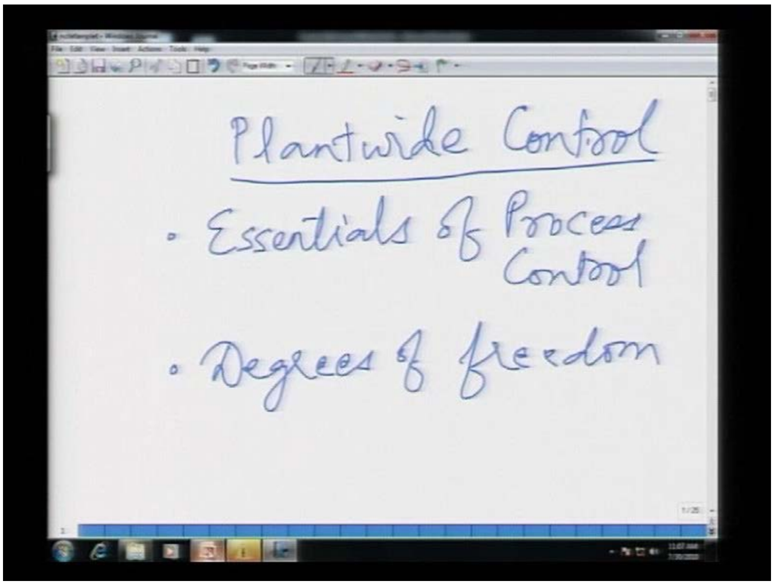
Plantwide Control of Chemical processes
Prof. Nitin Kaistha
Department of Chemical Engineering
Indian Institute of Technology, Kanpur

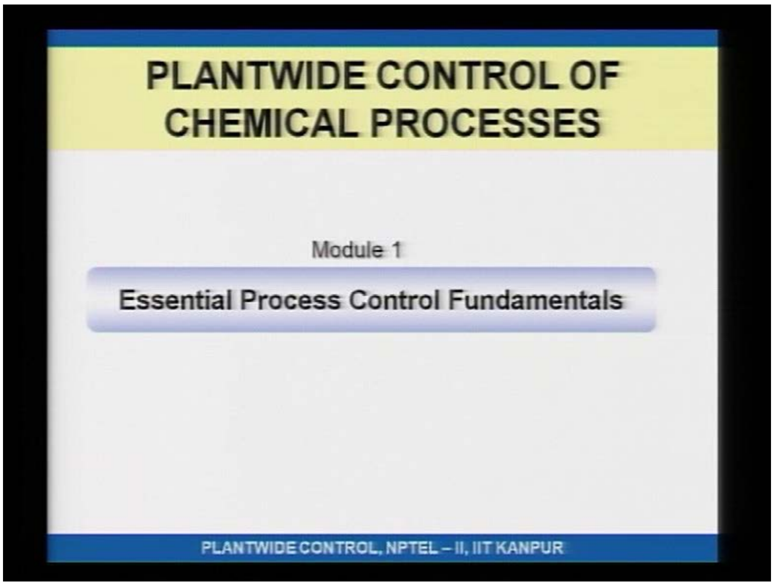
Lecture - 2
Process Dynamics and Negative Feedback
Input-Output Variables and their Dynamics
Basic transient response types
Combination of Basic response types
The feedback control loop

(Refer Slide Time: 00:28)



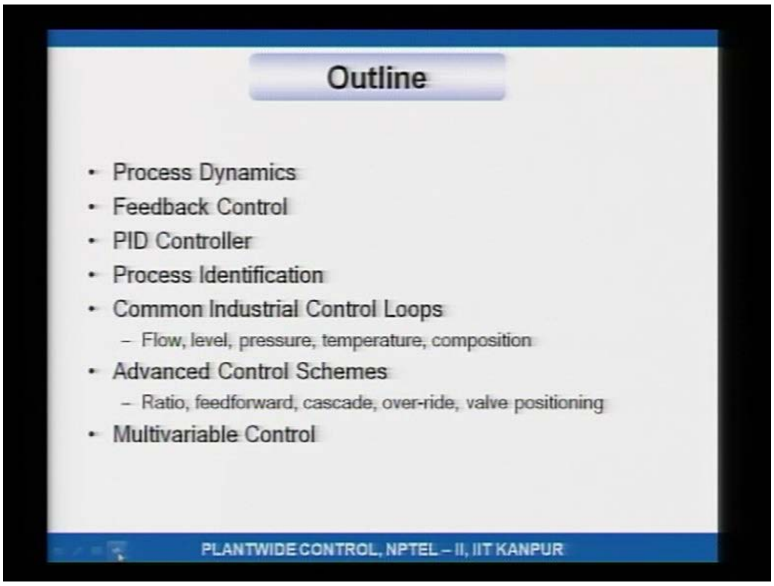
Welcome all of you, last time I gave you a brief introduction to what this course is all about. Just to summarize, this course is on plant wide control; and before we can go over how to design effective plant wide control systems for complex chemical processes with material and energy recycle. There are some essential things that we ought to know; and these essential things, I would categorize in to two items; item number 1 essential control, essential fundamentals of or rather essentials of process control. And what I mean here is, the most basic things in process control that you need to know as an operator or as an arrow or as an engineer. And also what you need to know is degrees of freedom of a process. So the next two modules, degrees of freedom; so the next two modules that we are going to cover may be next couple of lectures and another couple of lectures would essentially focus on these two aspects, essentials of process control that an engineer must know to design effective control systems and degrees of freedom of a process. These two concepts are quite fundamental and we will spend some time on this over the next few lectures.

(Refer Slide Time: 01:57)



So, let us get two essentials of process control, essential process control fundamentals that is the module that we are going to be looking at.

(Refer Slide Time: 02:03)



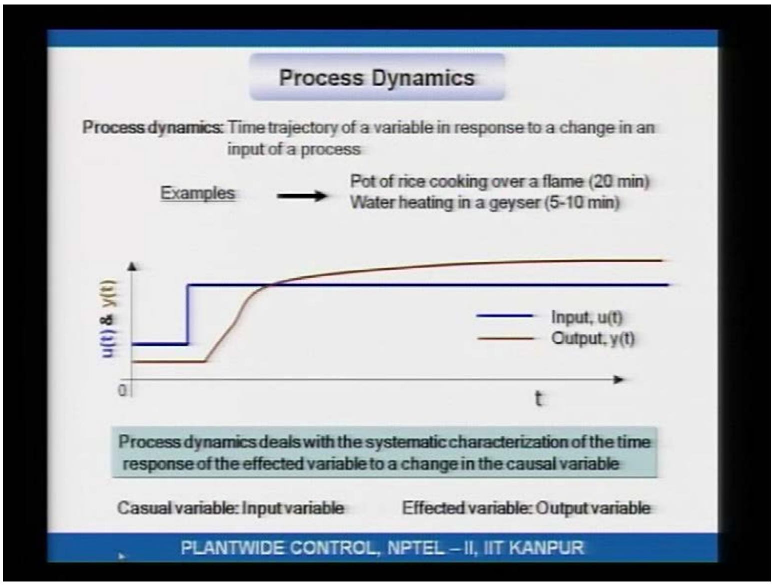
Now, the outline of the breakup of this module is, first we are going to look at what process dynamics is? What do you mean by process dynamics? Given that in response to a change a process, an output variable response in a certain way, how do you ensure that the output variable is kept? Where you wanted to be kept? That is a complete typically using feedback control.

Now, in order to do feedback control, there are various controller algorithms; the most popular of them in the industry is the PID controller. So, we are going to talk to in detail about PID controller, how you tune them? The PID controller requires some information so that it can be tuned well, and that information is gathered through process identification. So, we are going to cover the most basic process identification techniques that are popularly used in the industry.

Since the focus of this course is practical industrial application, we are also going to look at a few common industrial control loops, these loops are typically flows, levels, pressure, temperatures and composition loops. How do you tune them? What are the typical characteristics of these loops and so on so forth, then we will also look at a few advanced control schemes such as ratio, feed forward, cascade, over-ride, valve positioning optimizing control and so on so forth, which are, which are used employed routinely in industrial systems in order to achieve more effective or better control.

