Fire Protection, Services and Maintenance Management of Building
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Lecture – 24
Control Systems

So, having looked into issues like storage capacity, sizing, etcetera, etcetera. Now we can look into Controls, right. So, control in the basically we need some control why. As we have seen you, if you recollect, I will just draw it again for you right. Now, draw it again for you. We had some resource environment remember, resource environment, then the system service system right and then I have got the control environment; you know basically where I want to provide the services service, right.

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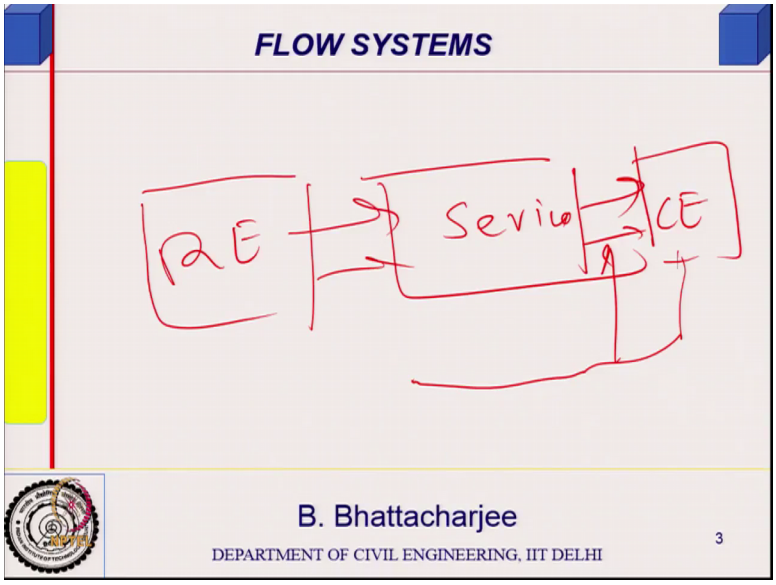

Now, this has to be in a controlled manner. This has to be this has to have control; for example, for air conditioning I have got temperature in relative humidity. Now, I must I will be supplying supposing is in a tropical climate. And in summer, I will be supplying cool air to the room which will observe the heat from the room and then exhaust out.

So, in such situation this, this supply has to be controlled depending upon the situation here right, depending upon the situation here. I cannot go on just applying and cooling it as I require because as a range, bottom range. So, there is a design range. So, I must get an information from here and control this supply. So, that has to be, so the control system

is required in order to ensure that I am supplying or maintaining my system is you know, system is providing the control environment is controlled condition as required; not more, not less.

So, this is why we need control system we need control system, right.

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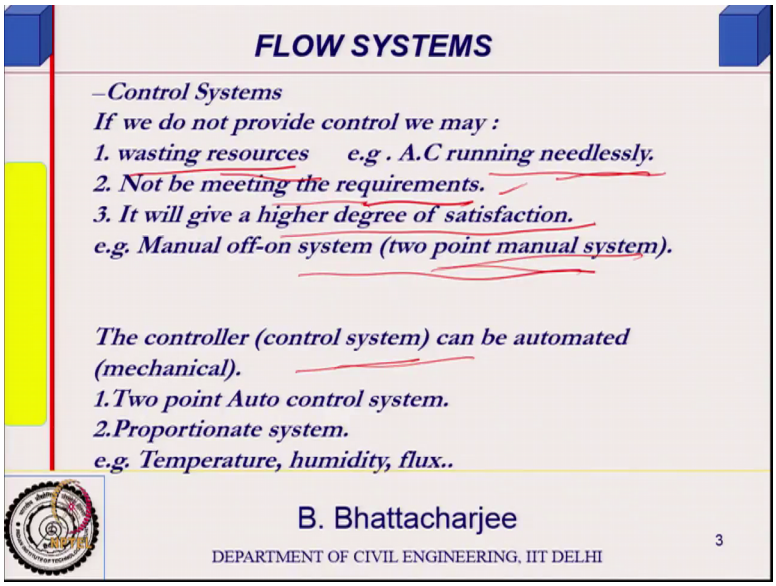

So, if we do not provide control, we might be wasting the resources, right. So, for example, air conditioning running needlessly. Now my office room let us say, right. I keep the air conditioning room because it is a small room that is what is a many many places you have manual off on control switch. So, I just put it on and do not bother to even one way is to feel very, put it off or other way I mean that is also a kind of a controlled by manual control by myself, I am feeling that it is too cold. So, I do not need a c put it off and so on or else I can just leave it on all the time. I mean so if you do know, if you have a control, then the source wastage will be relatively less, resource waste will be less.

