Process Control and Instrumentation
Prof. A.K. Jana
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 16
Feedback Control Schemes (contd.)

So, in the last class we discussed two control schemes. one is P-only controller and another one is PI controller.

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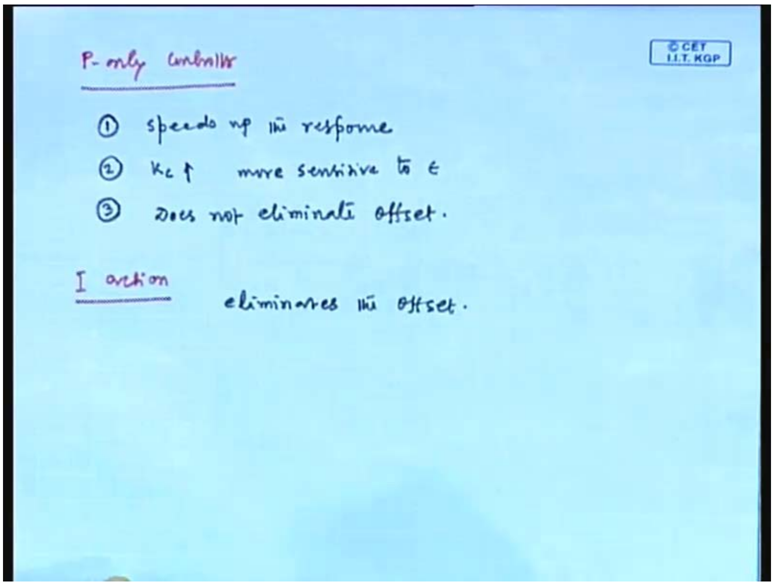

So, replace we discuss P-only controller, followed by PI controller we made few conclusions on this P-only controller. Like replace conclusion on P-only controller it speeds of the response of the close look process, it speeds up the response. Fine and with the increase of Kc values the controller becomes more sensitive to error signal, with the increase of Kc values the controller becomes more sensitive to error signal with the increase of the Kc to error signal Fine. The P-only controller does not eliminate offset, third conclusion the P-only controller, or proportional action we can say does not eliminate offset. P-only controller does not eliminate offset. The PI controller consists of proportional action and integral action. PI controller includes two control actions those are proportional action and integral action. So, if we consider the integral action then, we can say that integral action eliminates the offset.

This integral action eliminates the offset, and that is why is this integral tom is included with P-only controller to make PI controller. Now, today will study the elimination of offset by PI controller. How the PI controller eliminates the offset that we want to absorb?

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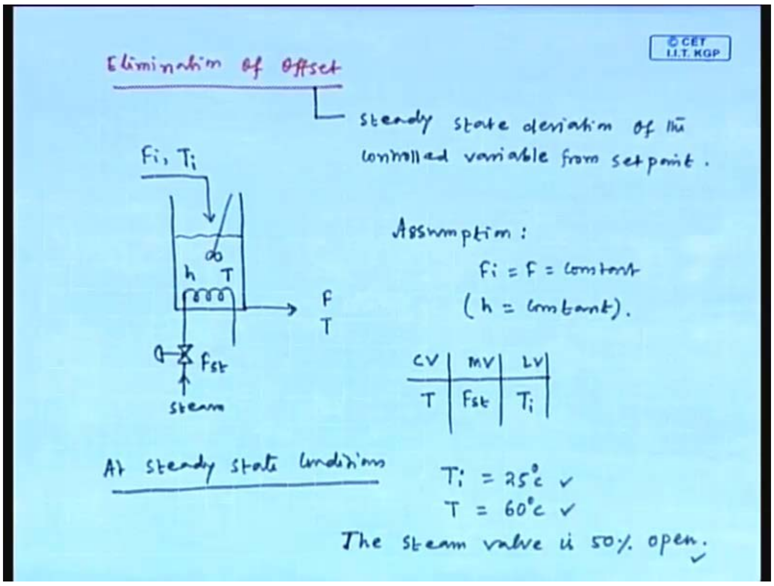

Now, we will discuss the elimination of offset, What is offset? As mentioned earlier offset is described as steady state deviations of the controlled variable from set point. Offset is the steady state devitaions, it is mention as earlier that the offset is defined as steady state deviations of the controlled variable form set point. The offset is defined as steady state deviations of the controlled variable form set point. Now, we will consider one example this is a tank heater Fi is the inlet steam flouride and Ti is the tempertaure of the inlet steam, the outlet is coming out with flouride F and temperture T, height of liquid in the tank is h and temperture is T

