INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

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Topic Lecture – 03
Architecture of Industrial Automation Systems

Welcome to the course on industrial automation and control.

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Today we are going to have lecture lesson 2 which is on.

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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 controller sensors operator displays various cabinets containing hardware so all these together make a factory work like an orchestra so today we are going to since it is a since it is a complex operation with various kinds of equipment which harmonized themselves with one another before we take, take a detail 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 so having said that.

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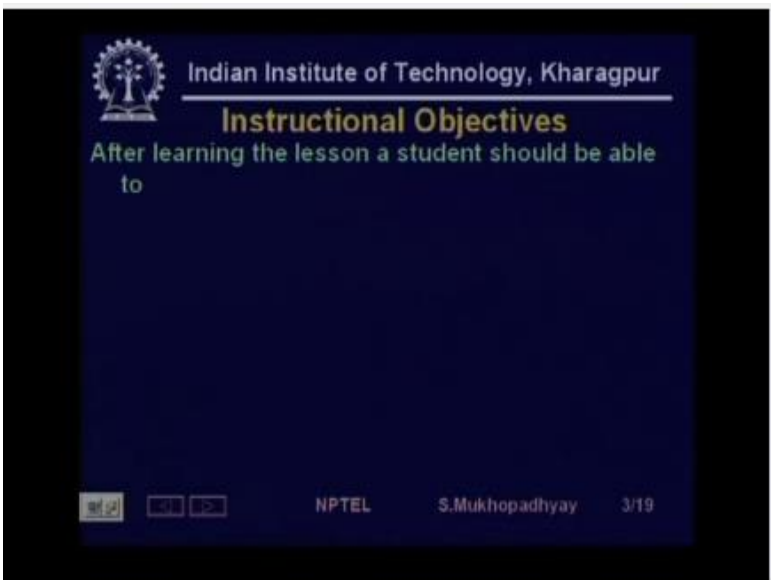

Let us look at the specific instruction objectives of this course so since the industrial automation system being a complex system is definitely organized hierarchically in various level so the first specific instructional objective is naturally to name to be aware.

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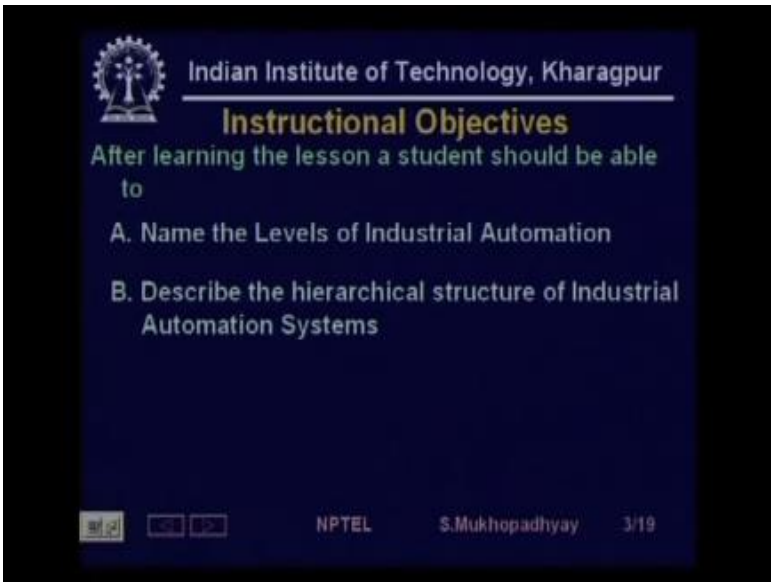

Of the various levels of industrial automation the second objective is to relate to describe the hierarchical structure of industrial automation systems by which I mean that to know what these levels do too just to be able to understand how in one interacts with another what one what information one accepts on from one 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 and specifically speaking.

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Since industrial automation is in a sense a lot of industrial automation actually is concerned 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 the distinction between the two so the last instructional objective is to understand the how automatic control is distinguished from supervisory control.