So, AC will not be running needlessly or sometime it may not be need you know meeting that it needs or requirement of the needs. You know, it is it is supposing you know capacity is there, but supposing they see somewhere else right and I do not have a control, it does not see my condition. I have a centralized AC or maybe it is scattering to three, four rooms and there is it you know it does not sound nobody comes and ask me in a way if it is human being then somebody can ask, are you comfortable ok.

But if it is not you know if you are no human involvement there, automatically it should sense the room temperature and relative humidity and then put it put the duck, you know put your supply on or off. So, if I do not do that, I may not be meeting the requirement all the time you know. So, this is what really; then, it will give higher degree of satisfaction obviously. Psychologically, you feel better you know you just do not things are under automatic control.

So, manual one is manual off on control system now of course, it is extreme case is and intelligent building where it senses your requirement of all kind and there is a computer control system which will automatically control. For example, you went another many kinds. For example, you enter the room it senses that a human being is entered through infrared sensor or something of that kind right, because body temperature is different than the air, so then immediately trigger off all the lights on right.

So, such kind this is; so it says some you need some sort of sensing in feedback system ok. So, then the controller system would work. Now, it can be automated manual control system, you know it can be manual control system right and manual control system always will be off or on. That is what we call as two point off-on control system.

Manual system will be on simple simply either offer on. So, we call it two points off on control system. Obviously, automated can be mechanical or electronic whatever it is. So, two point off-on control system the other something else is called proportionate control system, proportionate control system. So, what will you do? It will see proportionately from some proportion way we will see that, it will reduce down the supply.

If it is cool too much or it if it senses the temperature and then it will supply proportional to the temperature, you will see that and there are you know temperature, etcetera, etcetera. So, temperature humidity flux many things it can control in that manner.

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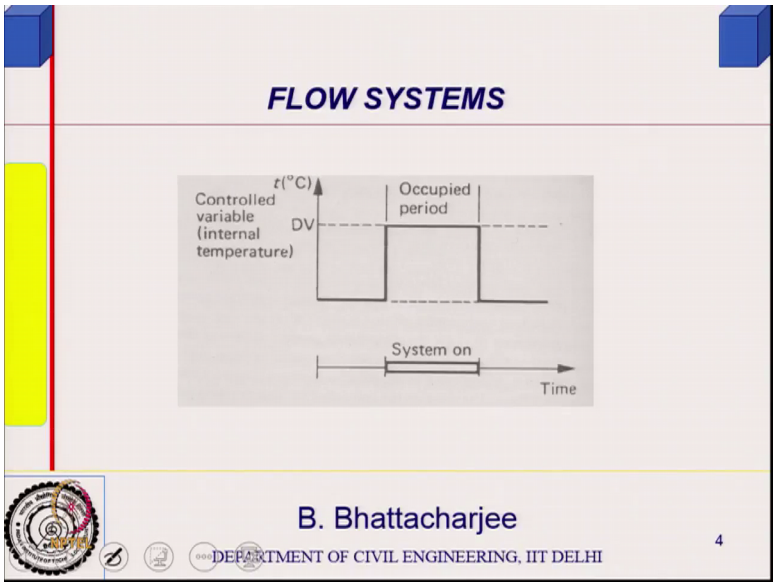

So, essentially it would be something like this. Ideally, it should be something like this. We have something called desired value or design value right; something called a controlled variable.

What is controlled variable? Temperature or relative humidity or lux level, temperature, relative humidity, lux level or even it could be noise level in a privacy of it is related privacy because I do not want any noise to come into my place. So, supposing I was sensing devices, there are there are systems maybe or if not there would be possibly. So, whatever it is everything fire we have already talked about automatic detection and a extinguishing systems sprinkler systems which works automatic.

So, when you put all of them in a building and make it a make it walk through a computerized system that is an intelligent or smart building. It has come along back 90's, it is not today's 90's is there. The Japanese they have experimented on some building. In India too there was a talk of these are 80's and 90's people talk of this. India heritage center is supposed to be supposed to be intelligent building. I am not sure how much intelligent it is at the moment over the years.

But that you have to see I am not very sure; similarly, CMC building in Mumbai was supposed to be an intelligent building. So, whether the things would be sensed, so ideally it should be like this. I have one variable, I call it controlled variable which is

temperature, relative humidity, lux level or whatever you want to control you know temperature related to fire and so on.

