Industrial Automation and Control
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Lecture - 02
Architecture of Industrial Automation Systems

Welcome to the course on industrial automation and control, today we are going to have lecture lesson two which is on which is on architecture of industrial automation systems industrial automation systems as a whole are quite complex entities. If you go to a factory, you will find a bewildering array of equipment controllers, sensors, operator displays various cabinets containing hardware, so all these together make a factory work like an orchestra. So, today we are going since it is a since it is a complex operation with various kinds of equipment which harmonize themselves with one another.

Before we take a detailed look at each one of them, it is useful to look at the look at the operation of the whole system and see how the various parts relate to each other. So, that is the basic purpose of this lecture to understand the how this complex system is organized, how what are the various elements in the system, how they relate to each other, what roles they perform how they interact with each other. So, that in short defines the architecture.

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So, having said that let us look at the specific instruction objectives of this course, so since the industrial automation system being complex system is definitely organized hierarchically in various levels. So, the first specific in instructional objective is naturally to name to be aware of the various levels of industrial automation. The second objective is to relate to describe the hierarchical structure of industrial automation system by which I mean that to know what this level do to able to understand how one interacts with another. What information one except from another and how does it what information does it give to the other.

So, that will describe the hierarchical structure then describe the essential functions that are achieved at each level. Specifically speaking, since industrial automation is in the sense a lot of industrial automation actually is concern with control and control is of two kinds as we shall explain shortly it could be automatic control or it could be supervisory control. So, it is important to realize distinguish between the two, so the last instructional objective is to understand the how automatic control is distinguished from supervisory control.

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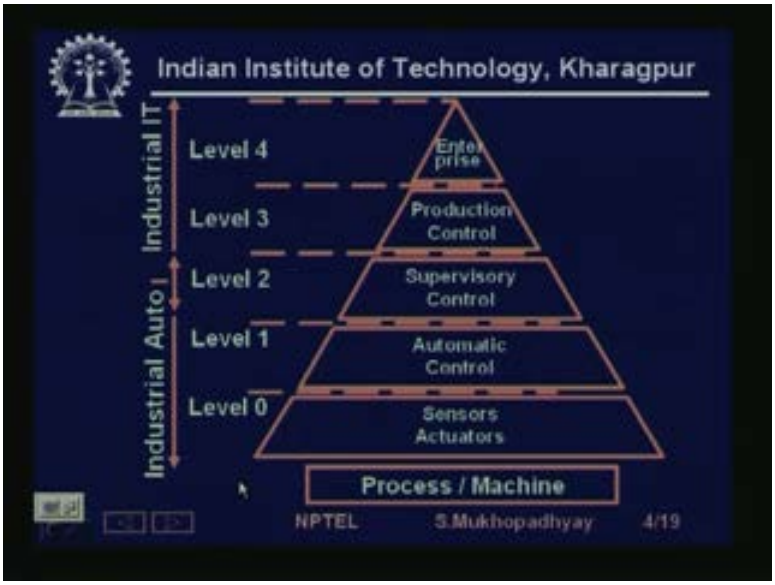

So, now let us look at the industrial automation pyramid as whole, why is it a pyramid, it is a pyramid because there are several levels. So, each of vertical dimensions we have the lowest levels of sensor and actuators, which interact with which directly interact with the process or the machine, so they actually get the signals from the process of the machine.

Now, these sensor and actuator are actually act as the eyes on the arms of the controllers, so on top of these we have the automatic control layer which is called level one.

Now, a number of automatic controls are again managed the at the supervisory control layer which we call level two, finally the operation of a particular shop floor as a whole is controlled. The whole overall manufacturing operation including maintenance production quality assurance inventory everything is manage at another level which is called production control. Finally, right at the top we have enterprise control which is which is more like a basically consist of management functions.

Here, not only the production related operations are considered, but even other operations like sales marketing new product development everything is considered and production is consider just of the part of it that is level four. Now, at this point we should mention that while this functionality is necessary for the overall control of for factory.

It often turns out that that not necessarily all these layers are perfectly automated what I mean to say is that generally sensors and actuators must be automated, there is equipment for it. Automatic control layers are also automated there are most operations are not manually controlled, but from the supervisory control layer upward. It is not always true that we have in a computer based automation for functioning of the, for performing the operations of that level. In fact, some of these operations may very well be done by human beings. For example, if you go to a if you go to the power plant or if you go to a big refinery, you will find that in invariably on the on the shop floor you will you will have you will have control room.

If you enter the control room, it is usually very large room where in the where in the center of which will you are you are very likely to find that there are number large computer monitors. There are a group of people who are actually sitting around these monitors and constantly looking at these. So, there are generally the process supervisors or the operators, who perform a lot of supervisory control function. So, at the supervisory control level there could be some functions which are automated while some functions could be performed manually also.

At the production control level, most of the operations most of the time are perform by humans with the aid of tools which help people perform the production control functions. So, that is why we have what is known as production manager or seen a seen a power

station we have shift charge engineer who is in charge of running the overall power system, over all power plant for a for a certain duration of time.

So, these production control functions are invariably a mix of manually as well as automatic tools. Similarly, enterprise management functions are also like that you have you have managers who use tools for performing there functions, so we have level 0, level 1, level 2, level 3 and level 4.