Usually you would be studying single input single output systems in your basic process control courses, but in practice, most practical systems are multivariable, what do you mean by multivariable; that means, that it is got multiple inputs and it is got called multiple outputs that need to be control some may even float . So, we will also cover a little bit of multivariable control because, most practical industrial systems are multivariable in nature.

(Refer Slide Time: 04:13)



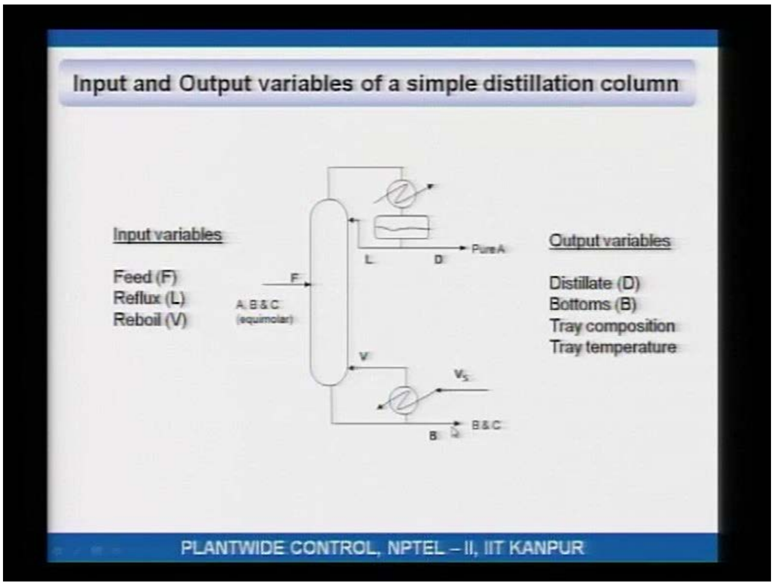
So, that is the outline for this module coming to process dynamics, what is process dynamics? We all know dynamics, they say the situation is dynamic; what does it mean? It means situation is changing. So, this change over time is referred to as process dynamics, specifically what it means is, if you make a change to an input to a process, how does the output variable respond over time that is known as that is referred to as process dynamics.

So, to define it, I would say process dynamics is the time trajectory of a variable specifically an output variable in response to a change in an input to the process. There are several examples and you need not to be a control engineer to appreciate this, you know, you know if you put a pot of rice on a on a on a gas, it takes about 15 to 20 minutes to cook. So, the cookedness of the rice is the output variable, the intensity of the flame is the input variable; once the flame is on, rice starts to cook and it slowly gets more and more cooked and finally, it riches it is desire state of cookedness and if you cook it for more than that it may even get burnt, you also, you know every day, we take a bath especially, in the winter season using a geyser and everybody knows that if I switch on the right now, which is the input of the process, the water will become hot in say 5 or 10 minutes, so it takes 5 or 10 minutes for the temperature of the water in the geyser to rise to whatever level I wanted to rise to.

All right so these some very simple examples that essentially show that an output variable changes over time in response to a change in the input. So, here is just a very simple example, the blue line is the input and the brown line is the output. Let us say the input is geyser off the heater power, the power of the heater which is 0, and then when I switch on geyser, which power goes to, whatever it goes to a 1 kilo watt and 2 kilo watts and let us say the brown variable which is the output variable is a temperature of the water in geyser, it is at ambient temperature and as the is switched on, what you have is the temperature nothing happens to the temperature for a little bit and then its starts to rise and it keeps on rising.

It may keep on rising or it may settle down to final study state value, so this is an example of the dynamics of the output variable which the geyser, water temperature in the geyser in response to the input which is the power input to the geyser, so essentially process dynamics deals with the systematic characterization of the time response of the effected variable to a change in the causal variable, the effected variable is also sometimes refer to as the output variable, the causal variable is also sometimes refer to as or usually refer to as the input variable.

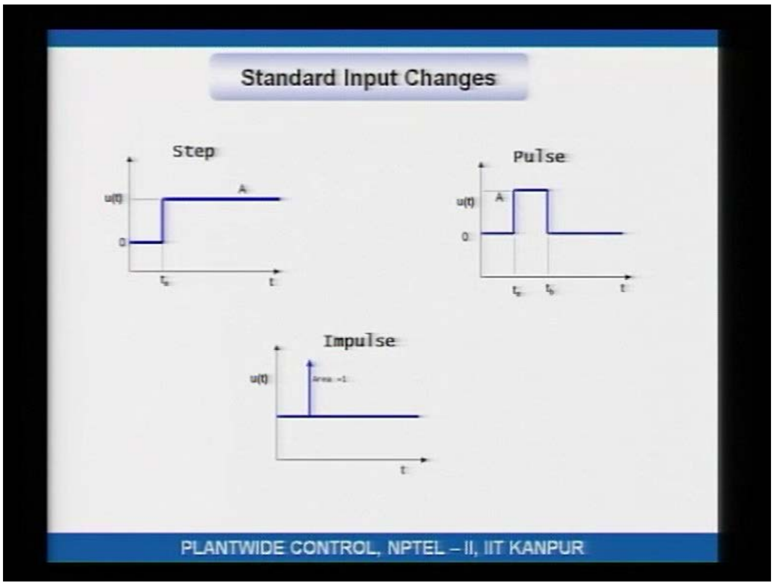
(Refer Slide Time: 07:13)



So, hear is for example, distillation column if there is a feed to the column, let us say it is an A B C mixtures, A being the lightest component, B being intermediate boiling, and C being the heavy component and you are doing a direct split, so what; that means, is you are taking out the lightest component of the top and everything else that is heavier goes down the bottom.

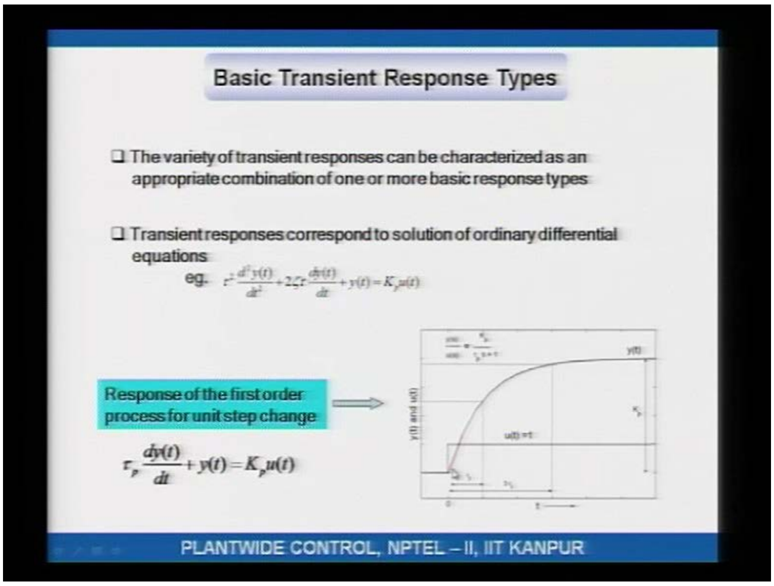
So, pure A is not pure a nearly pure A is obtained at the top and the B and C with some amount of A leave down the bottoms, so for this process, the input to the column or the inputs the column are the feed, the reflux in to the column and the reboil all right, and the outputs on the column are for example, how much distillate is coming out? How much bottoms is coming out? What is the temperature profile inside the column, temperature and composition profile? What is the purity of the distillate, and what is the purity of the bottoms? So, these are all output variables, in order to characterize your response in a systematic way, the inputs that are typically used are standardized, so there are certain standard input changes and in response to those standard input changes you get typical responses.

(Refer Slide Time: 08:37)



That is standard input changes would for example, B a step change, where you go from some level to another level and stay there, the input goes from some level to another level in a sharp step and stays there, you could also have a pulse, whether input goes up as a step and then comes back as a step after some time to the same value, you could also have an impulse which is a sharp sudden change, and this you know mathematically speaking; the impulse is a direct delta function, but in practice you never achieve, you never are able to achieve a perfect impulse for all for that matter your never able to achieve a perfect step, but never the less, what the step means is a very sudden change from one level to another level and impulse in example of that would be for example, you inject to tracer into a flowing steam that would be an impulse or that would be similar to an impulse, but not exactly the Dirac delta impulse, so these are standard input changes, and you would give these standard input changes to the process and then observe the output.

