Fire Protection, Services and Maintenance Management of Building
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Lecture – 20
Introduction to System and Flow Systems

So, we will look into now some concepts of flow system, because some of the services are flow systems. So far we looked into vertical transmitter transportation of human being that is also flow. But then you know it is you are allowing people to flow that is intelligent things to flow not materials. So now, we look into some of those other. So, services generally can one can consider it as a flow system, right. So, you know.

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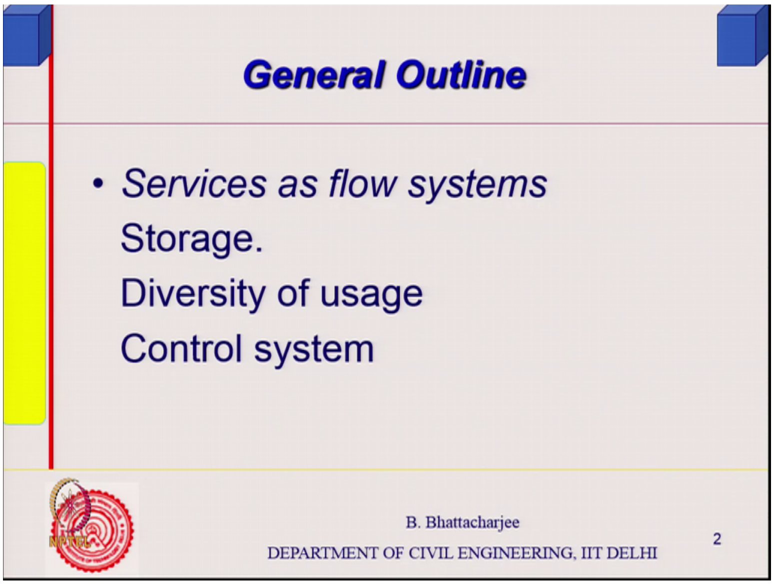

So, we give some outline of the general service system. Then usually you might have storage and of course, you might have diversity of usage, these are the concept we discussed. Some of it you might have studied at the undergraduate level.

So, let us see how it fits in and then we will look into the control system, right.

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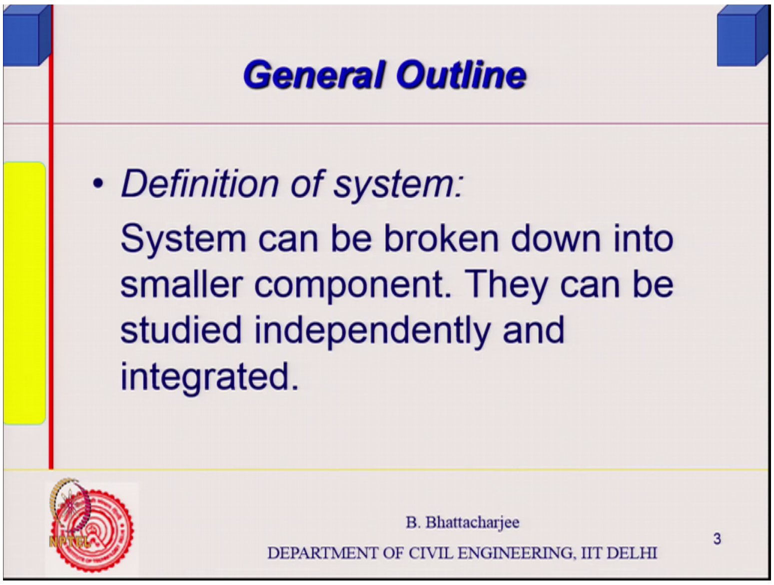

So, what is the system? Well, system can be broken down into smaller components they can be studied independently and then integrated that you might be knowing, might have come across somewhere. Services can be considered as a system. Because it has different component, and they can be you know studied independently and put them together. Now this is what it is. You have as, you have some input.

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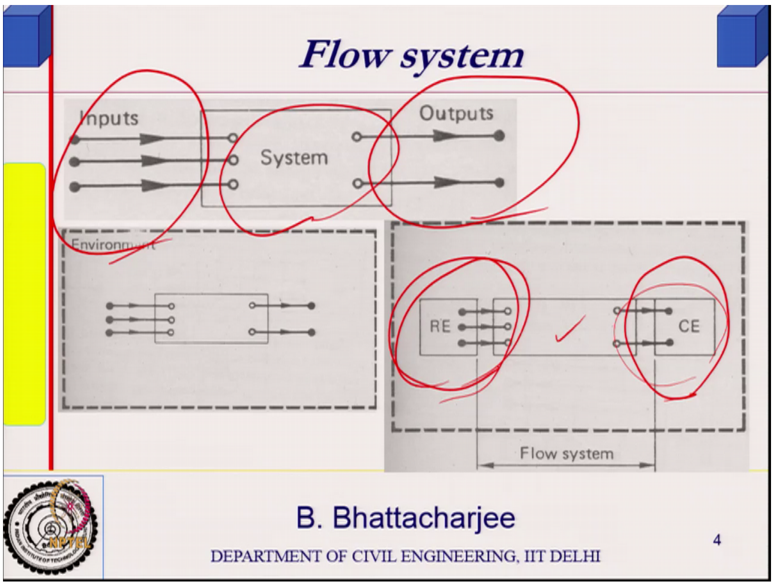

Some input into the system, the here is a system and you get some output, right?