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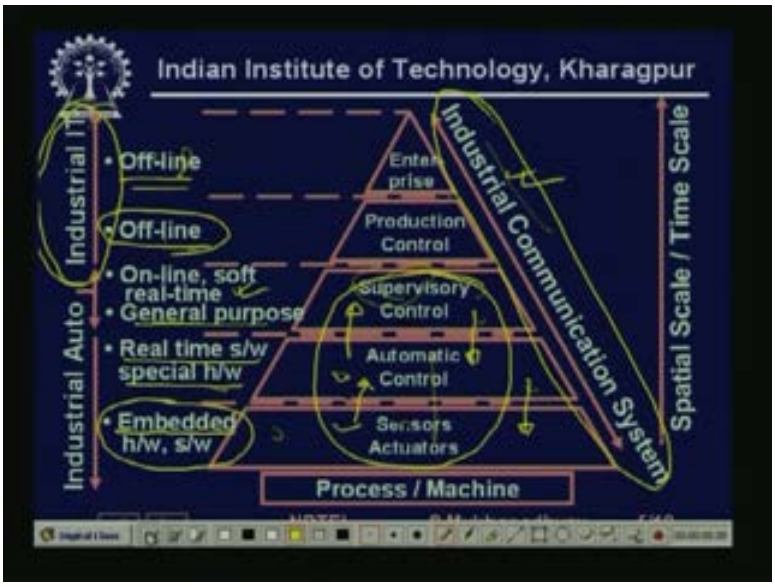

Now, having said that let us look at these levels and their natures with a certain some more detail. So, first of all, we will like to point out and this is why this system is called pyramid is because that as you go up the pyramid the spatial scale and the temporal scale of the time scale of a given system at that level increases, now what do I mean by that? So, for example, consider one sensor system one sensor system measures one process variable in the whole machine, so it looks at only that variable.

So, in that sense it is spatial scale is actually related is actually very limited, so in the whole shop floor, there are there are several machines in each machine there are several causes' variables and the sensor which that level 0 only looks at one of them. So, in that sense, it is specially its scope is very limited similar, but its interaction is over a very small times scale that is it gives over sampling times it gives values to the controller. So, each value it represents the variable over a very short time, so in that sense it has a very each value which comes out from the sensor has a very short times.

Now, as you go up for example, if you go to automatic control, automatic control also works at the sampling level in the sense that it computes control input control inputs for the plant at each sampling point, but why it is designed? Sometimes considerations are made of larger deviation for example, when you say that the settling time should be low.

Now, when you are considering settling time you are considering that if you make a step change then from one operating point to another how does the output reach from one level to another. So, typically you concerned about duration of time, which spans over several sampling times. So, if you go to supervisory control level supervisory control level one of one of the major function is to a change a set point and set point change is a not made every moment.

Control input changes are set to the plant every sampling time, but set point change are not made every sampling time, definitely they are made over, let us a typically some hours or and if you if you take a power system boiler. So, it will operate say at say at three o'clock in the night, it may be operating at 10 percent load at seven o'clock in the morning, it may be operated at 25 percent load at around nine thirty. There is huge amount of load comes in the power system because all the office is a open happen things like that. So, between nine thirty and eleven o'clock, it will it will ramp up significantly from let us a 30 load to nearly 90 load, perhaps then that 90 percent load.

It will maintain till again say let us say five o'clock, I mean after about five o'clock it will I mean evening will come and people will switch on various kinds of lighting loads. So, then you will get evening people, so when only when the load will significantly increase will the boiler operating point be changed. So, the operating point of a boiler typically gets change let us a say 7, 8, 10 times over day and it is change is also based on the I mean the decision for change are taken based on periods of hours.

So, in that sense it is on a large temporal scale, it is also on a on a on a much largest spatial scale because everyone sensor looks at one signal one automatic controller may be taking control action taking several sensors in to the account. So, in that sense it is spatial scale is now increased, now one supervisory controller will typically look after a number automatic control loops. It typically looks after one piece of the equipment like a like a like a boiler or a furnace or a distillation column typically they will have many automatic control loops. Similarly, a short floor may be made of several such units or

machines, so the production control is done typically at the shop level, while the enterprise control is done at the overall enterprise level.

So, as you go up you can understand that the time scale is increasing and this spatial scale is also increase that is why it is a pyramid and not a cylinder. If you look at it, so having clarified that let us look at the nature of technology, which is used for automation at these various levels. So, at the lowest level, when you have sensor, when you have sensor and actuators, so here you have mostly hardware things. Now, either they are actual sensing elements or there are package elements or electronic circuits or microprocessor they are they are generally very hardware oriented.

Now, we also having software along with that, but software is also very closed to the hardware in the sense that they actually interact very close to the hardware and the written specifically to for that hardware. So, in that sense we have lot of you know what is known as embedded technology at this level. So, this is this word embedded is because it is the kinds of actual the sensor is suppose to be embedded in the machine. So, you now all these technologies uses embedded hardware and software when you go to the automatic control level.

Then, it happens in many cases that there it is a it is a separate hardware it is not embedded into the process into the machine, it is a separate tangibly separate piece of hardware which runs again which runs real time software. The software is generally generic it is not very special purpose, but it runs on operate runs on special purpose hardware like you now like PLC industrial PC'S or some DSP processors. So, but the algorithms are generally generic like PID control PID control is very generic control algorithm which is use for a number of process control applications.

This software is real time in the sense that outputs must be generated within a given amount of time because every sampling time you have generate the control inputs should the plant. So, you have real time software hardware is special purpose or general purpose both are possible. If you go to supervisory control, you will find that hardware is mostly general purpose, it is general purpose computers of course, with a with a strong data interface because lots and lots of channels of data from the form the whole process come to this. The software is still online because it the difference between what is I mean some piece of software is called online if it acquired, if it interacts with external world.

So, it acquires is it works on the data which is continuously streaming in from the process using sensors and various communication channels, but it is not very hardware real time. By hardware real time, I mean up an application, I means software application is called hardware real time when the execution must be must be finished within as time deadline. If it does not finish then serious consequences may occur and the system a fail, but is generally work this could a generally mix up mostly soft real time in the sense that things must be done in time.

Even if, there is not so hard that is if you want does not one particular piece of computation cannot be finished in time, then some performs degradation may result, but in general this system as such will not fail. For example, one of the one of one of the main purposes of the this supervisory controller is to update the man machine interface that is whoever is the operator he has to be shown how the process the performing plot by graph plot various statics, etcetera. So, these are typically soft real time operations in the sense that; obviously, you cannot display variable 30 minutes after you have got it right.

