INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

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Topic Lecture – 50
Higher Level
Automation Systems

Welcome to lesson number 39 of the course on industrial automation and control, this is the penultimate lesson and therefore while we are ending the course we need to be aware of at least some of the other some of the things that we have not done in detail, in this course we have mainly talked about the lower levels of automation namely level 0 where we have talked about sensors and actuators. In some detail and level one which is automatic control and sequence control.

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But as we have discussed there are higher levels of automation systems there is level 2, level 3 and conceivably level 4. So in today's lesson we will try to take at take a look at it is going to be a brief look but take it nevertheless take a look at what makes level two, three and four so that we have some idea about them and get a more complete picture this is this is about industrial automation not so much about it turns out that the higher levels are more concerned with in information technology and software rather than you know automation technology and hardware. So therefore they have not been treated in detail in this course so here we go.

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So as usual instructional objectives and name the higher layers so either the student should be able to name the higher layers and name the major functions of each of the higher layers level 2 3 and 4 automation.

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And describe the many of them you know there are basic technologies which are involved in this are monitoring technologies, optimization technologies part of it gets manifested in planning and scheduling so students should be able to talk about what is process monitoring.

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How it is done, why it is important then planning and scheduling what is planning and scheduling and how you know how in the overall automated factory industrial information technology plays a role in you know coordinating integrating these complex operations for achieving for squeezing out performance getting productivity, efficiency to gain an edge of competitiveness in the market, okay.

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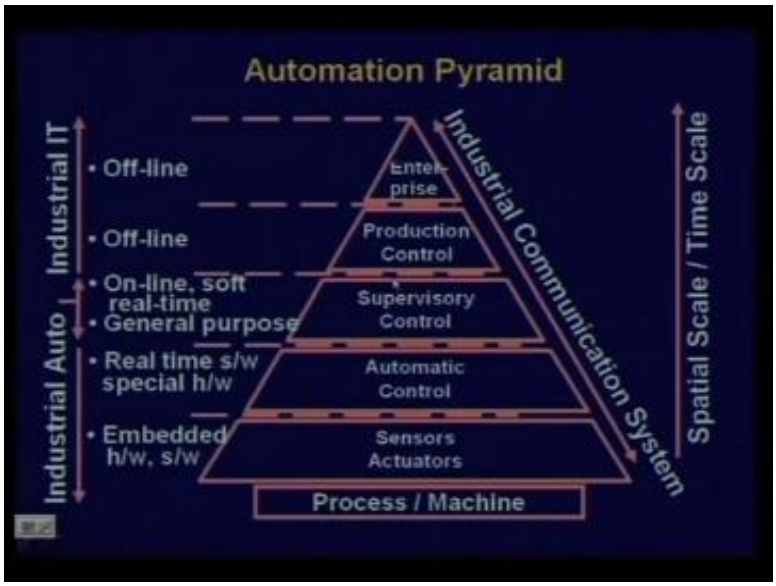

So we first take a look at the automation pyramid remember we had taken a look at this automation pyramid in the very early parts of the course, so here as we said that this is the automation is organic it can be viewed as a pyramid with the process machine with basic equipment the which is the ground and then you have the sensors and actuators which take information and provide control inputs. Then you have the first layer of controls automatic controls and in this course.

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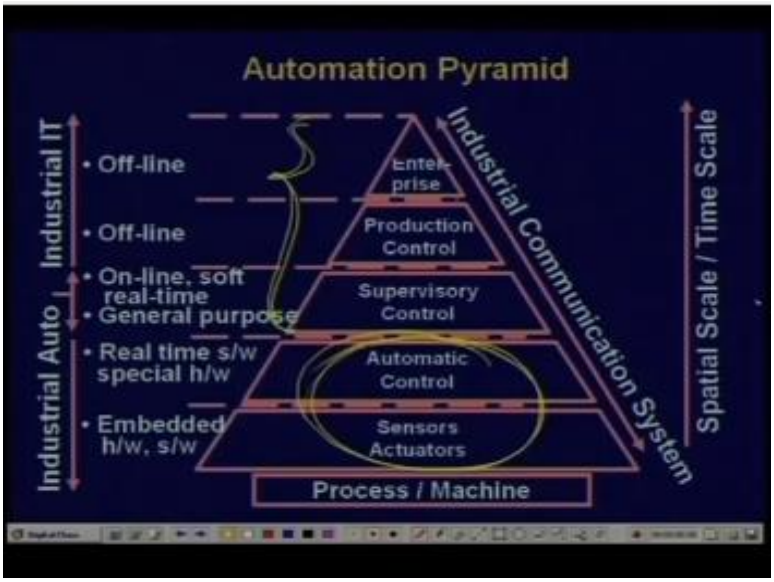

We have mostly been concerned about these two layers we will select three curve line so we have mostly been concerned about these two layers and in this lesson we will take at a look at the higher three layers. So all these layers are basically have different functionality and obviously the higher layers take feedback from the lower layers.

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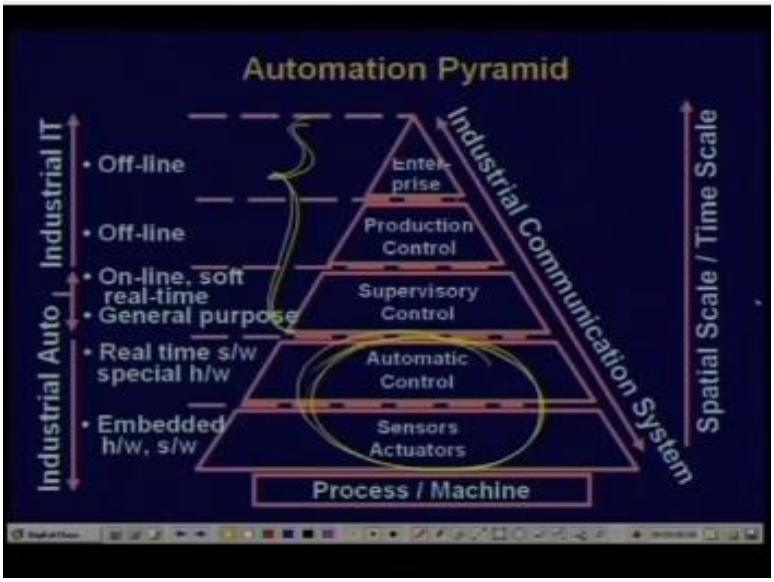

And they give reference commands or set points or to the lower layers as to what is to be achieved they set the targets for the lower layers.