A heating medium a steam is introduced through this coil with a fluoride of if suffix s T. Now, we are assuming here, that the inlet and outlet fluoride are identical and both are constants. We are assuming the inlet fluoride and outlet fluoride as constants and there both are identical. So, what it indicates there is no variation of height. So, height is constant if the both the inlet and outlet fluorides are equal and constants then there is no variation of liquid height. So, for this process what is controlled variable which one is controlled variable temperature, manipulated variable is steam fluoride which one is load variable. Fi is constant that is why load variable is Ti Fi is constant so Ti is the only load variable. Now, we are considering the steady state conditions as Ti equals 25 degrees 60 Celsius T 60 degrees Celsius and at steady state the steam valve is 50 percent open, these are steady state conditions. Next we will consider state change in the load variable, another thing I want to mention here, that this valve is ear to open. It means if, the input pressure is increased the valve opening increases; with the increase of inlet pressure, the valve opening is increases.

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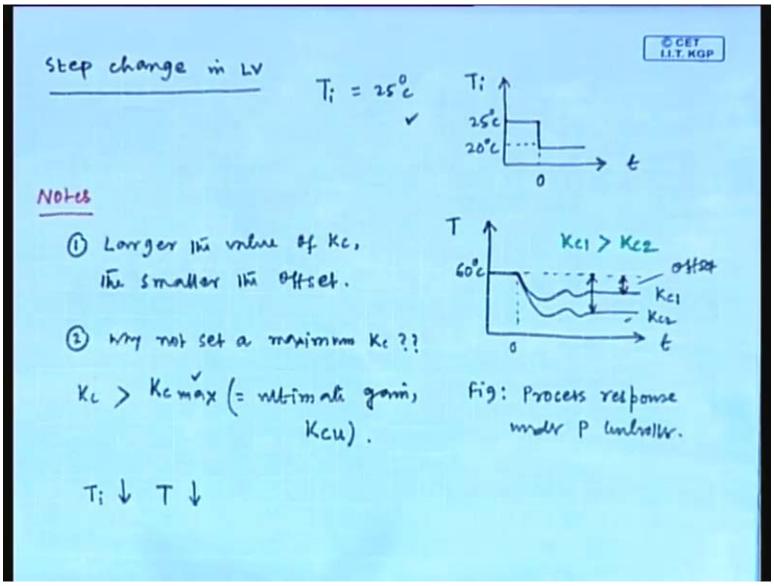

Next we will consider the step change in load variable, step change in load variable. As mentioned Ti is the load variable and steady state Ti is 25 degree Celsius. Now, we will introduce a step change in Ti that is represented in this plot this is Time, this is Ti, initially Ti is 25 degree Celsius now it is changed to… Suppose 20 degree Celsius at time t equals 0. We are introducing the step change in Ti that is 25 degree Celsius to 20 degree Celsius. Now we will Note down few points, the larger the values of Kc, the smaller the offset. values If we introduce this step change I mean 25 to 20 degree Celsius, then the process response under P-only controller like this, is t this is temperature. What is steady step values, values of temperature? 60 degree Celsius Now, if we introduced a step change at say Time t equals 0, the close look process responds like this, this at a particular Kc values.

So, we can write the title as process response, under P-only controller. If P-only controller is employed around that tank heater now, we introduced a step change in Ti then the process I mean close loop process responds in this manner. If we consider another Kc values, then process responds like this. If we consider a different proportional gain values then it responds like this. Now here Kc 1 is greater than Kc 2, this is the observation if we introduced a step change in Ti the tank heater system under P-only controller responds in this way. That is why, we concluded here that the larger values of Kc the smaller the offset. This the offset for the case Kc 1 this the offset, and for Kc 2 this is the offset. Now if this is the conclusion I mean larger values of Kc the smaller the offset the…

Why not set maximum gain? Immediately one question arise is why not set a maximum gain, for most of the process is there is maximum values of Kc there is a limit of Kc for the most of the chemical process is, there is a maximum values of Kc that we can represent by Kc max. If, we consider Kc greater than Kc max then, the process goes unstable for the most of the process is there is maximum values of Kc represented by Kc max if, we consider Kc greater than Kc max there is high probability of in stability problem. This Kc max is called ultimate Kc, this Kc max called ultimate gain. Represented by Kcu. So, we cannot consider arbitrarily large Kc values to reduce the offset, there certain limitation. Now, with the decrease of tow I what happens. In this case I mean we have consider decrease of tow I if, we decrease tow I if we decrease of tow I the temperature of liquid in the tank decreases agreed.