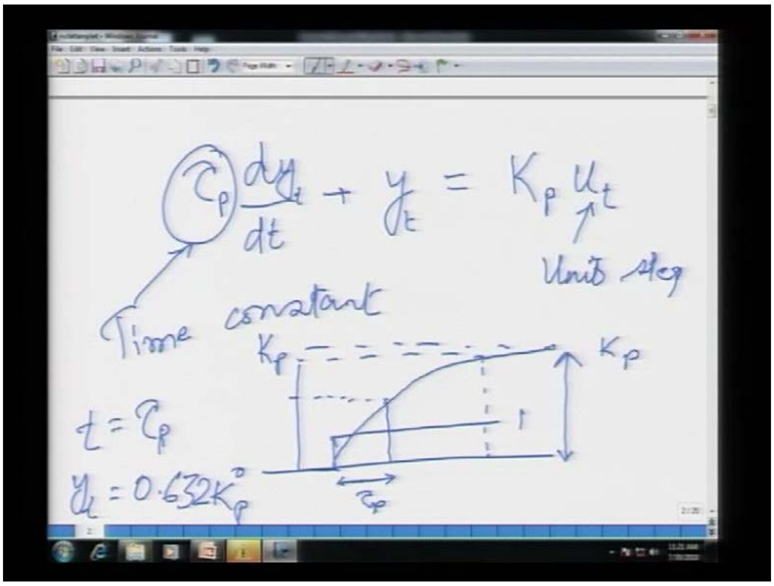
(Refer Slide Time: 09:46)



Now, there are certain basic transient response types, and it is like a you know human being can or can be categorized into different basic personality types, similarly no matter what the process you give a change to the input, the output will typically fall into some basic response types and it is these basic response types, if you combine these basic response types pretty much all the responses that are there possible can be all the possible responses are some combination of these basic response types for example and these transient response types or these transient response times this transient response types are typically solutions to ordinary differential equations, the simplest ordinary differential equations are linear with constant coefficients, time in variant.

Here is an example, the example that I am talking about is a second order differential equation and it is return over here, here is another example this is a first order differential equation, and you would see that if you give a step change to a first order system, the output would rise as an exponential and did not then Laplace transforms, but that is besides the point, so you are giving a step change and the output response as, a output response as an exponential of the total change in the response from the initial value to the final value, the output changes by 63.2 about two-thirds of the response gets completed in 1 time constant, I think I need to explain this well, so here is the differential equation may be.

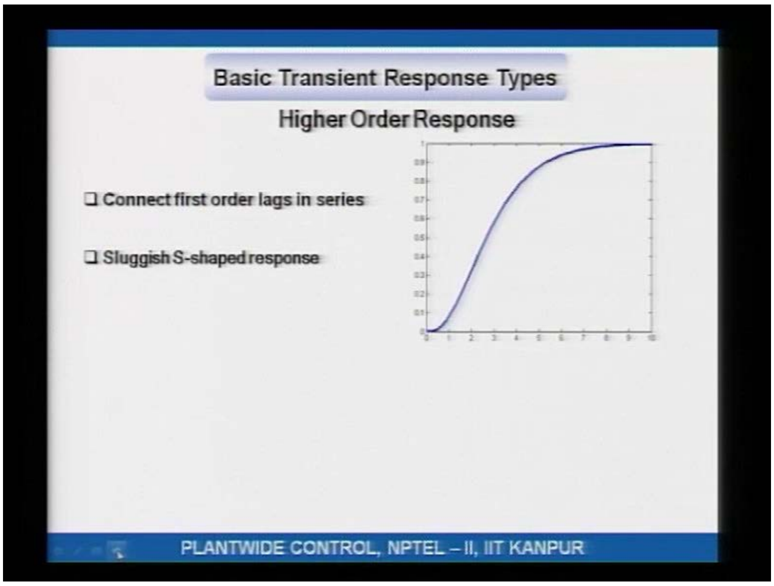
(Refer Slide Time: 11:50)



So, here is a first order differential equation, the simple differential equation d y by d t plus y is equal to k p times u, and y is a function of time u the input could also be a function of time, now if you, if the u is a step this tau p is known as the time constant of this first order differential equation, it is called the time constant; now if you give a step, if u t is a unit step, if u t is unit a step then if u t changes as a step, it goes from 0 to 1, 0 corresponding to the rest state of the system, 1 corresponding to a unit change then the output of this differential equation y could change like this, this is called the final steady state, where everything, where the rates of change or 0, so if you put d y by d t to 0 because at the final steady state d y by d t should be 0, if I set d y by d t to 0 at the final steady state if u t is 1, you will have y at time t tends to infinity is k p, so that is what you have, this is k p and if you look at the solution of this differential equation ,what you also have is that at t is equal to tau p, y t is equal to 0 .632 of k p.

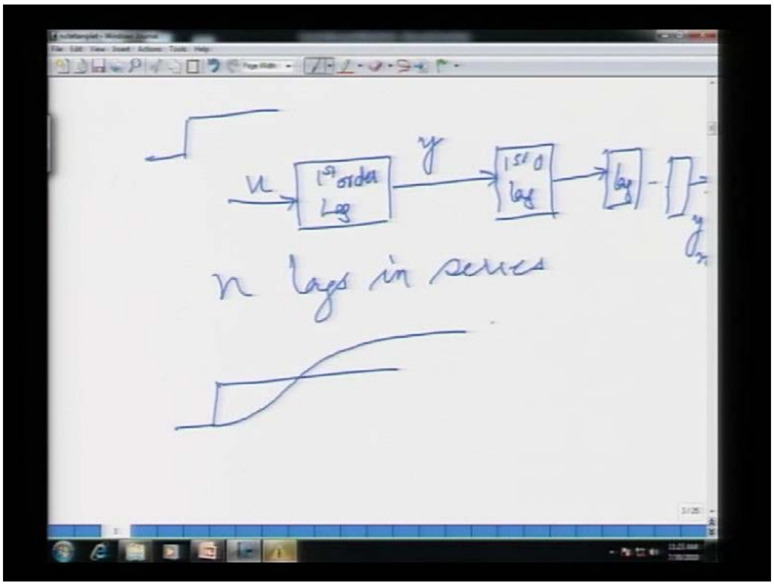
What that essential means is that 63.2 percent of the overall response gets completed in 1 time constant, similarly about 95 percent of the total response gets completed in 3 time constants, so in 1 time constant this is the total response, if this is the total response two-thirds would be about here, this would be 1 time constant, if you take 3 time constants which would be about here about 95 percent of the overall response would have completed, so this is first order this is , the this is the response of a first order system to a step change, by default we are going to look at step changes as our standard input, input change we are not going to look at pulses or impulses. So, this is the response of a first order process a process that is described by a first order differential equation.

(Refer Slide Time: 14:48)



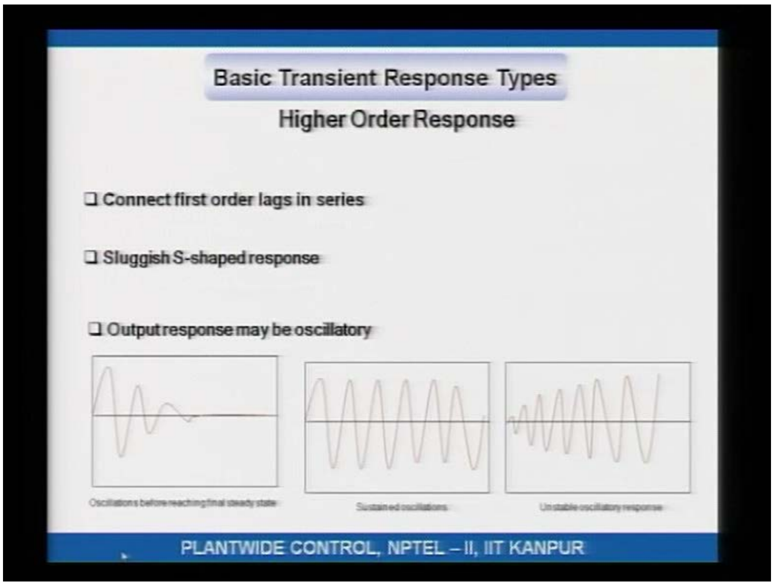
If you connect first order lags in series well, we will get back to here is my process which is a first order lag.