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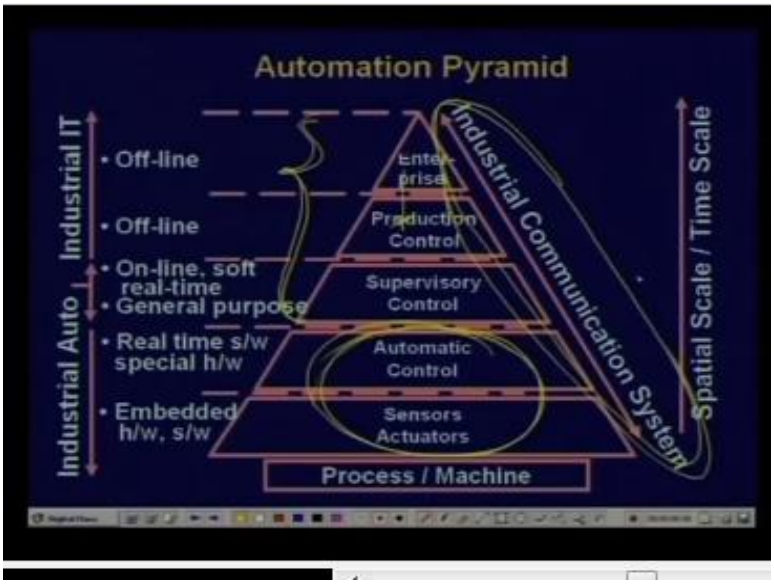

And therefore all these informations there is information passing back and forth so there is a communication system and we have already learnt about such a industrial communication system then there is a special time.

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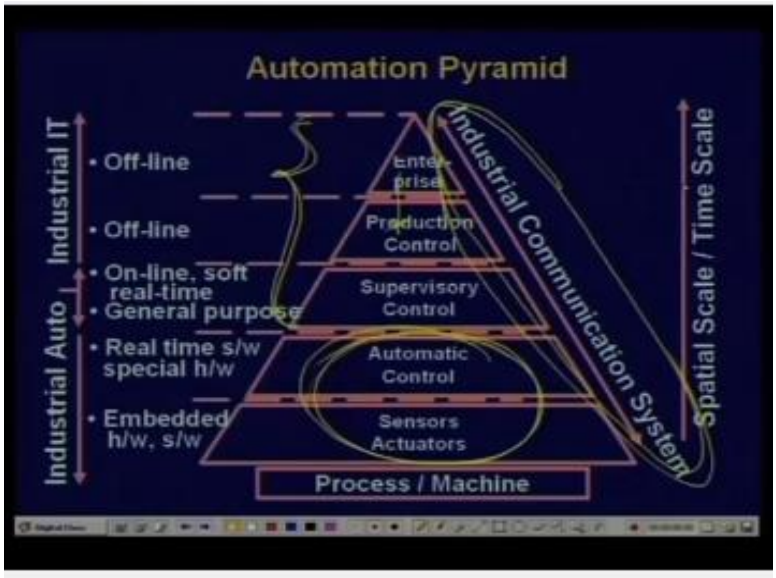

Scale time scale difference among the layers when the sensors and actuators look only at a part of the machine but look at it in great time resolution as you go up we the layer the layers of automation at those levels to look at much a bigger geographical areas first it talks about you know unit control where one piece of equipment is looked at then you talk about group level control where groups of equipment I looked at then you can talk about sharp level control.

You can talk about factory level control and so on and finally you can talk about enterprise level control, so as you go up your geographical extent goes up and your time resolution or your time scale also goes up which means that you do not look at things in on minute timescale but start looking at things interms of hours to days, days to weeks sometimes months, so when you are doing enterprise level planning and optimization.

You typically look at you know months of operation while if you are looking at automatic control level then you are typically looking at minutes level or signals at levels of second two minutes, right.

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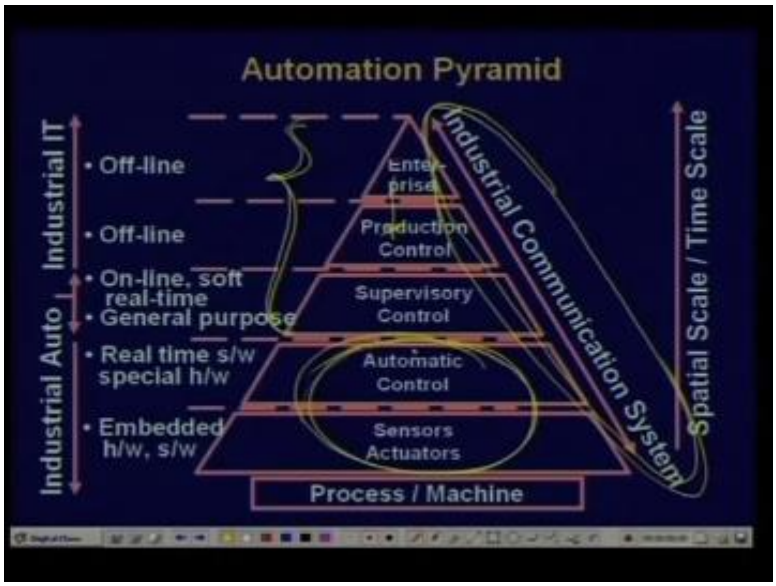

So we see that this is this is the way complex automation systems are organized and.

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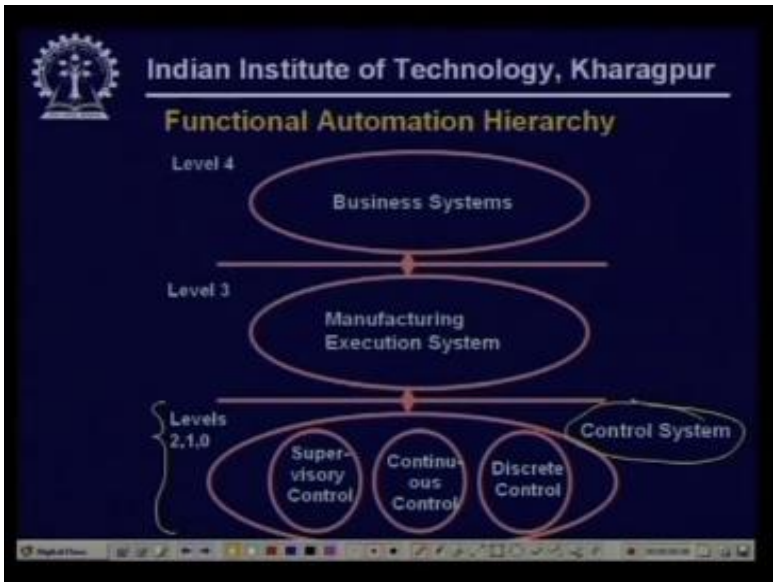

Functionally typically you will find that level 1 and 0 we have seen their levels 2, 1 and 0 actually basically constitute of control systems so they are they talk about they talk about physical dynamics they talk about the physics of the process heat transfer, mass transfer, signal value so they are you know kind of one kind of technologies so they have been clubbed level 2 10 they are all control technologies.

