Control Engineering
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Lecture - 01

We begin our series of lectures on control systems. I must tell you that I expect you to be reading a book side by side with my lectures as we go on. I will ask you to do some homework or do some home assignments of course, you will not be able to return them to me for my, for evaluation or comments but it is important that you do the assignments that I will present to to you that way only you can learn as we go on.

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Now, the subject is control systems what are control systems but before I give you the answer, let me tell you that in the room, where you are seated right now there are some situations, which I call control situations that is there are situations, where you would like to exercise control of some kind and you are able to exercise control of some kind.

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So can you look around you and find out what kind of control situations exists in the room where you are seated. I hope you have looked around, look at the light in the room, there may be more than one. Now, that is an example of what I call a control situation because as we all know, with every light there is a switch and so this is the simplest type of control situation, where you can either have something on or turn it off. These are indeed called on

off control systems. They can be as simple as a switch which turns a light on or turns a light off, there is no other option you can either have the light on or you can have the light off. Of course, it does happen once in a while that you try to turn the light on, you turn the switch in the on position but the light does not go on because of some problem with the light itself, may be the bulb has fused or the starter is not working or the choke is bad or whatever.

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So, in that case there is no control action possible, you like the light to be turned on but it just cannot be turned on but you normally expect that the light switch will work and you will be able to have the light either on or off. If the incident light that comes from the window is adequate, you may want the light off but if it becomes cloudy then the light is not enough you will get up from your chair and turn the light on.

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Of course, one can have a much more sophisticated illumination system as in a big lecture hall or a theater, where it is not just one light, which is to be turned on or off but a large number of lights. Some of which may have to be turned on depending on the requirements there is also a provision, for what is calling dimming of lights, the lights are gradually dimmed or gradually made bright.

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So, this illumination control is a big area but the simplest example of that is our ordinary light with a switch. Of course, when you have lights which can be dimmed then the control is not simply on, off and we will see more of such things a little later, what else do you see in the room around you, may be above you or on the floor or the wall, you see a fan example, there is the ceiling fan. Now, that is an another control situation.

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If it is cool enough in the room, if there very good breeze then you may not want to be fan on but if it gets hot, you will get up and turn the fan on. But there is something more that is possible with the fan usually there is also an arrangement for controlling the speed of the fan which is called the regulator. The fan regulator because you may not want the fan to run at only one particular speed you may want to adjust the speed depending on the conditions, some people like to have the fan on full speed others like me are uncomfortable, if the fan is on at full speed. We like to run it at a low speed just enough to produce some breeze and some ventilation or circulation of air.

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So, in this case the fan has a on, off switch of course you are able to turn it on or off but in addition to on, off control there is something more namely the speed can be adjusted. Now, the old kinds of fan regulators had what are called notches, so you change the speed from 0 starting position to position 1, 2, 3, may be full on you make it khat khat khat khat. So that is how you change the speed. So, the speed can only have a few levels as its values, the position is either 0, that is the fan is off or 1 or 2 or 3 or 5 or 6, may be it is full on that is at the maximum speed.

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So, here the choice is not between just on and off but it is between one of a number of levels or values such a set of values is said to be a discrete set. So, this is an example what could be called a discrete valued control situation. Here, we prove not between just on and off but between more than 2 possibilities namely 0 speed, full speed or speed in between 0 and full. Of course nowadays, we have regulators, fan regulators in which the speed can be varied

almost continuously. So, this kind of control action of control situation is called a continuous type of control action. You have a knob and you can turn it smoothly from one position to the other going all the way from almost stand still to full speed. So, besides the on, off control which has only which gives you only a choice between 2 values on and off.

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You may have a continuous type of control action in which on the face of it, you can vary the speed in any way you like or it may be discrete, where you can select the speed or whatever other thing, one is trying to vary between small numbers of values.

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So on, off control discrete valued control and finally continuous control, anything else in the room that you notice, you have looked at the illumination control, we have looked at the ceiling fan or the wall fan or the pedestal fan and there, what one controlled finally was the speed of the induction motor. Anything else, that you see and may be you are seated in a room, where there is an air conditioner or very often it is just an air cooler, air conditioner actually should condition the air should control the humidity and the quality of air and so on. It should provide air coming from outside occasionally. So that the air is refreshed but usually what we have are only air coolers, these are these are called air conditioner.

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Now here is another control situation, of course once again we have the on, off case. We may have the air conditioner switched off or you may have it on but here you do something else you set the temperature that we want, there is knob or a control on the air conditioner panel and you turn that knob. So, that it is or adjust it now a days there are a cordless control units for air conditioners, you point your cordless unit after setting it and the temperature gets adjusted. Now, here again you can set the temperature to any one of a range of values, may be going from 25 or 27 degree Celsius down to may be 17 or whatever, may be it is too uncomfortable but still whatever suits you. So, there may be what looks like continuous control action possible, you set it between a range of values but there is a difference between this control situation and the earlier one, where you turned the fan on the light on or off or adjusted the speed and what is the difference? The difference is as follows in the case of the illumination control or the control of the fan, the control action was, what can be called manual in the sense, you had to get up turn the light on or turn it off or had to turn the, turn the fan on or adjust its speed.

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So, this is called manual controller action and here is your first little exercise. I would like you to look up a good dictionary and find out how the word manual, manual originated, what are the or what is root of this word, as you know many English words have origin from either Latin or Greek or other European languages, which are older or related to English like German or Dutch or French and so on.