(Refer Slide Time: 14:57)



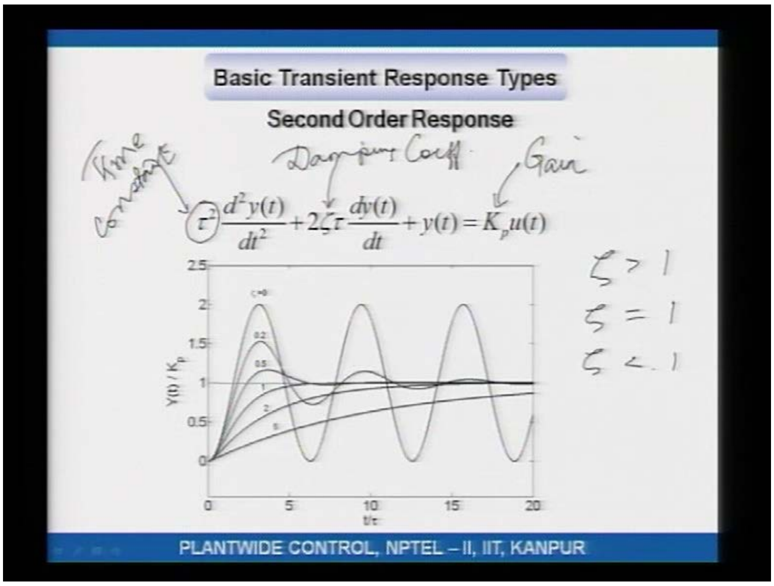
A first order ordinary differential is also some time refer to as a first order lag, you have your input and you have your output, if this output is further going into another first order lag, first order lag and if this output is further going in to another lag and so on so forth, what you have is lags in series? Let us say, there are n lags in series, then if you look at the output from the n th lag, if the input change is a step, if you changes as a step y n would change in this case something like in s shape, so when you see an s shaped response that essentially can be described by n number of lags in series, so if you connect first order lags in series, the output in response to a step change in the input changes as a sluggish s response, looked at conversely; if you looking at response that is s shaped it can be described by n number lags in series right, you could also have a second order differential equation.

(Refer Slide Time: 16:40)



The output would be oscillatory, first order lags in series s shaped or it or of a sudden exponential rise; these are very smooth responses, sometimes what you see is the response of the output to a step change in input may be oscillatory, these oscillations may die down in time as is as show in the first sub plot, this oscillations may be sustained just they keep, they just keep going on and on, and on, alternatively this oscillation makes usually blow up in time, so the first case is usually refer to us when are damp oscillation, sustain oscillation you are at the limit of in stability and if the oscillation of glowing of that mean in you are system is unstable, we are taking about little more about instability, but this are some are typical oscillatory response that you see in practice.

(Refer Slide Time: 17:34)

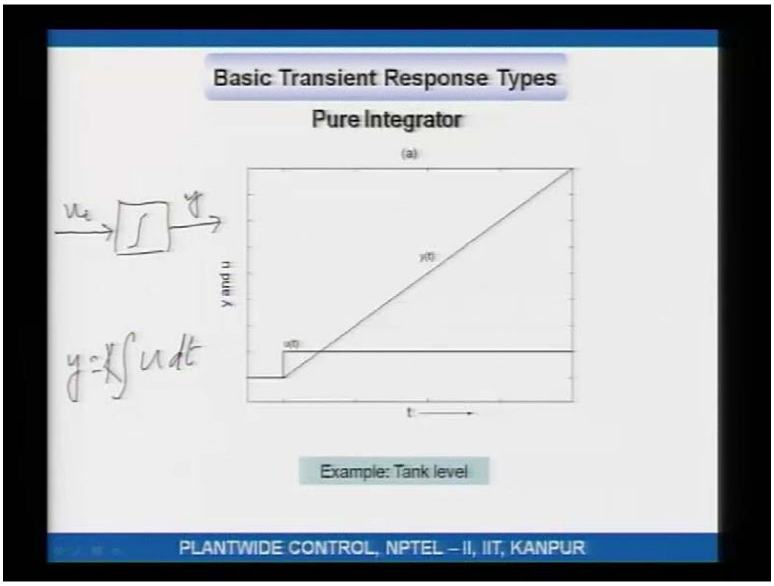


In order to get oscillation, the system has to be under damp second order at least; that is because, have may be is not appropriate to going to theory of differential equation, so let us, so hear is second order differential equation is simplest is type, and this guy tau is again is refer to us the time constant, this fellow si or zeta will be the symbol name is may be typical effect to as the damping coefficient, this is refer to as the again, process again, so know this damping coefficient could be less than 1,one more than 1, 0 or even less than 0, so as just drawn from response for different value of the damping coefficient and what you would see is?

The damping coefficient is, let us 5, you get a very sluggish response as the damping coefficient is decrease, damping coefficient 1, there is response a fast exponential is right is to the final study state value as the damping coefficient goes to below 1, you start getting oscillation, this the magnitude of the oscillation is increased as the damping coefficient goes down; at the damping coefficient 0, the oscillation are sustain at means that one died on, if you goes below 0, this oscillation will is actually blow up, so the damping coefficient actually characterize here second order system, if the damping coefficient what is symbol that gives as stable, if the damping coefficient is greater than 1, system is known as over damp.

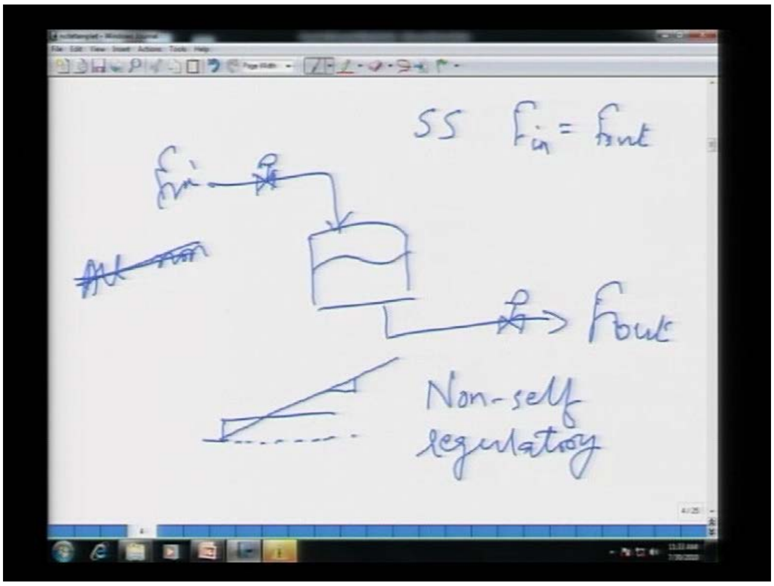
If the damping coefficient is equal to 1, the system is called critical damp, if the damping coefficient is less than 1 is called, for give my handwriting is not good that is my use this presentation paper, if the damping coefficient is less than 1, you have on under damp, under damp second order system will show oscillation, if you go into the theory of differential equation is, what you find is? The left and side can be described, you have the characteristics is equation is got roots, when epsilon is greater than 1, both the roots are real and not equal, at epsilon equal to 1, the roots are equal and real as epsilon goes less as damping coefficient goes less than 1, these roots become complex conjugated pairs and for oscillation the characteristics equation has to have at least once set of complex conjugated pairs, these oscillation or because the roots are complex conjugated pairs all right.

(Refer Slide Time: 20:51)



As in that about all the on the say on this, basic transient response types, pure integrators; what is the pure integrator? A pure integrator is nothing but, when of pure integrator and you have the input and you have the output, so if the input both of as a step they output y would be integral of u d t, so if u goes from 0 to 1 well, the output as gone in this as a ramp and the slop of the ramp is equal to k, what is the an example of a, of a pure integrator in process situation and the example is tank level, and just to explain it little bit more, so consider is very pure liquid tank.

