensure appropriate liquid level in the separator (Process interlock)
- Start heating as per SPI, stirring and pass N_2 through the batch (Sequential and logic control) at approximately 200 LPH (flow control)
- Charge the catalyst and stir (Sequential control) for 5-10 min (Timer function) and then charge B. Raise to reaction temperature (temperature control (servo)) as specified in SPI.
- Maintain the temperature (temperature control (regulatory)) till the desired conversion spec is obtained (Process interlock).

So, general checks was process and safety interlock and then within this fourth step what you have is pass the nitrogen at approximately 200 litres per hour. So, in automation what is going to happen is there will be a flow controller and that flow controller will maintain the flow of nitrogen at 200 litres per hour. So, there is a set point associated with it so this is a within batch control similarly the next thing is after the catalyst is charged.

You would increase the reaction temperature from the initial room temperature to a certain reaction temperature. Let us say it is around 200 degrees so there will be a temperature controller and here it is a servo control. It is not a regulatory control you are increasing the temperature set point change it is going from room temperature to some reaction temperature around 200 degrees.

And then again there is a temperature controller but this time it is a regulatory control you will want to maintain that temperature at that higher value till a certain conversion is reached which is a process interlock and then again there is a temperature controller this time it is a negative step change in terms of the set point you will cool it from the reaction temperature to 180 degrees or below.

So, again whatever is highlighted in the red all those are the within batch control objectives here.

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So, that is how the first two steps of a batch process control will come in a one is a sequential and logic control which will make it take it from start-up phase to the operating phase and then the things will be maintained at that stage by using within batch control we will take a short break here and when we come back we will look at the remaining two task for a batch process Thank you.