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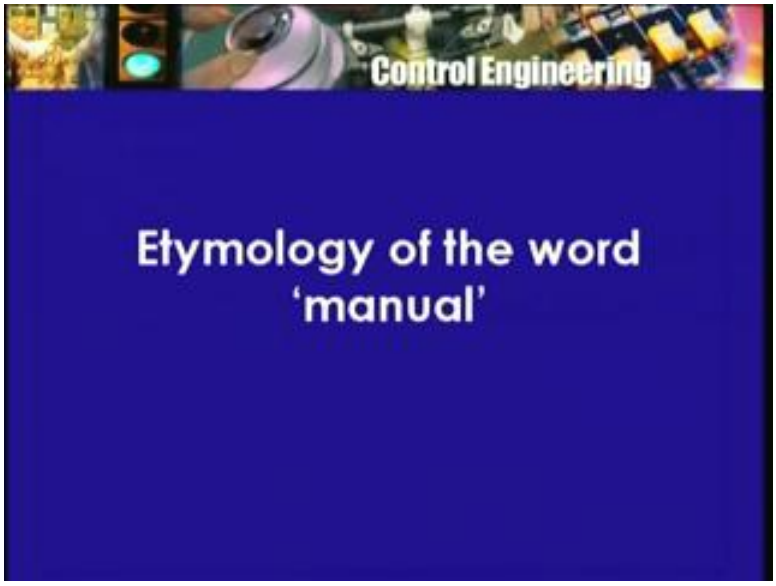

So, find out the origin of the word manual, so that is manual control. In the case of the air conditioner, of course the control was partly manual because you had to set the temperature, you had to set the knob or on the cordless unit, you had to set the temperature by pressing some switch or a button. But thereafter you do not have to do anything, what happens is that as time passes, it is a, it is getting hotter and hotter outside the temperature in the room. If the air conditioner is working properly will remain nearly constant at the value that you have set, you do not have to get up and change the setting or you know make it cooler or hotter, unless you change your mind, you want to change it then of course you can change it.

So, the control action here is partly automatic or in fact, the main control action is automatic. Once, you have initially set the control system and there is a major class of a control systems or control situations, which are like this, which are often called regulator type control system, in which things will happen automatically, after the regulator has been set and the value at which, you are setting it in chemical engineering literature is known as the set point. So, the set point in a regulator system, could be a temperature, it could be pressure, it could voltage, it could any one of these areas physical quantities which engineers need to control. So, that is one more example of a control system which you might find in a house or in the room, where you are seated illumination control, control of speed of the fan motor, control of temperature of the room, is there anything else in the room perhaps not but at a primitive level. Even a window or a door is an example of a control situation, think of a room or a house where there is no window but there is only a hole.

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So, you have no control but if you put a window then you have some control, you can open the window or you can close the window or you can even keep it partially open. There are, what are called spare rods for the window, of course very often the spare rods get broken or are not used and so windows keep on banging, when there is wind. But in principle, that is a control situation you can have the window completely open or you can have it completely

closed or you can have it partially open in a number of positions. So that you can control, may be the temperature in the room or the wind condition in the room, if it is too windy you might want to close the window, if it is, if there is hardly any wind, you might want to keep it fully open and things like that.

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Similarly, a door although usually doors do not have spare rods, you can either keep them open or you have to close them. But if you look at your house and see what are the control systems that you might find there besides the ones that we have already seen light, fans almost in ever house, modern house in the city, you will have this windows and doors, of course may be air conditioners, in some places you may have room heaters, in places where it can get very cold, you may have a room heater and again you may have a room heater of the automatic type.

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So, that you set the temperature and the room heater will turn on when the temperature outside becomes low, it will turn off when the temperature outside is rising. So, the temperature control provided by a room heater may be automatic what else, well in almost every house in the city, where you are fortunate in having water supply, which many of us just waste in the bathroom or in the toilet, there is a storage tank which we use for flushing the toilet.

Now, this is an example of a control situation which is very old, when we have tank of water, which gets spilled without somebody controlling the valve of the pipe through which the water is coming, the water will shut off automatically. So, when needed you pull the chain or you press the knob and the tank is completely emptied, we flush the toilet. Then the tank gets filled and you do not have to keep standing there, so as to close the valve after the tank is completely full, automatically the tank water supply will get switched off or shut off, when the tank is full. As an engineer, where you should take a look at this control system in a little detail. You should open the flush tank and see what is the kind of mechanism that we find, there some of you are probably already familiar with it. The idea is that the water in

that tank should be at a definite level. Of course, it will be below the overflow level you do not want water to overflow; on the other hand you do not want too little water.

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So, when the tank is emptied water will start falling in or flowing in the water level will rise and then the water level reaches a particular mark or a particular value. You want the water flow to be stopped. So, there is an arrangement called a float valve that is there is valve that is controlled by a simple thing that keeps on floating usually a ball, a spherical ball or ball of copper, hollow ball of copper connecting with a lever to a valve something as crude as that

such float devices are quite old. In fact, from your book, if it does say something about the history of control systems, what where some of the earlier control systems that people used. You may be able to find some information about such kind of water level control system.

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They appear to be as old as 2000 years, of course not for a domestic toilet but for other purposes. The problem was essentially the same you had a source of water; you have a tank where you wanted to store it. But you did not want to sit there and see it getting filled and then switch off the water supply, you wanted it to happen automatically. So like the temperature control of the air conditioner or the heater, it is usually done with a device called thermostat here. You have the control automatic control of level of water in the tank and as I said earlier, it could be other physical quantities like pressure in a boiler may have to be maintained and at a particular value or again domestic as well as an industrial example, is that a voltage has to be maintained at a particular value. The power supply company has this big job of maintaining the supply voltage constant at a specific value, the frequency of the supply has to be maintained constant.

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So, there are such situations, control situations, where one uses control system which are known as regulator type control systems. We will look at some of these examples, in a little more detail later on then if you come to the modern kitchen of course, you will find a number of control situations, in fact the house the modern is quite full of various appliances and devices which have to be controlled and we are able to control.

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For example, take cooking gas stove once again, we not only have it turned on and off but you have several positions, possible from shimmers that is low heat to high heat okay. Again there is a knob that you turn it does something, some valve opening somewhere with springs and you can have the amount of heat that you want. Then you may have an oven in the kitchen, where you will set the temperature you want to bake something or you want to

make a toast, toast your bread, you may want to set a particular temperature and then again automatically some action will take place or it could be microwave heater or a microwave oven or a microwave range. As it is called, where once again one may set not only temperature but one also sets the time for which you want the action to take place.