If Ti is in decreased the temperature of the liquid in the tank also decreases then, what is require to do for the controller? To keep the temperature at 60 degree Celsius, the controller needs to increase the steam fluoride. Now, we have consider at steady state the valve is 50 percent open but, if Ti is decreased to 20 degree Celsius then suppose the controller needs to open the value 60 percent.

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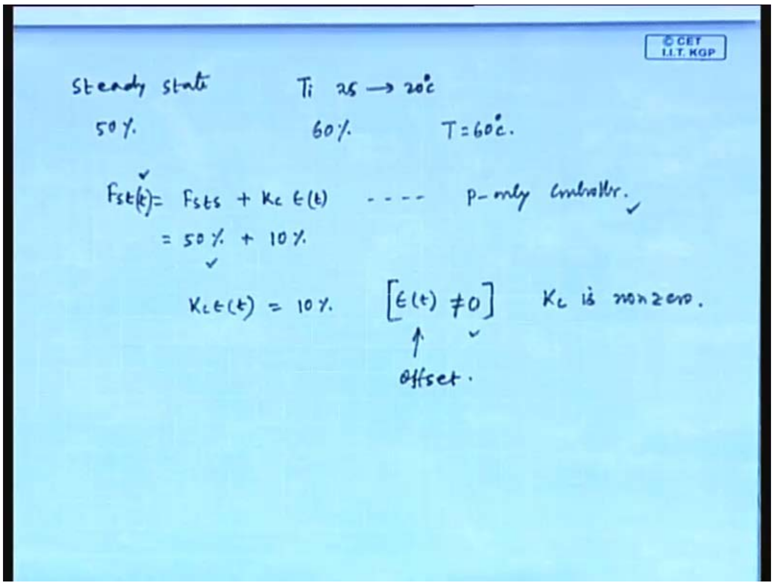

At steady state we have considered 50 percent opening of steam valve if the Ti changes from 25 to 20 degree Celsius, in that case suppose it is require to open it is require 60 percent open of the valve to maintain temperature at 60 degree Celsius. Now, our manipulated variable is Fst if, we consider P-only controller then we can write Fst equals Fsts plus Kc error t for the case of P-only controller, our manipulated variable is Fst. So, if we consider P-only controller then we can represent we can write this equation Fst equals Fst s plus Kc (Refer Time: 20:15) t. What is Fst s? Steady state values of Fst. If we represent Fst in terms of percentage opening then, Fst s is nothing but 50 percent because ,that is steady state values of Fst. How much the 2nd term will be? How much will Kc epsilon t? Remaining 10 percent, agree or not a Fst as is the steady state values of Fst.

We have consider 50 percent opening at steady state. So, Fsts we can write as 50 percent and rest Kc epsilon t will be reaming 10 percent. So What it indicates? I mean Kc epsilon t equals 10 percent. So, how much epsilon t? At least epsilon Tis not equals to 0. If Kc epsilon t equals 10 percent then epsilon t not equals to 0 because the controller gain is non 0 since Kc is non 0. So, epsilon t not equals to 0, it indicates there will be an offset because error is error not equals to 0 it indicates there is an offset under P-only controller. Next we will consider the PI controller, we will continue the same example and we will consider.

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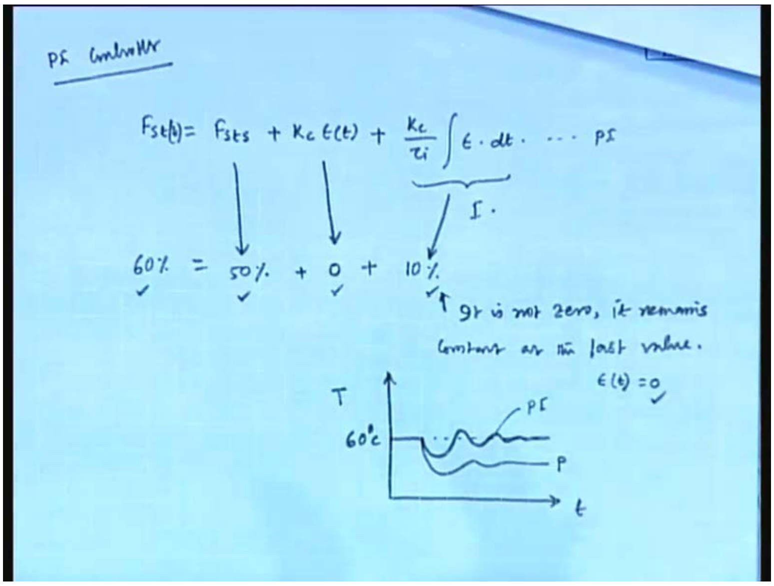

