Chemical Process Control
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Lecture – 39
Split Range Control and Override Control

Welcome back. Let us now look at the second and traditional advance control strategy, split range control.

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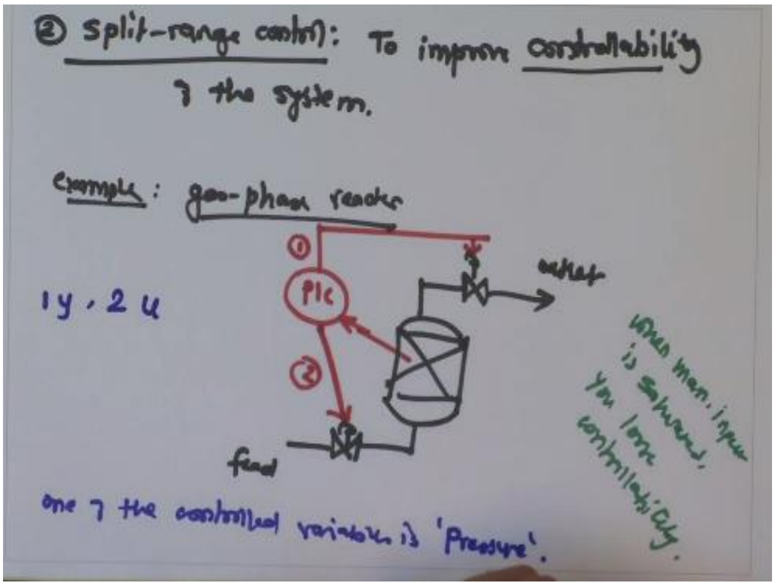

So split range control strategy is implemented to improve controllability of the system. So I am just using a very crude notion of controllability. Controllability has a very deeper meaning if you look at the literature of process control or in general control theory. What I want to represent by this is that you want to improve the range of disturbance across which you want to make the process to remain controllable.

So let me explain that with an example. Let us take an example of a gas phase reactor. This is the outlet, and this is the inlet and to control the inventory of this reactor we would have to control the pressure. So one of the controlled variables is pressure. Now if we go back to our lectures in the last week, you can see that there are two primary options in which I can control the pressure.

One is, I can control the pressure by using the outlet valve, by manipulating the outlet valve, such that if the pressure increases I will open the valve more so that more vapor goes out of the system. Or I can use the feed valve to control this pressure in such a way that if the pressure goes above the setpoint value I can reduce the amount of feed going into the reactor.

Typically, when we select the pairings between input and output, you want to have minimum effect of this pressure control or the inventory control on the actual operation of this process. So the actual operation is a reaction, and you typically control the feed. You use the feed valve to control the throughput of the system or how much material is getting processed.

You typically would want to control this pressure by using this outlet valve so that it does not affect the operation of the reaction or the productivity of the reactor. So you have a pressure controller which will be used to control the outlet pressure. So under normal circumstances, this is how this pressure controller will work if the pressure slightly goes above the value, this outlet valve will open.

If the pressure starts to drop you would want to close this outlet valve so that the vapor inventory inside this reactor is maintained. Now let us consider an abnormal situation that the reaction inside this reactor is going into a runaway so that a lot of vapor is getting generated and because of that the pressure keeps on increasing. So now as the pressure increases you will open the outlet valve.

But there is a limit up to which this outlet valve can be opened. So the maximum it can go is when this valve is completely open. In that case, it will have a certain open resistance, and then all that resistance will be dictated by how much vapor this gas or this line can carry. So when the valve is completely open, it is as good as that there is no valve and the entire pipeline is taking this vapor out.

But as they are considering a runaway situation where a lot of vapor is getting generated in this system it may not be sufficient to maintain the pressure inside this reactor or the pressure will keep on building because there is no way you can manipulate the pressure anymore. So you have lost the controllability because the manipulated input is saturated.