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You may want the microwave range to be on for 1 minute or 2 minutes or 10 minutes, you may want it at full power or at reduced power and so on. Then, there are other devices which involve electric motors for example, you have mixers, blenders things of that kind juicers where electric motors are being used and their speed is being controlled.

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Once again, usually it is not just on, off but for a mixer or blender you may have a number of values so discrete action usually various positions called chop, blend, liquefy and what not. So, we have gone around the house looking for control situations and found quite of few of them. Let us go outside now and see what are the situations, where one can exert some control. Well you have a bicycle perhaps and you ride a bicycle, you climb on to it, pedal it, get down from it. There is a lot of control action that is being used in such a simple thing perhaps that, what are the most important parts of bicycle riding. I have been riding a bicycle for a long long time. Now, so, I know it some of you may not have learnt it perhaps the most important is the act of balancing not falling off the bicycle trips to one side the balancing is one act, if you think about it, it is not really very simple but you learn to do it.

Then, the other thing is spearing you want to go somewhere, you have to use the handle, you take a turn to the left or a turn to the right and just a little push on one handle bar or the other other handle bar and the job is done. There is a control situation, of course, this control situation is fully manual, you are there on the cycle and you are turning the handle bar or you are peddling then of course, there are the brakes a situation may call for the use of the brakes.

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So, even an ordinary bicycle is an example of a fairly complex control system and of course, it is a manual control system and the human being you or I, who ride the bicycle that is the most complicated part of the control system, what exactly goes on in our brain, how we move or put our hand, it is quite a complex phenomenon. Somehow, we are able to do it, most of the time because once in a while we fail, we crash in to something or fall down or whatever. Now, of course one can go one level up, bicycle is probably too elementary thing.

So, perhaps you will graduate on to a scooter or a motor bike, a 2 wheeler, still there are same kinds of problems balancing is one, control of the speed accelerating, of course instead of pedaling. Now, you have something else either on the handle bar, grip bar or foot operated, accelerator pedal will be used to increase or decrease the speed. Again, there will be brakes on the handle bar or foot operated brake for slowing down the vehicle.

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So, a similar situation control of speed of the vehicle, control of direction with steering the same problems that one faces with the bicycle and once again, you are riding the scooter or motorbike. So, a very complex system is operating along with the motorbike compared to the motorbike, you are a much more complex system or compared to you, the motorbike is although it looks very complex, it is not really that complex a system.

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Of course, you can go one step further and graduate to a motor car here the balancing problem is over because it is a 4 wheeler, you do not have to do the balancing act anymore but you still have the speed control with the accelerator pedal and you have to brake the vehicle with the brake pedal.

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In addition, you may have more things like changing the gear for a car, which has a gear change mechanism and it is not an automatic transmission car and there is steering of course, you have to follow the road and steer the vehicle to the left or to the right. Again, a manually operated or a manual control system but these days people do talk of more sophisticated automobiles where, for example the steering column is not directly linked with the wheels, front wheels, which determine the direction in which the car will go. So and in the aircraft situation there are so called fly by wire that is, there is no direct mechanical connection between what the pilot operates and what the effect is.

Similarly, braking arrangement could be through power breaks, power steering is what the earlier one is called and so on. Of course, if possible one can move further up and fly and aircraft and there are control problems there, there is a control situation there, the most difficult perhaps and the most exciting parts will be the takeoff and the landing and comparatively easier will be maintaining, cruising at particular speed and at a particular height and if the weather is fine, there is no turbulence then there is very little work to do. In the aircraft situation, of course one does talk about things like autopilot thinking that the human pilot could be replaced and so the whole thing could be made automatic and one can think of people have thought of and there are situations where, you have automatic landing and automatic take off and automatic cruising also.

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So, the whole pilot less aircraft are examples where, there is no human being the whole control is automatic. So, there is a whole range of control situations or control activities, one can look at other places, one can look at industries think of what goes on and you will see

that there are control situations everywhere at an earlier time windmills were used for grinding flour may be and there was a control situation there.

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You may want to adjust the speed at which the flour is being the grain is being ground whereas, the wind speed is not under your control. So, some arrangement to be provided, so that the speed of grinding can be changed. There were watermills, the mill was operated by flowing water in a stream and again, there would be similar problems. You may want the watermill to operate at a particular speed whereas, the flow of water may be too slow or too fast. So, something has to be done to achieve this constant speed of operation, this as I referred to earlier is a regulator type of operation. In a modern situation, let us say one looks at a electric generating station, you see there are plenty of control actions taking place, what are the various kinds of generating stations that you know of although you may not all be electrical engineers. Today, we need to know a little bit at least of electric power generation and its use.

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So, basically what do you have, you have some device, some mechanical device which is called a prime mover which moves the generator, which generates electricity as you might call it. Now, the prime mover could be a hydraulic turbine as in the case of hydroelectric station. So, it is water flowing at a high which turns the turbine and on the same shaft is the generator electrical energy is produced and taken over large distances. So, that is hydroelectric generation requiring a hydraulic turbine. Remember, I mentioned earlier that the power supply company has to maintain a constant speed or a constant frequency, a constant voltage, which requires that the hydraulic turbine run at a constant speed, irrespective of the electrical load that the power supply has to cater to. So, this involves a very big control problem.

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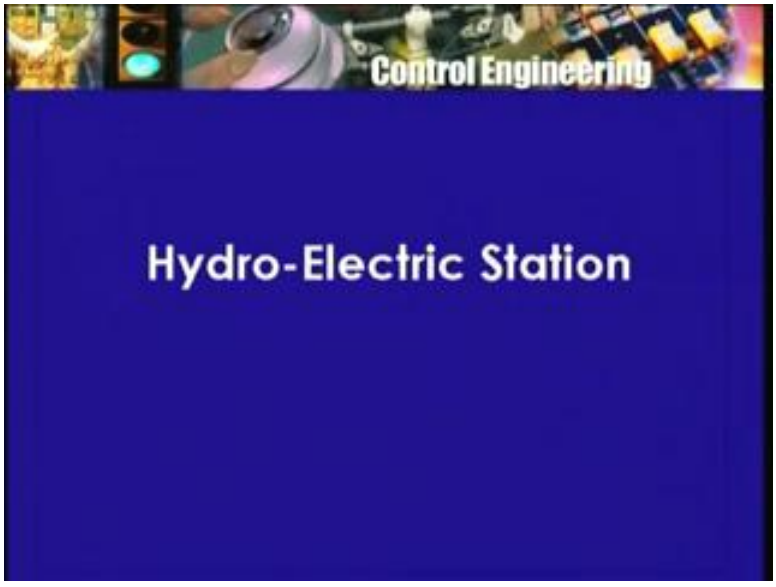

