Process Control and Instrumentation
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Lecture - 33
Advanced Control Schemes (Contd.)

In the last class we discussed one advanced controlled scheme that is cascade control scheme. And today we will start another scheme, that is constraint controller or override controller.

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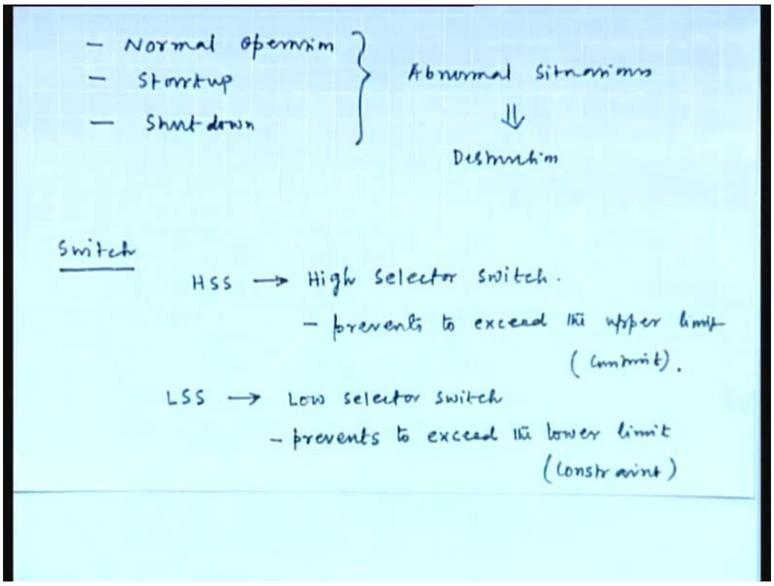

So, today we will discuss override control, and it is also called as constraint control. During the normal operation of the plant or during the startup or start down, some abnormal situations may arise, which lead to the distraction of equipment and operating personal. During the normal operation of the plant or during the startup or start down, some abnormal situations may arise, some abnormal situations may arise or some dangerous situations may arise, which lead to destruction of equipment and operating personal.

In these situations a special type of switch is used. One switch is like HSS - high selector switch, this is one type of switch which is used in abnormal situations, and this switch prevents to exceed the upper limit, it prevents to exceed the upper limit. Fine in every operation there is a certain limit in terms of upper limit and lower limit that should be

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Another switch is also used that is LSS - low selector switch, and it prevents to exceed the lower limit, which is also a constraint, fine. So, these two switches are commonly used in abnormal situations. Now, we will discuss the application of this special control scheme, constraint controller with taking one example.

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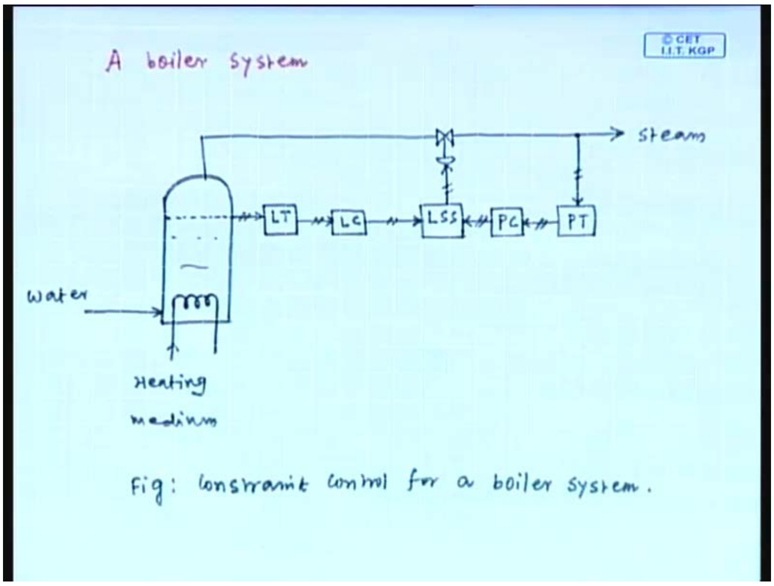