Now, as far as service systems are concerned, you have an overall environment which includes the building as a whole. Because service system you know this output goes to the building. So, it is the overall environment might be building. Might have flow systems. Usually like water supply, electricity, you know, even waste disposal, everything is basically or airflow system HVAC these are all flow system.

So, you have a resource environment in such one, and you have a control environment. For example, you might be this much be a this might be you know HVAC if I consider, it will it would work you know it would due to supply cool air, if it is cooling, then it will supply cool air, draw some resources. In this case the resources should be energy. Draw some resources, and in some cases it could be material also for example, in water supply system it draws the materials and also energy. And then work on to it, and then it puts supplies this to the control environment.

Now, control environment is nothing but the space room. Control environment is a space room where I need them. So, generally they are flow system. The components would be a resource environment; obviously, service system would be there. And then it works on to those resources and supplies the you know modified you know in some form the modified sub material, or it could be fluid to the control environment and maintains a control environment in the right condition that we desire. So, that is what it is.

So, therefore, this is what it is.

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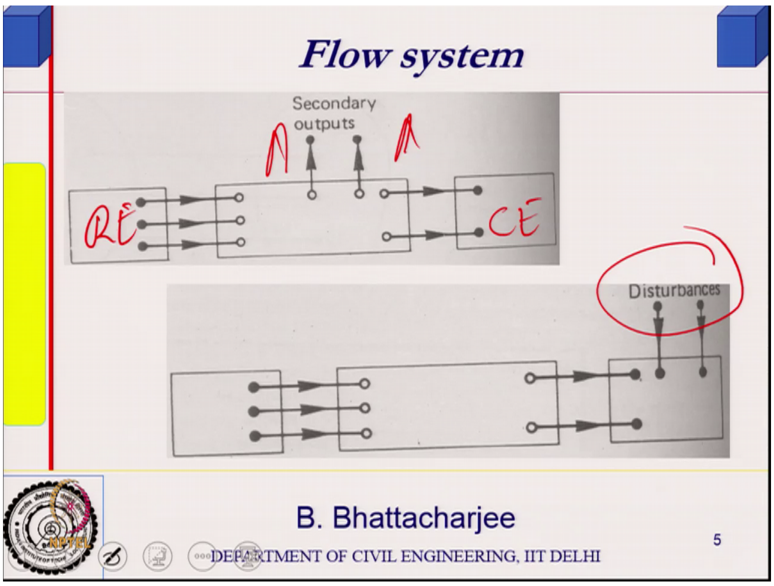

So, if I call this as resource environment, this is my control environment which is again doing this schematic. There will be some secondary outputs, right? Secondary output for example, you might you know it could be secondary output could be some heat losses, or even some sort of you know say it generates some sort of maybe you know like a boiler.

For example, earlier days we are using coal fired boilers. So, to generate some sort of gases after burning. So, secondary outputs could be desirable or not desirable you might be able to use those secondary output somewhere else, if it is desirable. And then there will be some perturbation from the surrounding environment also. The control environment will get disturbances from outside.

For example, outside temperatures would change, would affect that inside condition, you know so, that can be disturbances. So, what we see overall is a kind of air, I if I look at in a bigger way. So, we look at it in a slightly bigger way it is something like this. I have some sort of a resource environment.

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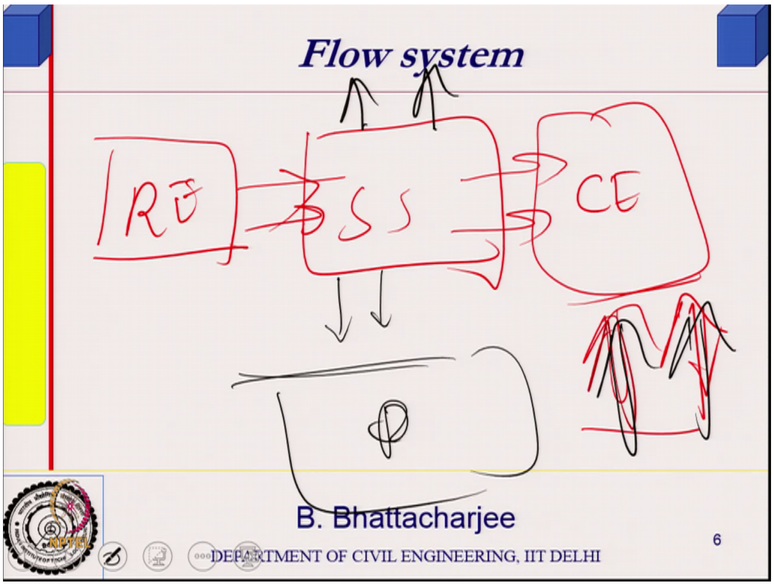

The resources should be materials energy whatever it is. Then I have the service system. You know, the service system takes this draws this resources, and handles it in some manner processes it.

And this is so, process resources, then pass on in some form some resources to the control environment, right. And it can have perturbations from outside, you know, some sort of outside some sort of outside disturbances some sort of outside disturbances could be there, disturbances from outside. And also you might have some sort of secondary.

Student: Disturbances.

Disturbances could be there secondary output also might be there. Some secondary output also might be there. But then this secondary output coming from this you might be using this as resource for, this source might act as a resource for some other service system, because there are several service systems in a building. Actually building is the most complex. I do not know whether I have mentioned this earlier to you, it is the most complex of the infrastructure. If you look at it bridges, you know, let us say, steel concrete composite based bridge, right? You have piers and then 10 piers. So, they are all same, right.