The generation could be with a different prime mover, the prime mover could be a steam turbine. In the earlier days, it used to be steam engines but no longer one uses steam engines, one uses steam turbine. So, it is a thermoelectric generator. Now, here it is the steam which has to be controlled the pressure and temperature of the steam coming from the boiler has to be such that the generator will run at a constant speed, so as to maintain a given supply

frequency and a given supply voltage, of course speed control is not the only thing, the load on the system will determine also the voltage that the power supply is producing.

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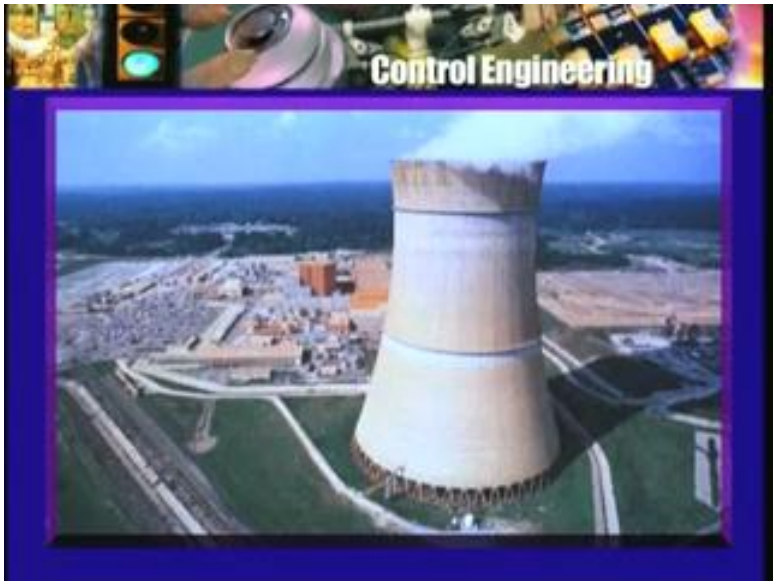

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So, there are other control aspects which are involved. A nuclear power generating station is essentially is a thermoelectric generating station instead of steam being produced by burning coal or oil or gas, you make use of a nuclear reactor, which produces a lot of heat and that heat is then transferred either directly or indirectly to steam and you have steam turbine which then drives the generator.

So, it is also a thermoelectric generating station. There are in our country now, commercial wind generating stations where, the generator is moved is connected to the windmill and so, it is the wind which propels or which moves the generator. There, as I mentioned earlier there is a controlled situation there because, the wind speed can vary, the wind direction can vary and you would like once again, it is possible to maintain the speed and the frequency and voltage constant. Of course, there are problems, so one may do it a little differently, one may want to generate a DC voltage and use storage batteries rather then generate AC voltage of a constant frequency and a voltage value. One may of course, we use a photovoltaic cells you may have seen some of these photovoltaic panels in many places. The photo voltaic cell will produce the electrical power.

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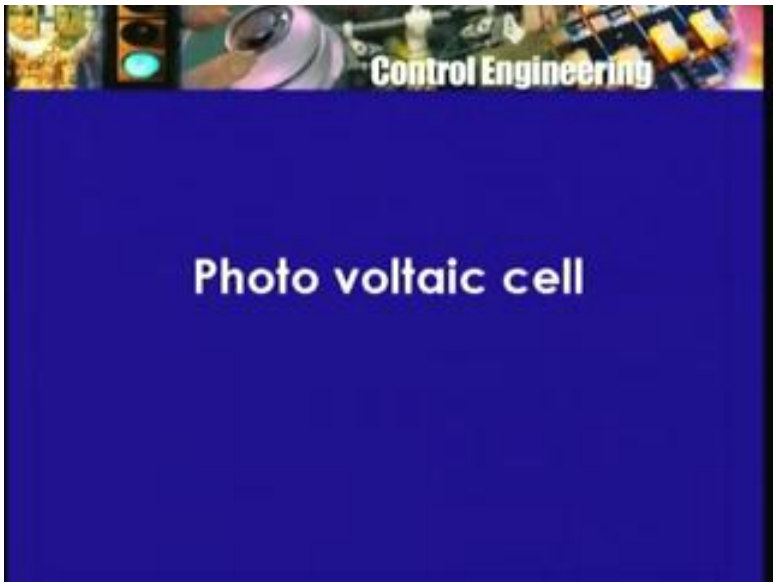

Now, as the day proceeds from morning to evening, you may have to move the array of cells to follow the sun. So that the maximum amount of radiation or heat falls on the cells and the cells produce the maximum amount of energy possible. Here again, there is a control problem of moving the solar panel to follow the sun, of course, if the sun gets obscured by clouds then what to do. So that is a an addition complication in the situation. So, electric power generation really involves a lot of control situations and control problems in production industry, in mechanical industry. For example, one can go to workshop you will see a lot of things in action which involve control.

For example, in machining one will operate lathe, milling machines, drilling machines papers, all kinds of machining devices which are of course, nowadays operated by electric motors. So, there again there is a similar problem controlling the speed of the motor or controlling the power that is produced by the motor. So, that the proper mechanical

machining action takes place, one talks about the numerical control machine tools you must have heard of a numerically control machine tool.

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In chemical process industry, again there are control situations almost everywhere right from the place where the oil exploration or the drilling has taken place, the oil wells, the oil has to be pumped up brought to the surface and then sent through pipeline then at the refinery, a lot of chemical processes have to be done on the crude, there is distillation, so there is heat production. I did not talk about this earlier although, I did talk about the microwave oven or the microwave vent where, heat is the amount of heat is to be controlled.