So, we will take a boiler system to discuss the application of this switch we will take the example of a boiler system. So, water enters at the bottom feed is water, and product is the steam this is a steam boiler fine. So, water is introduced here now for producing steam from water we need a heating medium, which is passing through this coil. This is heating medium, which is supplying heat and this is indicating the water level this is a water level this is the discharge line a control valve is installed in the discharge line fine. So, this is the schematic of the process

Now, we use to include the controlled scheme. So, first step pressure transmitter is installed employed to measure steam pressure, then a pressure controller. Here we use one switch that is LSS we will discuss why we have selected LSS. Another controlled scheme is also employed to maintain the liquid level. So, for that we need to employ one level measuring device that is LT then one level controller then the controller signal goes to LSS. LSS output is implemented through the control valve fine. This is the constraint control for a boiler system fine. So, what is our primary control objective our primary control objective is to maintain the pressure of the steam.

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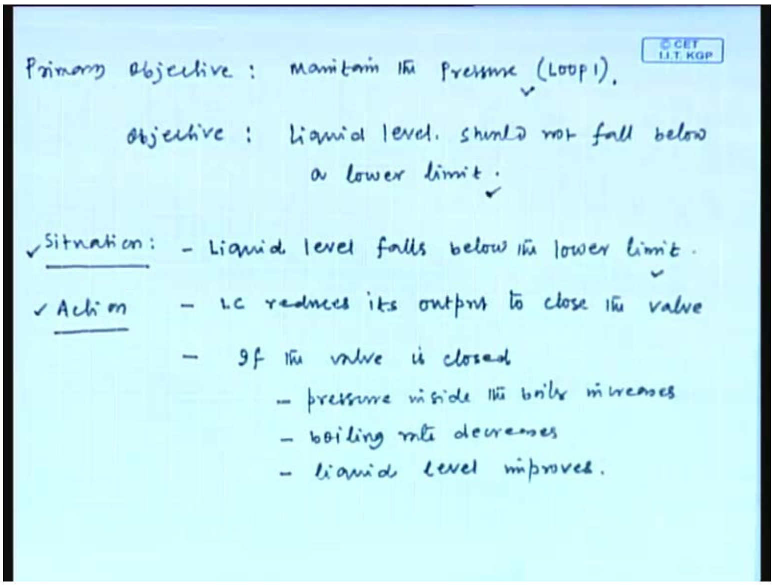

So, our primary objective is to use a pressure control loop for maintaining the pressure of the steam, suppose this is loop one and this is loop two fine. So, the steam pressure is controlled by the use of a pressure control loop this is the pressure loop I mean loop 1. So, primary objective is to maintain the pressure by the use of loop 1 at the same time it is require to maintain the liquid level. So, that this heating coil is immersed in liquid in water

So, along with the control of the pressure it is require maintaining the liquid level. So, that this heating coil is immersed in water fine. If it is not immersed in water this coil burns out. So, another objective is we need to maintain the liquid level. I mean liquid level should not fall below a lower limit purpose is to keep this heating coil immersed in water; otherwise the coil burns out fine. So, our purpose is to maintain the lower limit for the liquid level, which switch we can select LSS because it prevents to exceed the lower limit therefore, we have selected here LSS.

Now, we will consider one situation how it functions we will consider one situation suppose, a liquid level falls below the lower limit accordingly the level controller reduces its output fine. If the liquid level falls below the lower limit the level controller reduces its output to close the valve. So, the control action taken by level controller that is level controller reduces its output to close the valve. This is the action taken by level controller fine. This is the situation the liquid level falls below the lower limit this is the action taken by the level controller.

Now, can you explain it, why the level controller attains to close the valve. If the valve is closed what happens the pressure inside the boiler increase. So, what about the boiling rate boiling rate decreases. If boiling rate decreases the liquid level starts improving if boiling rate decreases then liquid level improves agree. Therefore, the level controller reduces its output to close the valve, fine. It closes the valve because it exceeds the lower limit. So, therefore, the crucial action is required to take from the level controller sides.