As long as you display it in time whether you have displaying it within 2 seconds are whether within 10 seconds is not a much consequence. So, to that extent, it is called software, software is I mean the hardware is general purpose, but the software is very special purpose. The supervisory control software for refinery will be completely different from that of power plant, which will be completely different from that of a let say a manufacturing. So, they are they are very specific to the machines the software for the hardware is general purpose. Production control does not bother about machines as such they do not they are not really concerned about the take an obstruct view of the factory how many pieces of equipment are being produce per hour.

Whether that piece of equipment is actually whether it is whether it is a gear or whether it is an engine box or whether it is nuts and bolts it does not matter. So, machines are looked at as general purpose serve I mean service providers or material transformer, so you give it you give a milling machine a blank it will producing a gear. So, what is a exact technology of the milling machine it is not of interest at off line level what is of interest is how many pieces of parts it can produce whether it is functional or whether is nonfunctional such things.

So, the software is generally off line and uses it does use various kinds of algorithms, but they are of a totally different nature. They do not generally they do not they are not concern as such with the machines themselves, but take an obstruct view of production similarly, for similarly, for enterprise level. So, at these two levels and two some extended that the supervisory level we are not, so much close to hardware that is we look at the process as an as an abstract entity and we take decision about them and we analyze the performs we also monitor them.

So, in that sense, the layers up to from some parts of some parts of supervisory control as well as production control and enterprise control I would like to term them as industrial information technology rather than industrial automation technology. You now automation has a kind of hardware flavor, it has a kind of hardware real time software kind of flavor. So, while industrial information technology also contents lot of technology resource optimization technology scheduling technology etcetera, but they are not concerned. So, much about hardware they are they are generally technologies and they are non real times.

So, in that sense I would like to distinguish between industrial automation and industrial information technology. So, in this course we will take we will take predominant focus is on this on the first three layers. We will see layer 1 and layer 0 very in some depth will also look at some automation technologies which now being deployed for supervisory control. Now, another thing that needs to be said is that these layers actually exchange information. So, sensors collect are continuously collecting samples of measurements which they are passing over to automatic controller. Similarly, the automatic controller is continuously computing control inputs, which they are passing over to the actuator.

Now, similarly, the information that the sensors and actuators or automatic controllers are receiving from the sensors part of it, they are actually passing to the supervisory control layer to see whether the control loop is working satisfactory or some set point change is needed. So, whether there is some malfunction some sensor has fail on the on the process output is going out in which case the supervisory controller must take some action. So, it can either change the set point or if there are two sensors, it can switch from one sensor to other. So, gives comments. So, you can see that there is continuous information flow from there is information flow from the lower level to the upper and from the upper level to the lower.

As information goes up because of the spatial and times scale information continuously gets aggregated up. So, you as you go higher and higher you get more and more time averaged information over part of the fact as you come lower and lower you will be you get more and more detail information about a smaller and smaller part of the machine. So, as you go up information get aggregated as you come down information gets resolved, so there is a resolution or refinement of it.

Now, how do all these information flow up and down physically how do transmit. So, now a day's I mean lot of stress is being put on, so there is use usually a communication system which actually connects all these devices, so that they can seamlessly exchange information same results.

In fact, lot of configuration management various kinds of things, so there is you see the industrial automation marked it will find lot of activity here and some new trends imaging in if the factories which will review in the course. So, having got this kind of an idea about the overall industrial automation system, you would like to take look at now about some more detailed look at these various levels. Before we do that, we must understand that much of this technology the much of the part the of industrial automation that we are go to concern ourselves with is a is a actual about control, so we should first see what are the elements of control of industrial control.

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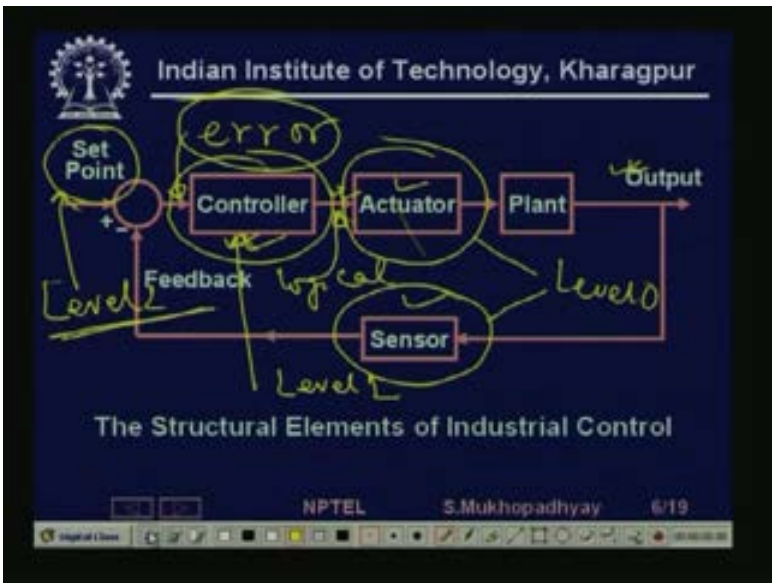

So, these structural elements, so what is basically done in control why do you control we control because we want that the outputs or some process related variable which could be temperature which could be pressure or we want them to behaving certain way we desire. So, we have some desirable behavior will pattern and we want achieve those behavior pattern that we want the we want the temperature to let us say ramp up in a certain over time the we held constant then after some ramp down things like that. So, obviously, we achieve it you how do achieve, you achieve it by comparing the about output with whatever you want and then, so to able to compare we need to feed the outputs, so that is done by the sensor.

I am sorry, this goes back this has to go back, so we do by the sensor then when you compare you get here you get what is known as the error. So, you give the error to the control, then the control know knows that what control input to the gives like that the errors minimize. Now, the controller is actually a basically a computing system, so it is input is a actually logical it is not physical input. So, before giving to the plant in the plant if you want to the change process variable you have the cause steam flow rate change or you have to cause some motion change some valve position change etcetera.