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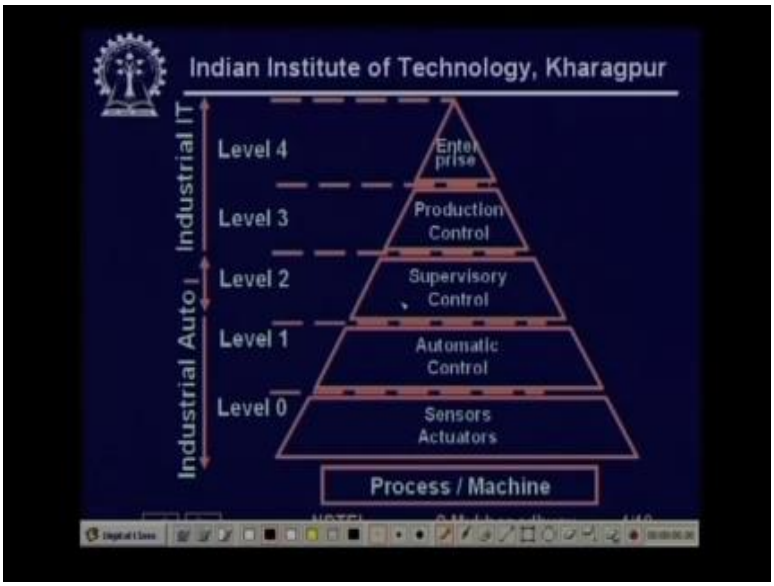

So now let us look at the industrial automation pyramid as a whole why is it a pyramid it is a pyramid because there are several levels so it has a vertical dimension so we have the lowest levels of sensors and actuators which interact with the which directly interact with the process or or the machine so they actually get the signals from the process of the machine now these sensors and actuators are actually act as the eyes and the arms of the controllers so on top of these we have the automatic control layer which is called level 1.

Now a number of automatic controls are again managed at the Supervisory control layer which we call level 2 finally the operation of a particular shop floor as a whole is controlled and the whole overall manufacturing operation including maintenance production quality assurance inventory everything is managed at another level which is called production control and finally right at the top we have enterprise control which is which is more like I mean basically consists of management functions.

Where not only the production related operations are considered but even other operations like sales, sales marketing new product development everything is considered and production is considered just as a part of it that is level 4 now at this point we should I should mention that

while these functionalities are necessary for the overall control of a factory but it often turns out that that, that no necessarily all these layers are perfectly automated what I mean to say is that generally sensors.

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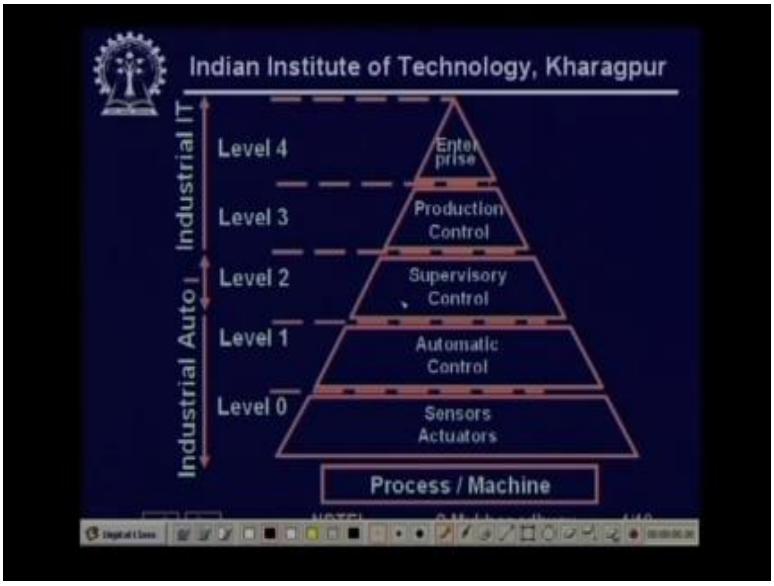

And actuators must be automated there is there are their equipment for it automatic control layers are also automated there is there are most operations are not manually controlled but from the Supervisory control layer upward it is not always true that you have in a computer-based automation for functioning the, the for performing the, 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 a power plant or if you go to a big refinery you will find that in invariably on the on the shop floor you will have you will have a you will have a control room if you enter the control room it is usually a very large room where in the when in the center of it you will you are you are very likely to find that there are a number of large computer monitors and there are a group of people who are actually sitting around these monitors and constantly looking at these so they are generally the process supervisors or the 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 performed 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 a production manager or saying say in a power station we have a shift charge engineer who is who is who is in charge of running the overall part system overall power plant for a for a certain duration of time so this production control functions are.