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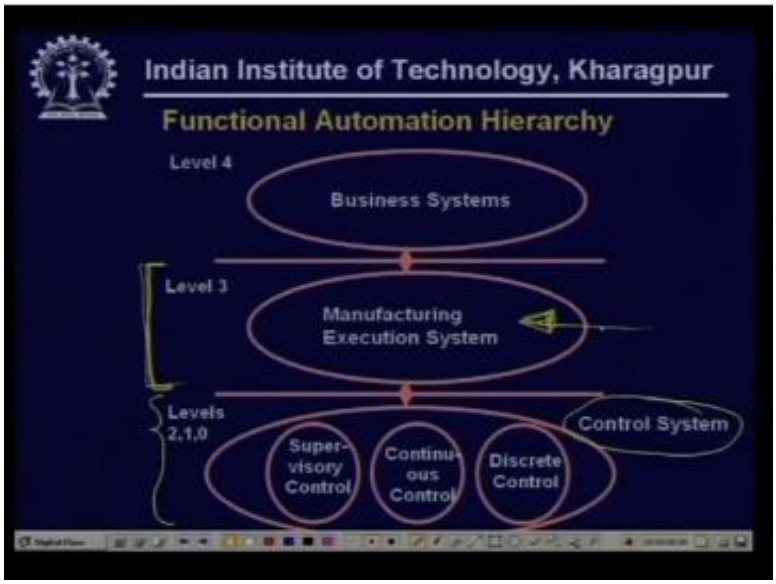

Beyond that you have level 3 or the sometimes the systems which are called the computing systems which support these the performance here and do the kind of computation that are required are called manufacturing execution systems, systems which actually planned production to take a check at resources track how particular how I mean how a particular order is being produce. Technical of quality, etc. So such systems are the manufacturing execution system.

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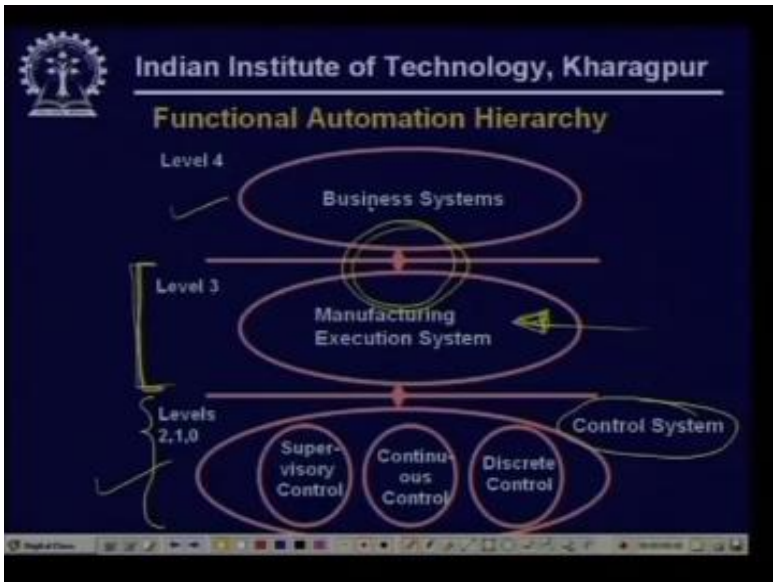

So they actually basically they are interfaces between the business and the engineering systems so they take on one side the interface with the business systems and take orders I mean production deadlines, etc.

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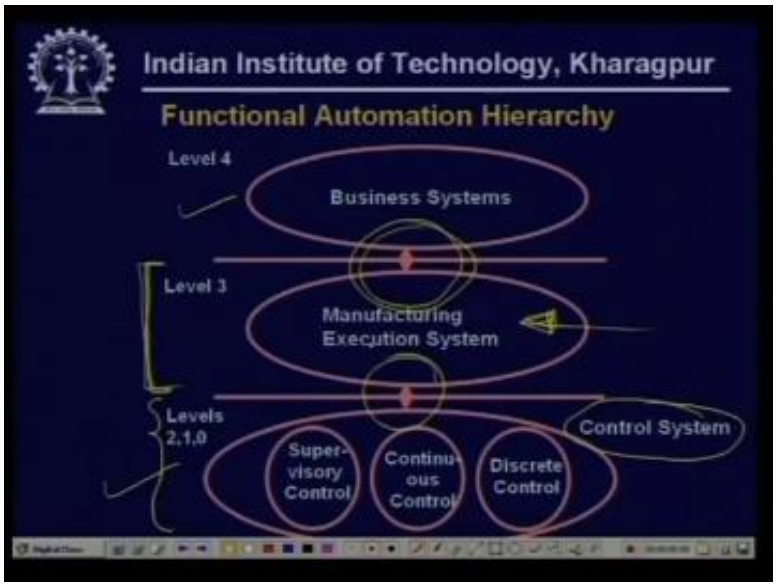

And on the other hand they actually produce the they take these targets from the business systems and they translate them into engineering targets exactly in terms of you know schedules of production what which machine to be used at what time and then and once these are.