So, some physical change has to occur, so for that you need what is known as a actuator, so the job of the actuator is to produce a physical change which is proportional to the logical change which is commended by the controller. Then, hopefully if that physical changes occur then that plant output will change in such a manner that the error will reduce, so this is the job of controller. So, now let us see we have identified the major elements, so the elements of sensor actuator and controller. Now, this desired value where do we get this desired valued from this we get from the level 2 that is a supervisory controller calculate this desired valued. So, here we have these two we have level 0, here we have level 1 and here we have level 2, so this is the relationship.

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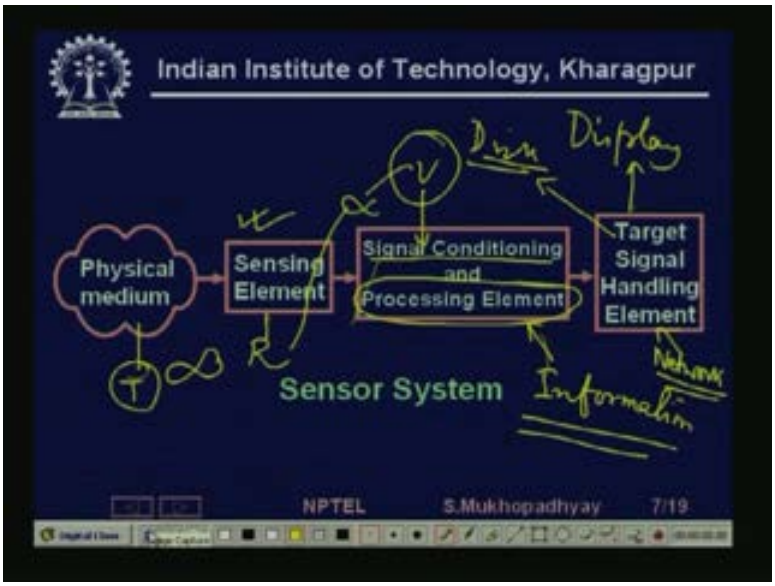

Now, let us see each of these levels, so first let us look at a sensor, so sensor what is the job is the producer information, which accurately represents a physical variable. So, obviously, there is some variable conversion required this information is generally first obtain in electrical form an after that it is convertor in to pure information from using you now digital electrons. So, what is necessary, very simple first of all you need something which will convert the physical medium let us say temperature it will convert in to some other form so that from electrical signal can be generated. So, maybe the sensing element will convert these to a resistance change, now this resistance change is still not an electrical signal, which can manipulate.

So, you needs signal conditioning, so you put this resistance in to some bridge and produce of voltage which is proportional to this stage station. So, all these proportional this is proportional to this and this is proportional to this, so finally the voltage is proportional to the temperature. Now, this voltage may content various know impurities noise etcetera, so you would do further some signal processing on, so you that you get more accurate voltage or you increase it strength or can do something. Then at this point you have got it in the information point form it is no longer a process variable physical neither electrical it becomes information, so this information now has to be used.

So, used in what sense, so you see you can either display it or you can transmit it to a controller or you can store it in some data base, so finally you have to use this. So, here

you may have a display, so by target handling element it could be a display or could be a network card it could be a network interface by which little get transmitted or it could be disk on which little be stored. So, depending on the use of the signal, you have you have you have get to deal with it is.

So, basically this is when an industrial sensor you will obviously is, find a sensing element. You will also find some signal conditioning element nowadays because of ruggedness of electronics this the signal condition is getting transferred into the sensor itself. You can have some signal processing like filtering, and finally it will be used in a display, so this is a sensor.

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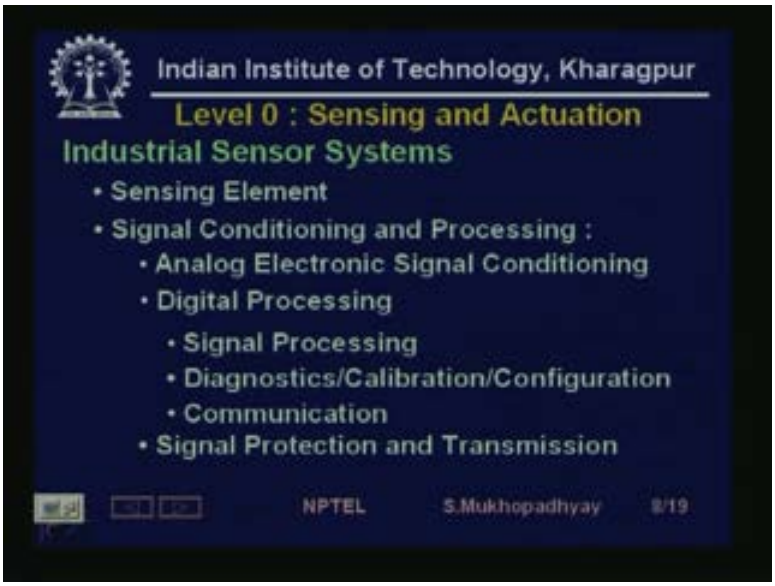

Now, let us take a look at some characteristic, so obviously, you having a sensing element one thing that means, to be mentioned is that industrial sensor apart from the basic sensing element. They also have now other protective elements like if you have a thermocouple, basically a thermocouple is of a as you have seen that they are as we will be seeing they are actually two pieces of wire. Now, here you trying to measure the temperature industrially you do not put those pieces of wire directly into the fire.

So, what you do is you have what is called of thermo well, so you put the thermocouple those two wires in the thermo well and we put the thermo well in as defined so that there is it, it does not get destroyed. So, when I say a sensing element, a sensing element could comes along with it is all this packaging and this packaging can have some effect on the

control performance of the loops because they have their own dynamics. Now, thermo wells have introduced times constant in to the thermocouples as we will see. So, you have sensing element after the sensing element we have signal conditioning and processing.