So, ovens are an example where the amount of heat that is to be produced or the rate at which, it is being produced and the time has to be controlled in metallurgical operations like the steel rolling mills. It is heat and pressure these have to be properly controlled. So, that from the steel ingot or bar, you can press and make it in to a steel sheet of a desired thickness and homogeneous uniform quality and that is a control situation which is really very very tough one and requires lot of ingenuity to solve the problems that are involved there.

So, you see that control systems are to be found in almost every walk of life right in the room where, you are seated to your house, to your devices which give you mobility, the bicycle, the scooter, the motor car, the aero-plane, may be the spaceship or the rocket which takes you to the moon and will bring you back or the rocket which sends a spacecraft to mars and lands it there to industrial situations where, power is being produced in generating stations, power is being used in workshops, in factories, in refineries. There are control situations almost everywhere, what is common to all these situations.

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You know, looking at this very simple point of view, what is control? All that, I have been telling you are examples of control actions but what is common to all of them. So, just a think little bit perhaps, you will agree with me that is, what is common in almost all these cases is that there is a choice.

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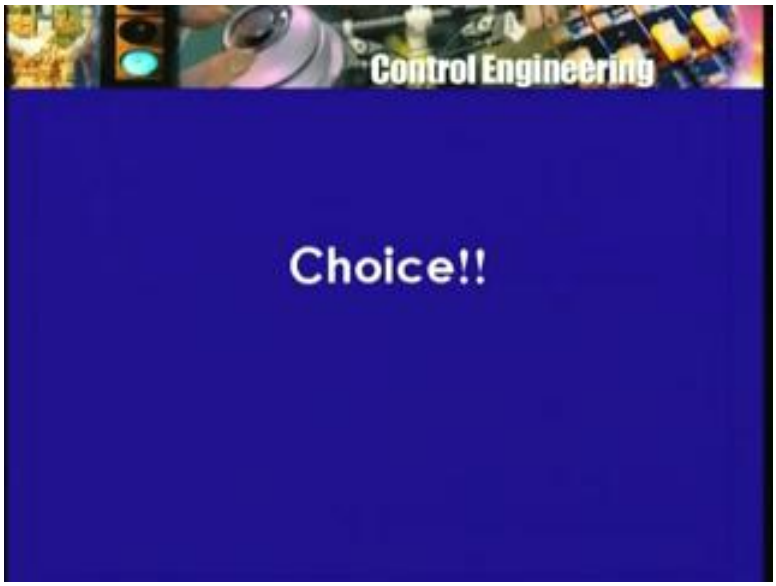

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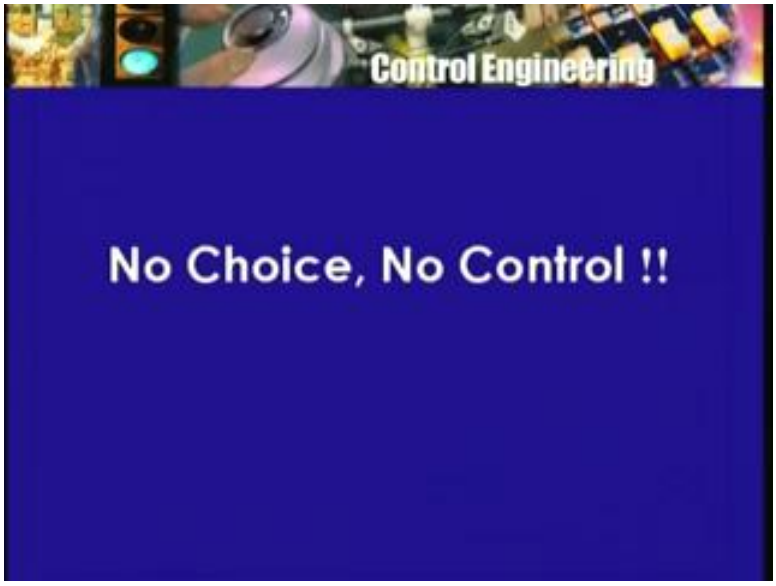

You can either do this or you can do that, you can select this or that or something else, there is a choice, if there is no choice, there is no control, things are out of control, if you cannot do anything about it. Let us say, the power supply has gone off or there is a power shut down and if I do not have any standby electric system or whatever, then that is it no control over the situation, the lecture is canceled or the movie show is off, no control.

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So, control is where, there is choice and what mankind has done, what engineers have done, what people have done in the past and are going to do is to provide a lot of choice and to enable us to exercise that choice. Now, I have pointed out one distinction earlier between manual control and automatic control, I said that, if I get up and turn on the light or turn it off that is manual control whereas, the air conditioner once I set the temperature, no matter what happens people come in, go out, outside. It is hot or cold, the temperature remains constant that is automatic control. So, in one case a human being is involved not only for an essentially setting but constant adjustment as and when necessary in the other case, it is automatic and I said that the flush tank, the automatic water filling tank is the earliest example of an automatic control system.

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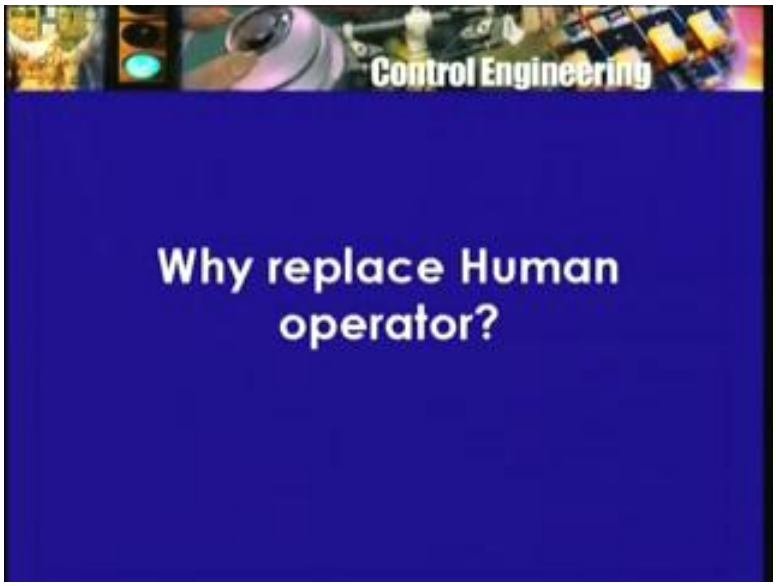