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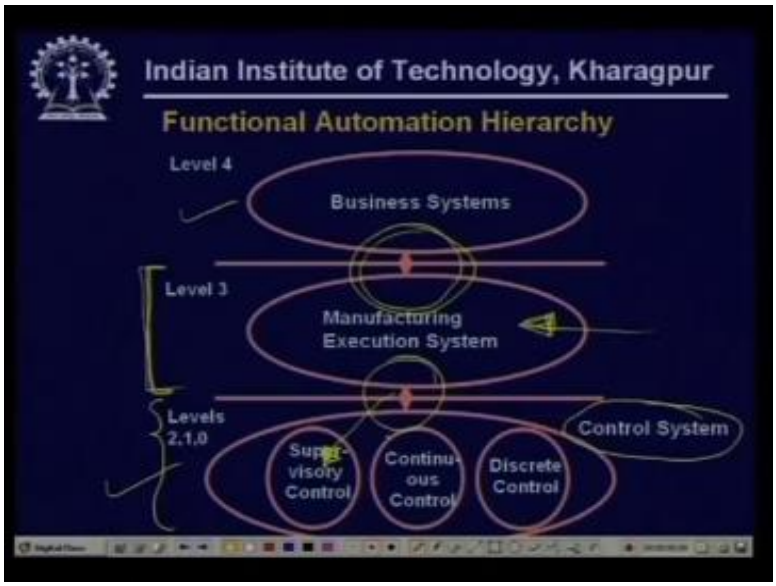

Now given I mean handed down to the Supervisory control system then the Supervisory control system can act according to that schedule and actually do commit execute the steps that are required to do the physical manufacturing, right.

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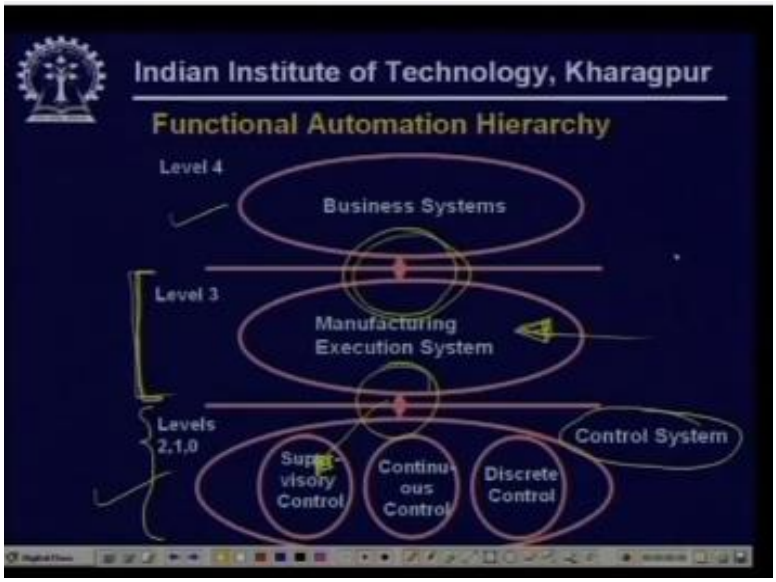

So functionally you can you can have I mean if you see the if you see the nature of technologies then you will find that this is one nature of technology which are which are essentially business systems enterprise resource planning, etc.

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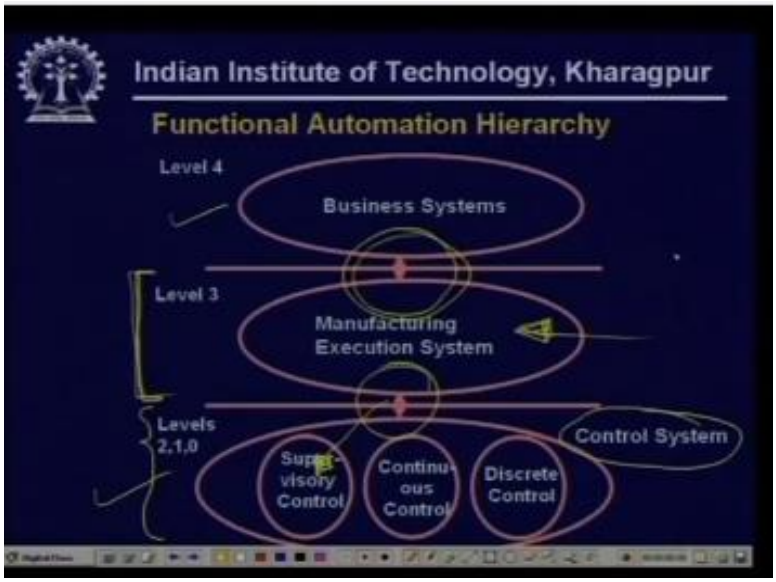

On the other hand these systems are still related to the to the to the engineering equipment but look at them as you know behaviorally and just I mean model them in terms of their functionality and they are you know some performance parameters and model the manufacturing process just like a sequence of operations while the actual physical entities are handled at the control system levels.

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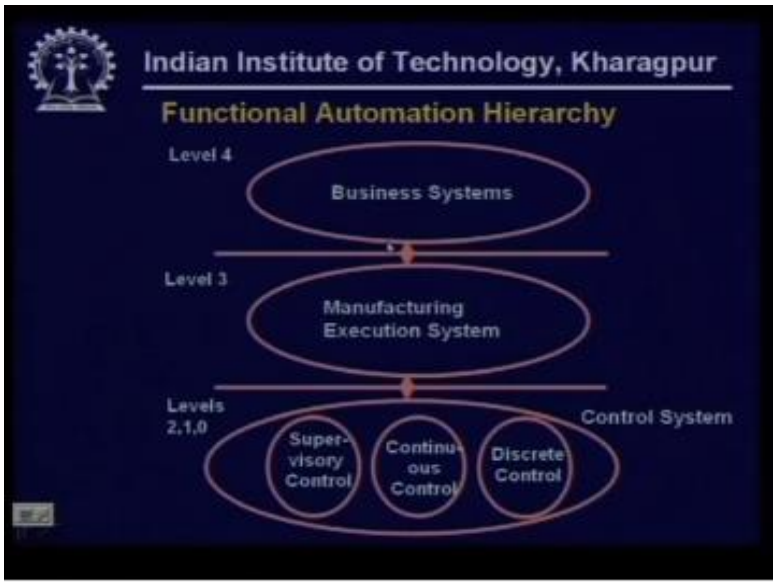

So this is the way it goes so we are going to talk about the Supervisory control manufacturing execution and to some extent of the business systems today.