So, this is control variable internal temperature one of them example and it has got a design value or desired value. So, what I should ideally, I should be when 8 o clock my office starts this is time or maybe 9 am it starts, it should straight away go during the occupied period and comes back to lower level right. System on for exactly my required time but if you look at the temperature, it will not be like this. This is the ideal scenario. The system has got some inertia. So, if the moment you put it on, it will not reach to the

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Or desired value right and when you put it off it will not come back to the same value.

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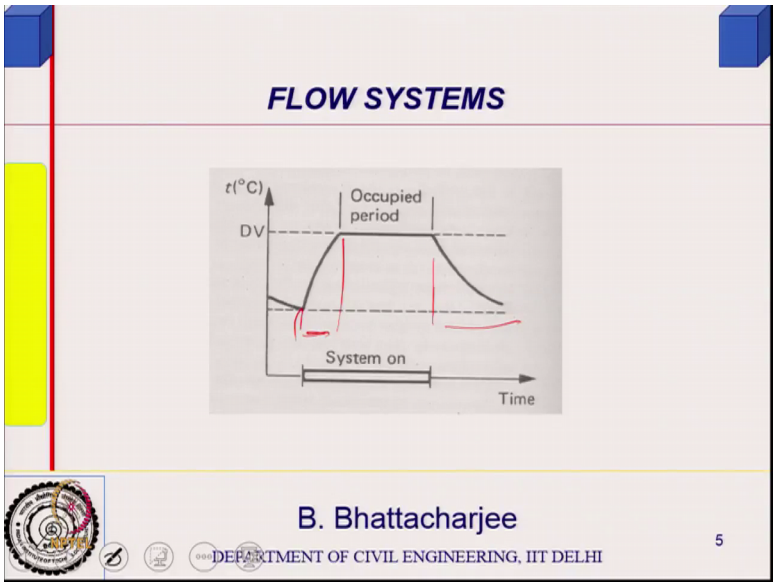

So, if somebody has to put in a centralized system, one we will have to put it somewhat earlier than this and system is on up to this time. Then once it has been put up, it would actually reduce down asymptotically towards the ambient situation otherwise.

So, system works for a longer period of time. And this is let us say you know, this is what we should understand that it does not work.

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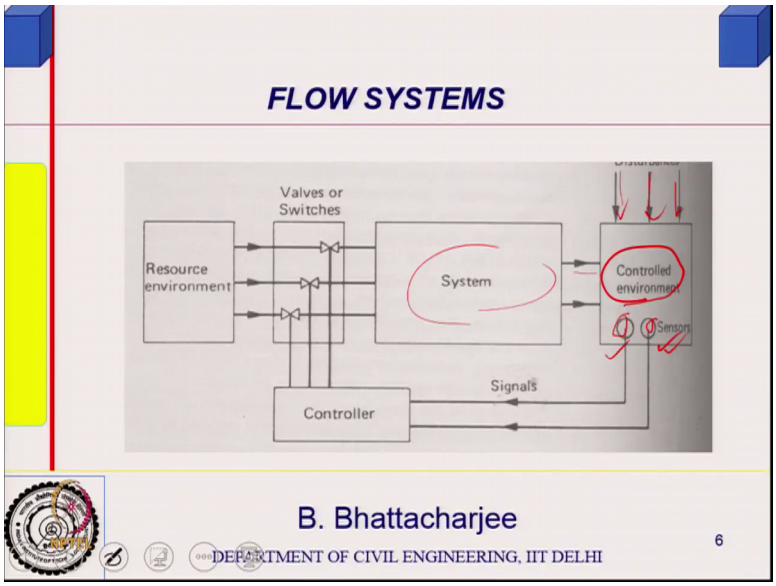

Now, essential component of such control system will be first of all a feedback. So, you have the control environment, you must have some sensors, you must have some sensors their; sensors control environment sensors. This we have seen that outside disturbances which will come for example, outside temperature changes relative humidity changes and all that.

So, these sensors will send the signal and there will be some valves which you control the flow, the service system is here, then it you know the flows goes according. So, it will not draw the resources as much as required if the temperature has already come down or if it is heating, temperature has already gone up. Thus, that you know the full heater will not be operating. So, there may be multiple of them. So, controller is the one which senses the through the sensors it gets to know about what are the temperature here.