So, the job of signal conditioning is to transfer to electrical form and then signal processing is to do further processing for some improvement. You are now making linearization suppose some signal is varying according to square we do we want to make it linearly variables. So, we can have square root operation we can have filter to strip out noise, we can correct bias we can add bias whatever we want. So, they in general signal conditioning means that converting to an electrical form generally analog and then signal processing is could be analog it is digital also. So, you have analog electronic signal conditioning followed by digital processing.

Now, digital processing could be a various type digital processing for what, so digital processing could be for signal processing let us say filtering digital processing could be for diagnostic calibration configuration these very modern functionality if you have micro processor you have you have lot computing power at your hand. So, you can do more than just doing filter, so you can you can for example, you can perhaps detect whether the thermocouple wire has broken, so whether is sensor is at all functioning, so that is diagnostics, does it go back, no does not go back.

So, that is diagnostics sometimes you could have you now sensors sensor characteristic some time degrade. For example, suppose a sensor develops a bias you can have algorithms to actually detect the bias and you can do it its own calibration, you can send information that I have. That is a sensor can send information or sensor can be interrogated and you can find information that it has developed a bias. So, readings will be interpreted according for greater accuracy or it can do it is own configuration management you know people send generic devices which are flexibly configurable. So, if it has the filter, what will be the time constant of the filter that depends of what signal it is filtering what is the bandwidth of a signal it is filtering.

So, if it is sensor in if it is filtering a flow sensor it bandwidth it will be larger than filtering temperature signal. So, it may be possible to even automatically set this filters. So, such the things are done by digital processing plus another major function is

communication. Now days, sensors are all going to be in a communication enabled, so they can, they will either connect to network. So, there have to connect some, you now remote terminal unit which will connect two network, so there is some there is digital processing done for this communication function also followed by.

Finally, there is signal protection and transmission that is you after finally, for everything you need to transmission the signal. So, you can have it where you can have network interface or some time you can have voltage to current convertor if you are having 4 to 20 milliamp a transmission, then you can have voltage to current convertor. If you are having RS 422 kind of transmission then they have specified voltage levels, you have to you have voltage conversion of that.

So, a typical what I wanted to show is that if you if you come across a typical industrial sensor system then what will it content and what it will contain what all do they do. So, if you buy, let us say is smart temperature sensor from a company and if you go through it is brochure, then you will typically find these functionality some of these functionality will be supporting. So, having said that let us look at the next element which is actuators.

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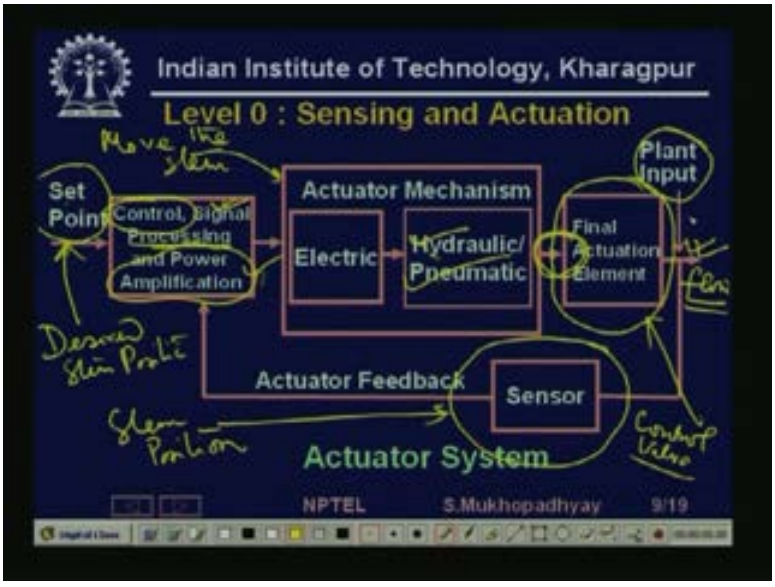

So, what do actuators do, actuator as I said they that they logical input from the controller and then the converted to physical planting, that is what they do. Now; obviously, what is necessity for this there is variable conversion necessary and generally one thing is very much necessary that these logical inputs are just logical they want have

power they have the information. So, you have to do lot of power amplification if you want to increase the temperature in a furnace then just saying that you make giving a signal from off for microprocessor is not going to do it. So, you have to take the signal and then you have to move some big may be fuel injection valve and when you have to change the speed of the fan which is which is putting air into the furnace.

You have to increase combustion rate only then temperature will increase. So, the main two things done, one variable conversion second thing is big amount of power amplification is to be done, so that is what is done by the actuator. Now, actuators we have to remember that here we are having a very powerful thing and not only that we want to have precise control, because our ob always our objective is to have precise one. So, here is a very powerful thing which will have control precise, so for that we always use feedback control.

Therefore, actuator themselves actually are feedback control devices they themselves take feedback for example, if you want to if you want to move a let us say I mean typical example I mean non industrial, but typical example is taken aircraft when it is flying. Then, it has to move it is control surface against huge amount of aerodynamic load and these control sensor motion must be very precise. So, unless you implement this actuator which the control sensor actuator in this case unless this all or let us say the speed of a motor unless you put this in a feedback, you can never achieve that precision.

So, therefore, actuator is a typically they actuator themselves is a controlled do, so they have there are own sensors they also have controllers sometimes they have some analog signal processing. For example, sometime it may happen that you now some the controller may give some control input, but in that control input sudden frequencies must be eliminated because they cause resonance they may lot of vibration etcetera. So, in such a case you can do some signal processing that you that input is given, but frequency filter out may be easy cannot filter. So, such signal processing may be done and obviously, power amplification some amount of electrical power amplification is done.

So, you use what known as servo amplifier is will take weak signals and will accurately exactly proportionally multiply them, but with, but we lot of power amplification. Now, after this you have some actually in a actuator, so much power amplification is necessary that it is always done in stages. So, you have power amplification first one level power

amplification which is in the electrical levels you take one electrical signal and the increase it is electrical power. After that, you have to if you want to increase power further often it happen that you go to different forms of energy.