The deck system might be a composite slab deck with you know steel plate girders, composite material it. That is the whole structural system. Then your service system of course, there also like lighting signal system and things like that. So, that is where it ends. Dams will be something similar, of course, dams you are monitoring also. But come to building, it is actually very complex, because it has too many items, a hospital building might cost of the services, might be much higher than structural cost. Structural cost may not be more than 20-25 percent, at best 30 percent. Cost of the lift, cost of the electricity supply system, the hot and cold water supply system, the plumbing system altogether, cost of maintaining the sterile condition or some oxygen supply system and things like that.

So, the cost in a hospital could be services cost could be very, very high, and handling the ending the waste. So, you might end up and also the architectural items, you might end up with some lacks of items in a building, unlike many other civil infrastructure, right. So, it is far more complex than many of them. And so, you have different services systems.

So, one output from secondary output from one service system my tax as a act as a resource for another system. For example, heat loss from some system you might use it again, you notice I use it and so on. So, this is all possible in more general case.

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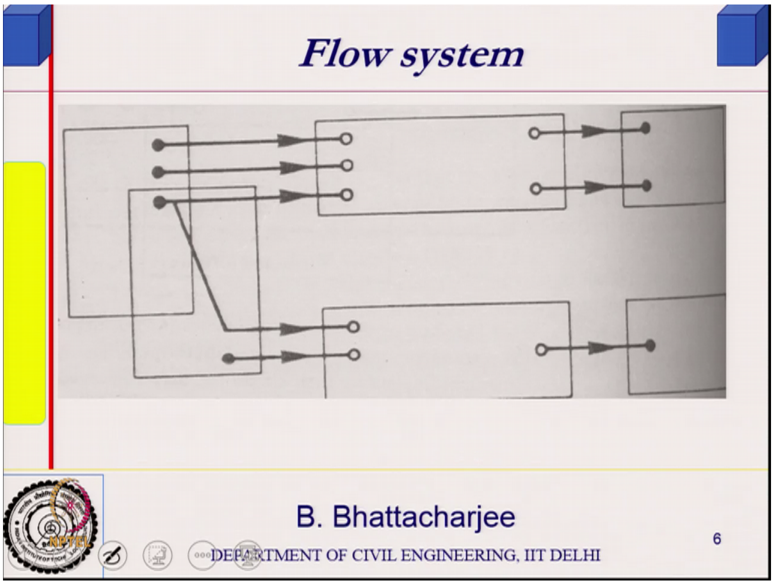

So, this is how this diagram shows you that, you have you know the same resource might be used by 2 systems; same resource must be used by 2 system; one resource, same resource must be you might be used by 2 system, so, more general scenario.

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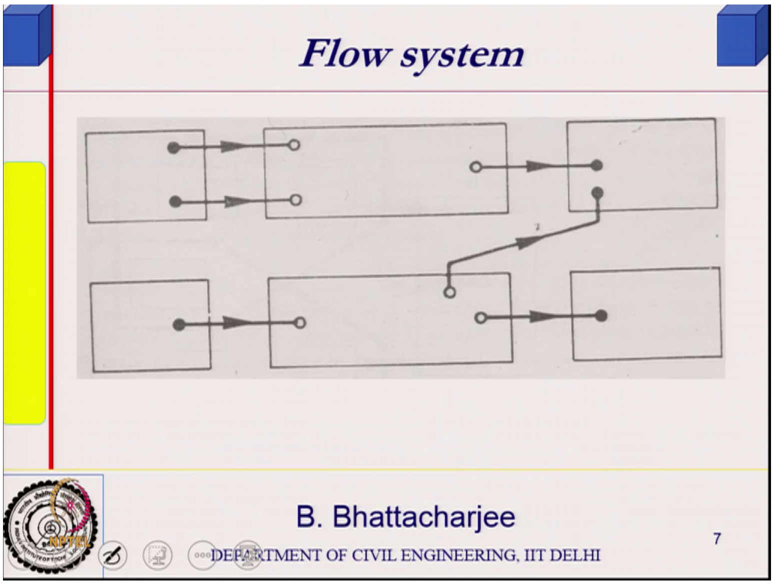

And this is output from one system goes directly to the control environment. And then lastly you might have a feedback. So, this is again this is you know the secondary output going as this goes to the second system. So, all combinations are possible here. Now then you can have a feedback, then you can have a feedback which we will discuss later on.

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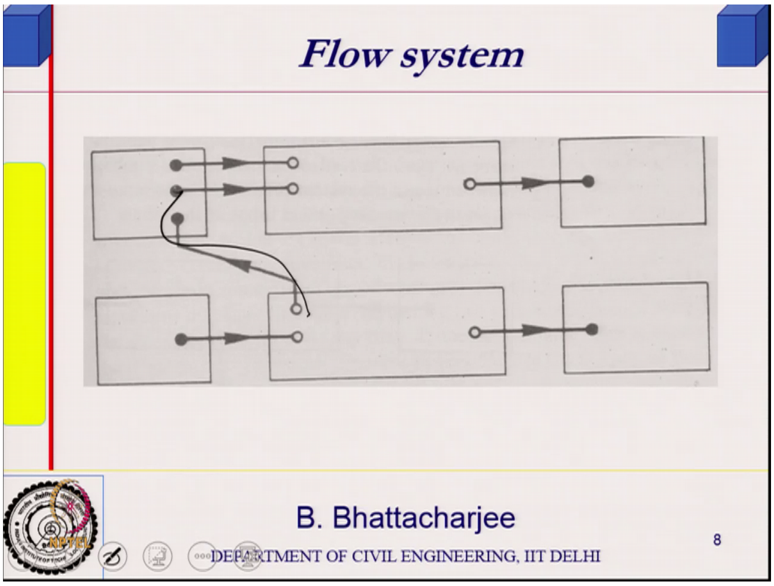

You know, for example, you want a control then you might provide a feedback.