When manipulated input is saturated, you lose controllability that means your controller no longer can do anything to prevent this pressure build up. Now the other way you can improve this response is, to reduce this additional vapor generation because of this runaway reaction you can cut down the feed.

As the pressure has gone beyond my control limit and the outlet valve is saturated, in such a case to ensure the safety of this system I can start cutting down the feed flow. As the amount of reactant which is going into the reactor is going down, the rate of reaction will go down, and the amount of vapor generation will go down and eventually it will close down the feed.

This way reactor does not have any input, all the material which is already there will find an exit path through this outlet and eventually you would be able to maintain, or you would be able to restrict the pressure build up to a satisfactory limit. So here what we are doing is to control a single control variable which is pressure we are going to use two manipulated inputs.

So you have one output and two inputs, but they are not simultaneously working. So what we are doing is initially you would want this pressure to be controlled by using the outlet valve, you do not want this pressure to be controlled by changing how much raw material is processed.

So most of the time this controller will be using manipulated input as the outlet valve and only when it gets saturated you would want the other manipulated input to come in so that you can still maintain or increase the range over which the pressure can be controlled. By using such a strategy, you are going to improve the performance of this system to any unanticipated large disturbances. So here the way this control strategy works is you would split the control action between manipulated inputs.

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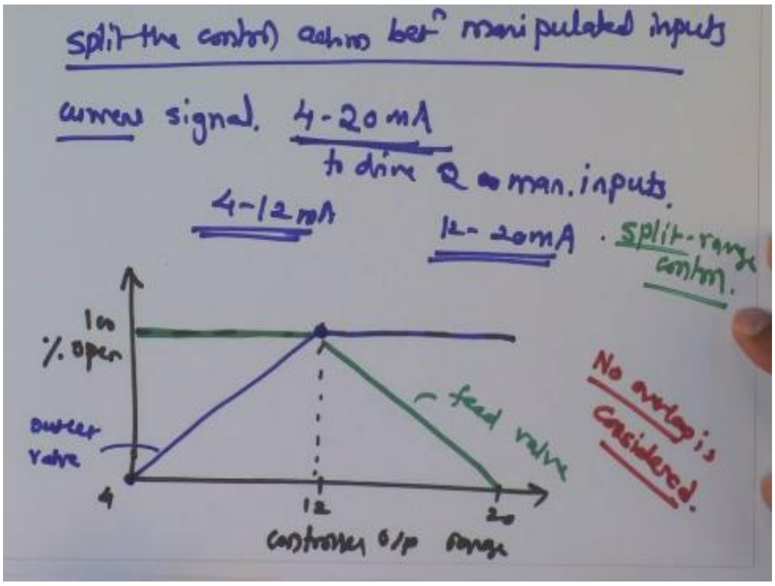

So how do we split this automatically? You can recall that when your controller gives a signal to the manipulated input, it goes as a current signal. Earlier it used to be a pneumatic signal; nowadays the standard is to use a current signal which is between 4 to 20 milli amperes, wherein 4 milliamps says the valve should be at its 0 state and 20 says the valve should be at the other extreme state.

So if it is fail-close type of valve, at 4 milliamperes it will be completely closed, and at 20 milliamperes it will be completely open. So here we are going to use the same range to drive two manipulated inputs. So to do that we will have to split this range. So we can split this range as 4 to 12 milliamps and 12 to 20 milliamps. So one valve will operate predominantly during this range, and the other valve will operate during this range that is why it is known as a split range design.

How is it going to work? So this is controller output range. So This is 4 milliamps, then 12 milliamps, and this is 20 milliamps, and here I show the percentage opening for the two valves, where this is 100%. So now what I want is initially we would want that during 4 to 12 milliamps the pressures should be controlled by using the outlet valve.

So when the pressure is 0, the outlet valve should be completely closed. When the control signal is at minimum, and when it reaches halfway range you would want the outlet valve to be completely open. So this is my outlet valve, and then after that, it should always remain open during which the other controller is active.