PI controller as long as the error is present the PI controller keeps changing its output by integrating the error. If, we see the controller equation Fst equals Fst s, plus proportional term Kc epsilon t plus integral term; that means, Kc divided by tow y integration error dt. This the PI controller equation. So, this is the integral term as long as the error is present the PI controller keeps changing its output by integrating the error.

Now, if we consider Fst 60 percent. How much is Fst s? 50 percent, How much is this 1? PI controllers eliminate the offset. If that is the case then error should be 0. So, Kc if silent is 0 and this term, is 10 percent. If we see the plot, we observe that the PI controller the process under PI controller reaches at steady state values I mean the process PI controller remains at steady state temperature. But for the case of P-only controller there is an offset. So, this is the process response under P-only controller and. So, this is the process response under PI only controller. Now, you see if we introduced state change in PI from t 25 to 20 degree Celsius then there is need to open the steam value60s percent opening there is need to maintain 60 percent opening of steam valve. So, this is 60 percent and steady state values is 50 percent if, PI controller eliminates the offset then definitely error should be 0 that means this is 0. So, remaining 10 percent is indicating the integral term this remaining 10 percent is provided by the integral term. So, it is not 0. It remains constant at, the last values I mean epsilon at a last Times step is 0. But the sum of remaining errors, pervious errors provides 10 percent the last error that is epsilon t equal to 0 and the sum of pervious errors, provides 10 percent opening. So, this indicates that the error I mean, steady state reduced to 0 under PI controller. So, we will discuss this with more rigors proof later.

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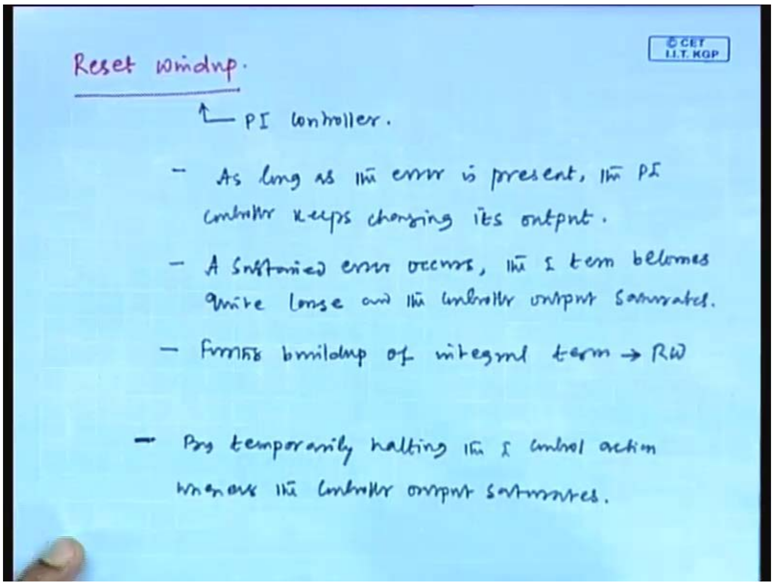

Next topic is reset windup of reset windup happens for PI controller, Now, for PI controller we know that, as long as error is present PI controller keeps changing it is output by integrating the error. For PI controller we know that as long as error is present the controller keeps changing it is output integrating the error. As long as error is present, the PI controller keeps changing it i s output by integrating the error. When a sustained error is happens the integral term becomes quite large and controller output eventually saturates an a sustain error

Further buildup of integral term is referred to as reset windup further buildup of integral term, is referred to as reset windup. So, as long as error is present the controller keeps changing it is output integrating the error minus sustain error occurs integral term becomes quite large, and the controller output eventually saturates, further buildup of integral term is called reset windup. Now, to reduce the reset windup there need to devise anti reset windup.

