BUILDING ENERGY SYSTEMS AND AUDITING

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Week - 02

Lecture - 08

Lecture 08: Electrical Machines and Appliances System

Welcome to the NPTEL course on Building Energy Systems and Auditing. We are in module number 2, where we are discussing building energy systems. Today is the third lecture of this module. So, we will discuss the electrical machines and appliances system. So, mostly the appliances and the electrical systems used in the building, what we can think of, are the pump for water supply, and also, we will discuss the two types of vertical transportation systems in the building: elevators and escalators.

So, commonly, some of the appliances which are commonly used in a particular building are And, those are the stable again, it is available in the NBC; there is another part of the table. So, those are electrical illumination and other appliances. So, mostly, this particular rating, what rating we can consider whenever we design something or we want to estimate some kind of the electrical energy required for any kind of equipment in a building. Because, if you want to see the total energy scenario, the energy requirement of a building in a holistic manner, we have to consider the heat gains, internal heats, and all, and also the appliances and the instruments which I am going to use for my day-to-day life.

The water supply network is another very important part of the services, and we all know that it requires a lot of attention and a lot of energy because we have to actually pump the water from a particular storage tank in the underground storage tank to the overhead. So, the flow diagram will be like that: we can take the incoming water from any kind of the incoming source, municipality or the corporation. We can store it initially in a fire tank, and then the overflow water can go to the water supply tank, which is underground; UG stands for underground. Then we require a booster pump; we may operate booster pumps

once a day, twice a day, or maybe more than twice a day if it is required. This booster pump can also take the water from the underground water by some suction pipe.

So, sometimes I may require more, my demand is more, but the corporation may not supply that much. So, I have to have my own water sources. So, underground water sources are definitely used by people. Through the booster pump, the underground water or maybe the storage tank water in the underground can be lifted to an OH water tank, which we call the overhead water tank. And from the overhead water tank, through the distribution pipe and by gravity, we send it to different floors, different points in toilets, in the food plaza, in the kitchens, and some of the other areas where water is required.

This is the typical network. So, these are some of the photographs. So, in the basement of one of the buildings, this pump is installed. So, we need to have some initial understanding to estimate the total water requirement. The NBC provides us with some recommendations.

Again, I am not going into that detail. So, just for a very minimal amount of discussion, I want to say that we have to see those areas also, not only the occupancy. You have to see that you require some water for the main water supply, which can easily be calculated by the NBC provisions. We require water in the kitchen, and sometimes in the laundry if your building has a laundry. If the building has a chiller plant for your air conditioning system or so, you require water. It is also required for landscaping. So, we have a supply first, we store it underground, then we have a main storage in the underground which is not for fire, but for the water supply. This we have to have as a split storage as per the requirement, and we can actually send it from the overhead tank or so.

So, now my understanding or my area of concern is the energy requirement of this particular water supply, mostly if it is pumping. So, in a building from the municipality water main through a ferrule, a ferrule is a kind of attachment from the municipality line or the corporation line to a private line. It is a kind of nozzle kind of thing. So, a ferrule is one of the very important things that will be provided by the corporation. And it comes to my area, and then we have a water meter, we have some check valves.

Finally, that comes down to an underground tank, from the underground tank to some pump, I will take it to the overhead tank by this rising main. So, this pump I need to operate, and I first want to see what is the horsepower or maybe the kilowatt rating of the pump I require for running that. So, that is one of the important things. And from the

overhead tank, it can be supplied to each and every flow. So, let us find out this equation for the pump, and we want to estimate.

So, first of all, we need to see how much mass of the water has to be lifted. So, the mass of the water can be found out by the volume of the water that I want to lift multiplied by the density of the water because the volume multiplied by density is nothing but the mass. So, this is one of the very fundamental relationships. Then I want to find out this mass, as I mean to say, what is the rate of mass I am going to send because it is a flow, it is a flow of a fluid.

So, the rate of mass is the rate of volume flow multiplied by the density. So, I got the next equation: Q, this Q is nothing but V/s. Volume per second. So, it is something like m³/s will be my Q, the rate of discharge flow rate is this m³/s multiplied by the density, which is some kg/m³. So, it gives me kg/s.

$$\frac{Vol}{Sec} \Bigg| \quad \frac{m^3}{Sec} \times \frac{Kg}{m^3} = \frac{Kg}{Sec}$$

So, how much kg/s water I am going to send. So, next is this particular power required to lift. So, the energy required to lift per unit time. So, that will be one of our very equations for a relation for energy estimation, which is mgH. So, mass multiplied by gravity multiplied by the height of the lift.