When the outlet valve is controlling the pressure I want my feed valve to be completely open and only when it is saturated at that time we would start cutting down the feed flow, so this is my feed valve. So you can see that the feed valve is operational only between 12 to 20 milliamps and during the 4 to 12 milliamps the outlet valve is active. So we are actually splitting the control range into these 2 controllers.

And here we are considering that there is no overlap. But it is not necessary, we can also do a design where there is a fair amount of overlap between these 2 actions, so this outlet valve may go between 4 to 14 milliamps and in the feed valve might cut down from 10 to 20 milliamps. So all sorts of options are possible. So here it was just an example where I did not consider any overlap. Let us consider another example to illustrate this.

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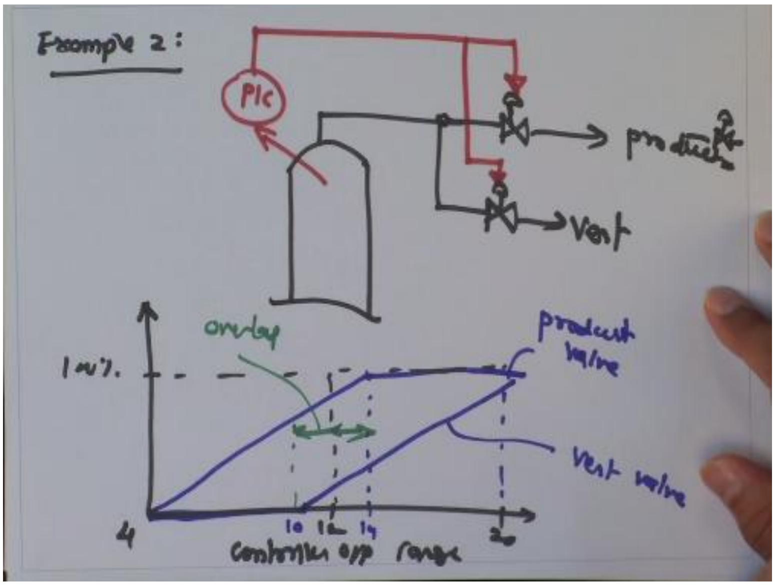


So let us consider the top of a distillation column and we want to control the pressure so in that case this is a gaseous product. This is going here and the pressure can be controlled by manipulating the product flow. Now this product goes to another customer many times or at least the example where I am considering it goes to another customer and then the customer may have his own valve on the same line.

The customer may have another valve on the same line and if he closes this valve then irrespective of whether we open this valve completely or not you will not be able to maintain this pressure because when you have 2 valves, one is open and other one is pinched effectively the net resistance will happen on this customer valve and then you will not be able to control the pressure.

Typically you also have an additional line which is known as a vent line. if such a situation happens that the customer is actually pinching the valve and it is not giving you a good control then you can have a split range control design where, if the pressure is not getting regulated because of the product valve you will use the vent valve.

Now under normal circumstances, you would not want to use the vent valve to control the pressure because this is a loss of product. When you are venting the product, you are not getting any value out of that. So this action should only happen when this controller is saturated. So if I want to do this, I want to show you how the split range will happen here. So controller output range again we are at 4 to 20 milliamps, and this is 100% opening.

What you would want under normal circumstances is the product valve to be used to control the pressure, and then the vent valve should be closed and in such a case let me also show you the design where you can have overlap between the 2 actions. So let us say that between 4 to 14 the product valve is going to be used as a controlled variable and after 14 it will remain constant.

So this is product valve, you do not want the vent valve to be open between 4 to 10 milliamps, only when this product valve is close to saturation, you would start opening the vent valve, and it will go up to 20 milliamps. So this will be vent valve. So you can see that here the action, the split range is slightly different than the previous case so that here you have two parallel lines rather than 1 increasing other decreasing.