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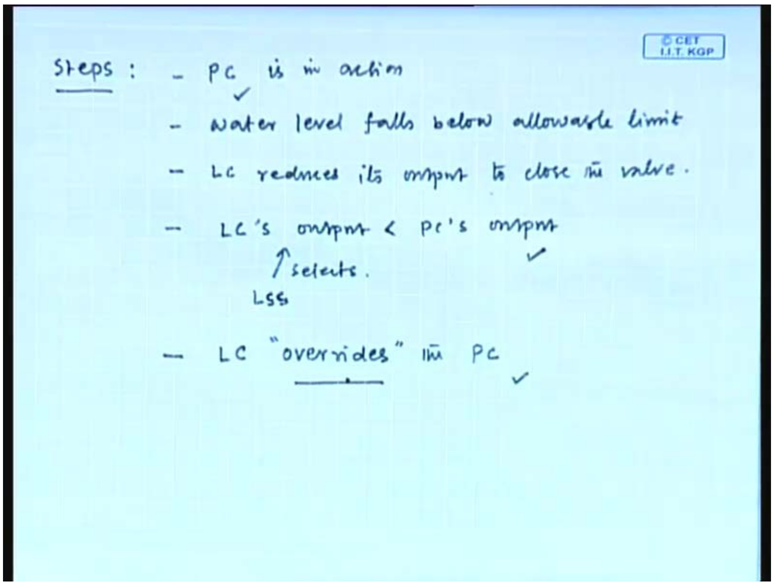

So, this is a situation and corresponding action taken by the level controller. Now I am just trying to highlight the steps initially the pressure controller is in action initially the pressure controller or pressure control loop is in action then the water level falls below the lower limit water level falls below allowable limit. This situation we have considered, and then level controller reduces its output to close the valve fine.

Now, when the level controllers output drops below the pressure controllers output the LSS selects the level controllers output signal this is very important point. If level controller output falls below the pressure controllers output, then LSS selects the lower value LSS selects the level controllers output. So, you see previously the LSS, this is LSS previously the LSS selects pressure controller output. Now as the liquid level falls below the allowable limit the level controllers output reduces, and when the level controller outputs falls below this pressure controller output the LSS select this lowest amount I mean level controllers output.

So, we can say that the level controller overrides the pressure controller. We can say that the level controller overrides the pressure controller fine, therefore this controller is also called override controller. Previously we discussed the reason to call it constraint controller and this is the reason to call it override controller fine level controller overrides the pressure controller. So, in this example we have discussed the application of LSS, LSS selects basically the lower output signal for case of HSS the fact is opposite HSS selects the higher output signal fine. So this is about the constraint controller.

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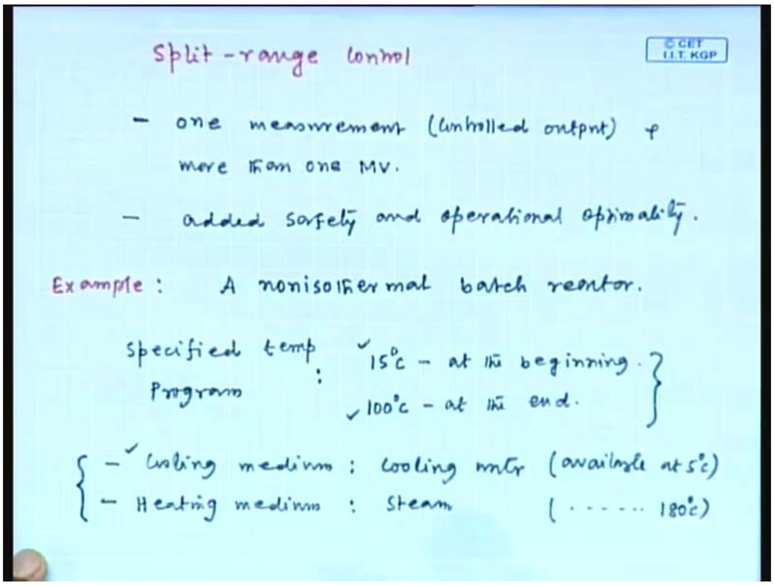