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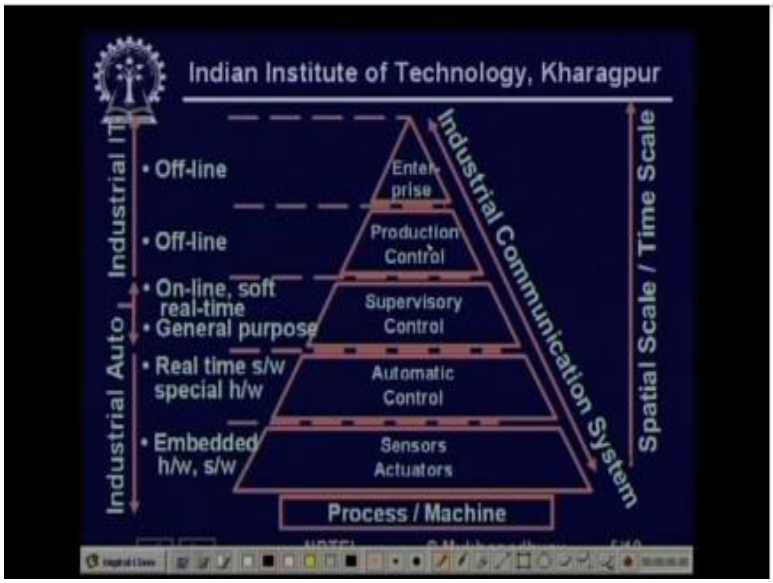

Invariably a mix of manual as well as automated tools similarly enterprise management functions are also like that you have you have managers who use tools for performing their functions so we have level 0 level 1 level 2 level 3 and level 4 now having said that let us look at the these levels and their natures with a certain some more detail so first of all we would like to point out and this is why this system is called a pyramid is because that as you go up, 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 a in the in the whole shop floor there are there are several machines in each machine there are several process variables and the sensor which is at level 0 only looks a tone of them so in that sense it is specially its scope is very limited.

Similar but its interaction is over a very small time scale that is it gives over sampling times it gives values to the controller so each value 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 time scale now as you go up for example if you go to automatic control.

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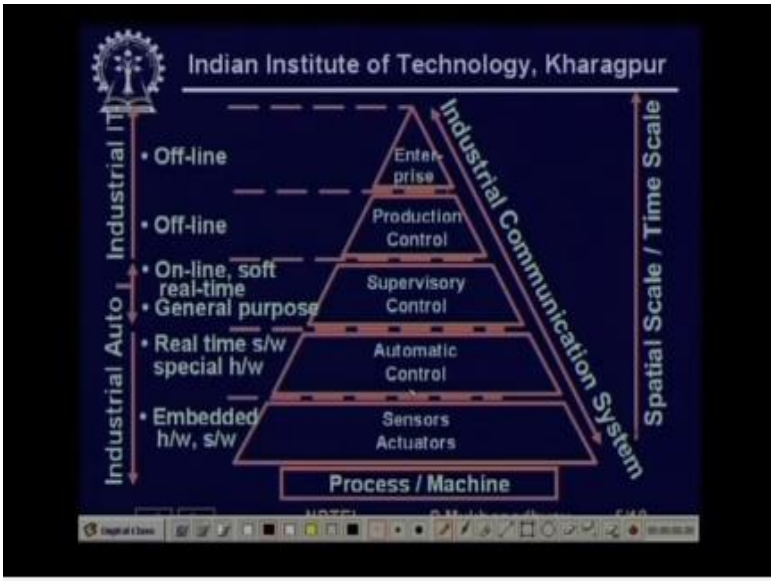

Automatic control also works at the sampling level in the sense that it computes control in control input for the plant at each sampling point but why it is designed sometimes considerations are made of larger duration for example when you say that the settling time should be low now when you are considering settling time you are actually 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, so typically you are concerned about a duration of time which spans over several sampling times right so if you go to supervisory control level supervisory control level one of the one of the major functions is to is to change the set and set point changes are not made every, every moment control input changes are fed to the plant every sampling time but set point changes are not made every sampling time definitely they are made over let us say typically some hours if you take a power system boiler so at it will be say at say at 3 o'clock in the night it may be operating a ten percent load.

At 7 o'clock in the morning it may be operated at twenty-five percent load at around 9-930there is huge amount of load comes in the power system because all the offices open up and things like that so between 9.30 and 11 o'clock it it will it will ramp up significantly from let us say thirty percent load to nearly ninety percent load perhaps then that ninety percent load it will maintain till again say let us say 5 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 the evening peak load so when only when the load will significantly increase will the boiler operating point be changed right, so the operating point of a boiler typically gets changed let us say seven eight ten times over a day and it is change is also based on the I mean the decisions for change are taken based on periods of hours right so in that sense it is it is on a larger temporal scale it is also on a on a on a much larger spatial scale because.