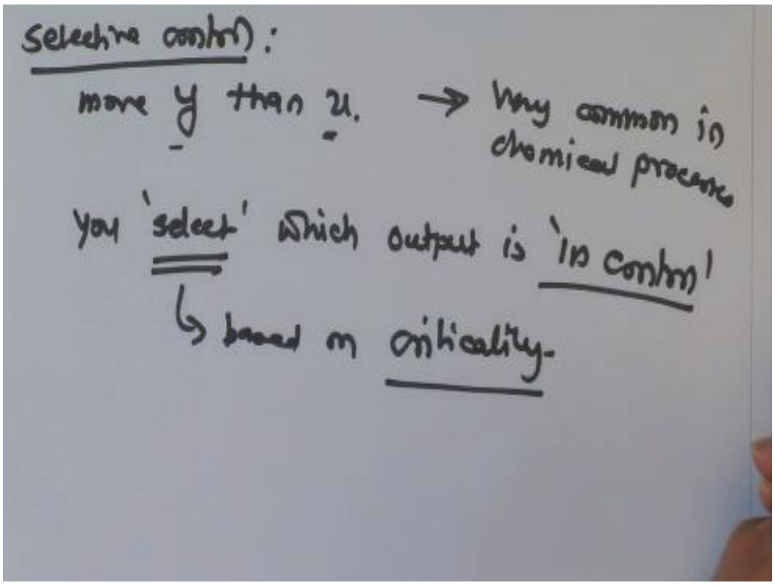
And you also have a degree of overlap. So this between 10 to 14 you have an overlap of actions. So you can see that between 4 and 10 only the product valve is in action between 14 to 20 only the vent valve is in action and between 10 to 14 both the valves are in action. The reason why you want to have an overlap is towards the end of this control range one valve is almost closing, and the other valve is opening, and typically there is very less change in the flow.

Typically, the valve will not start allowing any flow until the valve opening is 10% to 15%. So to allow for that much change to happen, you typically go with an overlap. So even if here up to 12 you are saying that the vent valve is opening the vent flow would not have increased much and here this would have mostly plateaued, the product flow would have plateaued out.

Essentially when this product valve is completely saturated then only the vent valve will open and to account for this opening and closing these ends where the flow does not change much you would want to have an overlap. Similarly, there are certain cases where you can also have a dead band where up to a certain range you do not want any control action to be taken, and that is done when these 2 actions are mutually exclusive.

So you do not want any mixing between the 2 actions. A very commonly used example here is a batch reactor where you use the same jacket for heating as well as cooling. So up to a certain range, you would use the hot fluid or steam as the manipulated variable to increase the temperature and then towards the later range you would use cooling water and you do not want to mix steam with cooling water.

In such a case as protection, you generally have a dead band where no control valve is operational. So you can also have a dead band inside this split range. So that is about the split range control. **(Refer to Slide Time: 17:47)**



Let me now consider the next type of advanced control strategy which is selective control. It is opposite compared to split range control. So in split range control, we had multiple manipulated variable to control a single controlled variable. In selective control, you have more controlled variables than manipulated inputs. So in such a case, you cannot pair all the control variables with the manipulated inputs, and this is very common in chemical processes that you have a lot of control objectives.

But you would not have that many handles into the process to control all of them. So what we essentially do is we try to keep one so you would want to control only the key output. So you select which output is to control, and this selection is based on criticality. So what you have is whichever control variable is critical you would manipulate it using the manipulated variable, and only when the other controlled variable becomes critical, you will shift the controller from one variable to the other. So let me explain this through an example.