So, there are many os to devise this. So, one we will discuss here, I mean one we will mention here reset windup is reduced by temporarily halting the integral action. Whenever, the controller output saturates, reset windup is reduced by temporarily halting, the integral control action whenever the controller output saturates this is the one way to devise the anti reset windup. So, next we discuss the third controller that is PID controller proportional integral derivative controller.

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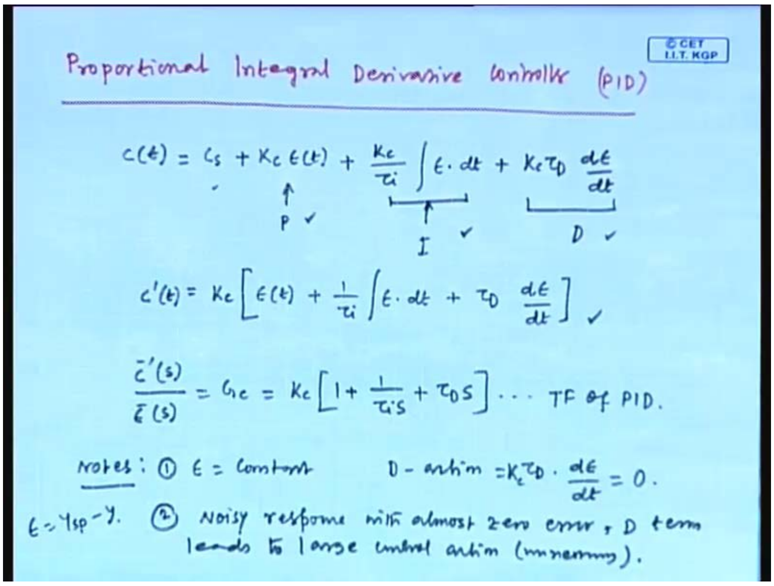

Next we will discuss proportional integral derivative controller. In soft this is PID controller the name suggest that, the controller includes three actions proportional actions, integral actions, and derivative actions. And if, we consider manipulated variable if we represent manipulated variable as c, the PID controller can written as Ct equals C plus Kc epsilon t plus Kc divided by tow y integration error dt plus Kc tow d, d error dt this the proportional action this is the integral actions and this one is the derivative action. and C s is the bios signal I mean the error is 0 the controller output is C s.

So, we can we can rearrange this equation as C prime t, equals Kc error t plus 1 divided by tow i integration of error dt plus tow d, d error dt we can rearrangePID controller in this form. Now, we should derive the transverse function of PID controller by taking lap plus transform if we taking lap plus transform and if, we rearrange then we get is C bar prime is divided by epsilon bar is which is Gc and Gc equals Kc, 1 plus 1 divided by tow is plus tow ds this is the transverse function of PID controller.

Now, you observe one thing that, if the error is non 0 What about, the derivative action? If error is constant and non 0 what about the derivative action? 0 there is no existence of derivative action. Because derivative action is equals to Kc tow D dr dt if error is constant then the differentiation of that with respect to Time becomes 0. So, this point we can note down as replace point. Second if for a noise response with almost 0 error. For a noise response I mean for noise y, because it is Siloam is y set point minus y.

So, noise response means noise y, with almost 0 error D term leads to large control action. Although that is not needed for noise response 0 error d term leads to large action derivative term leads tolarge control action although that is not required. So, you can say this unnecessary you can say this is the drawback this two are the drawbacks of the PID controller, and error is constant there is no action from the derivative action, and there is noisy error the derivative action unnecessarily is large. So, these two are the drawbacks of the PID controller. Next we will discuss the control actions one is deduct action another one is reverse action.

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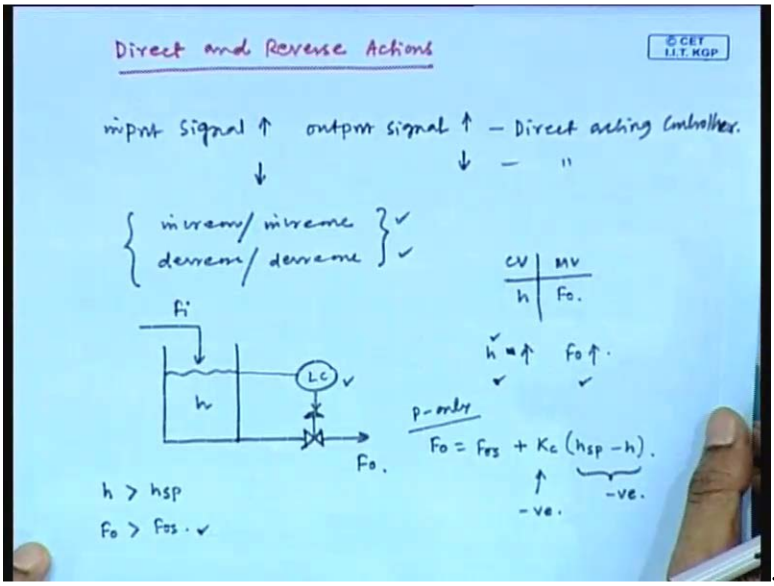