Now, why do we want automatic control system are not manual control systems. Enough think about it, what could be the various reasons for requiring that is human being be replaced by a device. At the human control action be made or be changed or replaced by an automatic controller, what could be the reasons for such a desired thing. Let me, give you an example, which is about 100 years old. Now and there is another little bit of home work that I would like you to do. About a 100 years ago, find out exactly, when a Nobel Prize was awarded to an engineer for implementing a control system, this was done in Europe in Scandinavia, find out whether it was done in Sweden or Norway.

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You have heard of light houses, these are small islands or rocks rocky portions jutting out from the sea and they provide, they constitute a risk for shipping. Of course, this is 100 years ago, so there was no radar, so one could not detect such things from a distance by using radar. You depended only on sight, the captain would be on the look out or somebody

standing much higher, may be on the mass would be on the look out for such things and then you have to steer clear of these obstacles.

So, light houses they are quite old in human civilization those of us, who are living only on land, we are not bothered by a light houses but communities such as Norway and Sweden which have a very long shore line, which are depended on fishing and shipping and so on. For them, it has been very important and the shores are very rocky in that part of the country. So, think of a light house, what is a light house? Light house is a essentially some kind of a tower, which is built on that rocky portion or small island and of top of the tower you have a beacon, you have a light. Now, there is a problem here because that light has to be kept on especially at night, when ships would be able to just see it from a distance and steer clear of the rock.

Now, the problem is that this place may be so small and may be isolated, you may not want a person to be there, so that at night he turns on the light, the beacon is on at night and in the morning, when the sun comes out or you just turn it off. Again, 100 years ago, so electrical power situation was not as, what it is today taking a cable to that island this is may be 100 kilometers off the shore that was not going to be an easy and cheap thing, you cannot think of a generating station there except a small one perhaps.

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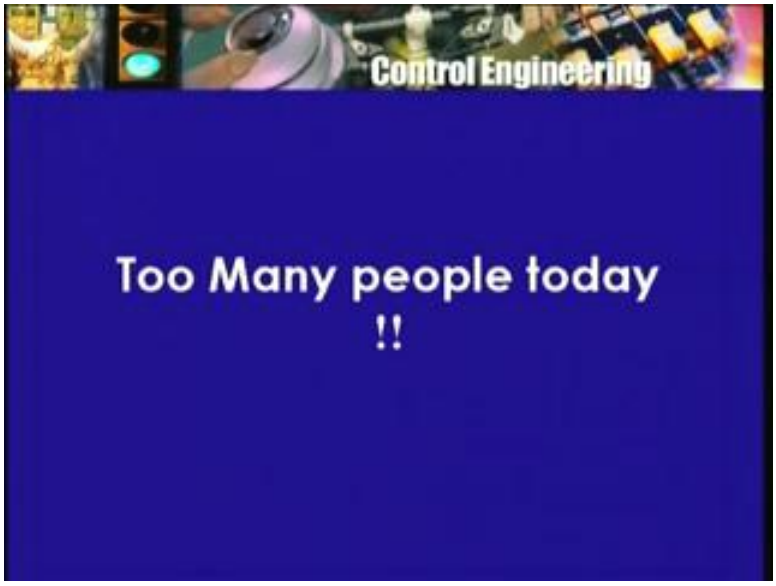

So, perhaps you would have some supply of oil or some such fuel and the light would be of a crude kind or you could have may be one could think of a diesel or a petrol engine which drives the generator, which then produces the light. But, the problem is that the island is not

going to be inhabited by an attendant, it may not be possible to keep a person there. Now, once again the situation at that time and that place was different. Today, probably in our country, they are no problem, we have enough number of people looking for a job.

So, people will be very happy, if they are given a good salary to go on to such an island and just do this job of turning on the beacon in the evening and turning it off in the morning. You do not want it on all the time because it will be consuming fuel and then somebody has to replace it and then there could be a time, when there is fog. So, it may be day light but there is fog, heavy fog, so even though the sun has risen, the visibility is poor. You would like to have the beacon on but again, there may be no human being who is going to see whether, it is foggy or not.

So, this engineer devised an automatic control system which will in someway sense the light and turn on or turn off the beacon and since, there were so many such light houses to be powered around the coast line and this whole thing involved money because you need fuel, you need replacement of the fuel as time goes on. So, there was an engineering problem and his system resulted in a lot of savings of money, of energy and the system was more reliable.

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Well, think of a human being, who is on that island all by himself, he is supposed to turn on the beacon at evening and he is supposed to turn it off in the morning, what if he goes to sleep, he does not wake up or he goes around somewhere, loitering or you know. So that is something where automatic devices sometimes do better and usually do better than human being, human beings are liable to make errors, errors of judgment one gets tired. You know

pilots, if there are piloting an aircraft continuously for many hours, you can imagine how tiring it must be think of ordinary truck drivers or locomotive drivers or yourself on a trip may be a, 1 hour ride or a 3 hour ride driving yourself is not exactly enjoyable whereas, an automatic device may be more reliable. So, where reliability is very important, you want something to operate, you want to be sure that it will operate.