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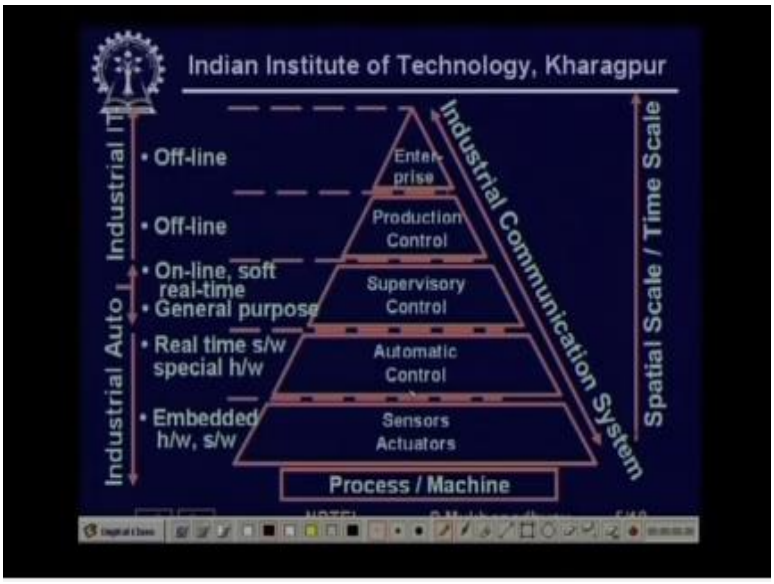

Every cent one sensor looks at one signal one automatic controller may be taking control action taking several sensors into account so in that sense it its spatial scale is now increased now one supervisory controller will typically look after a number of automatic control loops and it typically looks after one piece of equipment like a like a like a boiler or out or a 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 sharp 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 and the spatial scale is also increasing that is why it is a pyramid and not a cylinder.

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If you look at so having clarified that let us look at the nature of technology which is used for automation at these various levels so at the at the lowest level when you have when you have sensors and when you have sensors and actuators so here you have mostly you have hardware things are you know either they are actual sensing elements or their packaging elements or electronic circuits or micro processors there they are generally very hardware oriented nowadays we are also having software along with that but software is also very close.

To the hardware in the sense that they actually interact very close to the hardware they written specifically for that hardware so in that sense we have a lot of you know what is known as.

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Embedded technology at this level so this is this what embedded is because it is the kinds of actually the sensor is supposed to be embedded in the machine so you know all the this technology is 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 offer it runs on special purpose hardware like you know like PLC is industrial pcs or some DSP processors so but the algorithms are generally generate like a PID control peering under is a very generic the control algorithm which is used for a number of process control applications but this often is real time in the sense that outputs must be generated within a given amount of time because every sampling time you have to generate the control inputs to the plant so you have real-time software.

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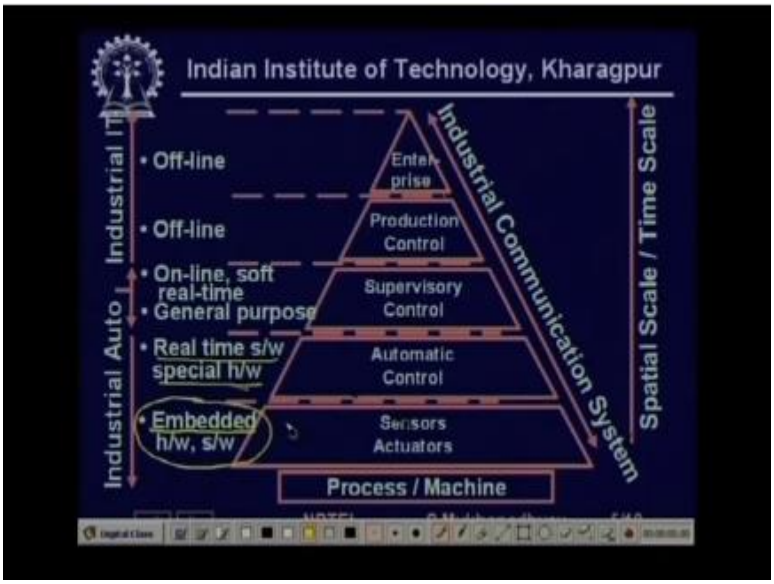

Hardware is special purpose or general purpose both are possible if you go to supervisory control you will find that hardware is mostly general-purpose it is general-purpose computers of course with a with a strong data interface because lots and lots of channels of data from the whole process come to this the software is still online because it the difference between what is I mean some a piece of software is called online if it acquires if it interacts with the external world so it acquires so it works on the data which is continuously streaming in from the process using sensors.

And various communication channels but it is not very hard real-time by hard real-time I am i mean the application I am the software application is called hardware real time when the execution must be must be finished within a time deadline if it does not finish then serious consequences may occur and the system may fail but these generally work this could are generally a mix of mostly soft real-time in the sense that well things must be done in time but even if but they are not so hard that is if you one does not one particular piece of computation.