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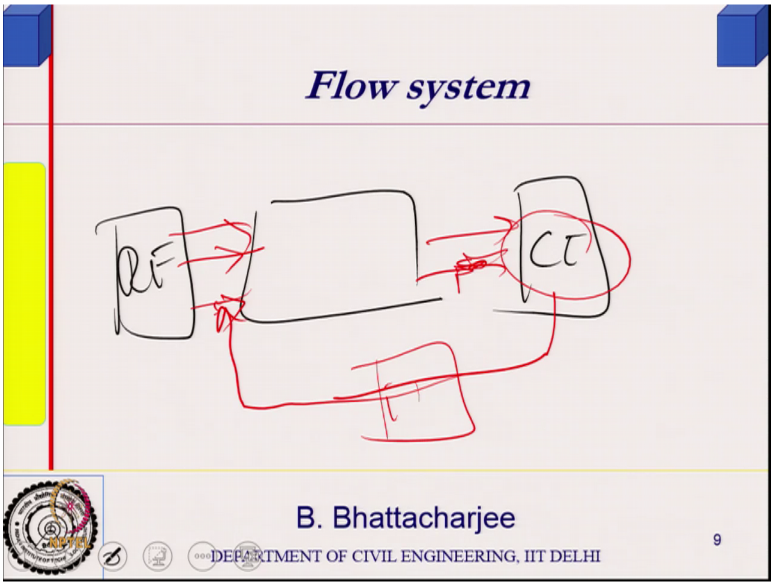

So, this is your resource environment. This is your control environment, and you want, you know, there might be flow is somewhere here from this one to this. So, you might provide some sort of feedback to this. If you want this control environment to be 100 percent under control fully control, then you can have a feedback. So, if you have a feedback some system feedback system, which would you know you sense the putting sensors on to your space and providing feedback. And then have controls on this, the floor level or supply, you know to the service system might be control. Finally, this has to be controlled.

So, finally, you know so basically extreme case would be what is called an intelligent building or smart building. Where you have a lot of control, some of it will be discussing, but just as an introduction I just told you. We will come back to this actually this control later on when we talk of control environment more. Now flow systems, 2 laws are very common or similar laws. One is a continuity, right one is the continuity, and another is one is continuity, you know.

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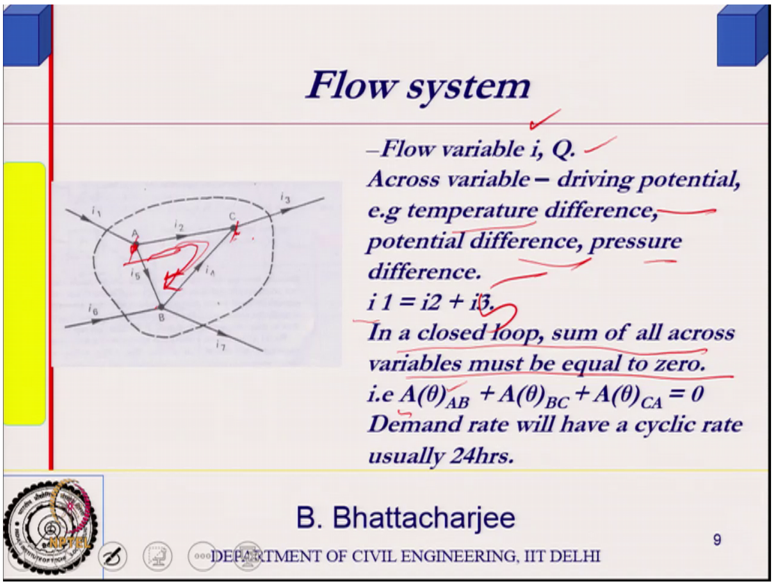

So, continuities like Kirchoff's law or any law for that matter, at any joints you will have so, in such flow system, you will have basically some support some sort of a circuit.

So, you will have, you know, network of connectors, and at any junctions you will have 2 things there is a loop, there can be loop, and there can be junctions. So, in flow at any junction should be same as outflow. That is what is your, you know like continuity equation. So, coming you know, it is and the other is a; so, there are 2 types of variables one can recognize. One we call as flow variable other is a cross variable.

Because to have any flow, I need a potential difference, for current to flow I have electric potential difference, for sensible heat to flow I need temperature difference, for flow of water I need head difference or pressure difference. So, there is a, you know like so, across this is nothing but across variable. So, across variable and flow variable. So, flow variables are i Q etcetera, we denote generally by i current Q flow rate of flow. So, across variable is basically the driving potential, more or less generalized law.