So, mass I already know, which is this Q x ρ, the flow rate multiplied by the density, g is the gravitational acceleration, and h is the amount of lift. So, m x g x H will definitely be supplied, and that will give me the power. This is not the energy, this is the power because if I see this Q multiplied by this thing, Q x ρ is your kg/s x g, g is m/s ^{2}, this gives me the force multiplied by h. So, this is the energy per second.

So, that means it is watt. So, it is the power. So, we can understand that from this equation. So, we have this equation with us.

$$Power = \frac{Q \times \rho \times g \times H}{\eta}$$

Q = Flow rate in m³ / sec
ρ = Density of Liquid (water = 1000 Kg/m³)
g = Gravitational Acceleration = 9.81 m/s²
H = Total Head in m
η = Efficiency of Pump in decimal
Unit of Power will be in Watt

Of course, finally, we divide that by η, η is nothing but the efficiency because any motor or anything has some kind of efficiency, although it will not run with 100% efficiency. So, we have to decrease that particular thing with some kind of efficiency or so. So, this is the equation. So, total head, how much we have to lift, I have to know, and what will be my flow rate or so. So, let us go to another GATE examination where this particular problem was asked in 2016.

A pump is installed in an apartment building to lift the water from the ground level to a tank on the top. The tank capacity is 10,000 liters. The total head of the lift is H = 18 meters. Pumping time is 30 minutes. So, I can find out what the flow rate is.

Assuming the acceleration due to gravity is 10 m/s² and the efficiency of the pump is 80%. So, I have to find out ink W what will be my required power for the pump. It is very easy. So, the capacity I know is in liters. So, I have to actually change it to m³/s. That is my flow rate.

So, this is the liter I divide that by 1000 because 1000 liters is 1 m³, and I divide that by 30 minutes. So, I have to pump it within 30 minutes. So, 30 minutes I transfer to seconds: 30 x 60. So, that means 0.0055 m³/s will be my flow rate. And the density of the liquid is 1000 kg/m³, g is the gravitational acceleration, and all these things ahead and the pump these things are there.

So, I use this equation and then I got that the pump will require almost about 1 point. So, it will be almost about 1.25kW. 1.25kW, and I can also change this to 2 HP because in horsepower, by dividing that watt by 746 watts is equal to 1 horsepower. So, sometimes we go and actually the pump is rated in horsepower. So, almost about 1.7 HP pump is required.

If I want to pump that particular water in 30 minutes. So, here there are two types of head or maybe three types of head we will discuss. The first one is called suction head. Suction head is the height between the pump and the underground tank. How much is the rise? That is how much you are rising from below the pump. That is the suction head we have to suction pressure we have to introduce. And then, there is another head called the delivery head, which is how much is the distance from the pump to the overhead tank. That is the delivery. So, the total amount of lift, which is called a static head, is nothing but the suction head plus the delivery head.

So, that is the two. You have to just add mathematically how much is the suction head and how much is the delivery head. Sometimes the suction head may be 0, we are just lifting from the same level. So, it is 0, but definitely there will be some delivery head. Now, there is another head called the dynamic head, which is actually due to the friction and there may be some pipe bends and some losses will be there. So, that also can be found out by this formula: K x V²/2g, where V is the velocity of the fluid or the water through the pipe, and K is a loss coefficient which will be given to you.

And so, that way we can also find out the values of this dynamic head and we can add the static head and the dynamic head to find out the total head. So, in this particular problem, I have given a pump and I want to find out what is the capacity of the pump I require. So, here I have to pump to a 30m overhead tank location. The height between the pump and this thing is the pump has to be located 6 meters above the underground tank. So, this is my suction head, this is my delivery head, and I also have to find out the dynamic head because I have given friction coefficients and all those kinds of things.

First of all, I have found out these 36 meters, this 6 plus 30, is my total static head. I also found out the velocity of the pump because I know this is the flow rate. Because 1800, sorry, 18000 is the liter that has to be delivered by, I think, 40 minutes. I think it is 45, not 45, has to be there. I will correct it afterwards. So, this will be my total amount of delivery, and then this is the velocity of the water through the pipe. I divide the flow rate by the area. So, this is the flow rate divided by the area.

How I got the area is because it is given that the diameter of the pipe is 100 mm. So, I have π x r². So, 50 mm I have transferred it to meters. So, I found out the dynamic head is very small with respect to 36, you know. So, the dynamic head will be really small.

So, sometimes you may calculate it, sometimes we actually leave that one. Just for our academic sake, we need to see and check that one. So, the total head is now 36.34, and I used the formula and found out the power required is almost about 2.9kW. So, let us go to the next, the elevator. The elevator, we all know, is the passenger elevator which actually takes care of our vertical transportation.