Cannot be finished in time then some performance degradation may result but in general the system as such will not fail for example one of the main purposes of this supervisory control.

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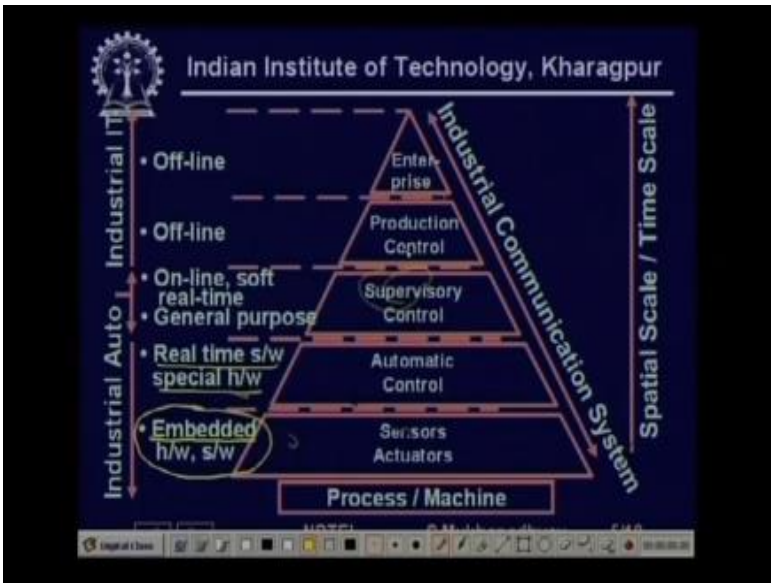

Layer is to update the man-machine interface that is whoever is the operator he has to be shown how the process is performing plot the graphs plot various statistics etc. So these are typically soft real time operations in the sense that obviously you cannot display a very 30 minutes after you have got it right but as long as you display it in time whether you are displaying it within two seconds or whether within 10 seconds is not of much consequence so to that extent it is called soft real-time software is I mean the hardware is.

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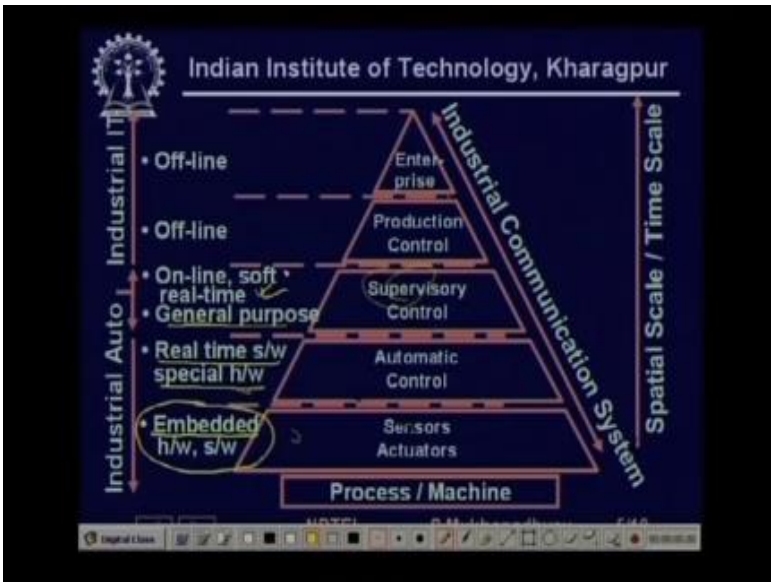

General purpose but the software is very special purpose that is supervisory control software for and for a refinery will be completely different from that of a power plant which will be completely different from that of a let us say a manufacturing plant so they are very specific to the machines the software for the hardware is general purpose production control does not bother about machines as such.

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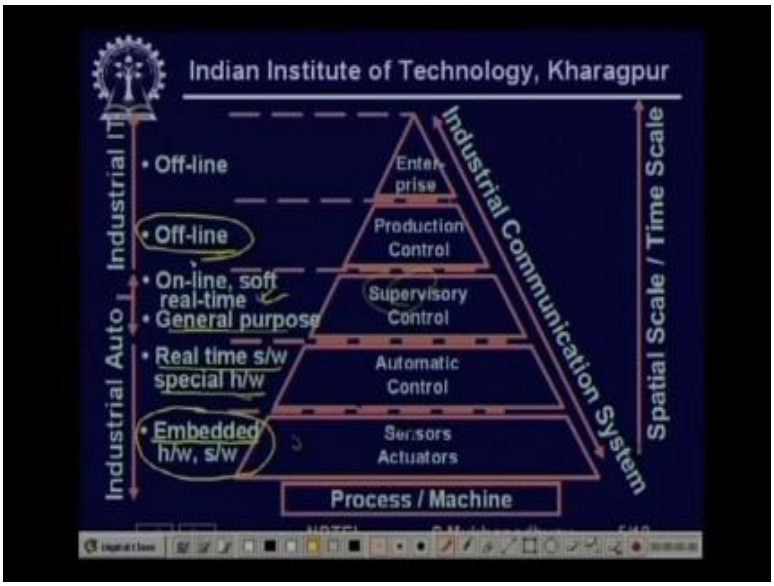