The temperature the sensors could be whatever we have talked about earlier also; for example, in temperature it could be thermistor, you know or even bimetallic strip some of which are not I mean it has to be efficient depending upon what you are looking at thermistor or thermocouples or whatever it is, some kind of temperature sensing device, it sends the signal to the controller which actually would you know, this a you know essentially the electrical signal.

So, this controller will send signal and close or open the bulb depending upon the temperature sensitive. If the temperature is much higher than the design value, then it

will supply more. And if it has come below the design value, it will supply less or if it is two point of uncontrolled switch when as soon as it reaches a value what it will do? It will simply call put it off automatically. This can be done, this is you know this modern electronics and electrical systems, they can do it very easily there is no problem.

For example circuit breakers as you know, if the current goes high up, automatically it shuts off you know. So, that there I mean this is this control subject by itself. So, therefore, their electronic systems or electrical systems, they can help us doing this and this is what the essentially the component of a service system which controls. So, you will have sensors, you will have controller and that controller is connected there bulbs or switches, rest of the things are all same, rest of the things are all same right.

So, two point off-on control and proportional controls right. Let us see I will come to this. First, let me go to two point off-on control.

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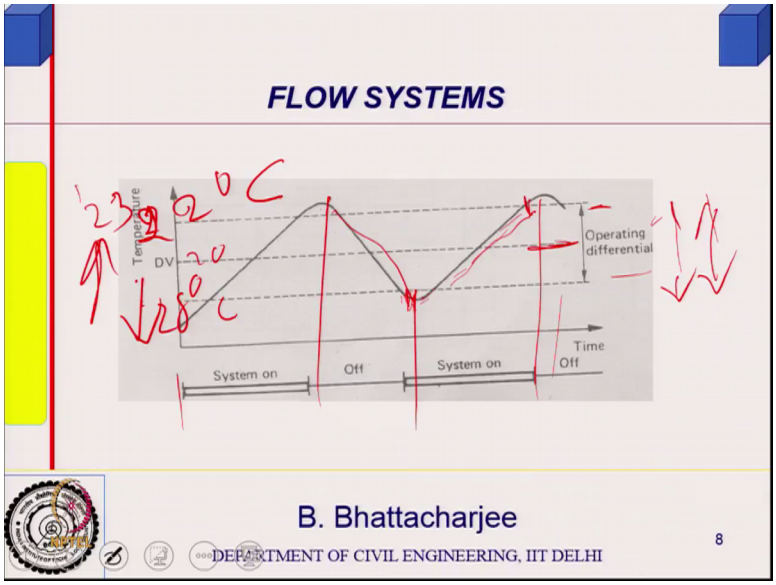

If it is because some definitions are there, I said that there is a desired value but you cannot keep it exactly same at that point, you will have some deviations from that on the plus side and some deviation from that on the minus side. So, this is called operating differential, operating differential.

If you have a two point of uncontrolled switch, it switches on here. The moment it switches on, it reverses the direction. You know for example, this temperature was this is

a heating system. Let us say or if my temperature is downward right say, this is this something like 22 degree centigrade or 22 degree centigrade and this I am talking of Indian scenario, 22 degree centigrade. And this is 28 degree centigrade right; higher temperature on the lower side because my desirable temperature or design temperature is 25 degree for my comfort requirements.

Now, if I have to point off on control switch what will happen there? As soon as I put it on, it is now at 28 degree centigrade it is reached. So, I should put on my system, then only cooling will be done. So, it starts cooling, starts going towards the 25 degree centigrade, but it will not stop because you have to have a operating differential, you should not put off the system as soon as it goes to 25.

Because then it will start again heating up quickly. So, we will never reach. So, what you do? You have another 3 degree, 20 degree, you decide that I will start at 28 degree and 22 degree it will put it off. So, what happens is 20 starts cooling goes up and at the moment it reaches 22, it puts off two point of–on controlled. So, 20 degree and this is called operating differential.

So, when it comes to the extreme level of operating differential either it comes to, either it switches off or switches on depending upon which side of the desired value or desired value of the you know controlled variable you are. If you are on the higher side you know that you do not require control. Then it will put it off. If you require supply, then it will put it on and if it is heating system, the temperature will be upward. It could be something you know like western countries maybe this is 20 or something they want to give. So, it goes to 20 depends upon how better control you have, 25 degree or plus minus 5 degree or plus minus 3 degrees you want to have, so 23 right.