Next we will discuss another advanced controlled scheme that is split-range control. We discussed the cascade control scheme previously. And in the cascade control scheme there was more than one measurement, but one manipulated input for the cascade control scheme more than one measurement and one manipulated variable are involved. But for this split-range control the fact is opposite. One measurement, but more than one manipulated variable involved, for split-range control one measurement which is basically the controlled output or you can say controlled variable. And more than one manipulated variable are involved fine. This split-range control provides added safety and operational optimality. And these controllers are not very common in chemical engineering fine, split-range controller is not very common in chemical engineering.

So, we will discuss the concept of split-range control with taking one example. We will take one example to discuss this split-range control we will take a non-isothermal batch reactor to discuss this control non-isothermal batch reactor. In this non-isothermal batch reactor the temperature varies with time fine. The specified temperature program is given as the batch reactor starts, I mean at the starting at the beginning of the batch operation it operates at 15 degree Celsius. At the beginning of the example operator the temperature is 15 degree Celsius. And at the end of batch operation the temperature is 100 degree Celsius. So obviously, the temperature changes with respect to time in the example batch operation and it is common for batch operations.

So, if we want to maintain 15 degree Celsius or near to that temperature we need to use one cooling medium. If we want to maintain 100 or nearby temperature then we need to use one heating medium so here basically if cooling medium is cooling water cooling water can be used as cooling medium, which is available at 5 degree Celsius. Similarly, if as heating medium steam is steam can be used, which is supposing available at 180 degree celsius? So, these are the two medium, which can be used to maintain the temperature of the example non-isothermal batch reactor.

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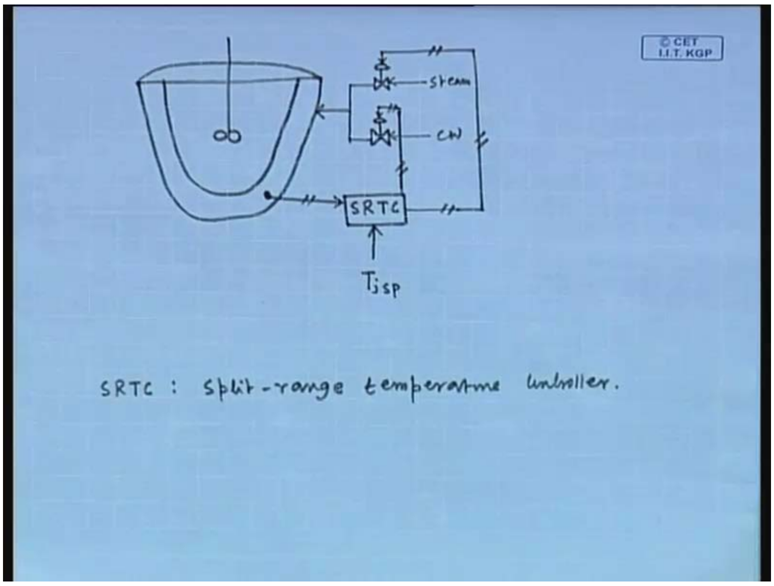

Now, we will try to configure the split-range control for this example system. This is a schematic of the non-isothermal batch reactor this is jacketed batch reactor fine. One valve is used for cooling medium and another valve is used for heating medium. Now the split-range temperature controller can be used to manipulate the cooling water, as well as the steam SRTC is the split-range temperature controller fine. This is the jacket temperature T j. So, we need to give the set point value of T j is the jacket temperature and sp has been used to represent the set point.

Now, the control action directs to manipulate the steam, and this is also used to manipulate cooling water, then this action in combined form is implemented fine. So, this is the split-range temperature control for a non-isothermal batch reactor. This is the jacket temperature, which is measured and this set point of the jacket temperature is also supplied to this split-range controller. Then this controller manipulates both steam as well as cooling water for maintain the temperature throughout the batch operation, which varies from 15 to 100 degree Celsius, fine. So, this is the split-range controller.