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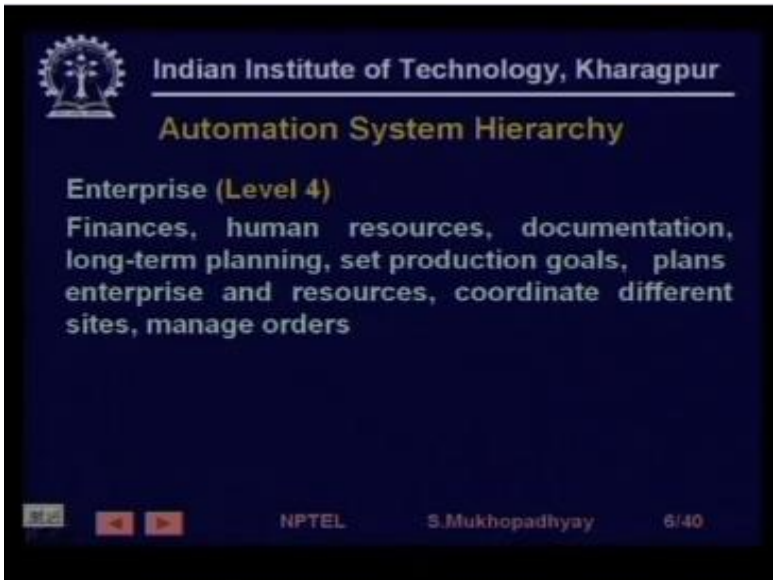

So if you look at take a brief look at the various levels at the highest level you have a you have enterprise level systems or business systems where you talk about finances, human resources you talk about documentation you talk about long-term you know capacity planning whether you need to looking at the order looking at the market whether you need to set up a new plant or you need to acquire a certain kind of machine. You what kind of production goals you want to achieve.

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And these are these are the kind of things that are actually done at the at the enterprise levels and we are going to this is just for our awareness we are not going to be we are not experts on this and neither are we going to deal with this in a course.

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But it is good to know that this is what the business system does it actually finds out basically it is directly interface to the market and it actually finds out that what should be the what should be the you know kind of production resources and production schedules so that profit can be made.

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Below that is level three so once these this enterprise level comes with comes out with orders and provides you know schedules of various will be the capacities which are going to be available then the manufacturing level actually sits down and says okay so now I have to make so many pieces of this over such time with such kind of resources, right. So now how am I going to actually do it?

So when am I going to make what and how am I going to schedule my machines and when I am going to maintain what when I am going to take off a particular machine and then give it for maintenance so all this is done at the manufacturing level.

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So typically you know you do a.

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So once you have done that then you know then you know the exact production sequence and when what will be produced, so you have a you have a kind of schedule now you can you can send this schedule that ok now you know everything is fixed up so now you produce actually physically produce according to this schedule. So then the supervision level actually takes this and so make the firstly it makes the production that is it actually finds out the configurations of these machines as they have to be configured for a particular manufacturing.

And they actually run these machines according to this download the configurations and then gives the proper commands such that the machines actually start producing and they also supervise the overall production process.

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They actually optimize and deploy control strategies so they actually manage the whole production sometimes it is done sometimes it is done automatically sometimes it is done manually.

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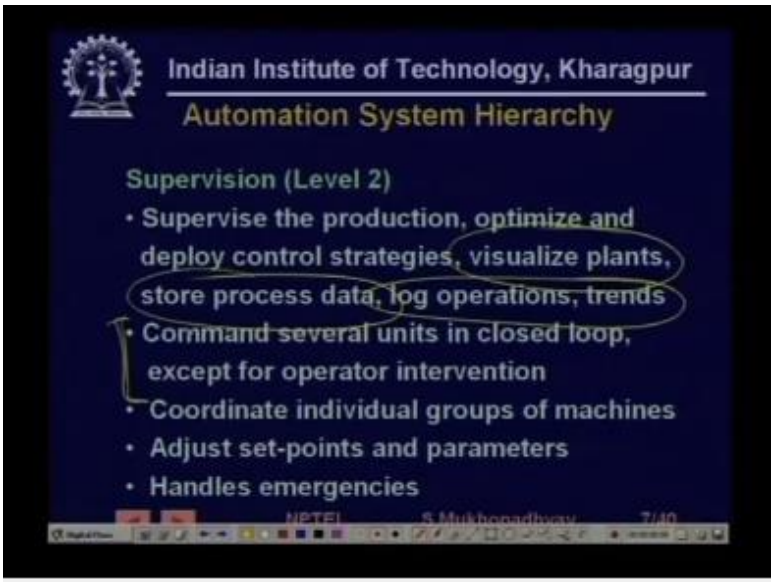

So when it is done so you so American citizen manually that is using operators so a these systems visualize give the operator of view of what's happening in the plant they also store process data for future use they do a lot of documentation which can be used later on for you know quality tracking purposes for process improvement purposes they actually they actually command several units in a very coordinated fashion like that crest volume and quality of production can be reached.

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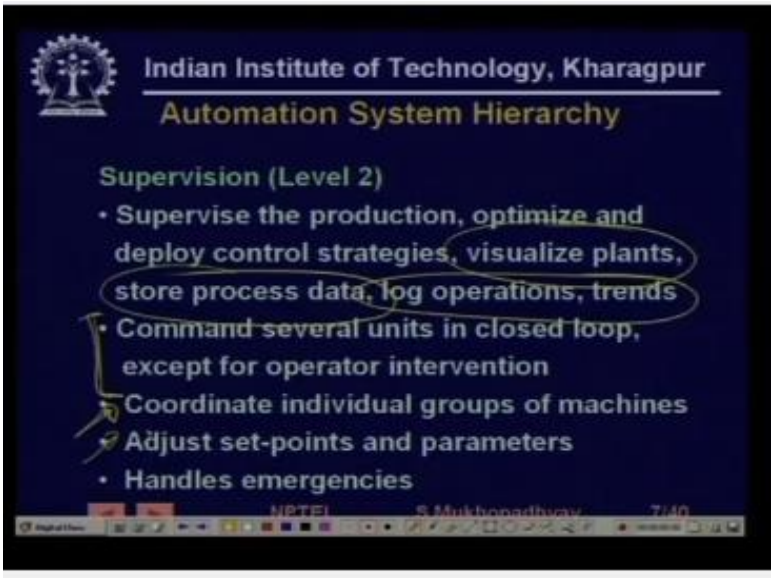

So the coordinate individual groups of machines and they give them appropriate set point so that you get products of a certain quality and of a certain volume.

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And they also handle you know plant emergencies shutdowns failures, accidents etc. So they actually manage the production process.

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You know that you have the actual automatic control in this case refer to as unit control and below that you have the field level are you sensing an attack position since we have done this in detail I am not going to spend time on this.