So, 20 you know 20 degrees this the moment it is at 18 or something like that or 17 it will start heating goes to 23, it is so on and so forth. So, this is two point off-on control see, this is two point off-on control suits right. So, this is system is on for this period of time, you know it starts here system is on fourth this period of time, then system of during system of time it comes down and then again goes back. So, this is two point off-on control systems.

The controller does the job, it just puts it off. You have got thermostats refrigerator, simple example. So, what it does? It measures the temperature right. The moment the

temperature desire, it is cooled down to the level it puts it off and again it starts. So, you can do the same thing for all other systems, many other systems you can do the same thing it, puts it on heaters. For example, while cold heaters these days which, you find you know portable heaters, you find that they are with the thermostatic control. So, thermostatic control is simply two point off-on control system ok.

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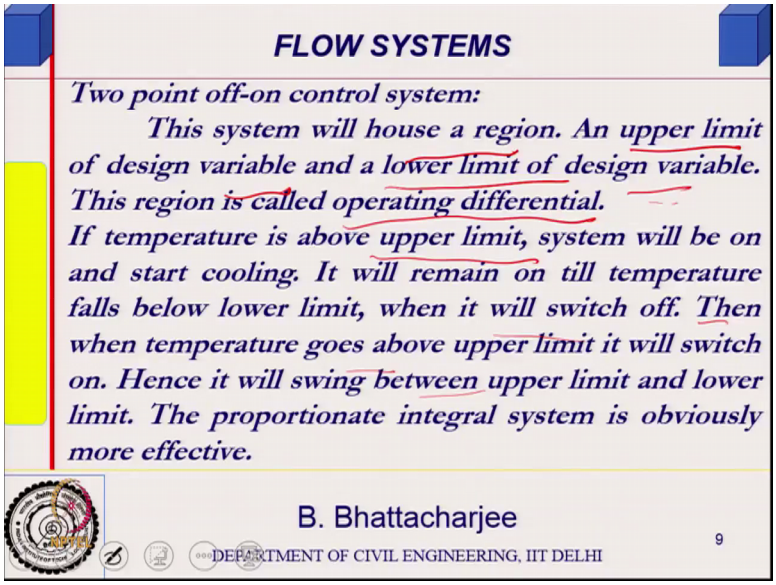

So, let us look at the next one, two point off-on control system. This system will house in a house a region an upper limit of design variable and lower limit of the same, that is my control variable actually temperature. So, this is called operating differential as I have shown in the diagram. If the temperature is above upper limit system will be on and starts cooling in case of cooling scenario. It will remain on remain on till temperature falls below lower limit.

When it reaches when it when it will switch off you know when it is switched off switches off. Then when temperature goes above upper limit, it will switch on again in case of cooling situation and it will swing between upper and lower limit.

Student: Lower limit.

Upper and lower limit right, upper and lower limit, the then you have got something called proportional control system. So, a proportional control system looks like this.

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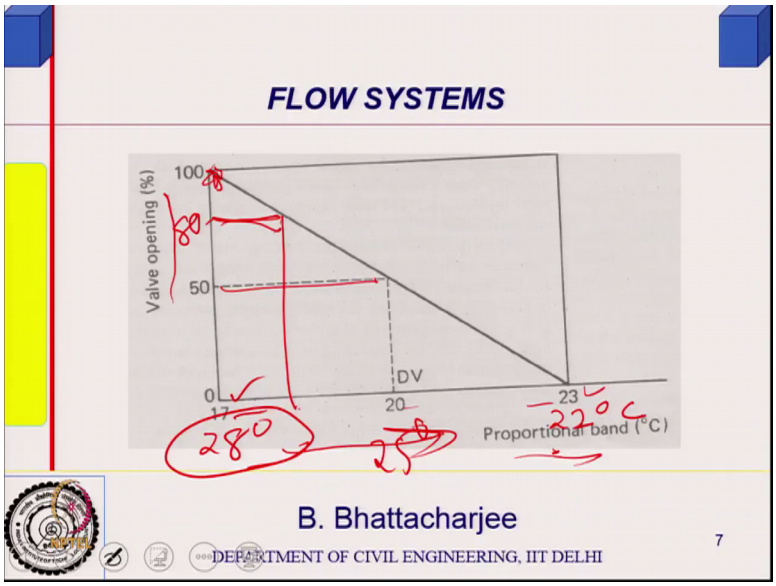

What it does is, it is this is for this is my, this is my you know, this is my control variable temperature here temperature in differential right. So, in case of in case of cooling system as I gave them same example, this will be 28 degree centigrade and this will be 22 degree centigrade; in case of heating system, it will be 17 to 23 right. So, what will happen when it is 28 degree centigrade in proportional control system, bulb open 100 percent bulb will be open.