So, there are several factors that depend upon the rating of the elevator. So, it is the capacity of the elevator, how many persons have to be taken into account, the average weight of the passengers, the acceleration, and the maximum speed of the elevator. And there is a counterbalance weight that is also required to be estimated. So, this is a governing formula to find out the power requirement of the elevator, where N is the

number of rated passengers because we all know that elevators are given as 6-passenger, 8-passenger, 12-passenger, and so on. So, that is the N. MP is the motor power that comes in watts.

And 75, this particular number 75 stands for the average weight of each person. So, let us take that one 75, g is the acceleration due to gravity, s is the recommended speed of the elevator. Or the rated speed of the elevator. We may sometimes say it is the top speed of the elevator. CF is the counterbalance factor which actually plays a kind of small role in the motor mechanism, and it has an efficiency of almost about 85% we can take.

So, for this particular problem, it is a very straightforward problem. A 16-passenger elevator, I want to find out how much is the capacity. How much is the rated motor power? How much motor do I have to install? So, I have values like this: N is 16, 75 is the weight, G value is known, I know the value of S is given as 1.6 m/s as the rated speed, counterweight is 0.4, and efficiency is 70% or so.

So, by virtue of that, I got this value. Of 16.14 kilowatt will be. So, I have to purchase a motor to run that one, or maybe it will be actually installed with the elevator system itself, which is around a 1620kW motor. So, that is estimated for an elevator which is taking care of 16 people with an almost maximum speed of 1.6 m/s, which are two very important parameters. From the energy consumption point of view, what we can do is, in case of energy consumption, we have to see how long it is operating per day.

So, how much per day it is operating, how much is the total stoppage, what is the journey time, and all those. Energy consumption is the motor power multiplied by the running time. So, motor power comes in kilowatt, and running time is in hours. So, kilowatt-hour I can find out, and total running time I can find out. Find out the total running time, total number of stops per day, how much is the stops, and the average trip time between those stops or number of starts per day, and those kinds of starts mean one from one level it starts, stops over here, again it starts, number of starts, and the average trip time between these starts.

So, suppose there are three starts. So, there are two such trip times or whatever. So, that way, you can find out the total amount of run, total amount of hours of run. And with this particular formula, the motor power multiplied by the start, total start and trip time,

average trip time, we can find out, and by some kind of average method or maybe some kind of survey, and then I can find out the total power estimation.

So, in another problem, I have calculated that one. So, the average power of the motor is 45kW. And it has been estimated as 2 peaks. So, for 2 hours of peak time, it has 240 starts per hour, and for the other 6 hours, it is non-peak time. So, 6 plus 2 plus 2 totals 10 hours of operation.

So, for the other 6 hours, this activity is the stoppage or the start is almost 40 starts per hour, and we have also estimated that 10 such starts take about 75 seconds on average. So, we have to find out. So, first of all, I have this formula: the MP value is 45, total starts per day is 1200 because for 2 peak hours, it is 240 per hour, and for 6 non-peak hours, it is 40 per hour. So, 1200 starts per day. And now I want to find out what the trip time is between the starts.

So, I have data that 75 seconds is the average time taken for 10 such starts. So, I can find out the average trip time like 75 by 9 because why 9? Because If there are 10 such starts, there are 9 such trips, one minus. So, 8.33 seconds is the average trip time between 2 starts. So, this is now very easily I can calculate.

So, total This much amount of running time in seconds because 8.33 is in seconds multiplied by 1200 is in how many starts. So, this is also in seconds. Total this much number of seconds is the running time. Divided by 3600, so total hours, and multiplied by 40. So, that way I can find out that it is almost 750 kilowatt-hours is my running energy requirement for this particular lift to run for a day.

Next, let us go to the escalator. Another electrical equipment which we use in the building, particularly in the mall, in the airport, in the railway stations. So, again, two parts I want to see: how to find out this motor capacity and estimate the motor capacity, and from the motor capacity, how can I find out the number of kilowatt-hours used for a particular day. So, for the escalator also, there are some parameters we need to know: how much is the vertical height it will actually cover.

What is the efficiency of the motor box, what is the running speed, the angle of inclination if it is steeper or it is gentle. So, based on that, it will change the power requirement. I also have to know the rise of each step or so. So, in that way, I can actually find out the total number of passenger weights and multiplied by some angular ways or the inclined way of disbursement or the displacement. So, if I want to find out the

maximum weight of a person, sorry, not person, maximum weight of the people in a particular escalator, I am assuming that the whole escalator from the from the ground to the top is full of people.

Sometimes it happens at the airport, sometimes it happens at the railway station. So, it is full because during busy times when a train arrives or maybe two or three planes arrive suddenly. So, there is a crowd. So, that will be the maximum. So, how will I go about measuring the weight of each passenger, the number of passengers on each step?