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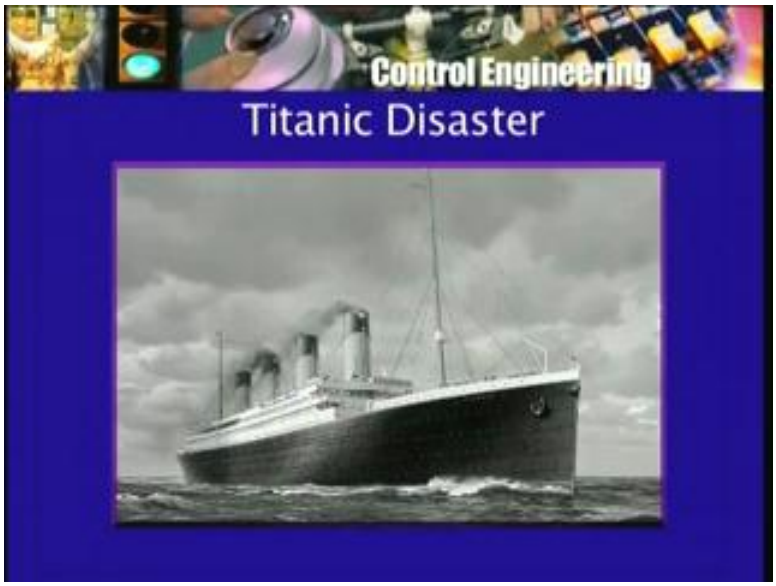

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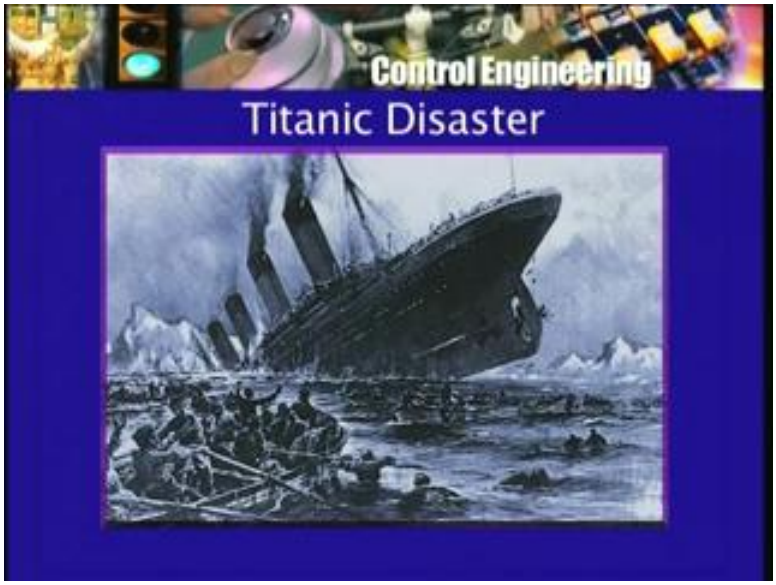

You may want to make something automatic although, if you have a person there, if you give him a job, it is all right but may be its too risky, you cannot take the risk, you cannot say well it, well what happened is you know, I just dozed off and a ship hits the rock and people are killed and the drowned and what not you know the Titanic like disaster. If it is because of the lapse by one person, it is something certainly one would not like to happen.

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So, this is one reason why human beings very often are replaced by machines, are machines always reliable, whether yes or no because machines can also go wrong, machines can also fail. So, you need to require they need to be properly maintained, you need to look at the power supply whether the power supply is reliable things like that, so it is not that just you have a machine and it becomes reliable. There is the additional problem of keeping the machine operating reliably, but at least the human beings problem has been removed, is there any other reason, why one would like to use automatic devices rather than human beings.

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Well, the accuracy that is possible with automatic devices is much greater than perhaps the accuracy with which human beings can control a situation. So, where you want more accuracy you want more precision, you want finer control it may be necessary to replace a human being by an automatic device. Suppose, a temperature has to be adjusted or controlled an operator, may be able to keep it within plus minus 1 degree Celsius or may be plus minus .1 degree Celsius. He has to read on the dial, what the temperature is he has to make that adjustment and as it happens, you know think of a situation where, the adjustment has to be made continuously, you can overshoot the mark, it is too much then you reduce it, it is too little you go on playing like this.

So, because of the way, we are you know we can control ourselves. Of course, we do, we do ride bicycles, we do ride motorcars drive them steer them and what not, still the precision is limited. So, where things are to be done more precisely, you have to put in an automatic device, if something has to be kept within say 100 of a degree Celsius or 1000 or voltages

have to maintained or frequencies have to be maintained within .1 percent or even less than that much of error is to be tolerated, there may be no option.

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You cannot have a human being sitting there and twiddling a knob and setting it, seeing that it is at the right value. The human being is not just adequate in many of these situations and of course, there are situations where, it is just too risky for a human being to be there and of course, the latest that one is hearing about is the spacecraft that landed on Mars and is doing exploration on Mars that is an example, where at this point it is cheaper and safer to put a spacecraft on Mars and control it from a distance rather than to send a person there or send a astronaut and do the job.

Of course, we did see astronauts landing on the moon, they did something but before the astronauts landed on the moon, I think there was a spacecraft which also landed on the moon, what was it called or was there a dog which landed on the moon. I think the Soviets the Russians had perhaps put a, no the dog was put in orbit only before Yuri Gagarin went around there was a dog called Laika. If I remember right, who was tested. Similarly, I think the Soviet Union had put some device on the moon, they did not put a human being on the moon, the Americans did it. So, there are situations where you just do not want people to be in so these are situations which require remote control and so, things have to be made automatic.

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There is one more very familiar situation now, that is one hears about it one hears a lot about so called robots, one talks about robots, one even has robot toys, robot that will walk or a robot that will pick up something from one place and it will put it down in another place. We have told that there are automobiles which are assembled using robots and what not, why why does one want to have robots.

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Now, there may be similar reasons for example, man power is expensive that could be reason, why you replace a human being an operator by a robot or the kind of precision that is required, a human being cannot provide, a human being gets tired fatigued same job for hours together, the human being is liable to make errors of judgment arising out of fatigue and things like that. So, you may get a better car, if it is assembled by a robot rather than, if

it is assembled by a line of factory workers working on a conveyor belt kind of situation. Of course, it is fun to have robots which can do things for you, I sit here and I want a glass of water. So I have a robot, I command it fetch me a glass of water and the robot goes to the table or gets me water.