So, we can have if we have motor driven actuator then some time it is driven directly from the power amplifier or sometimes it may driven from it may be driven using hydraulic or pneumatic devices. Now, there are certain advantages specially hydraulics can a handle lot power in a small volume So, in a small hydraulic motor you can handle lot of power, so when you have large power devices we use hydraulic and pneumatic. So, they are also like a amplifier they are also like power amplifier only they take and electrical signal. So, you have electro hydraulic or you have electro pneumatic typically actuators.

Finally, at this point of time you have got you have generated that necessary process input which you wanted to cause with a lot of power. So, that will cause now even that may go through for example, if you if you have if you have if you have hydraulic element, it will finally produce what it will probably we applied to this stem of a valve. So, the tremendous pressure will be created to the stem of the valve it will, so still you have you have the valve because you want to control flow, so what you want to control here is flow.

Let us see, so for controlling that you need to move a valve this is the final actuator element. So, you have a control valve now you need to open it or close it now how do you open it or close it. So, you need to move it stem, so this hydraulic system will actually move the stem. This sensor will sense stem position and this controller will give input such that here is the desired here is the desired stem position. So, this controller will give input, so this is a total close loop operated valve actuator which will control flow in the plant which in term may control temperature whatever.

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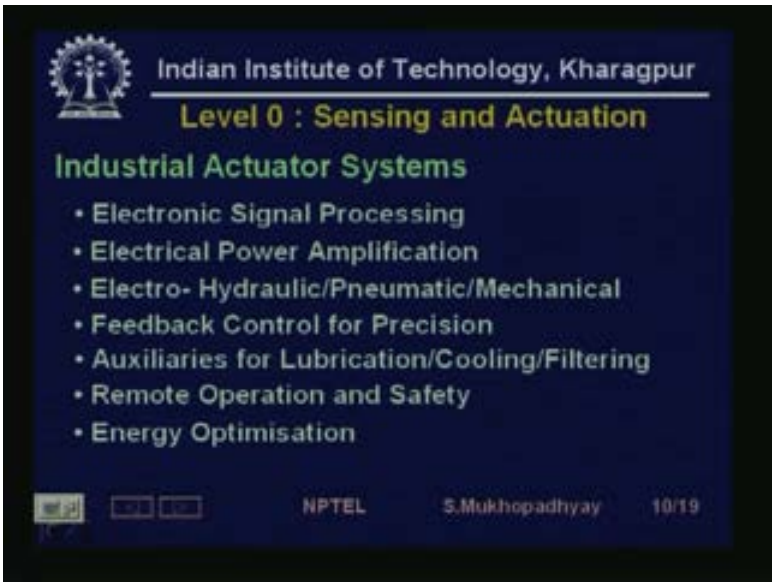

So, have you understood this operation let us now look at the actuator what you find just like we did for industrial sensor did let us see what we are going to do for the actuators. So, the industrial actuator system see will find again you will find electronic signal processing you will find power amplification. As we have said we will find electro hydraulic pneumatic or mechanical elements we will find feedback control for precision exact value will be reached. We will find lots of auxiliaries, because these devices are to operated they are generally power devices. So, they need additional auxiliaries systems for lubrication cooling filtering, etcetera.

You will have you may have subsystem which are used for remote operation these a actuator are need not been operated just from closed they may be operate from a distance. So, regularly done power system when you have when you have in on man substations, so we have some how do you closes switch are open a switch we just from some remote control station. You give a signal and the switch and the circuit breaker opens or closes, so this circuit breaker is actuator. Similarly, for safety you have find lots of you now various kinds of really pressure release valves are, so these are various kinds of interlocks because these are you now powerful devices, so if they malfunction, they may be call accidents.

So, special systems are used similarly, you a since they consumes of amount of energy. You will find special system which will which will try to save energy in the actuator

itself rather than freewheeling or some switching off, I mean unnecessary energy devices you may find technologies for this.

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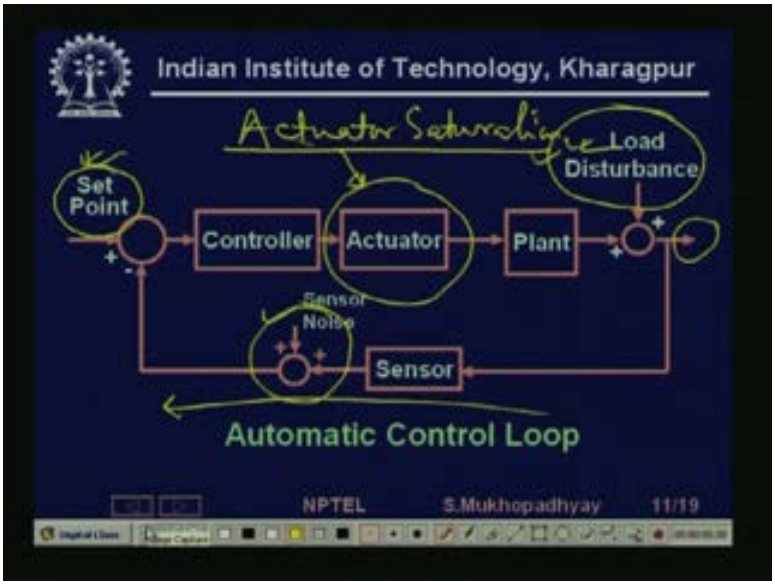

So, typically this is this is what will find in an in an industrial actuator with then in the future classes we look at various kinds of industrial actuator in detail. So, now we have covered sensor then actuators in level 0, now you can to level one which an automatic control loop you have already seen the automatic control loop we at that time you have seen these structural elements of the loop. Now, what are the saying, we will concentrate on what the loop is going to do what is the job of the loop as I said before the job of the loop this has changed let me go back yeah lock this. So, the job of the controller is to maintain the set point that is it job which is given from some the supervisory control.