So, temperature difference, potential difference, pressure difference, at any node you know this is i 5 actually. At this node i 1 is equals to at node A, i 1. So, you generalize one would talk about at any node incoming flow must be equals to outgoing flow, right. So, that is one type of row. So, in a closed loop, sum of all across variable must be equals to 0. This is the other, you know, other law; that is, if you measure in a systematic manner, the sum total of across variable from A to C, C to B and B to A must be equals to 0. Because you know the at this point when I come back, it must be equals to 0. Now thing is that across variable A to C is equals to minus across variable C to A. So, I write it like this A variables say theta, you know, A theta that is this is in this one I am writing it in this manner, A B. So, A B plus BC plus CA must be equals to 0. Well, we understand that CA is nothing but minus AC, CA is minus AC.

So, you know this is one aspect. So, this is the law for almost all flow system, this will be the law. We will see that how it applies where it applies will; these are Kirchhoff's laws actually. And second one is also Kirchhoff's second law [FL], first one is. So, you might call it, is it compatibility? Not really, this is continuity for sure that is continuity. So, that is general that is basic very general.

The other issue is most important thing for almost all services because it is dealing with the human being, right dealing with the human being. So, we organize our activity in 24 hourly cycle; that means, every day you go to the office at maybe 9 am right; so, 24 hourly cycle. So, that is you know we look into look everything into we will have as usually 24 hourly cycles. So, any demand on the services is also 24 hourly cycle. I mean, I might have for example, the classroom right. So, my cooling requirement might start from sometime around 8 am in the morning, or maybe 7:30 because you might put it on earlier.

Supposing is 2 point often control switch or whatever it is. And then it will finish off by 5, but after that no requirement, again it starts at 8. So, it is again 24 hourly cycle. For certain period of time I have the demand, for certain another period of time, but they said 24 hourly cycle and everything else is also similar. So, services also we have 24 hourly cycle. And it could be something like this, you know, it could be something like this.

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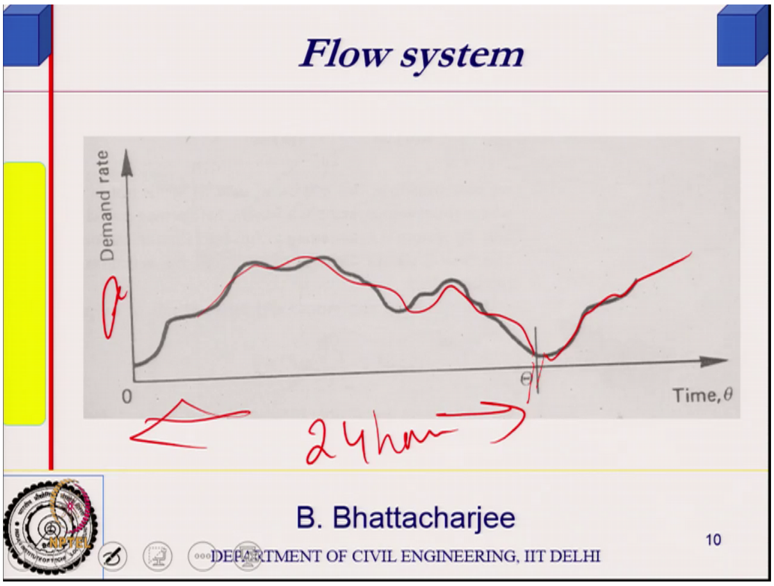

I can think in terms of demand rate, demand on anything, right, the electricity, cool air. So, it will fluctuate from time to time in the day. And then after a time period which is generally 24 hours again it will, I can think in terms of a 24 hourly cycle of demand for almost everything. So, this is more generalized that is what I was saying. And in this one it may so happen that my demand rate of course, as we have seen it will vary.

I mean it can be simple simplified could be something like this, it is possible right, but usually demand would vary usually demand would vary in a arbitrary manner as we have drawn, but some manner it would vary. Now, it varies I must if I match the supply exactly with that, then I do not need any storage. But it is difficult to match exactly with that I cannot match it I will not be able to match it.

So, usually where there is a demand or in the part of the system itself, if there is a mismatch between demand and supply, I need some sort of storing. So, that means, for example, you know you have resource environment.

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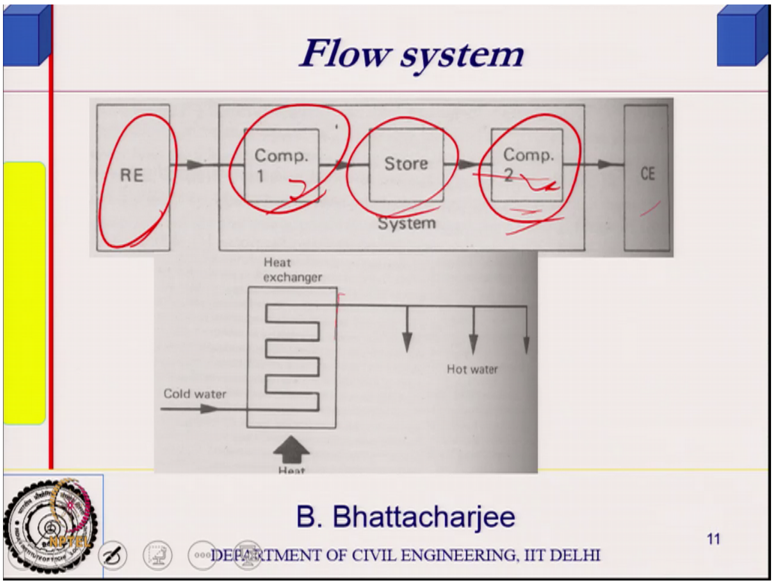

Some component within the service system and some other component within the service system; now it draws the resources from component 2 draws resources from component 1 and it is demand would depend upon the final demand of the control environment.