I am lazy, I do not want to get up and pick up my glass of water, if I have a robot at my command it will be nice. So, this is just a humorous example, but there are people who and there are you have seen situations in movies where, you have these automatic devices doing things which human beings would do earlier. But robots are important, industrially they are important in atomic power stations for example, or atomic research laboratories where, the things are very risky for human beings to operate or handle. For example, one thinks obviously of uranium samples, radioactive material which cannot be directly handled. So, one may want to handle it indirectly with the help of robots.

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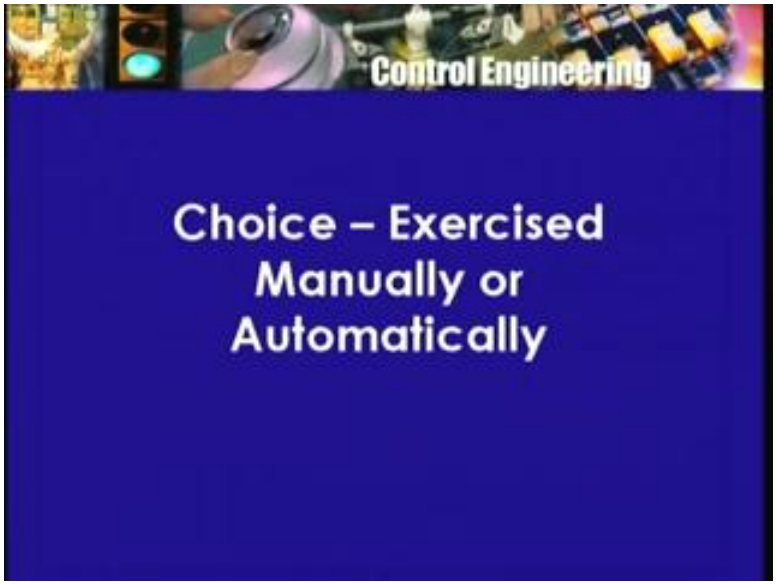

So, robotics has seen a lot of development in the recent times and it is a very major area of control system activity. So, you see that control systems are almost to be seen everywhere, we need them in almost every walk of life. Of course, this is qualitative description but basically you see to it that the control situation involves choice, what you do is provide choice that choice may be exercised manually by a person or it may be done automatically to achieve certain purpose and we will take a look at this in a little more detail, what is that purpose, what is the goal of a control system, we will be looking at some examples in more detail to illustrate this idea. I talked about in the beginning with the simplest namely on, off control system, next higher level was discrete action or discrete control system then going

beyond that was the continuous action control system, one on a similar line could talk about control systems, which are said to be discrete time or discrete event control systems.

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Once again, there is a very familiar example for many of us of a discrete event or a discrete time control system. Can you think of it? Well, those of us who have used or who have lived in high rise buildings make use of the lift or the elevator. Now, that is a situation control action which is a discrete event kind of control action. You are on the ground floor and you want to go to the 10th floor, the lift is somewhere else, so you press the button, the lift comes down to the ground floor level, may be the door opens automatically or it has to be opened manually. Again, there could be a manual or an automatic action then you get in to the lift cage and press a button for going to the appropriate floor.

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So the action is sought of discrete you 0th floor to 10th floor, you go there then, you get off then, somebody calls it to some other floor, it goes to that floor. So, the control action is of this sort, it consists of a sequence of actions, lift goes from 0 to 10th floor, may be 10th floor to 6 th floor, then 6 th floor to 2 nd floor and it is governed by so many things, by people who are pressing button who want to use that lift.

So, this by and large is referred to as a discrete event or a discrete time control system, where the action does not take place all the time for example, the lift may simply at the ground floor level because, nobody is operating it, nobody is wanting to go up or come down. So, there is no action taking place, so it is only when something is to be done that the lifts comes in to action, it goes up or moves down. So, this is an example of, what is called is a discrete time continuous system whereas, there are continuous system, there are systems which are operating continuous all the time. Think of the thermostat regulation of temperature in a room with an air conditioner, you cannot have the thermostat operating for 5 minutes and then not operating for the next 15 minutes doing whatever, you know it wants

you want the thermostat to be in operation all the time. So, as people come in the room becomes a little warmer the thermostat where, you have set the temperature will produce more cool air and if people go out, there are only few of us in the room should not certainly become very chilly then, the amount of cool air that is being circulated with be reduced.

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So, this is an example of a continuous time system where the action is taking place all the time and most many industrial examples are of continuous time. Although, there are discrete time systems also machining operations for example, can be of the discrete type that is certain actions are to be done in a particular sequence. In a way a digital computer is an example of a discrete time control system, what produces the discrete time in the computer, some of you perhaps know better than me but there is device a called a clock. So, this clock and the pulses that it produces is the discrete time keeper of the operation of the computer and things take place at discrete instance of time.

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Although, of course, you can say that voltages are changing all the time or currents are flowing on the time and so on. But, what is of importance see, what is happening at some discrete moments of time, at one clock pulse, this is what is happening. At the next clock pulse this is what is happening and so on and in the old fashion block diagram of the computer there is what is called a controlled unit inside the computer. It is the unit which determines the sequence in which the operations with take place. So, there is control unit inside a computer also, the computer can be looked upon as a discrete time control system and it can also be regarded as a discrete level control system because almost everything in the computer look at.

You may think of a transistor or you may think of a memory cell it is either on or off, it is either plus or minus, it is just yes or no, 1 or 0. So, it is a discrete level discrete time control system or discrete event control system. So, this is another important classification of control systems discrete time versus continuous time and earlier one that I mentioned was discrete level versus continuous level, the one more that I have been talking about is manual

versus automatic. So, you can have a variety of combinations of control system. We will look at some more aspects of control system before, we take a specific examples and look at it from a more detailed and perhaps, so more mathematical point of view.

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So, do not forget to do the homework what was the homework, you have to look up the word manual and while you are at it you might also look out the word automatic in your dictionary, find out what are the roots of that word of those two words manual and automatic and secondly, find out who was given the Nobel prize about 100 years ago, an engineer, a control engineer was awarded the Nobel prize when, where, what is the work that he did, I told you some things about it try to get more details about that.

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