Now, here we were controlling not the off and on, but control is operating throughout the time right, controller is operating throughout the time. When it is at highest temperature in a cooling system, it will open up the valve fully 100 percent. Now, the moment it comes to 50 percent right, 50 percent 50 percent, it will corresponds to the mean value of my 25 degree centigrade it should and when it goes to the cool lower limit 22 degree centigrade, supply will be 0, right.

So, it is proportionally it does not put, you know there it was two point; here it is proportional. If it is at highest temperature, so I design it like this highest temperature. So, linear simply linear from the 100 percent at the maximum temperature and 0 percent at the minimum temperature for a cooling system and proportionally it will, so for example, at mid point it could be 20 percent you know at mid point 25 degree centigrade, supply should be 50 percent.

At here the supply would be, bulb will supply if you control the bulb maybe the flow it will be controlling. So, it would be possibly 80 percent or 75 percent or whatever it is. So, this is called proportional control system. This is called proportional control system, right. So, in proportional control system what will happen? It and if it is heating let us say, so I will start from 17 to 23.

When it is 23, it has already something we warm, it puts it on and then when it is you know 17, it will be a 100 percent and at mid point, my design value desired value of the control variable, it would be at 50 percent. So, that is how I design it but there is a problem with this kind of system, what will happen?

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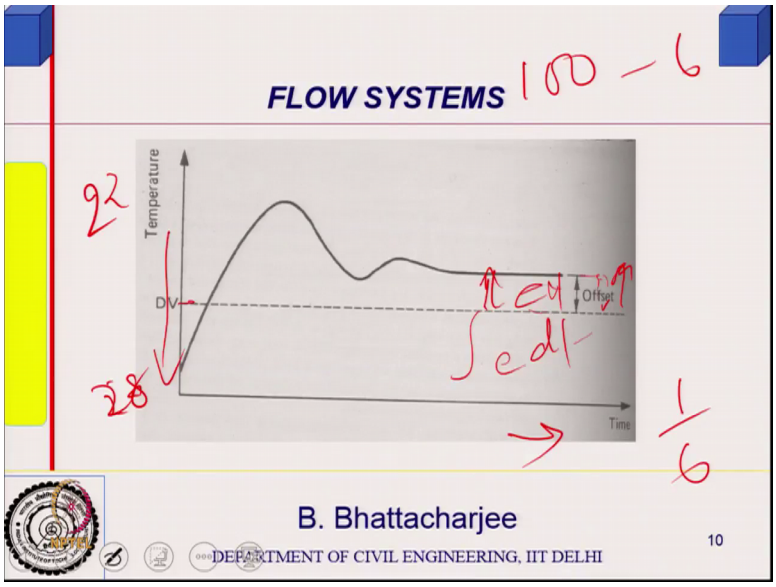

The system will have a problem that it will always try to because is on all the time, it is not off at all. So, it is on all the time. So, what will happen? When it is let us say in heating system, in heating system you know it is time wise, it is on all the time. Now, my temperature in the heating system let us say this is 20, you know somewhere here is 28 and here it is 20, you know 22 or whatever I talked about 22 or so, right 22 or so degree centigrade. So, what will happen? It is on all the time. The bulk which is maximum value right at 28, but supposing it is at near 22, 23 still there will be some supply, how much increase of supply actually 1 degree out of 6; 100 percent, 100 percent for 6 degree difference.

First for one degree, how much is the percentage? 1 by I mean 100 by 6. So, when it is at 23 still, 16 percent supply will be there I mean 84. You know it will it will actually continue to supply 16 percent. Supposing it goes to the coolest point, 25 is my desirable value and I said 22 is my limit after operating differential is 22. So, when it is 22, it will make it 0 right.

But immediately, it will go you know system has got your system is getting perturbation from outside, outside temperature inside. The moment it goes to 23, it will supply something like 16 percent. I mean one sixth of 1, 6 supply will be there because 6 degree 100 percent. So, one degree means one sixth of the 100; one sixth of the 100 is something like 16 point something. So, it will supply the valve will operate at 16 percent supply. If it goes to 2 degree, it will operate it 32 percent supply and so on. So, this is never off. For a very short period it might be off the moment is goes to 23, it will power supply 16 percent, but then at 16 percent supply the rate of cooling will not be as much. So, it might go on slightly higher up to 20 you know that 20 3 and so on so forth.