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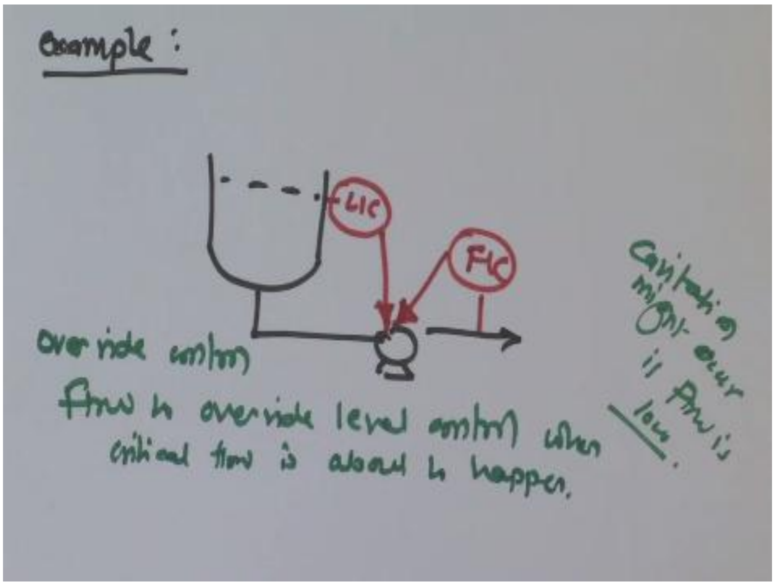

So let us consider that you have a tank where you want to control the level, and there is a pump at the outlet. So you can change the flow and accordingly you can control the level. Usually you have a level controller, and then that level controller will change the speed of this pump, and if the level goes beyond its set point value you will increase the pump speed so that more liquid is pumped out and vice-versa.

So under normal circumstances, you would want to control the level inside this tank. However, it might happen that if the level is very low, it will try to reduce the pump speed and then the outlet flow would go to such a low value that the pump cannot push out that much low flow. What we would end up with is a physical limitation in terms of minimum flow, we also call it as cavitation, if the flow is low.

To avoid such a case, you would also want to maintain the flow above a certain minimum value. Under normal circumstances, the speed of the pump should be manipulated by the level and only when this flow goes to a very low value which is dictated by the safety limits you would want this flow controller to take control of this pump speed.

So the way you can incorporate that is by using what is known as an override control. So you want the flow to override level control when critical flow is about to happen. So what you would do in such a case is that, let me redraw the same figure.

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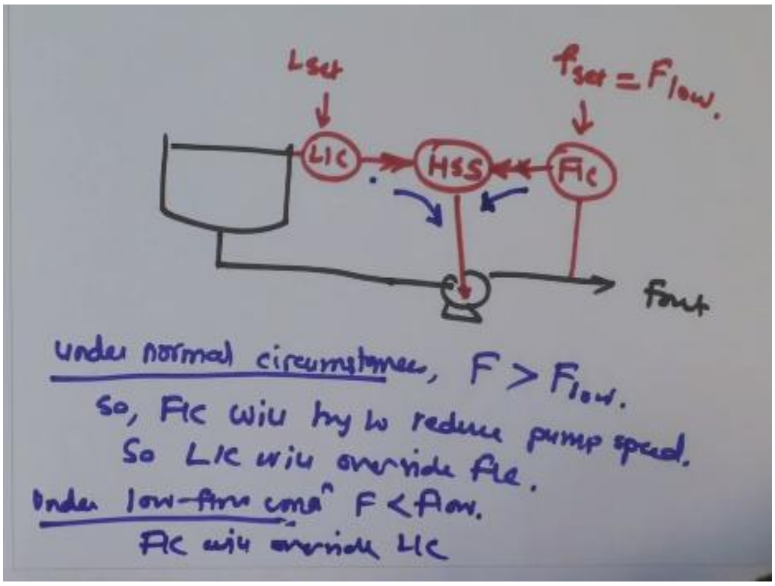

You have a level controller which is going to give me some signal. We also have a flow controller which is going to give me a signal. This is the set point level and the set point for the flow is whatever is the low flow which is supposed to happen from a safety point of view which is acceptable and then accordingly it will also give you an action, and you will select whichever is the highest action among the two and then that will be translated to the pump.