So, why should the set point change why is it once I set it carefully why should it change it change is because of disturbance. For example, suppose you are cutting metal now the metal is in homogeneous, it is the metal which are cutting that is the piece of that is a steel not homogeneous. You have set of particular cutting speed depth of cut feed you have you have set on and the machine is rotating, now suppose the there is some parts come where the material densities is different, then the speed will fall speed may fall.

So, if speed falls in metal cutting the quality of cutting suffers and you have no control over what kind of material qualities you will supplied to you in the in the raw material. So, for example, supposing you have rolling mill, so in a rolling mill the load on the

shaft is depends on the depends on the depends a two things depends on the material that is you rolling and depends on its samples. In facts I mean in we are talking about hot roll it. So, as you are vary the temperature, various the loads on the motor will vary enormously and therefore, the speed will vary; now you do not want to allow that. So, what I am trying to say is that because of these load disturbances if you set particular speed that may not be obtain to ensure that you have you have feedback control.

There may be sensor noise also there is feedback may be erroneous, so it is basically because of these two that the control problem because of nontrivial plus many other things may happen. For example, one of the things that are very regularly happens since that the actuator saturation this is the very regular thing in actuator saturation, that is the actuator cannot really drive enough input in to the plant as the controller wants. Actually, the controller makes unreasonable demands on the actuator the actuator cannot give it is because of these things that the control problem is not elementary and you have you have various kinds of difficulties. So, we will look at the having said this let us look at the various kinds of things that you find in an industrial control, sorry.

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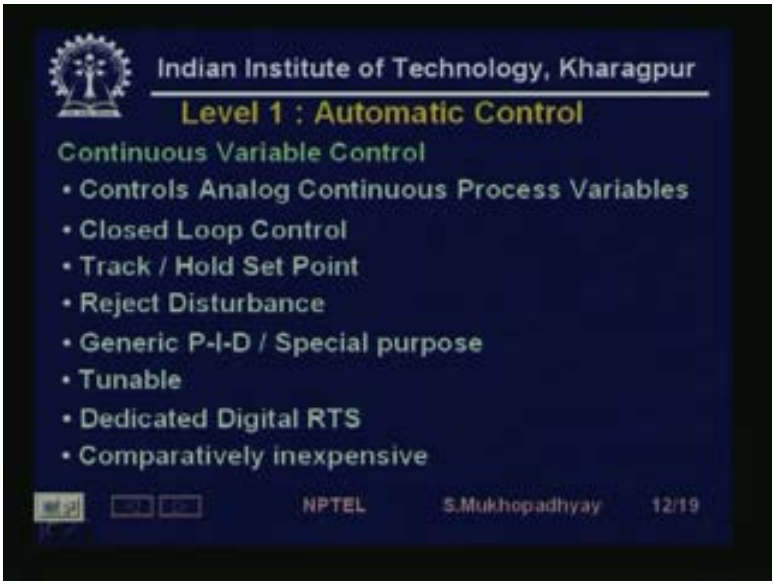

So, let us look at automatic control automatic control again I must mention these have not mention can you have two types the first type is what I called continuous variable control. That is what we have are familiar with we have already most of have a taken a course in that called automatic control system or control system or controlling

engineering. There, we study mainly continuous variable control, where we are interested in controlling the value of a variable of a let that temperature be 200 degree centigrade. That kind of control where the where the temperature is a continuous variable, in the sense that it can continuously vary overtime, take any value.

So, this control will control analog continuous process variables that are fine and typically we apply what is what we understand by close loop control which we have seen. So, the main objective is to track or hold set point that is the output should follow the set. Some special purposes controllers now because they are generic they have to tuned for a specific plant. So, we have set controller gains for that specific plants and that is called tuning, so these controller that tunable and they require tuning from time to time.

They are implemented typically on digital real time system like basically a processor system with an interface with these sensors and we an interface to the actuators. So, it is it is it is kind of microprocessor base system and they are these are generally even an expensive typically a control system is less than five percent cost of plan it controls. So, the controller is actually very cheap although it does have a very critical job. So, this is what you find in automatic control, now let us automatic continuous variable control.

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Similarly, you have sequence or discrete event control now it discrete event control, what you what you have is that you have control of discrete valued process variables that is

variable which cannot take continuous values. Either there are the take discrete values like you now on and off or low medium high, so you have to control. So, now if you values are all constant values, so there is not much point in trying to control the values. So, what you control, so you try to control these sequence, so what happens after what or you control timing there is a when exactly will these valve closed that is five minutes after the valve opens you should switch on the pump.

Similarly, 2 minutes after the pump is switched off you should switch of the valve, so such if things such control is called discrete event control. So, obviously, they use sensors which are also discrete there is the if of like you now limit switches just sense without something is in is in this position or that position pressures. It is sensor whether the pressure is high or low photo switch sensor whether a part is a placed on the conveyor belt or not, so you use this kind of sensors.

You have lot of interlock or alarms, so you do interlock and alarms processing in this typical hardware. This is used for the discrete event controls are program will logic control some time industrial PCs and some time could be very special purpose dedicated processors.

So, they obviously, do not need tuning and they are, so you have status sequence in timing control. So, one good thing about them is that unless the control logic changes there are need tune. So, this is the story of automatic control, now will one last thing that will consider here is supervisory control. We will stop here today, because production control and enterprise control or functions, which you are not going to cover in great detail in this course. So, we will introduce them later if you have when you have one to introductory courses introductory lectures lessons in this course.