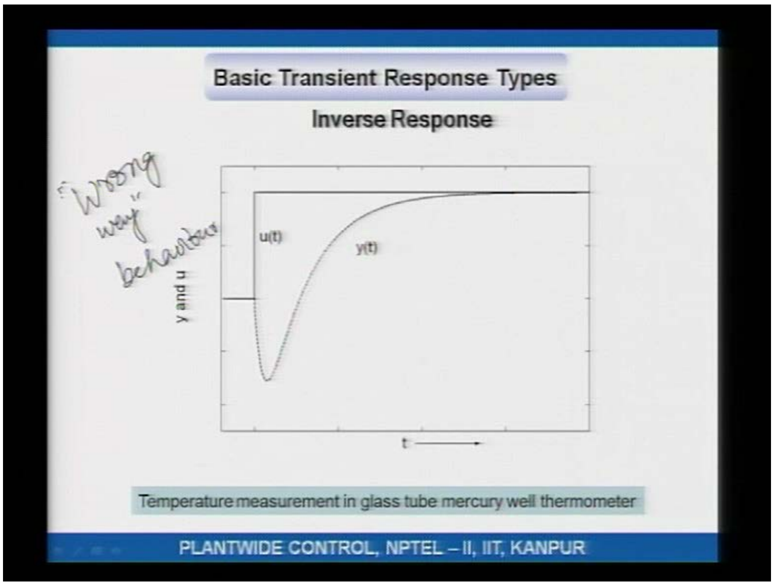
(Refer Slide Time: 21:43)



Liquid is flowing in, liquid is flowing out and you got some hold of some liquid level in the tank, if got flow value at the input flow and also value at the output flow, now if the level of level is constant; that means, the level is not changing that indirectly impulse the inflow is exactly input out flow, at study state, at study state flow in is equal to flow out, so this is the f in, this is the f out, now let us say at time t equal to 0, the flow in goes up slightly as a step, what we happen to level, flow out is maintain at the same value at the before, so flow out remains at this same value, flow in goes up, the level well slowly start to rise and it keep on rising right, this is an example of pure integrator in chemical process levels in liquid tanks, what as mean, what implication does it have, what it means is the level unless you balance flow, the level is higher rising on decreasing as such variable also sometime on the refer to as non-self regulatory, so liquid level in a tank is a non-self regulatory variable.

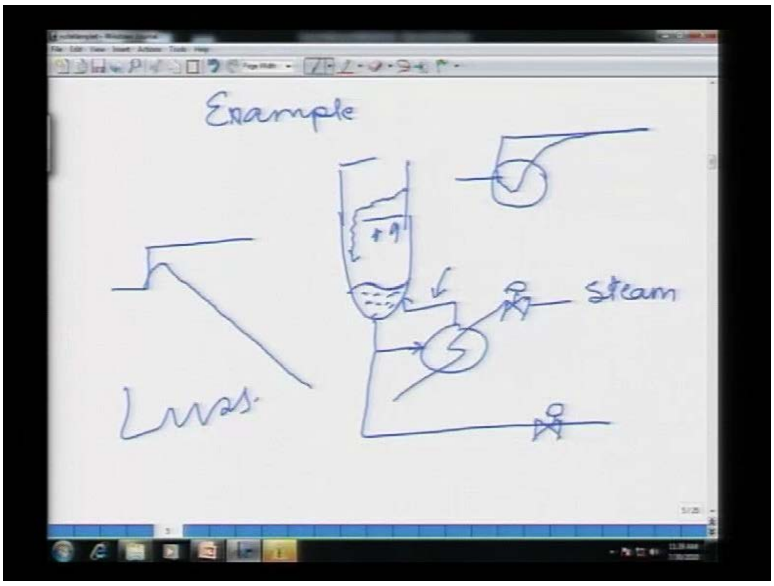
What is mean? It means the liquid want the liquid level want regulatory itself, you have to control the level, so the level does not, so the tank does not over flow or run dry, because the flow are not match right, so what that essential imply is, all non-self regulatory variable in a process must be controlled, because they want to regulate themselves, you have to adjust the input and output or some variable, so that in this particular example case, where the where the non self regulator variable is the liquid level, so the liquid level does not reach in unsafe condition; for example, the tank over flowing or the tank running drive, why is the tank running drive in undesirable situation, because there is the pump that is pushing the liquid of out, if there is no liquid in pump, the pump going to burnt that something is not desire, so all liquid levels in a process must be control, must control all liquid level in a process.

(Refer Slide Time: 24:33)



Here is an inverse response, u give the step change, the output goes in the wrong direction first, in the other direction first, turns the round on and then goes back up, so the initial direction of response is in some sense, the wrong direction; this is also some time refer to us wrong way the behavior, wrong way behavior; another common example of inverse response of chemical process is is the level inside boiler in example of inverse response process.

(Refer Slide Time: 25:24)



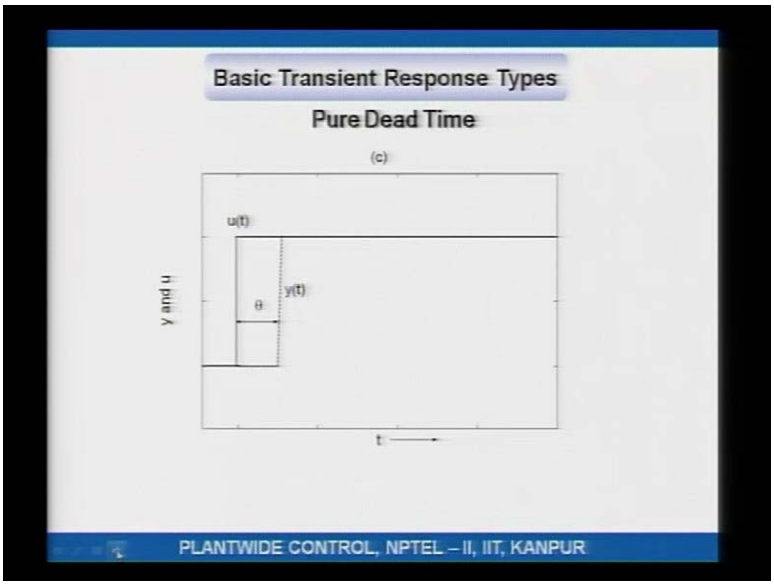
Example of inverse response, considered a distillation column, you got the distillation column, you got the reboiler, you are putting in steam, the liquid in the reboilers boils and this reboiler send and this reboiler is send back into the column and of course, so of the liquid is drawn out and in the column their at trace, their at trace in column down and come say out, so this liquid on this tray is which is actually flowing down and collecting in the bottom some, this is bottom some, let at say in increase the re-boiling boil put, let us saying increase the steam flow, in other words what are you saying in open this steam value, the more steam is going into the reboiler, because more steam is going into the reboiler, this flow would into increase the amount of vapor going into see into the column would increase, so you expect because the amount of vapor that is going in to the column is increasing, you would explain expect the this level should go down, because it is this liquid that is getting boiled right, that is getting reboiling.

So, you expect that if the steam is increased, the level inside the reboiler should decrease, what you what find is that actually what happen this? If you increase the steam, steam flow, the level actually first increases and then decreases, it shows actually in inverse of the response all right why this is happening? It is happening because the vapor that going on to the tray is about actually pushes more of the liquid could down, so the so the, so the level rises in the bottom some, also as the liquid is getting is more heat, there are more number of interact bubbles in the reboiler, and those and interact the bubbles loss at the interface to rise up, so because of this two things, initially the level steam to rise and an of course, the later on because liquid is getting remove at the faster away, the level goes to goes on to decrease, so this is an example of an inverse response.

Another example would be probably a thermometer, so if you have a thermometer which alcohol in it as the temperature sensitive fluid, let us say that thermometer to coming contact with a hot fluid, now you would expect, because of because the thermometer is one of the hotter, you expect the level or the alcohol in the in the indicator which level should rise up because of temperature is hotter what are actually will happens is? The level the metal, because of it good conductor, let us heated of rather quickly, so it expand, because it expand the alcohol level actually initial drop, so then of course, the alcohol also gets heated and then the alcohol level because of the heating goes on to rising, so if you, if you if you look at the response of a alcohol thermometer, if the input temperature is raising like this, the dynamic response of the temperature integral indicated by the sensor by the thermometer would look something like this.