They do not they are not really concerned about their they take an abstract view of the factory how many pieces of equipment are being produced per hour whether that piece of equipment is actually whether it is a gear or whether it is an engine a box or whether it is nuts-and-bolts it does not matter so machines are looked at as general purpose are I mean service providers or material transformers so you give it a you give a milling machine a blank it will produce a gear.

So what is the exact technology of the milling machine it is not of interest at this offline level what is of interest is how many pieces of parts it can produce whether it is functional or whether it is non-functional such things right so the software is generally offline and it uses it does use various kinds of algorithms but they are offered totally different nature and they do not generally they do not cause they are not concerned as such with the machines themselves but take an abstract view of production similarly for similarly for enterprise level so at these two.

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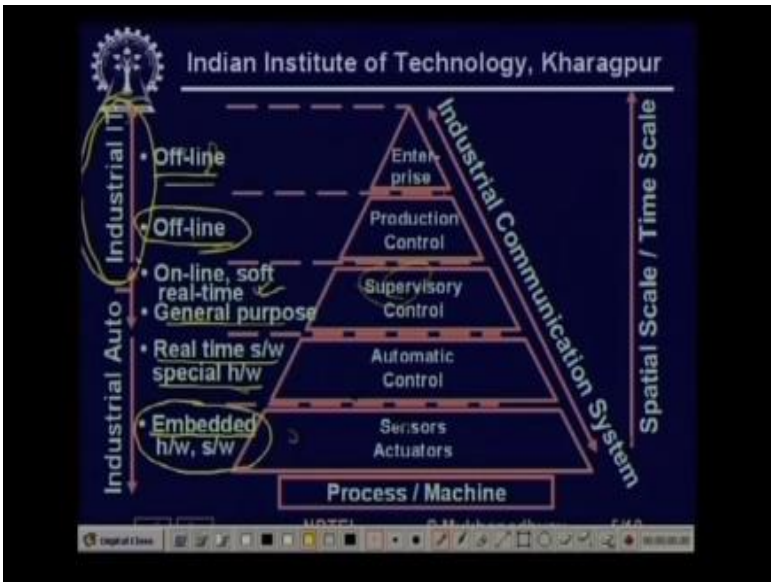

Levels and to some extent that the supervisory level we are not so much close to hardware that is we look at the process as an as an abstract entity and we take decisions about them and we analyze the performance we also monitor them so in that sense the layers up to from some parts of some parts of supervisory control as well as production control and enterprise control I would like to turn them as industrial information technology the other than industrial automation technology you know automation has a kind of hardware flavor it is a kind of hardware real-time software kind of flavor.

So while industrial information technology also contains lot of technology resource optimization technology she do linked technology etc. But they are not concerned so much about hardware they are generally technologies and they are non real-time 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.

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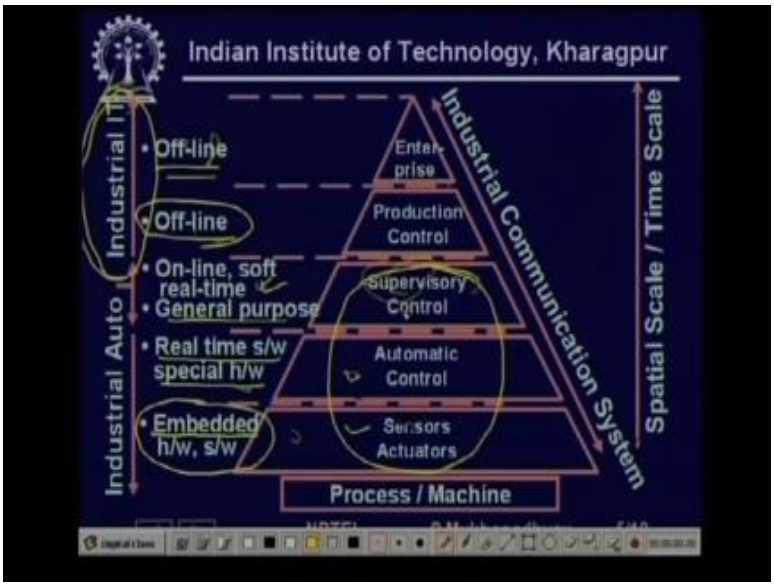

Focus is on this on the first three layers we will see layer1 and layer 0 very in some depth we will also look at some automation technologies which are now being deployed for supervisory control so that now another thing that needs to be said is that these layers actually exchanged information so sensors collect count 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.