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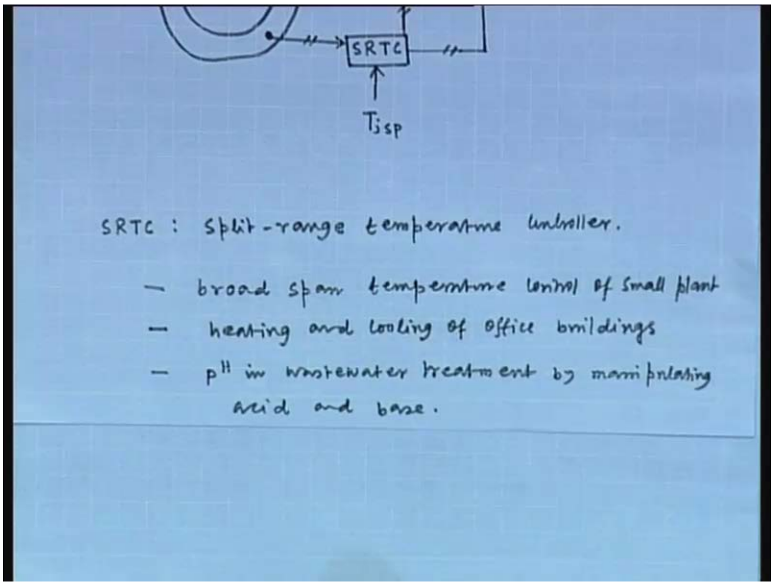

And this controller is used for broad span temperature control of small plant this is used for broad span temperature control of small plant or pilot scale plant. This is also used for ear bound heating and cooling of office buildings, this is also used for ear round heating and cooling of office buildings. This is also used to control PH in waste water treatment plant control PH in waste water treatment by manipulating both acid and base fine. So, these are the typical examples of split-range control scheme. In the next we will discuss another advanced control scheme that is feed forward control scheme, we have started feedback control scheme like PEPI and PID controllers. So, now, we use to discuss another control scheme that is feed forward control scheme.

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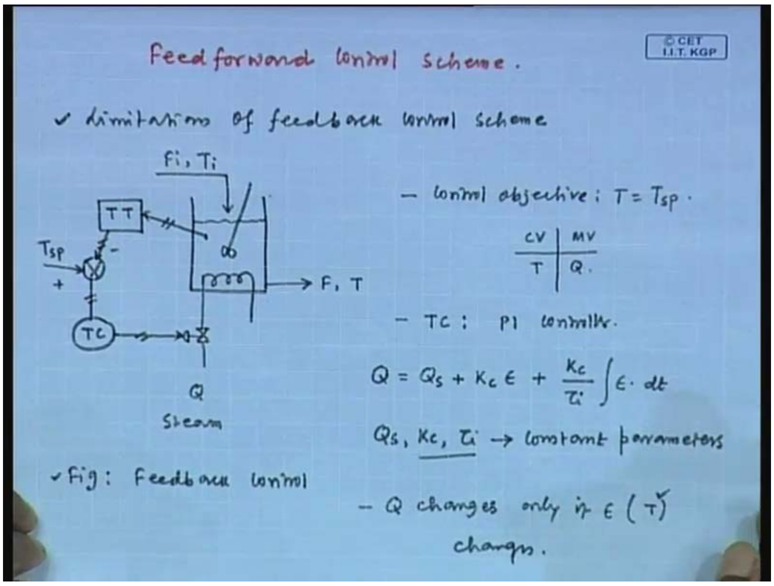

So, before discussing this feed forward control scheme, we are interested to know the limitations of feedback control schemes fine. Then we will proceed to discuss this feed forward control scheme. So, what are the limitations of feed forward control scheme sorry limitations of feedback control scheme, this point we use to discuss. So, for that we can take one example like a heating tank system, which we discuss earlier.