We will discuss next Direct and Reverse Action. So, as the input signal to the controller increases the output signal from the controller should increase for direct acting controller you note down this point, as the input signal to the controller increases the output signal from controller must increase.

For direct acting controller, similarly we can say that, as the input signal to the controller decreases the output signal from the controller must decrease, for direct acting controller. So, we can say that if, the input signal increases the output signal should increase for direct acting controller in reverse we can say that if, the input signals to the controller decreases the output signal from the controller should decrease. Therefore, for deduct acting controller these two terms are used increase another one is decrease we will take one example to discuss this action direct action. This is a liquid tank system our controlled variable is liquid height and manipulated variable is suppose if not, So, to maintain height we need to employ one level controller, I am not showing the sensor comparator extra here, direct deduct we put here the block for level controller. Now, if height increases suppose if height increases. What is required to do for the controller? The controller should increase if not or decrease if not, the controller should increase if not. If height increases the controller should increase if not to maintain the height at it is desired values. You see the input signal to the controller that is height, if increases the controller is increasing the output signal if not. So, this is direct acting controller this level controller is direct acting controller. The input signal height if, increases the controller increases accordingly if not.

So, this direct acting controller. Now, we will write the controller equation. Suppose is level controller is P-only controller according to the controller equation is written as if naught equals if naught is, plus Kc height set point minus height suppose this level controller is a P-only controller. Accordingly we can write the controller equation as, F naught equals f naught is plus Kc error error means eighth set point minus 8. If height is greater than 8 set point.

So, what will be F naught it will be greater than F naught s or less than F naught s it should be greater the F naught s agree. If, height is greater than 8 set point. Then the controller require to maintain this condition, I mean F naught should be greater than F naught s. If the height is greater than 8 set point then what about this term positive or negative? It is negative now, how it is possible to maintain f naught is greater than F not is Kc if Kc is negative, if height goes above, set point values of 8. Then from this equation it is clear that the error becomes negative. Now, controller is required to maintain F naught is greater than F naught s that is only possible and Kc is negative. So, we need to remember that we should remember that for direct acting controller gain is negative. This is the most important feature of direct acting controller for direct acting controller the controller gain should be negative.

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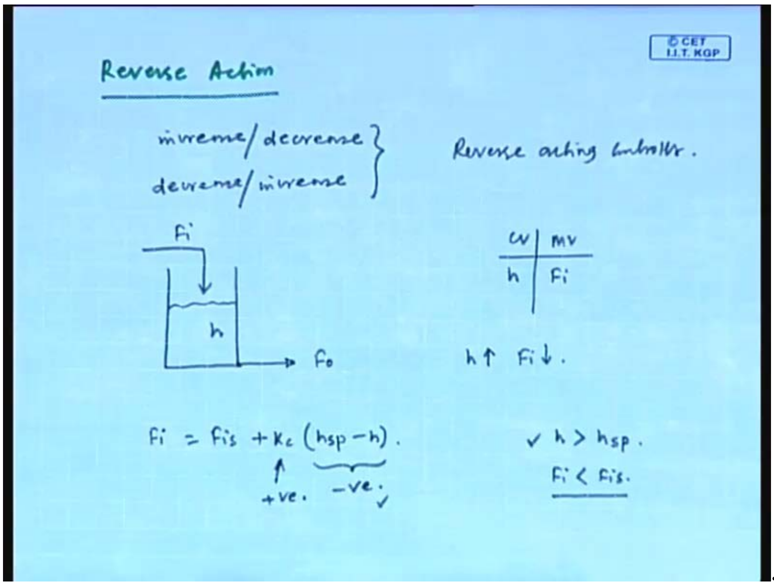