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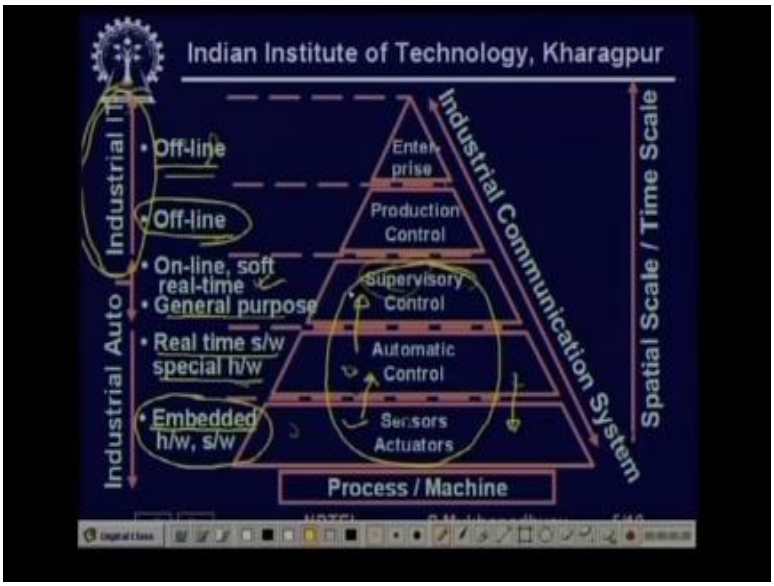

Actuator now similarly the information that the sensors and actuators are that the automatic controllers are receiving from the sensors part of it they are actually passing to the supervisory control layer to see whether the control loop is working satisfactorily or whether some set point change is needed so or whether there is some malfunction some sensor has failed and the process output is going out in which case the Supervisory controller must take some action.

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So it can either change the set point or If there are two sensors it can it can switch from one sensor to the other so it gives command 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 and as information goes up because of the special and timescale information continuously gets aggregated up so you as you go higher and higher you get more and more time averaged information over a part of the fact as you come lower and lower.

You get more and more detailed information about a smaller and smaller part of the machine so as you go up information gets aggregated as you come down information gets resolved so this resolution or refinement occurring okay now how do all this information flow up and down physically how do they transmit so nowadays I mean lot of stress is being put on so there is usually a.

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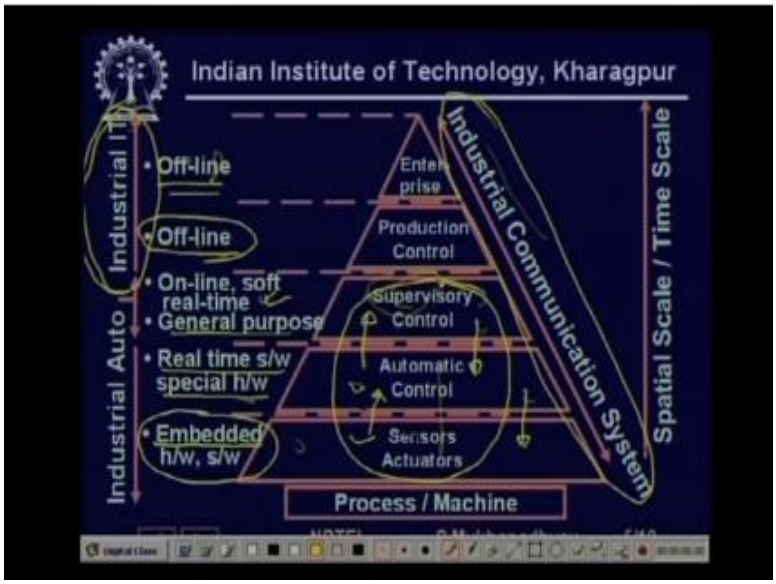

Communication system which actually connects all these devices so that they can seamlessly exchange information send results in fact do lot of configuration management various kinds of things so there is a if you see the industrial automation market you will find lot of activity here and some new trends emerging in the factories which will review in the course so having got this kind of an idea about the overall industrial automation system we would like to take a look at now we will try to take some look about some more detail look at these various levels and.