So, we will take a heating tank system to absorb the limitation feed is entering at a flow rate of Fi with temperature Ti. The product is coming out at flow rate F and temperature T. A heating medium is used to maintain the temperature, suppose that heating medium is steam, which has the flow rate of Q fine. We use to discuss the limitation with this example taking this example. So, what is the control objective is to maintain temperature at its set point value. So, we can say that temperature is the controlled variable and corresponding manipulated variable is steam flow rate that is Q, fine.

Now, we use to employ one feedback control scheme. So, we can configure the feedback control scheme. Now first we need to measure the temperature by using a temperature measuring device denoted by TT then that measures signal is compared with set point value. Then this signal is used to calculate the control action and then this action is implemented through the control valve fine. So, this is the feedback control of the heating tank system feedback control configuration for the heating tank system.

Now, you see here we have used one controller that is TC, suppose this is a PI controller the temperature controller, which we use to maintain the temperature is suppose a PI controller that is a feedback controller. Now how can we write the I mean, what will be the equation for this PI controller manipulated variable is Q. So, Q is equal to plus Kc multiplied by error plus Kc divided by tau i integration of error dt this is the temperature controller equation fine.

Now, in this equation you see Q s, K c and tau i are constant parameters. In this PI controller equation Q s which is the bias signal K c is a proportional gain and tau i is a time constant, these three are constant parameters fine, last two are the tuning parameters. Now Q changes with the change of which variable error signal so we can say that the Q changes only if error. That means, if temperature changes because T set point is again the constant Q changes only if error, that means, only if the temperature changes fine. So, what we want to say that this feedback control scheme takes action only the temperature changes detected otherwise you can it cannot take action, anyway we will consider one situation to elaborate this.

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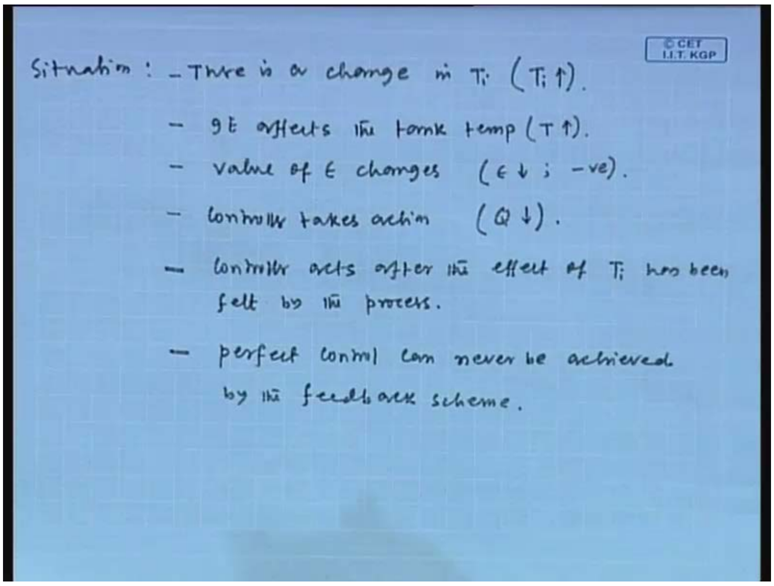

Suppose there is a change in T I, T i is a disturbance variable, there is a change in T i. You see in this example T i is the disturbance variable initially the process is at steady state now we are considering a situation that is there is a change in T i. Suppose T i has increased. So, it will affect the temperature in the next step we can say that it affects the tank temperature agree, what will happen temperature will increase or decrease temperature will increase. So, what about the value of epsilon changes, fine. Basically this error signal decreases and it becomes negative, if initially the process is at steady state fine at steady state error is zero, because t set point and t both are equal.

Now, if temperature increases then this the value of epsilon becomes negative, then the controller will take action, because error signal has changed, so according to this equation, if error the value of epsilon changes then Q changes fine. So, we can say that in the next step controller takes action how Q decreases or increases Q decreases.

So, you see the controller acts after the effect of a disturbance has been felt by the process the controller acts after the effect of T i has been felt by the process agree. So, it is not possible to afford the impact of T i by the use feedback controller. It means that the perfect control can never be achieved by the use of feedback controller agree. So, how can we get the perfect control, we can get the perfect control. If the controller takes perfect action before the disturbance effects the process isn't it we can get perfect control if the controller takes perfect action before the disturbance effects the process.