Now, it may not match, you know, matching exactly with the supply rate might be difficult, rather I will provide a kind of storage. Whenever I need I will actually draw it, whenever I need I will actually draw it, whenever I need I will draw it, right and store it. But if I store it too much then the cost of storage will increase, right. And or cost of supply might increase if I actually try to match exactly.

So, we try to do a balance we try to do. So, when do I need storage? When there is a mismatch between and demand and supply; so, I provide the storage. For example, you know you can look into this is a cold water to hot water supply system. Now this one is a heat exchanger where I will be heating the cold water, right. And it would be drawn, the hot water demand would be hot water demand would be varying, it would be fluctuating.

So, if it is fluctuating, then here I might store. At the top level, hot water will be there, cold water enters at the bottom because convection will put it up, right. And the capacity of this system storage would depend upon how the mismatch. Because but I cannot go on infinitely because if I do it the cost of storage will increase.

So, we try to optimize this between 2 thing; one try to match, you know, try to change the supply rate to the supply rate which supply rate which you would you know and the cost of supply also depends upon the supply rate itself. Because your network cost would increase depending upon what is the you know pipe sizing if it is pipe case or things like that, insulation in case of hot water and all that.

So, network cost will increase depending upon the supply rate and storage cost will increase if I increase the size of the storage. So, I try to balance between the 2 and design it and let us see how we do it right, design it in this manner.

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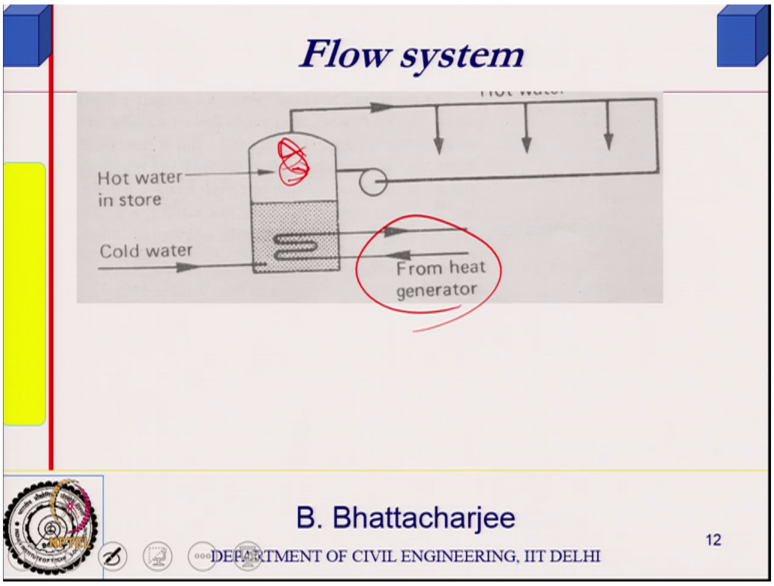

So, this is another example. For example, I might have hot water here, same one, diagram is different, hot water is here, cold water is here. So, capacity of this heat generator or heating element or whatever it is; this also depend, because rate you know this is relatively I mean finally, if this is be in terms of hot water means some energy also. So, mass into specific heat into the quantity of hot water that is available. So, it will depend upon how much is my demand onto the system.

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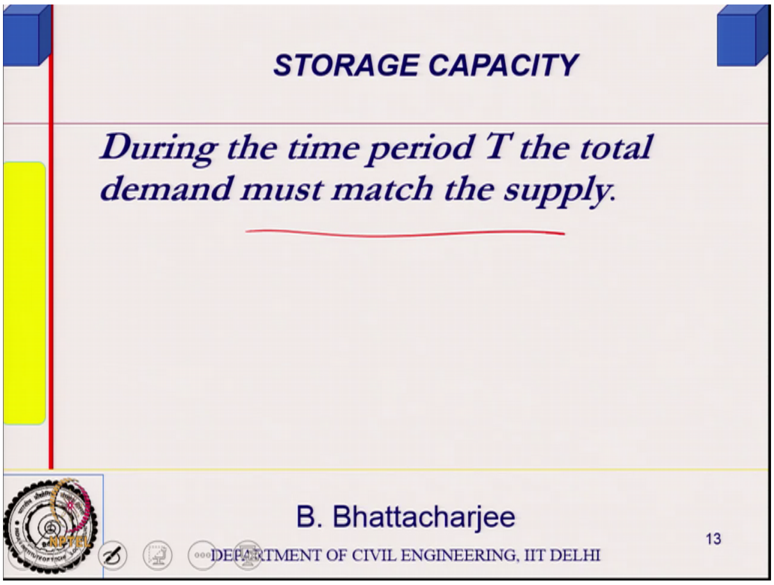

So, during I can think in terms of during time period T total demand must match the supply. This must be the case all the time. Might have some small amount of buffer, but by enlarge it must match.

Otherwise what will happen? If my demand is more and supply is less, obviously I will fail, my system will fail. And if other around if the store you know if the supply is more demand is less, then I will be continuously go on storing. And must you know like storage will bust or whatever it is it will overflow. So, therefore, it must match in some manner. So, mathematically simply one can write, if I define supply as S theta, you know d theta, and demand is D theta d theta.