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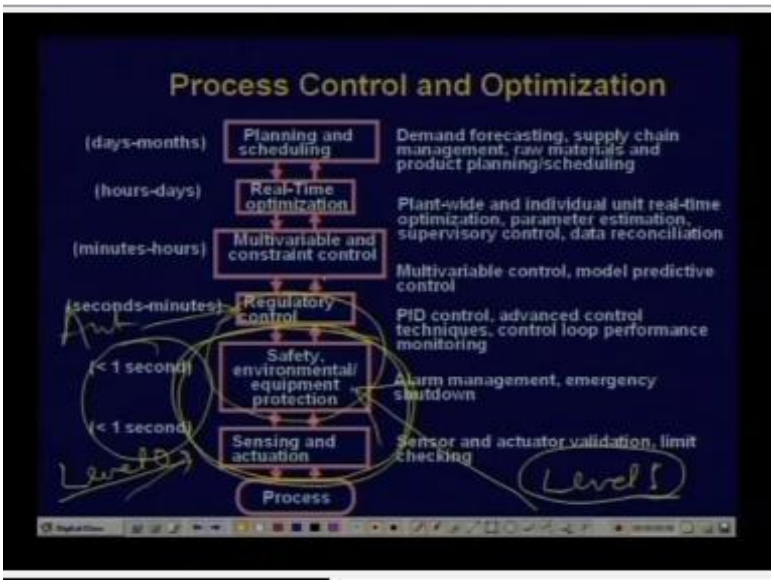

So this is a picture which shows that you know in a typically in a process control situation not an order not a discrete manufacturing scenario the kinds of technologies that are used so you have and also the time scales that I was talking about so you have at the bottom level you have these sensing actuation, protection, alarm systems which typically work at sub 1 seconds kind of time scales.

Then you have the day what they call regulatory control or which we call automatic control so this is a kind of you know level 0 then some of it is actually level 1, level 1 and then this as we said that you need to give very good set points to these automatic PID loops.

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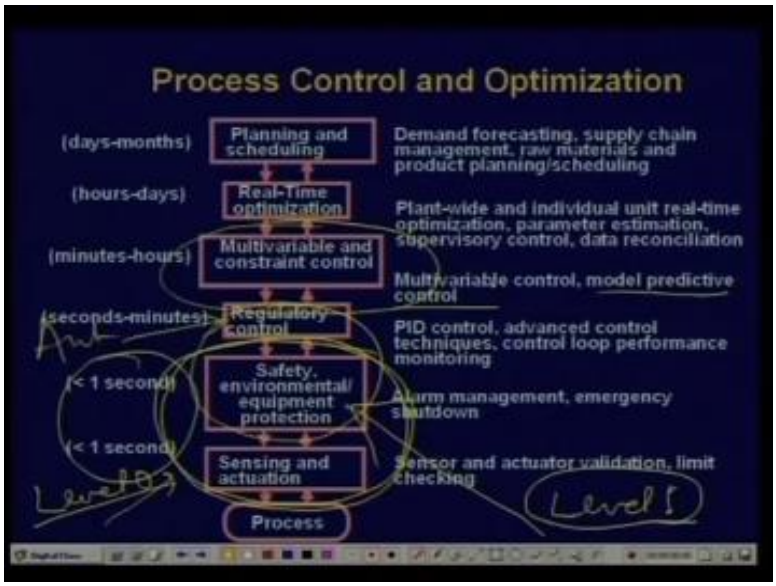

So that is again computed by you know multivariable control models where you consider the interaction among the various variables you do what is known as model predictive control is a very modern technology which is which is used for using number of process plants.

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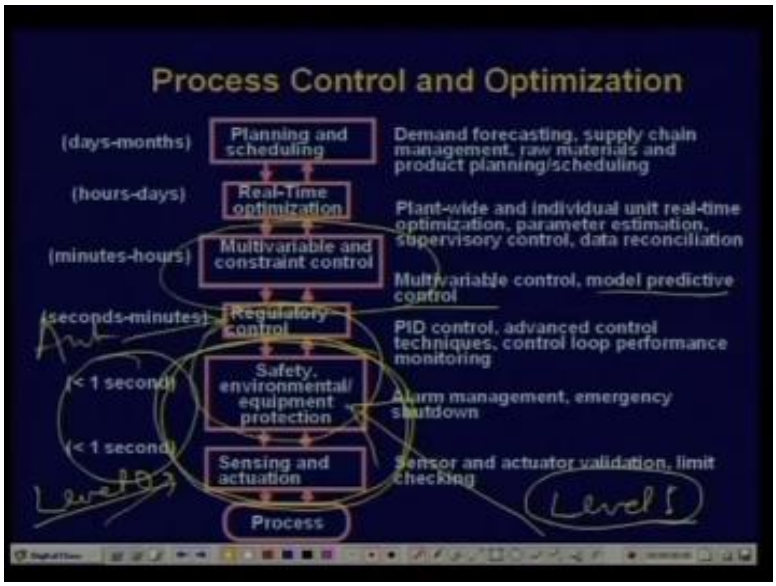

So here you are talking about you know set giving set points which hold for typically for over the over minutes hours kind of risen.

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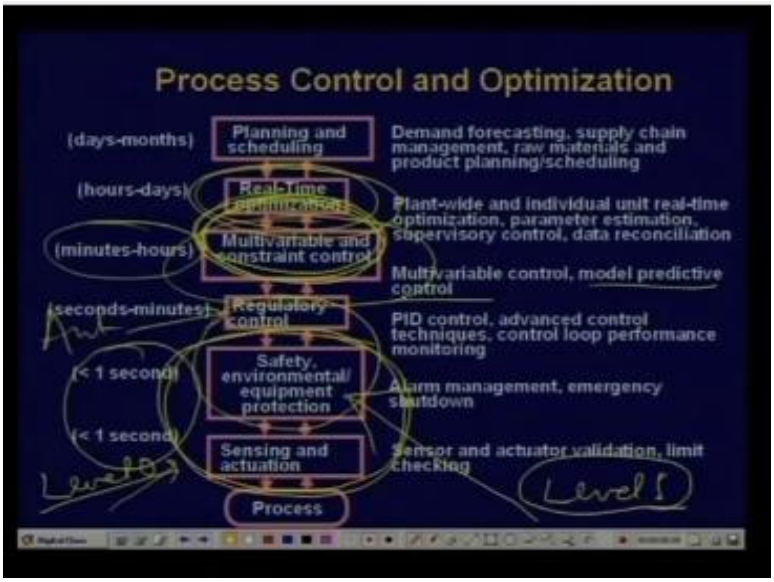

And then you have you know you have real-time optimizations where the item optimization is also done at the level of multivariable and constraint control so you have real-time optimizations for you know actually for various kinds of excuse me I have to switch off my mobile phone.