Reverse- next we will discuss the reverse Action. It is just reverse of direct action. So, the definition is as the input signal to the controller increases the output signals from controller should decrease for reverse acting controller, as the input signal to the controller increases. The output signals from controller should decreases for reverse acting controller, or as the input signal to the controller decreases the output signals from controller should increase for reverse acting controller. If we continue the same example, What will be the manipulated variable? For reverse acting controller, height is the controlled variable. So, if I should be the manipulated variable for reverse acting case. You see if, we increase the height What is require to do for the controller? The controller should decrease a Fi to maintain height at its desired values. If height increases the controller should decrease a Fi to maintain height at it is desired values; That means, it is reverse acting.

Now, we will write similarly the controller equation a Fi equals a Fi is plus Kc, h set point minus 8. Now if, height is greater than 8 set point a Fi should be less than a Fi if height is greater than 8 set point the controller should maintain this condition that a Fi is less than a Fi. Now, if height is greater than its 8 set point then, the error becomes negative. Now, how the controller can maintain the Fi less than a Fi s? If Kc is positive agree if height is greater than 8 set point then the error becomes negative. Now, to maintain a Fi less than Fi is Kc should be positive. So, similarly I mean like direct acting controller unlike deduct acting controller the controller gain should be positive for reverse acting controller.

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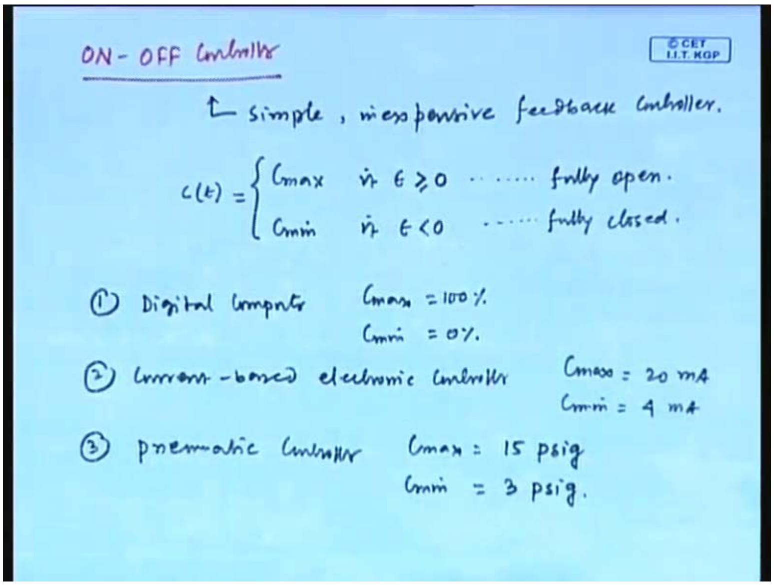

Next we will discuss another controller that is ON-OFF Controller. ON-OFF controller this is the simple inexpensive feedback controller. like, an ideal ON-OFF controller. We can represent as, Ct equals Cmax if, error is greater than or equal to 0 C t is the controller output. So, error is greater than 0 Ct provides maximum values Cmax; that means, we considering control value C provides 100 percent opening. So, if we considering control valve as a Final controlling element then Cmax indicates full opening of valve.

Similarly this Ct becomes Cmim if, error less than 0 the controller output becoming the minimum value of C and error less than 0 if we consider control value as a Final controlling element. This indicates full closing I mean this indicates fully closed, there is no intermediate control action either maximum values or minimum values that is why the name On-off. Now, we will considering few cases like, for digital computer implementation Cmax indicates100 percent and Cmim indicates 0 percent. If, we consider a current based electronic controller this, Cmax indicates 20 million empire and Cmim 4 million empire, for current base electronic controller the maximum values is 20 million empire and minimum is 4 million empire similarly we consider numeric controller pneumatic controller maximum values is 15 psig and minimum values is 3 psig.

If we consider pneumatic controller c max is 15 psig pressure and minimum is 3 psi g. What is the use of this on-off controller? On-off controller is used, in home heating systems. controller is used in domestic refrigerator, on-off controller is also used in laboratory furnaces, Another thing we can say that if, Kc values is very large for P-only controller then controller behaves like on-off controller. If Kc values is very large for P-only controller then, the controller behaves like on-off controller. Definitely the proportional controller are more efficient than on-off controller. The proportional controllers like P, PID more efficient than on-off controller.