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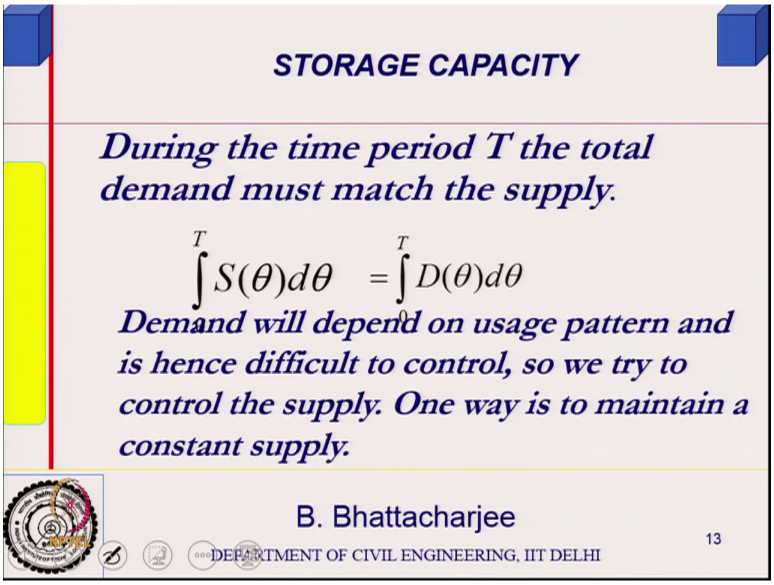

During the time period, my cycle this must be matching, right. So, you can you know this must be matching, and therefore, demand will depend upon usage pattern as we know, demand depends upon usage pattern and it is difficult to control. Demand is according to the usage pattern, depends upon occupancy type and some case of randomness also might come in there. Some sort of randomness also comes in a might coming there.

And it is difficult to control so, what you try to do? We maintain a constant supply which is cheap. For example, supply the rate is constant. I might supply for certain period of time then stop and then again supply or I can have a continuous supply, right. So, my rate of supply is constant, usually we maintain because it will be otherwise costly depending upon the cost part of it, and maintain it constant supply.

So, what is the minimum constant supply that I can find out? Minimum constant supply would be minimum cost is you know. So, finally, of course, I can always talk in terms of cost of supply.

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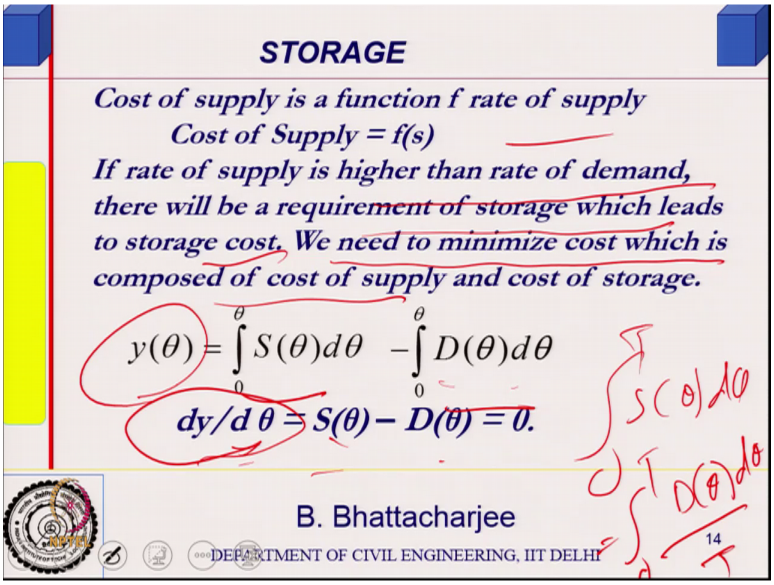

Supply is a function, you know, cost of supply is a function of rate of supply, that I have already mentioned. If rate of supply is higher, then rate of demand there will be required storage which storage cost. So, we do not need to minimize the total cost which is composed of cost of supplier cost of storage.

So, we have tried trying to get a model for this, kind of a scenario, right. And storage would depend upon difference between these 2. If they match during any period of time, cumulative supply and cumulative demand. Difference between these 2 up to that period of time, whatever is the difference that I must store. And that is actually y theta let me call it, that I must store. You know, storage will depend upon this.

And if I write it dy d theta, differentiate this, then I will get S theta. So, the page where storage would become 0 would corresponds to where supply rate is equals to demand rate, right? Where supply rate is it goes to demand rate, right? Now what is the minimum supply rate?

Because we said that, you know, over the time period S theta d theta must be equals to D theta d theta. Over the time period there must be same. So, minimum supply rate and I am keeping my supply rate constant. So, minimum supply rate is simply this divided by time period, then minimum supply rate, just let me write it separately, minimum supply rate would be D theta 0 to t 1 by t.

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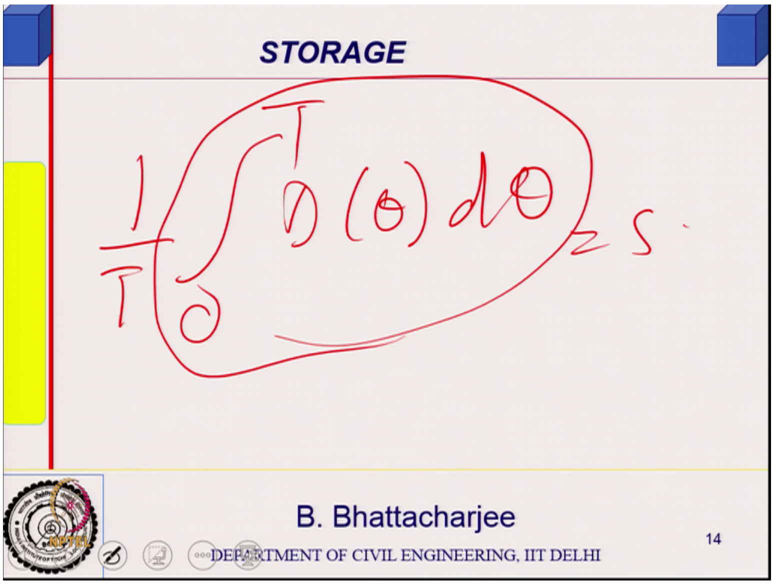

That will be a constant supply rate, isn't it?