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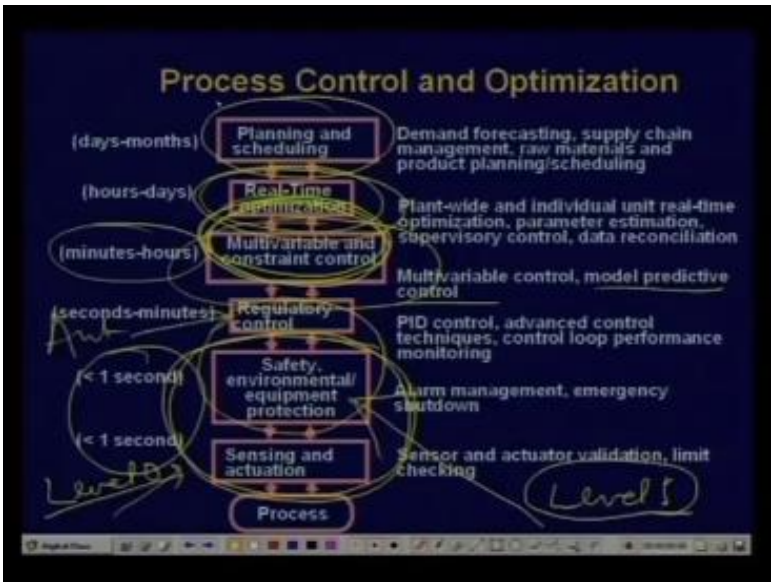

So and then finally on top of that you have the planning and scheduling modules which again as I said that that decides what is to be made and typically work on Days months weeks kind of timeframe.

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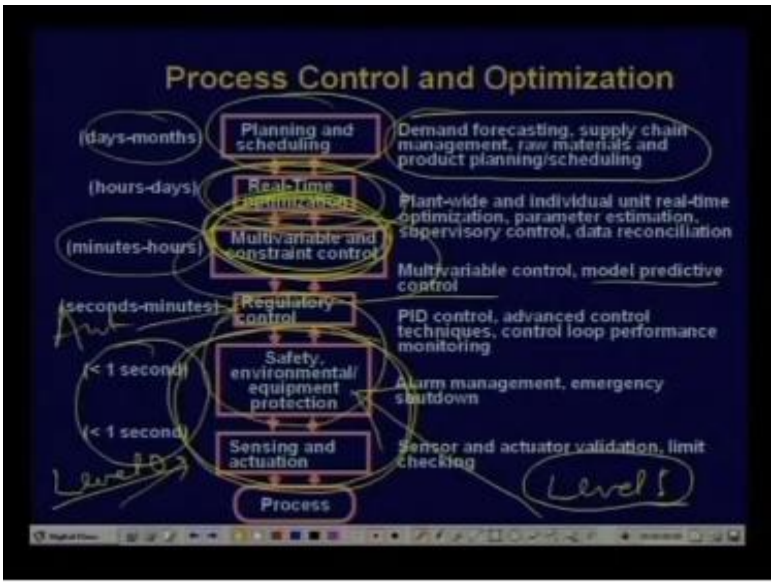

So this is a diagram which shows the various kinds of technologies that they are used for example for planning scheduling you have to do demand forecasting you have to do supply chain you have to if you know want to know that what sort of what is what should be schedule that you have to know, what kind of orders are going to come, what is your inventory, what time does it take to actually procure raw material from the market so that is that is supply chain management.

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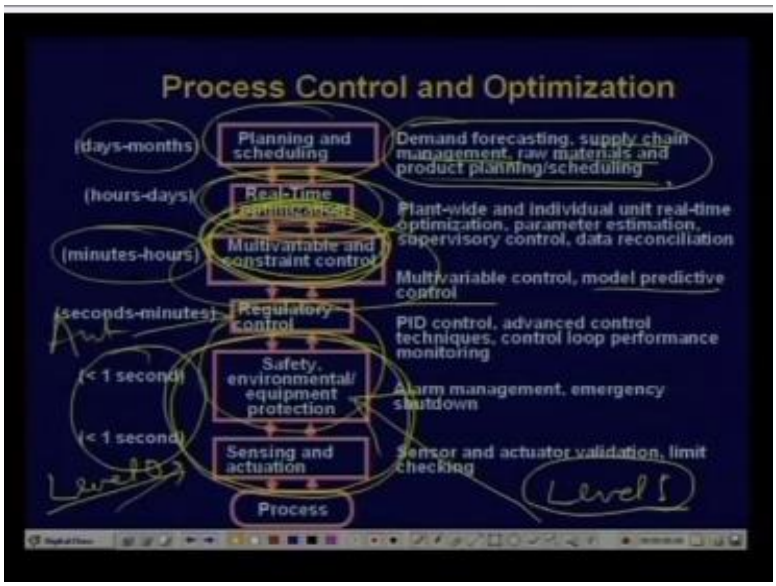

In raw materials and product planning and scheduling so they at this various stages you use different kinds of techniques and there are very advanced software tools today available which actually help you know plant managers.

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Take these decisions.

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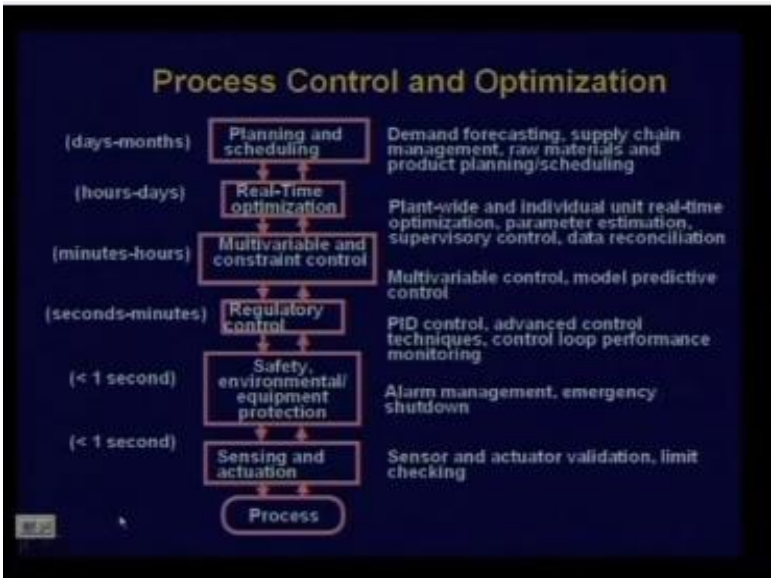

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So we come to here.