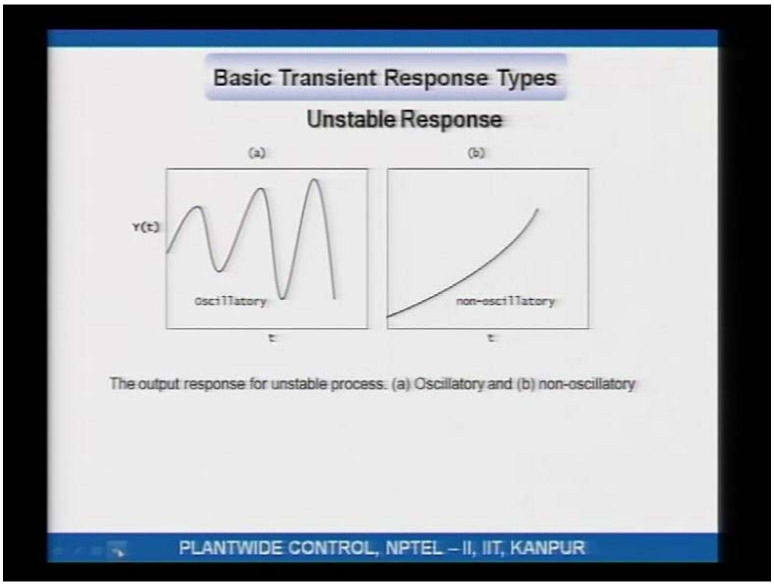
Of course, finally, it will becomes the same as the actual temperature because the everything thermal equilibrium, you can this is the inverse response on, this is another example by the way the level is non self regulatory, this example the temperature actually the output actually settle to as final value you, so it is self regulatory, but never the less the inverse response of the wrong way behavior is there, another example of wrong way behavior in process system is pact bet reactors what happens is? Impact bet the react is because of the conductivity of because heat can get conducted backwards through the packing, sometimes what you have is? If you are increasing the temperature of the feed, you would expect the temperature of whatever is coming out of the that pack bet reactor to also increase, but they can show wrong way behavior and this has been study of the quite extensively by the less and coefficient wrong way behavior also occurs impact bet reactors, so this are some of the example of where you see inverse response in process system getting back to our presentation, they are showing of example of temperature measurement in glass tube mercury well thermometer.

(Refer Slide Time: 30:03)



Basic transient response types pure dead time, so you make change know that happens of the output after some time output goes to same value as the input, so there is of pure dead time and this is because of transformation lags.

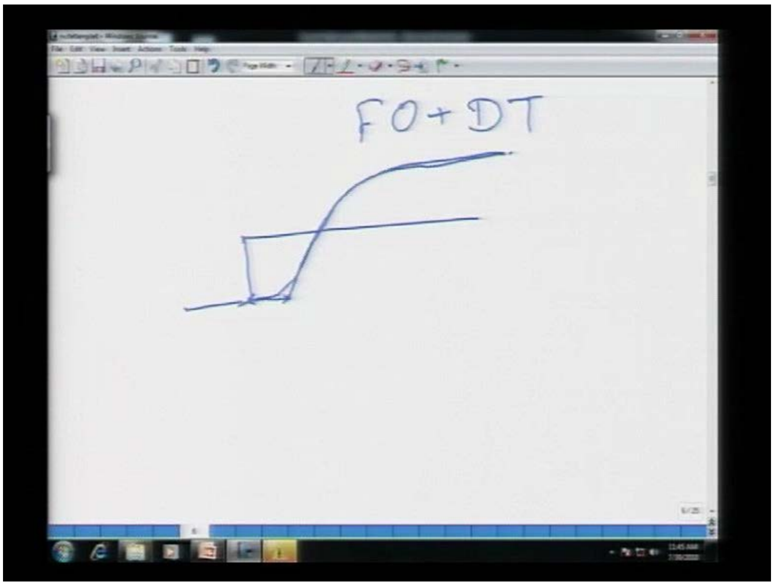
(Refer Slide Time: 30:18)



There are also unstable response is one example, let me want to already come across, in an oscillatory response on say oscillation are blowing up, you could also have a non oscillatory response, where the temperature which is just keep where the output just keep in increasing is, where is an exponential raise in the temperature, this can happen in reactors; in non oscillatory exponential rise into temperature, this can happen in reactors non exponential rise reactor temperature keep shutting up, so well that is that, is called run away reaction, Bhopal gas tragedy that was the runaway reaction that happen because what are seen into the methyl acetate gas tank and methyl acetate water react with exothermically, and so what happen was, because water got into the tank, because it live pack temperature of cold tank start to rise and as the temperature of the cold tank was rising, reaction want on faster, so the more, so more and more heat was realized and so that temperature of that tank kept on increasing, kept on increasing ever faster exponential essential rise in the temperature and finally, the gagster burst out and you know you have that tragedy on December 4 I think may be December 3 rd , 1984 that is which is it was news recently.

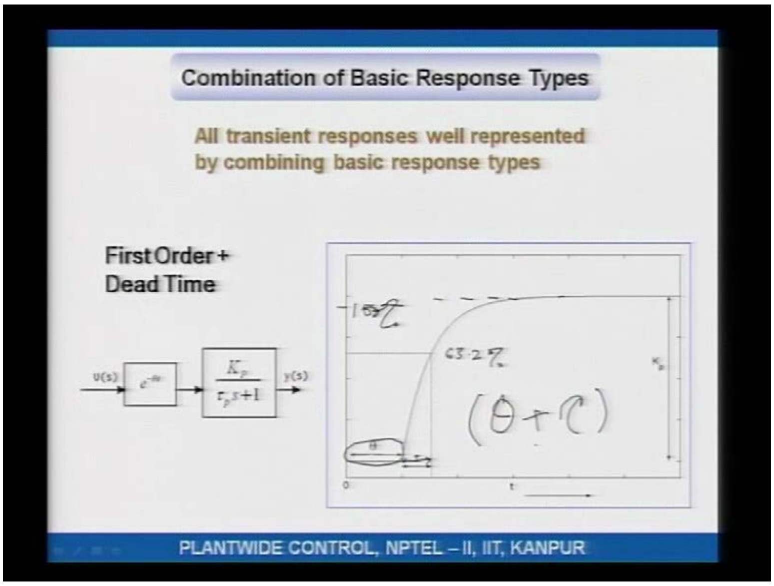
So, that is that is in unstable explanation rise in temperature is called on runaway reaction, so that was the runaway reaction which actually falls on the for category of non oscillatory response on so of the unstable type, coming back to process that dynamic, we are train to characterize the response of on output to with change input, so we have study the way of basic response types of first order lags, the pure dead time, second order response which could be oscillatory, which could be non oscillatory, unstable responses that or oscillatory or non oscillatory and so forth. Now regardless of what type of system we are looking at whether in each and airspace system or chemical system or mechanical system, the dynamic response of any process can typically well represented by a combination of this basic response types, coming back to chemical process is because to there are very large hold of in or process or process is very sluggish and the s shaped curves is very common, is a very response to a change in the input I just you clarify again.

(Refer Slide Time: 33:02)



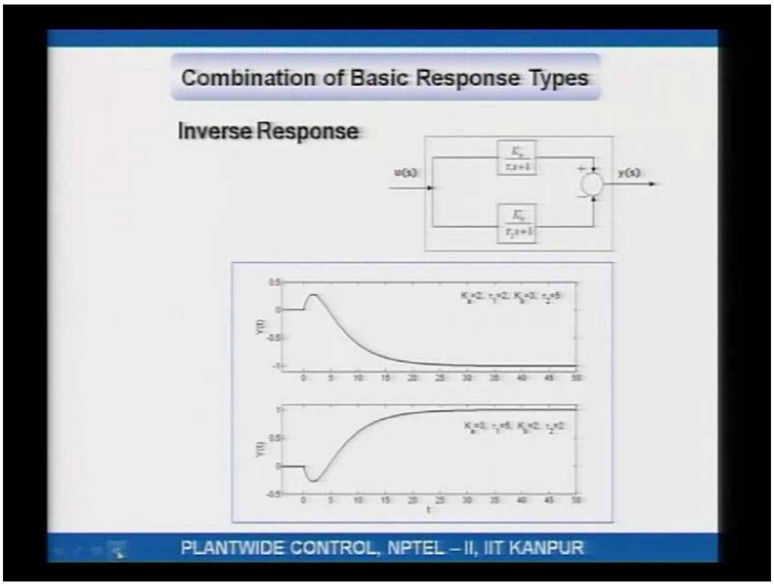
So, if you give us step change, many at a time in chemical process in response would be nothing happens so some time and an you get a slow rise and finally, the response settles is to final study state value, so this exponential n lags in series many a times represented as combination of nothing happens for some time a dead, dead times and then an exponential rise, so the first order, first order plus dead time D T dead time, so this first order plus dead time modules or very commonly employed to represent that dynamics of many chemical systems that show this sluggish s shaped response.