And, the number of steps in a particular, suppose you take a screenshot of an escalator. So, there are suppose 18 steps and, on each step, there are 5 people. So, there are 90 people because 18 multiplied by 5 people per step. So, you can find out. So, like that, I can first find out the number of steps.

So, the number of steps is RE divided by RS. What is RE? RE is the vertical distance from the ground to the top of the escalator, that is RE, and what is RS? RS is the vertical step riser; how much is the riser. So, that will give you the number of steps. And I will find out the number of passengers in that particular state, maybe 3, maybe 5, maybe 2.

If it is very narrow, sometimes it is in the case of metro stations, and we may say it is 3, 4, maximum 3, 4, or something like that. In the case of railway stations, sometimes it is large. So, anyway, whatever the case may be, we have to see how many passengers can stand in a particular row. So, the mass of one person, then the mass multiplied by gravity, is your weight. Divided by the number of persons, n. What is n? n is the number of persons per step. It may be 1, sometimes 1.5, that may be some steps. It is a little too able-bodied for one person, one is one, or through three children, something like that.

So, sometimes we may say it is an average of 1.5, and this is the number of steps. So, this way, I can find out the amount of weight, the total passenger weight. Now, we have to go back to our class 12. This weight is on an inclined plane, and this thing is moving. So, if this weight is moving at an $\angle\theta$.

So, you have to counterbalance the $W\sin\theta$ component, $W\sin\theta$, because this is θ. So, if this is θ, then this is $W\cos\theta$, and this is $W\sin\theta$. So, the $W\sin\theta$ component is a force multiplied by the speed, s, which is the speed. So, that will give you. So, what is force? It is Newton. What is speed? It is m/s.

So, what is this Newton meter? It is energy that is J/s. So, that is your watt. And η is the efficiency; it is unitless. So, I can easily find out the motor power. So, I need to know how much the inclination is. Is it 30°?

Is it 60°, is it 45°, or is it very gentle, like 20°, 25°, or so? And the average speed is almost like 0.5 to 0.75. So, let us do a problem. The motor is used to drive an escalator with a rise of 12 meters. So, your 12 meters is the rise, the running speed is 0.75, the angle of inclination is 30° to the horizontal, and the vertical riser of the steps is 200 mm, almost 8 inches.

Assume 3 passengers per step, and the weight of each passenger is 75 kg, considering 80% efficiency. So, first of all, let us find out the total amount of weight of the people. So, in that, I have used this equation: the 75 is the weight of one person, this is your g, and this is what is 3? 3 is the small n. What is the small n? The number of passengers.

Per step 3, this 12-meter is the total vertical distance between the ground to the top of the particular escalator, which has a 30-degree inclination, but each step is 0.2 meters or 200 mm. So, the total number of steps is 12 divided by 0.2. So, if I multiply, I will get this much kilo Newton as the weight of the—I think it is not kilo Newton; I will rectify that—it will be in Newton. That much Newton will be the total amount of load, the total amount of the weight of the passenger. In that particular escalator when it is running full. And I multiply the sin θ multiplied by 0.75, where 0.75 is the velocity.

The maximum running speed divided by 0.8, the efficiency. So, I have to actually think for a for a motor for this escalator, a 62.1 kW motor to run this particular system for the 80% efficiency with the fullest amount of load. How can I find out the energy consumption per day? Again, we have to see some of the things: the rating of this motor, this particular mechanical design efficiency, the landing levels, the travel times, the stoppage times, and all.

So, this is the equation. So, where I can just have multiplied this particular energy equation, which I have derived a little earlier. With this T, where this T is your total time or efficiency in hours—I mean, the total time of the operation per day. So, we have to estimate that one: how many hours it is operating, and S is Ssinθ g n—all these things are your as we have discussed earlier, what is n? The total number of passengers using the escalator per day.

So, all these things are there. So, what I have found out here, I mean, try to give an example: a shopping mall where the average work time will be 8 hours per day. The angle of inclination is again 30° with the horizontal, and the rated running speed is 0.75, which I have kept the same. The estimated footfall of the escalator is 900 per day. So, that is your 'n', and this 'n' is now 900. The estimated footfall per day of the shopping mall is 900, which you need to survey and estimate.

The average mass of each passenger I have kept as 60 kg, 30° is the inclination, this is the rated speed, and 8 hours of operation. So, if I put all these things over here, then I found out that per day it will be 1986.5 kWh, which will be the power demand or energy requirement of the particular escalator. So, that is all for today's lecture, and these are the references. So, what we understand today is that the appliance load, which comes from some BIS code of NBC or sometimes we prescribe from some kind of brochure of the equipment, the brochure also gives that. We also discussed the energy requirements of pumps, elevators, and escalators today.

So, thank you very much.