So, it is pattern of rise is something of this kind with time, but it tends to create an offset. You do not get at 25, you will get it, you do not get at 25, you tend to get it at maybe 23 or 24. So, you always get a temperature lower than the design value in case of cooling. In case of heating, it will be above the design value. If the design value was 20, you will tend to the offset over a period of time. And you will find there is a constant offset all the time and it will tend to you know, it will tend to keep it warmer than what is required.

Now, this means wastage of money, this means wastage of money. You know your course you need 20, you are getting 21. You need 25, you are getting 24 all the time someone whatever, what are some offset will be there. So, we generally control it, we generally control it. So, proportional control system is a, small problem which is it will try to create an offset, it will try to create an offset right on the higher side right, higher side on the design value higher; I mean here not the absolute higher comfort value I am saying you know.

So, it in case of heating, it will be one degree higher maybe or some degree higher you know fraction of a degree higher. In case of cooling, it will be fraction of temperature lower. Similarly, for any other thing, if you are controlling, it will be of this kind. So, this

offset can be minimized or reduced down right and actually it will bring in inefficiencies, it will bring in inefficiencies of the system.

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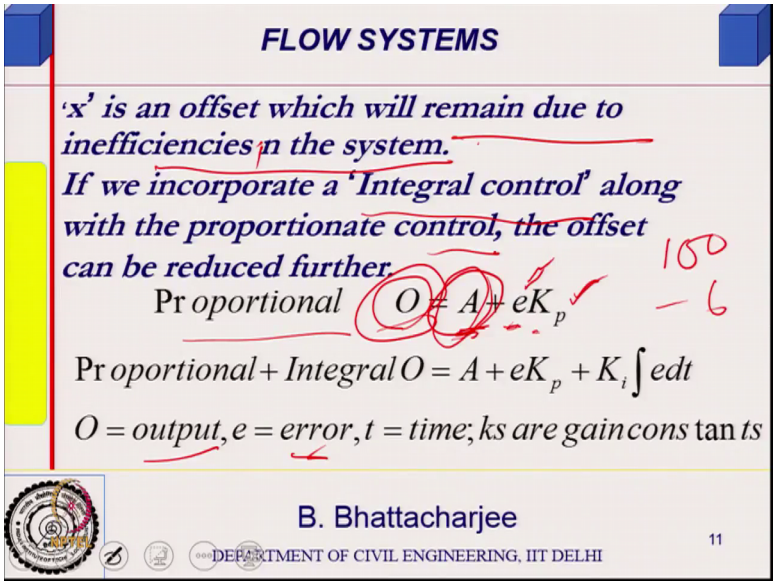

So, x is an offset which will remain due to inefficiencies in the system, in the system inefficiencies in the system. The proportional control tends to create an offset. There is something called integral control along with the proportion of control then offset can be reduced. So, what is does? It measures the offset over a period of time right, measures the offset go on measuring the offset over a period of time and you know it actually this is the proportional I have got some fixed value plus a kind of a value depending upon where error; depending upon error, how much you are off, right.

So, supply is linear if you look at look back at this, let us look at back to this, this is linear. So, this is linear with temperature right. This is supply is linear. So, if I call this supply as defining you know this is linear. So, let me redraw this, let me redraw this here see this is this is linear actually. So, O is that varies from 100 percent to 0 percent. O is the value varies from 0 to 100 percent; O is the output 100 percent to 0 percent. So, at e equals to 0, there is a value of A, value of output. It means your supply cool air supply that is A, that is A, right. Now, if e is plus is plus error is plus; that means, in case of cooling, it is actually negative. In case of heating, it could be positive depending upon the sign could be accordingly plus or minus would reduce accordingly.

So, he e K P is a slope of that line, K P is the slope of that line; for example, over 6, 100 degree; 100 percent over 6 degree. For one degree, it is 16 point you know I mean 100 divided by 6 because I said that 22, 28 operating differential is 6 degree. So, this KP is nothing, but the slope, slope of that line e is the error. So, KP is the slope of that line. So, KP is the slope of that line right, e is the error. If the value KP is nothing but 100 divided by operating differential operating differential right, 100 divided by over that is the amount of change in the output for unit change in error.