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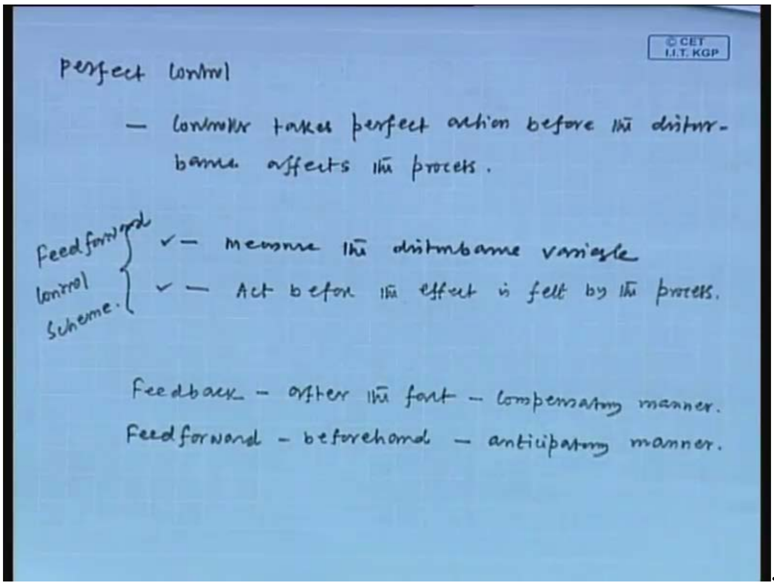

So, perfect control we can achieve, if the controller takes perfect action before the disturbance effects the process agrees. So, what is require to do to take the perfect control action. So, for perfect control action first it is require to measure the disturbance which is effecting the process this is the first point. It is required to measure the disturbance which is effecting the process. So, what is require to do to achieve the perfect control action first it is require to measure the disturbance variable, fine. First it is require to measure the disturbance variable in the next step the controller should act before the effect is felt by the process. So, for perfect control action it is require to measure the disturbance to know the change in disturbance variable, and then the controller should act before the effect is felt by the process. And this is the mechanism of feed forward control scheme and theoretically it can provide perfect control fine.

So, we can say that the feedback controller acts after the fact in compensatory manner and feed forward controller acts beforehand in anticipatory manner. So, feedback controller acts after the fact. I mean after effecting the disturbance to the process in a compensatory manner, where is a feed forward controller acts beforehand in an anticipatory manner fine. So, theoretically we can achieve the perfect control from the feed forward controller. Anyway before going to discuss the theory, we use to just configure the feed forward controller taking one two examples.

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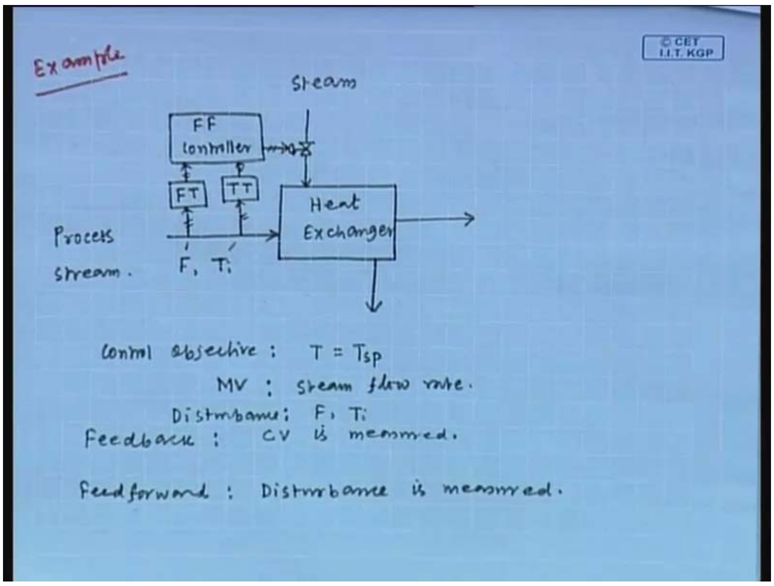