So under normal circumstances, as the outlet flow is above the minimum flow value what this flow controller is going to tell me is that my current value of flow is higher than its set point, so it will try to reduce the speed of the pump. So under normal circumstances my F > F low. So FIC will try to reduce pump speed. So the output of this will be lower than the output given by the level controller as we are using a high selector switch this action will carry forward.

So LIC will override the FIC. So under normal circumstances, the level will be in control, and it will manipulate the speed of the pump. Under low flow condition when the flow goes below F_{low}, the output of the flow controller will try to increase the speed of the pump and because of that it will have the higher value, it will take control.

So FIC will override LIC so that it will prevent any cavitation of the pump. So by using this high selector switch, we can control both levels as well as flow above their respective values. So, in this case, you can see that level is a primary controlled variable and the flow has a set point which is driven by the safety conditions. Let us consider a more interesting example here.

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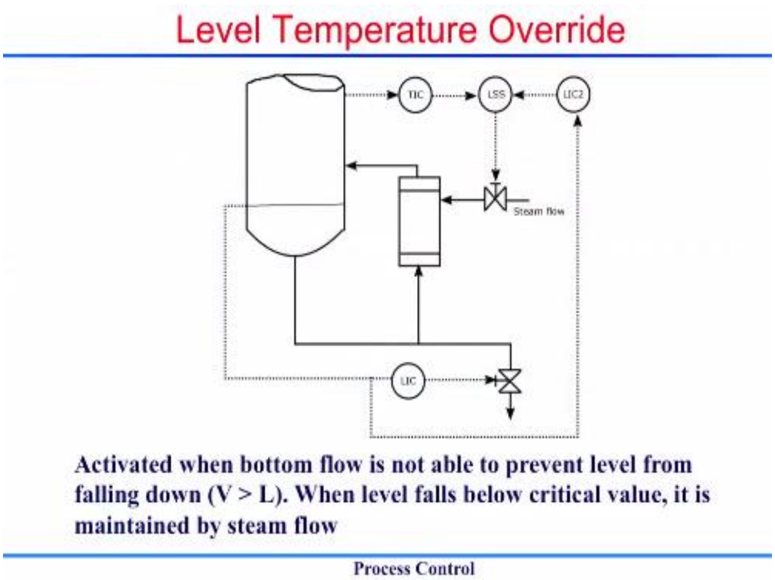

So here is a distillation column and at the bottom of the distillation column you typically control this level and it is also known as the sump level. Here we are considering a control situation where you want to control the bottom's purity by using the steam flow. So steam is used to control the bottom's composition and then the level is controlled by using this product flow.

So in this example let us consider a case that this level keeps on falling and that is happening because you are vaporizing more amount of liquid and in such a case as you are having a level controller here which is using this outlet valve. The maximum it can do is it will close this valve. Now if you close this valve, all the liquid is going to go here, but still, if you are vaporizing more stuff than what is brought down from the level above it is not going to maintain the level.

In such a case what you have is a secondary level controller which will have a set point which is given by this critical level value. Only when the level falls below critical value, this controller will give you a lower value of steam flow and then because of this low selector switch even though the composition controller is asking for more steam to be put into the reboiler this level controller will take action and it will reduce the steam flow.

As you reduce the steam flow the amount of vapor which gets generated will reduce and accordingly the level will start building up in the tank. Now note that the level controller set point here will be a typical operating point, and this level controller will have a set point which is given by the critical limit. So this controller will take action, or it will override the composition control here.

I am showing it as a temperature because typically you would control the composition by using some reference temperature. So under normal circumstances, the steam flow will be manipulated in response to any fluctuations in this temperature, and only when the level keeps on falling below the critical level, you would want this level controller to override this particular composition or temperature controller.

So you can see that this selective control or override control allows you a trade-off between 2 controlled objectives depending on the severity and that is why it is known as the selective control. So we will take a break here, and when we come back, we will look at the other control strategies. Thank you.