You know unit error for unit error which could be positive and negative. So, that is what it is it would be only 0 when at certain value of error right because A minus this would be there. So, it would be 0 and some value it will be 100 percent. So, we know that actually we can find it out. So, an integral proportional integral system, I have something else. So, what we do is, we measure we try to find out the edt, try to find out the error over a period of time, right.

Student: (Refer Time: 27:52).

Continuously you try to find out edt which is the area under this curve; you know this area, you are trying to find out this area, this area.

So, area under this is the error, this error, offset error, error, integrating over the time edt. So, you try to edt, so there is a offset is there. Now, if offset might change how to change? The error might change because if you had another interior control system to try to reduce it down. So, this is what we are doing is we are integrating it. So, edt and multiply it by a factor, multiply it by a factor, edt is the area under that curve.

Student: K i t.

Sorry.

Student: K i t

K i is a constant it will be multiplied, you know you must multiply depending upon how much you have multiplied. Actually it should be minus these total things, things should be minus. I mean depending upon each sign of the e or whatever it is, this should minus and this bring down to the offset should be output should be as close as possible in such a manner that depending upon the offset. So, K i is a constant, K i is a constant which

would depend upon basically it is a constant that if the error in unit time, you know it is a area under the curve for unit area under the curve, this should be the adjustment. K i is the adjustment for unit area under the control variable and type curve, area under the control variable and time curve.

So, for unit area over a period of time unit area, it tries to, so k s are gain constant. These are called gain constant. So, this is a gain constant which is nothing but the slope of the climb. These another gain constant K i is another gain constant for integral control right. This is KP for P subscript for proportional control, I for integral control. So, that is what is done and you know this is basically our understanding. So, if my point here is to people if you somebody is saying they are providing you a controller in a service system, you ask them what kind of controller it is. If it is of course computer control, that would be far better, that will be far better; obviously, that would be far better you know intelligent system.

So, it actually the microprocessor and things like that I mean the computer would control it. So, controlling digitally is much better system. So, you have a total control room where everything is controlled together, all variables are controlled together but obviously. Now you understand and proportional integral control system is better than simply proportional control and far better than two point open control.

So if you are installing something, you good to know this kind of you know this knowledge should be availability.

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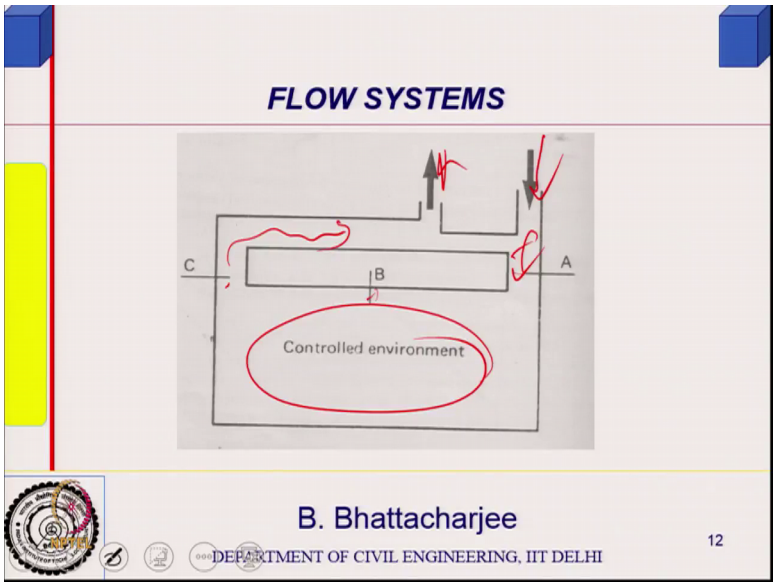

The lastly the sensor locations, now sensor should be located in such places where this is your inlet point, this is your outlet point. So, sensor should be located at points like you know control environment. You should have sufficient sensors. So, typically A, B, C are the sensor location. At the entry point, you have something and at the near the you know exit line somewhere you should have a sensing device and somewhere in between you might have a sensing device as well, right.

So, that is what it is. So, that is what it is. So, this is the general discussion on control system. I would have one lecture will devote one lecture to intelligent building sometime later on, right. Some sometime later on and you can understand that this your initial investment will be somewhat higher particularly in functional building, because here the cost of control controls are very much there, but if it is a large functional building, it may be worthwhile, because it would actually give you better comfort, and also reduction in cost. For example, energy cost right even the air conditioning system; energy cost wastage would not be there.

So, that is about the control system and general discussion on services.