Because you know my supply rate this is the total supply I require during the time period. And my t total demand, sum total of all the demands total cumulative demand during the time period. And this must match in the cumulative supply during that period, right? And if I have a constant supply rate S, then S multiplied by t must be equals to this, because it is constant it is not varying with theta.

So, 1 by t average simply averaging the demand, averaging the demand rate that would give us, right.

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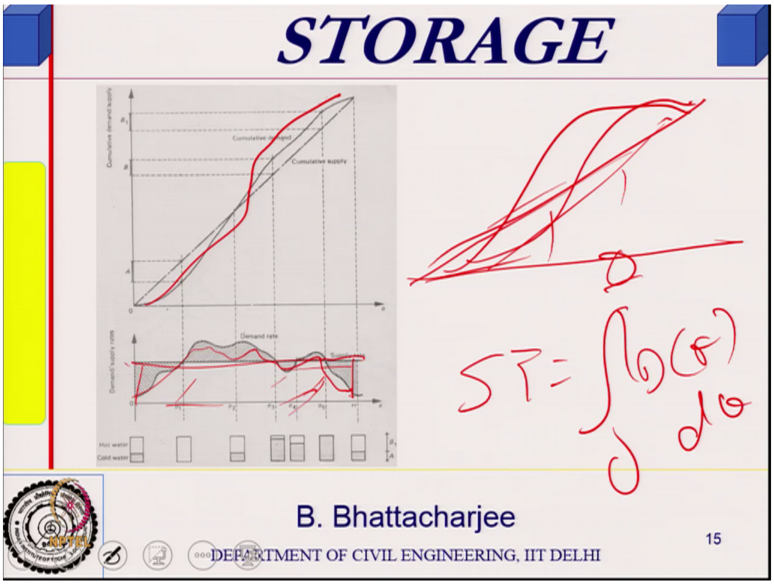

So, that is what it is. So, simply graphically you can find out like this; which you might have done sometime you might have done in water supply system, but essentially it is like this. So, this is my period 24 hourly period, cumulative demand I have plotted like this, which will go on increasing which will tend to become as an S curve sort of, right, which will tend to become an S curve sort of. And if I join like this, constant supply you know or it is this is the demand profile, the area under this curve is this much.

If this divided by T this area is same. This rectangular area is same. Because S into T is equals to I said area under this curve integral 0 to T d theta d theta you know. So, integral so, area this is cumulative. So, at any point of time if you want to find out it will be theta. So, basically constant supply rate I can find out if I sum up all the demand over 24 hours divided by 24 that will be the constant supply rate which I must maintain.

If I supply lesser than that I will not satisfy the total 24-hour day demand. So, that is the minimum the constant supply rate. Now I can increase the supply rate, but do not supply for 24 hours depending, upon my convenience, right ?

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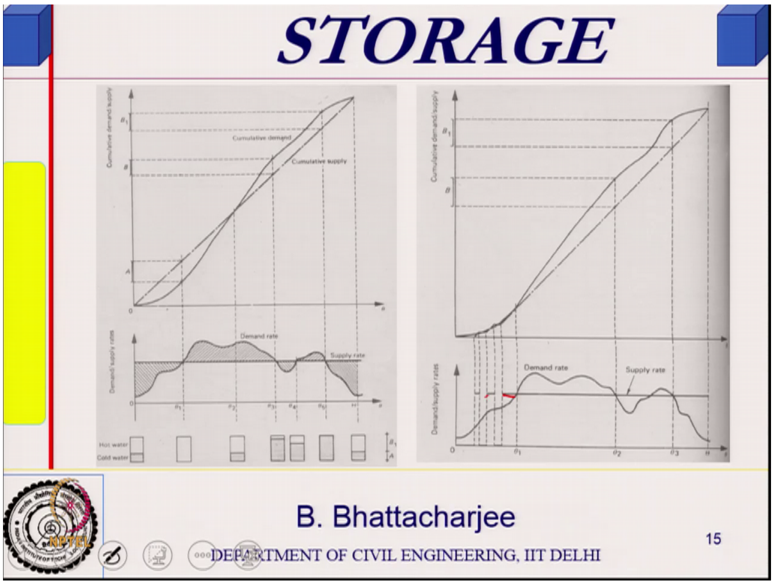

So, what I do is, I stop in between these gaps are there.

So, I can have intermittent supply, increases the supply rate have intermittent supply and do it in such a manner that my storage gets reduced. So, I will find that store supply rate I increased storage should reduce, I choose it in that manner, and I will have several storage and corresponding supply rate, several separate and corresponding storages, right. And then I find out the best out of from them best from them right. So, that is what it is yeah. So, I think we will stop next class we will look into this model.