(Refer Slide Time: 33:59)



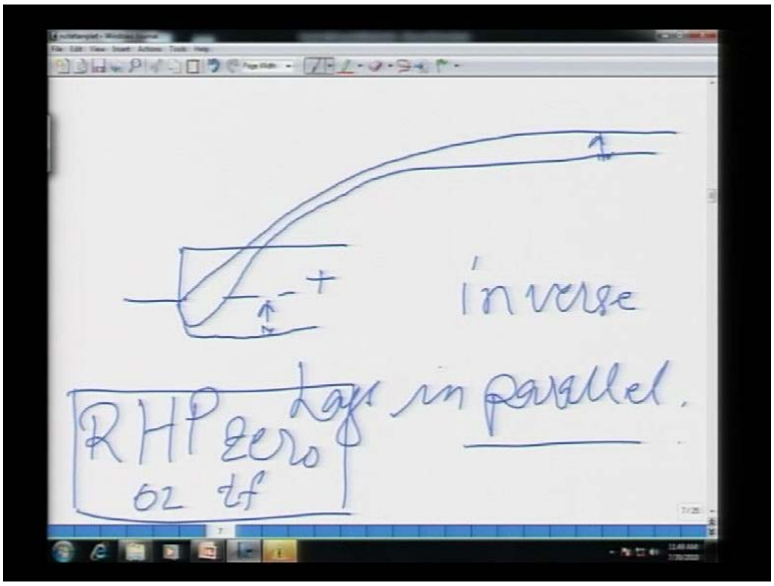
So, all transient responses can be well represented the by combining basic response type and one such combination which is very commonly employed is very chemical process modeling is first order plus dead time. So, in a first order plus dead time module, nothing happens for the dead time and then there is an exponential of first order the final state and the response rises is to 63.2 percent, if this is 100 percent, the response rises to 63.2 percent in 1 time constant, so over all the response takes theta plus tau units, time units to go about to complete about two-third of the hole way correct, so this is very commonly employed routinely employed in chemical process modeling inverse response how could you response.

(Refer Slide Time: 34:57)



How could you represent inverse response is that we talk about, that we talk about well it can be represented using to lags in parallelly.

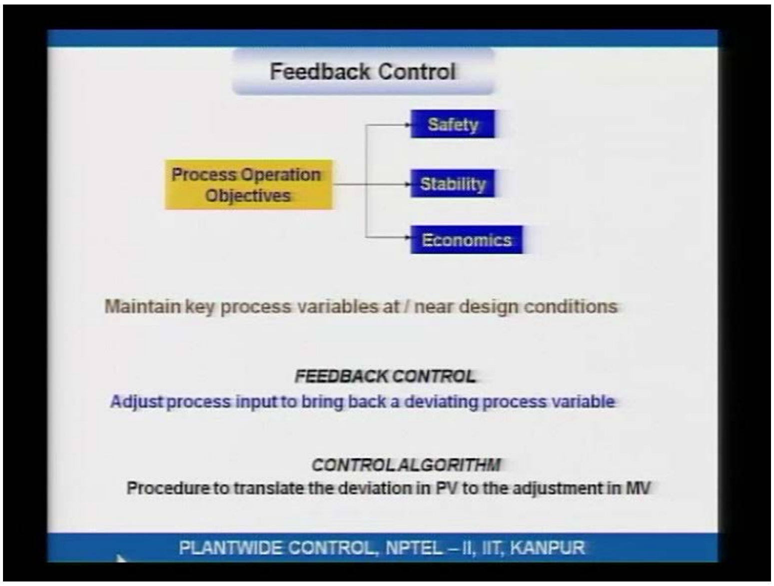
(Refer Slide Time: 35:12)



Consider so you are giving step change time t equal to 0, one of the lags is a sluggish first order response with large again, so what happen there it is sluggish first order response whether large gain, the other lag is a fast transient response in the opposite direction that is negative gain, so it is fast, but is small negative gain, so if get fast response, but is small negative gain, when you add the this two up the overall response could look something like this, you know this difference would be whatever this gain is right, so this is how an inverse response is module as lags in parallel, in process dynamic pallor if you have, if you familiar lags of Laplace transform which we should be un inverse response corresponding to a right half plane 0 in the open loop transfer function, but that we says the point of think conceptually, you can clearly sees that if you got sluggish large again first order response and way and, and fast small gain in the small, negative gain response in the response use some the to of what we will get up the output could be the in inverse response.

So, getting back to presentation that is got here showing, so the inverse response, you got this ,minus this and then what you get in inverse response all right, this is just two example of, where I will used different values of the use gains and the taus to show that we can inverses response in that direction or in this direction, so different values of gain and time constant for the first lags, the different value of the gain and tau constant of the second lags and what you get in inverse of the response in the with the negative, with the study state negative gain and here get in inverse response, whether positive study state gain all right.

(Refer Slide Time: 37:35)



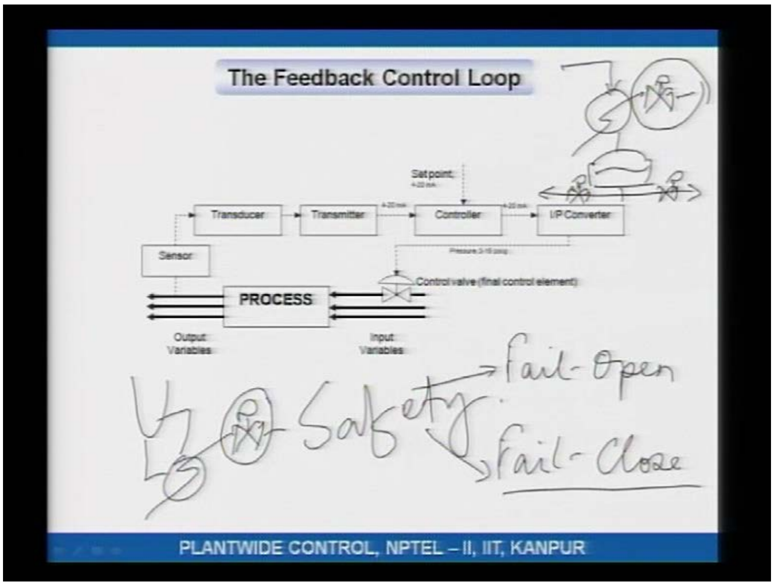
Now, we come to feedback control, getting back to the previous lecture that you had the objective of on operation, we must of operate the process such that the operation does not create, an unsafe situation is never creator, and wide do we want to wide and unsafe situations because we are the dealing with chemical that are hazard in nature, little bit of gas, little bit of, we can n number of people can perish, one explosion n number of people perish, so safety is or prime important, we want to operator your process in a safe manner. Stability, why stability importance? Because, if the system is unstable typical we will end up the in a safety hazarder, in a hazarder situation and last, but not least economics operating the process actually to make money. So, you want to ensure safety, stability and finally, you want to run the process to such a manner that you make profit.

So, in order to ensure safety and stability, this typically boil down to maintaining keep process variable at or near design condition, what as mean? For example, we would like to operator reactor act its design operating temperature, you would not appreciate to large variation or large excursion in the large reactor temperature from it is design operating temperature, because it could lead to run away for example, now in order to maintain key process variables at near design consider, near design condition, the variable may go away from which design condition because certain input to the process changed, there are certain disturbance and so and so forth, now in order to maintain it at its desired value, you can change some inputs, so if their reaction temperature is increasing well increase, the cooling of the reactor which and everything exothermic reaction and the increase cooling will bring the reactor temperature back to set point.