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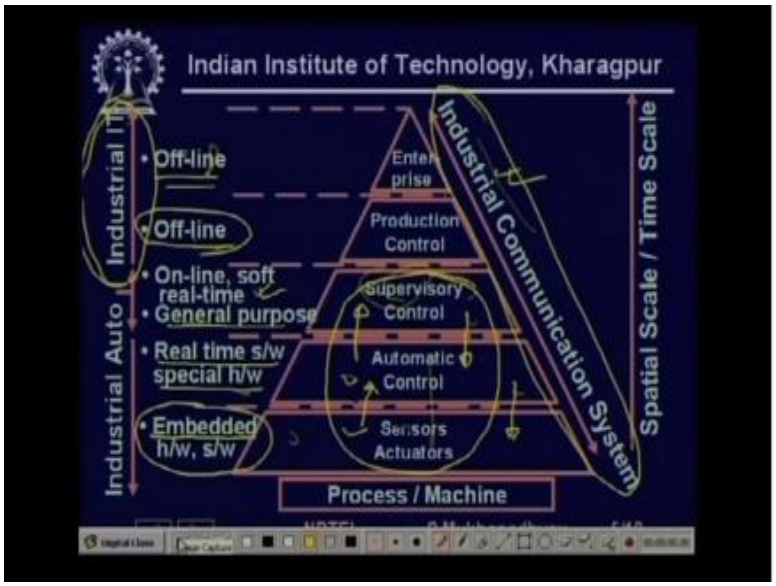

One before we do that.

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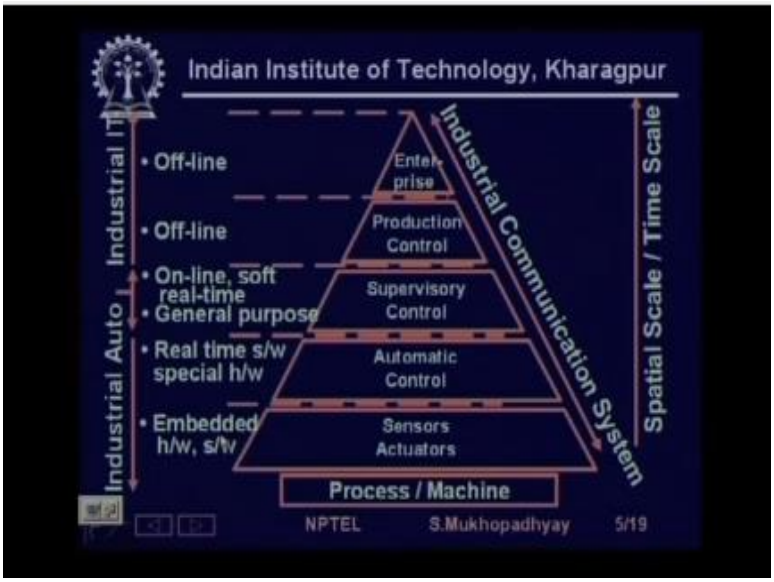

We must understand that much of this technology the much of the part of industrial automation that we are going to concern ourselves with is a is actually about control so we should first see what are the elements of counter of industrial control.

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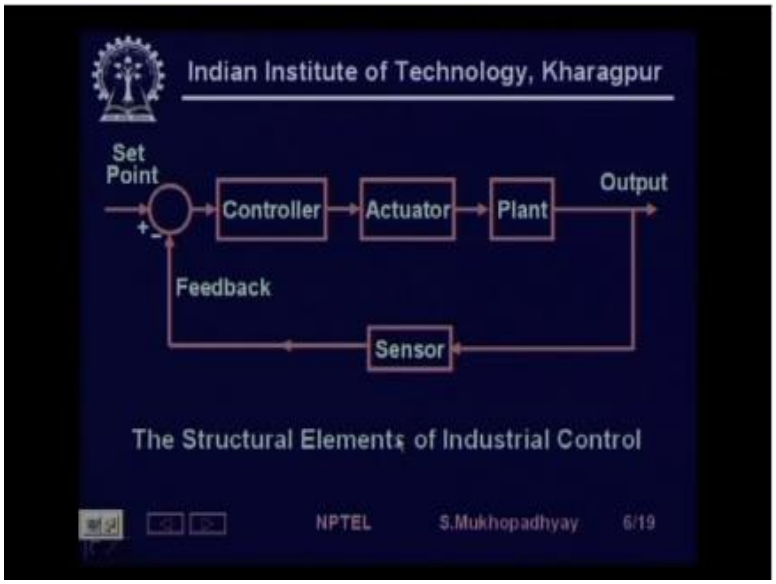

So the structural element so what is basically done in control why do we control we control because we want that the outputs or some process related variables which could be temperature which could be pressure or we want them to behave in certain ways that we desire.