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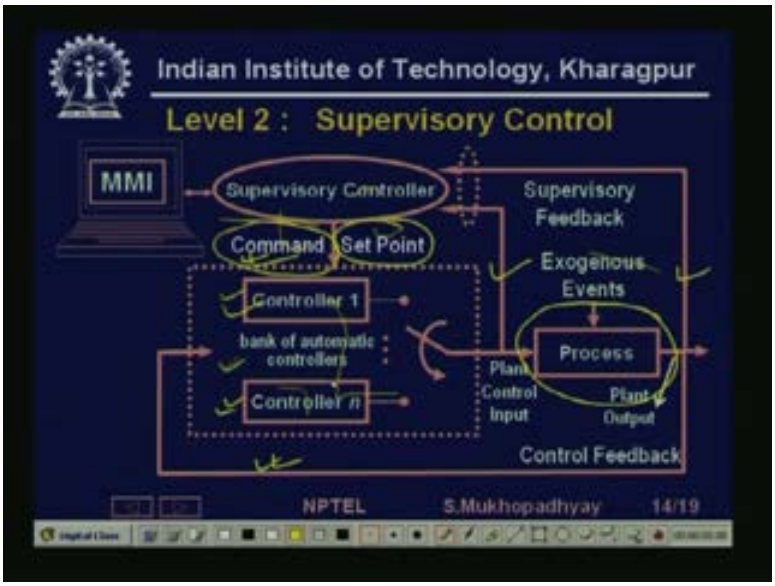

So, let us look at these pictures, this picture explains what a supervisory controller does. So, previously we had seen one control loop now I am fine this is the process that we want to control. So, this is the process this is the feedback of the control loop, but we are having a number of controller here. So, suppose one controller is a working, so said that what the supervisory control does it gives command it gives set point that is the automatic controller just maintains are temperature it does not known what temperature to maintain.

If it is told that you maintain 200 degree centigrade, it will do it is best to maintain 200 degree, but whether to maintain 200 degree or to maintain 150 degree that the automatic control a does not know, that information must come from the supervisory control. So, it is give set point, but it does another very important thing that is it is not always that you are going to use the same controller.

For example, the controller that you may be using during the time that if that a plant is started up from let us a cold condition or when a plant is shut down they are actually totally different controller. So, you may have more than one controller. So, if you are doing start up you use this controller. If you are doing shut down you use another controller when you are doing normal operation, you do you use another controller. So, you must give commands as to which controller to use when that commands comes from the supervisory controller, so it gives various kinds of commands.

For example, suppose there is there is some accident or there is some the some malfunction in the equipment immediately you have to do emergency shutdown. So, the supervisory controller must understand that there is a malfunction, how does it understand because it also gets the process inputs and outputs. So, based on this process inputs and outputs it does lot of calculation to always check whether system is working nicely, if find some problem immediately will give various commands to ensure which controller to use where. So, supervisory controller actually manages a number of automatic controllers, so having said that let us see it is basic I see, so what are the future of supervisory control, I am sorry what is this happening here.

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So, first point is set point computation, one very important thing is that set point computation is very important in manufacturing from the point of view of energy quality and production volume. Unless you give proper set points, you will not get product of certain quality you may be wasting lot of energy in producing it and the amount of production will also fall. So, that is why supervisory control is, so critical and it is sometime and it is a often done by very experience operator is manually, so it is very critical for manufacturing. So, it does start up shut down and various kinds of emergency operations it does control reconfiguration and tuning. You may have to change the controller from time to time it does performance monitoring is the loop properly tune is there a sensor malfunction it continuously checks.

It provides an operator interface; it provides with nice graft to the operator whose also sees they are generally based on. Obviously, all this can be done base specific to equipment it cannot be otherwise. So, the work as I said in hard soft hard and soft real time scenario, so having said that, we will them also very expensive, because there are specific to a process.

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We will skip this slide all together because we do not want to, so we are just looking at various elements in these things. The product process scheduling material handling maintenance management inventory management quality management and resource optimization technology they are as I have mentioned they may be online, but the non real time some of the may be online.

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So, finally, we have a lesson review, so what you have done in this lecture we have looked at the hierarchical structure of industrial automation. We have looked at level 0 these sensor actuators what do and what technology is found in them you have looked at level one automatic control. We have also looked at continuous variable and discrete event control and distinguish them we have looked at supervisory control and we have understood how the different from automatic control. Finally, we just to get cursory look cursory look at production control enterprise control we are not going to even the have a look at not going to have a cursory look, because this is essentially a business management operation.

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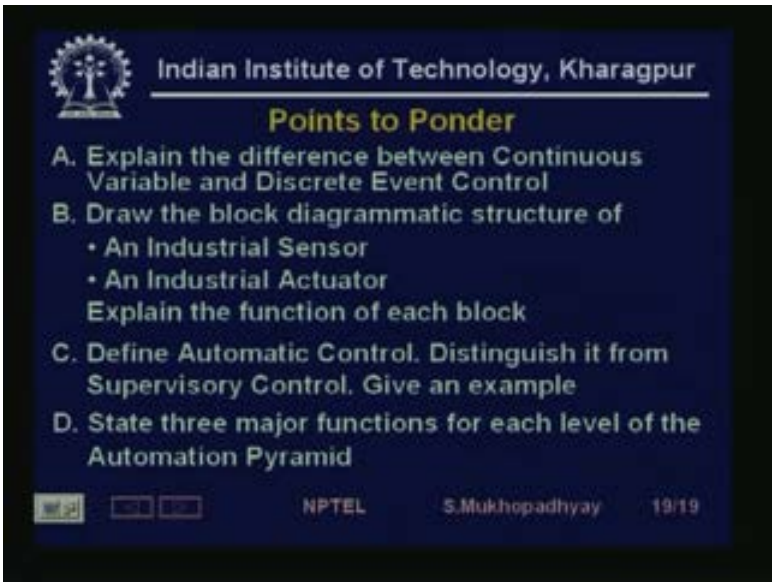

So, here we have some problems points to ponder for example, can you explain the differences between continuous variable and discrete event control can you site two or three differences can you draw the block diagrammatic structure of an industrial sensor. Given example, let us say you look at it some industrial sensor and then try to identify that what of various block diagrams and what are the various sub subsystems in it. What are their functions, can you define automatic control and distinguish it from supervisory control with an example. Finally, we can state three major functions for each level of the automation pyramid, so these are problems for you to pond around.

Thank you very much.