So, this is the basic idea behind feedback control, you are just a process input to bring back a deviating process variable back to which desired value, the desired value is of on refer to as the set point, so you have the process variable measurement, in feedback control, what you doing is here take you are looking at the measurement and if you it is deviating away from the set point; based on the those deviation your deciding the set point by how much you should change the input in order to bring that deviating variable back to the set point, and this procedure that you used to translate the deviation in the process variable to an adjustment in the input variable which is also refer to as the manipulated variable is called the control algorithm, how do you translate the deviation in the process variable into change in the input to the process into the manipulate is the variable that is done by a control algorithm, it could be very simple, it temperature is increasing.

For example, this air conditioner, we know the thermostat if temperature increase has increased beyond the certain limit, switch off the compressor or other switch on the compressor, if the temperature gone down beyond the certain limit, switch off the compressor. So, this is simple algorithm, it is a control algorithm all right, which is call on off control, the compressor either on or off depending on warrior temperatures.

(Refer Slide Time: 41:29)



The control that is an implicated that is most popular in d in d industry is more sophisticated than this on off control example that is give you very rudimentary, what you have is, you have a process, you have different sensor in the process which are indicating flows, temperature, pressure, compositions, molecular weights, melt flows indication and so and so forth, so there is a sensing element; whatever by the sense signals for example, it could be a slight change in the stress that sensor sees, this mechanical or whatever sense signal is convert to and equal to electrical signal using a transducer, a very common example of transducer is Wheatstone bridge, now the transducer will give you an electrical signal which is say for example, in milli volts or in volts or milli amperes or whatever.

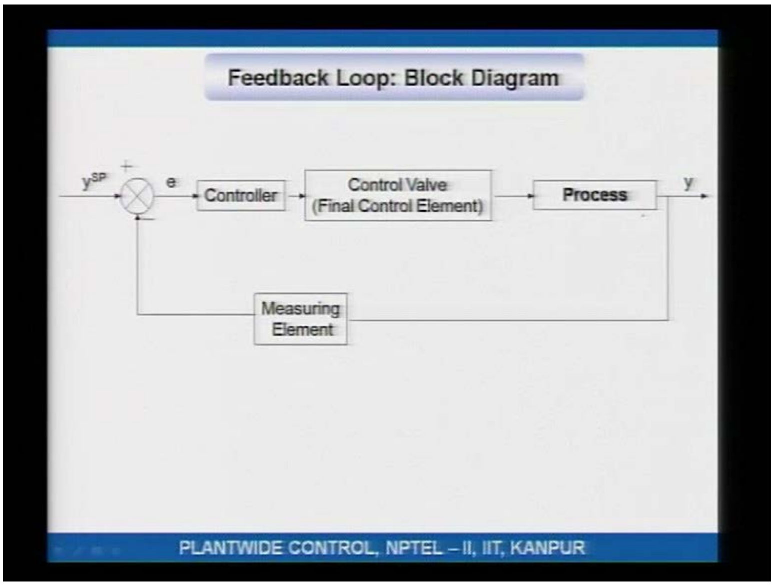
Now, for standardization, the input to our control is always between 4 to 20 milli amps and the output from the controller always 15 to 20 amps, why do you want standardization? So, that every manufacturer is manufacturing the same type of controller, so you can by or control from here, from there ,from wherever and show them that will take same kind of inputs that take give you a kind of output and it is standardization across every one, so that transducer a gives a single, gives the signal which may be in volts milli volts excreta, excreta, but this signal needs to be converted into signal that can be taken by the controller, so the transducer gives a electrical signal is converter to 4 to 20 amps signal, but by the transmitter, the controller thus its calculated since and then it outputs 4 to milli 4 to 20 milli amps output signal, now in chemical process is the control the manipulated variable is typically some flow of somewhere for example, you would be manipulating the steam flow into the heat exchanger in order to keep the temperature of a process stem at its desire value, alternatively you may be adjusting the cooling water flow in other to cool a steam and so and so forth. So, typically what gets adjusted or manipulated in order to hold and output attitude set point is some flows somewhere in the process, now how do you adjust flows using control valves, how do you move control valves as well, how do you move the control valves well, typically control valve will have a spring at diagram and then air is pressing again that spring, if you increase the pressure, if you increase the pressure of the air the valve closes, if you increase, if you decrease the pressure of the air the valves opens, so there is the instrument air that is supply to all the valves and this air by varying the pressure of this air, you are changing the position of the valve and as the position of the valve changes, the fluid flow read changes and this is what is the manipulated variable.

So, now, the output show the controller is the 4 to 20 milli amps signal, what you need to do is convert that in equivalent pressure signal which is the pressure being the exacted the by the instrument air against the valve, so this is done by I to P converter of current to pressure convertor and again the output of I to p convertor is standardize, it is between 3 to 15 psi gauge, so the instrument air, so 4 milli amps for example, make a response to 3 psi and 20 milli amps make a response to corresponding 15 psi, so the I to p convertor gives the desired pressure on the air and because the air pressure because the changes the valve actually moves it as a open as it as closes.

The valves can also to be two types; it could be fail open that me right this down, it could be valve could be fail open; that means, if the air supply fails, the valve if open is full they would be 100 percent of open, it could also be fail close; that means, if the airs supply for some reason is taken away fails than the valve will fully close, if the systematic valve is pressure bring is applying how the spring is oriented, if the spring in this at the air pressure, there is applied of this, well valve will close as their pressure is applied, if the air pressure fails the spring make the valve fail open, if the spring is this fail, if the spring is if this fail on the air pressure is applying this fail as you applying air pressure valve actually opens and so it the fail close valve, where do you using process situation is fail open and fail close valves, valve this is determine by safety and in example of that would be for example, you got steam going into reboiler and distillation column, you would like this valve to be what if the instrument air fails to this valves, what would you like should this steam flow become maximum fully open or should the steam flows is 0, all safety detailed if the air supplying failing, the valve should actually close, so that too much heat is not supply to the reboiler and this is the get does not burnt right.

So, this valve should be fail close if the air supply fails, the valve should close, what is an example of fail open air valve? If you take condenser of the column, you got the condenser in the column which is taking hot vapors, condensing heat, putting heat into reflex valve and some of it is given back to the column the other is taken out the distillatory, you take a condensed to the column, this cooling water valve what should could be fail open or fail close valve, if the air supply to the valve fails what would be like, you would like that whatever hot vapor like this coming, it should get condensed is to no matter what, in order to mention that this cooling water valve must fail open, if the air supply tills cooling water is at max. So, that the hot vapor that is coming gets condensed regardless of whether air supply there or not right, so this valves should be fail open, so the processing situation determines what type of value you will have?

(Refer Slide Time: 48:44)



You have the process, there is sensor that is measuring the output, this is a measuring element through the this includes transducer, this is saying what the output is, what may temperature, flow or pressure is, you would like the temperature flow or pressure should be a set point, the difference is error, this error goes to controller which are typically PID controllers, the controller outputs the signal which goes to the final control element which is typically air control to value, and because the control value moves the input the process changes, and hopefully if you got everything right, the change in the input would be such that deviating, we will be broad back to normal and broad back to desired value, this is just block diagram of a feedback control loop.

Very common example of feedback control is as suppose you go you go take a bath, if got the hot fluid coming from hot water coming from this geyser, you got the cold water coming from we know from the tank, over head tank, you want the temperature as a water to be comfortable may 37 to 40 Celsius, so what you do you open to cold water and you open the hot water and then adjust the two valves such act the temperature of the mix steam is what we would like to be, so the like to be comfortable bath, this is an example of feedback control your body is sensing, your body is sensing what temperature water is, if it is uncomfortable, if it is too hot ,you will either increase the cold water and flow or you will decrease the hot water flow, if it is cool, we will increase the hot water flow right, so this is one example, another very common example is driving a cycle, driving a cycle would be feedback, you are balancing cycle is essentially feedback control, it goes this way, it is adjust handle such does it maintain; that means, straight, so depending on which will going on to will make on adjustment in your handle position, so that remains balance, so balancing in a cycle is a also in a example of feedback control.