Before going to discuss the or before going to analyze this feed forward controller, we just use to configure the feed forward controller with taking two examples. So, first we will take one heat exchanger, this is a heat exchanger this is process stream and this is the output of the process stream. Here one heating medium is used, that is steam for maintaining the temperature of the process stream fine. Now for the feedback controller the controlled variable is usually measured, but for the feed forward controller the disturbance is measured. For feedback control scheme the controlled variable is measured, it is very obvious if you see the equation of any feedback controller like P or PID fine, and feed forward controller the disturbance is measured, fine.

Now, for this heat exchanger our control objective is to maintain the temperature of the process stream. Our control objective is to maintain the temperature at its set point, what is the manipulated variable; manipulated variable is steam flow rate. This is the manipulated variable, what are the disturbances? One is process stream flow rate another one process stream temperature T i. So, flow rate and temperature T i; these two are the disturbance variables.

So, we can use one measuring device for the flow rate measurement and another measuring device for the temperature T i. So, this is for F and this is for T i, then one feed forward controller block can be included and then this control action is implemented through this control valve fine. So, two disturbances are involved in this process and they are measured, then that measure signal go to this feed forward control block and then the control action is calculated and that is implemented through this final control element. So, this is the feed forward control scheme for this heat exchanger.

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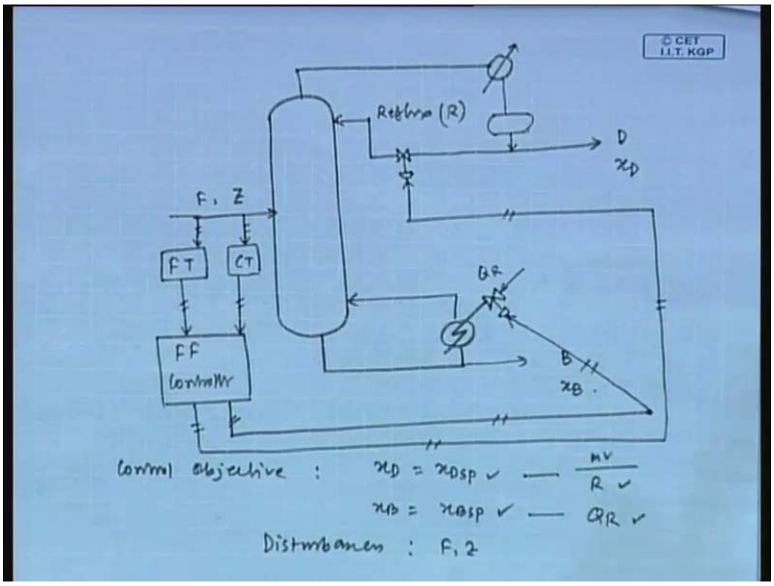

Another example we can take that is a distillation column. One control valve is employed for reflux rate and another valve is employed for heating medium fine. So, this is distillate, which has the flow rate of D and composition of x d that is mole fraction basically, and in the bottom loop the flow rate is suppose B and composition is X b. Feed is introduced, here with feed flow rate is F and composition is Z. So, what is the control objective, the control objective is to maintain X d at X d set point. Similarly X b at X b set point. Control objective is to maintain the product quality at the top as well as the bottom.

So, what are disturbances involved here, one is feed flow rate another one is composition. So, we can use flow measuring device FT and composition measuring device CT. Then one block is included for feed forward controller fine. For this top loop X D the manipulated variable is reflux flow rate R, and for the bottom loop the manipulated flow rate is manipulated variable is Q R, Q R is basically the revolver duty. Then this is implemented for Q R and another one is for R fine. So, control objective is to maintain X D at X D set point X B at X B set point disturbances are F and Z and manipulated variables are R for X D and Q R for X B. So, this is the feed forward control scheme for the distillation scheme. In the next class, we will discuss the theory involved with this feed forward controller.

Thank you.