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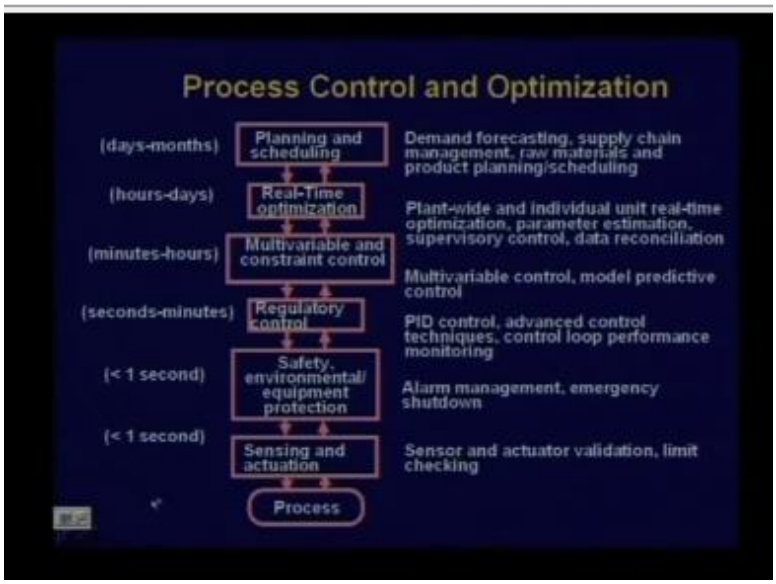

So now we start talking about the various levels and we start with from level two, so level two is supervisory control.

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So the major functions of supervisory control are the following so you have a so you first o fall optimal set point computation so you when you are supervisory control is typically concerned about a group one machine or a group of machines and they have to be there operations will have to be coordinated so you have to give them optimal set points so that they can achieve the performance goals of the production.

Like you know typically let us say a supervised I mean a super vision system we let us say they if you take a steel plant then you have a blast furnace feeding to the steel melting shop or the basic oxygen furnace and then basic oxygen furnace feeding to the continuous caster so you need to give set points to all of these for example the continuous caster will have a set point given to it of the casting speed that is at the speed at which the slab is going to come out of the caster.

Now obviously that is going to be decided based on the kind of molten steel supply situation right. So the molten steel supply situation depends on the basic oxygen furnace so you see that these say these the set points firstly the continuous caster casting speed specification has to be given based on stuff there are there are some other considerations also like for example that there is a there is a phenomenon called breakout. Where if you if you do not give the proper cooling

set point I mean cooling system control and the proper casting speed then sometimes you know you know I mean molten metal can actually come out of the slab and then you have to stop production and there is a lot of problems, right. So there are other technical considerations but there are also considerations related to related to coordination among the different units. So all this is done by the Supervisory control layer.

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Similarly, one has to do one has to supervisory control always looks at the process and sees with us whether things are going fine for example breakout detection as I was saying that whether by looking at the temperature profile by looking at the mold levels whether it is possible to the system is always monitored such that whether we can detect the possibility of a breakout and then immediately take corrective action, so that breakout does not offer so that would be like process monitoring.

Similarly, if process reconfiguration in tuning you know sometimes it happens that you need to retune your controllers because the process slowly changes or because some because there may be some there may be some there will be some problems with the raw material quality or there

may be some problem with the with some the power source like let us say the pressure source may have a we have a low pressure problems.

In such cases sometimes you may have to retune your controller like that it gives optimal performance interms of quality efficiency energy efficiency sensor, so the direct result of monitoring is reconfiguration tuning as and when necessary, similarly sometimes this is done all this is done manually so if it is to be done by operator then the operator has to be given a very good insight about the things that are happening in the plant which may be quite far away from the control room. So there is a process visualization system man-machine interfaces which have to be provided.

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And similarly process event management so you know I mean something keeps some along goes some pressure level suit shoots up one has to find one has to activate strategy is shut down mechanisms emergency mechanisms such that the situation is managed with the least amount of production loss with safety and reliability to the personal and the equipment no so such things are typically handled at level 2 or these are the functions of the Supervisory control.

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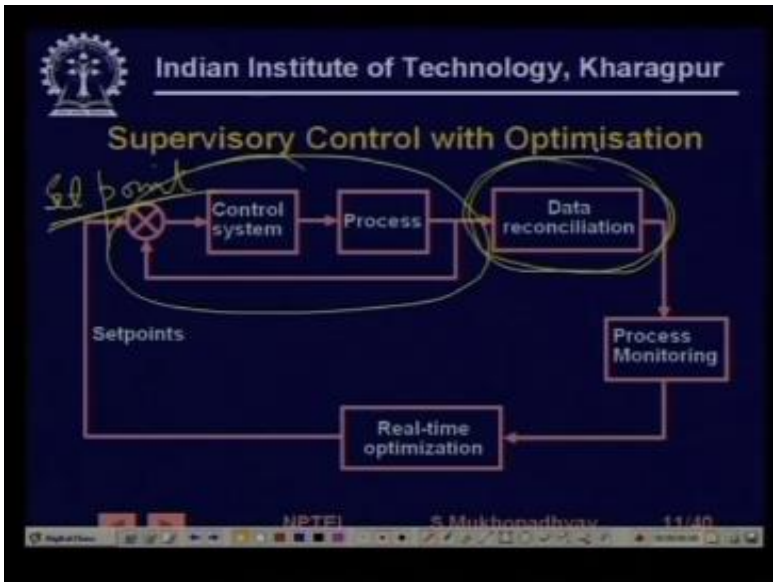

So essentially when you are giving a set point there is an there is a there is an element of optimization involved in this so that that is shown here that this is your this is your automatic control loop you know so this is your automatic control system this is your set point this is the set point and this is your system closed-loop system, so you always try to find out that so first of all you get the data from the process.

And you actually reconcile it that is you they may contain noise some sensor may be the they may be inconsistent because of various reasons so first you before making take decisions you reconcile the data that this all the signals make sense according to you know standard mass balance, energy balance equations of the process. So once you do that then you have here you have got.

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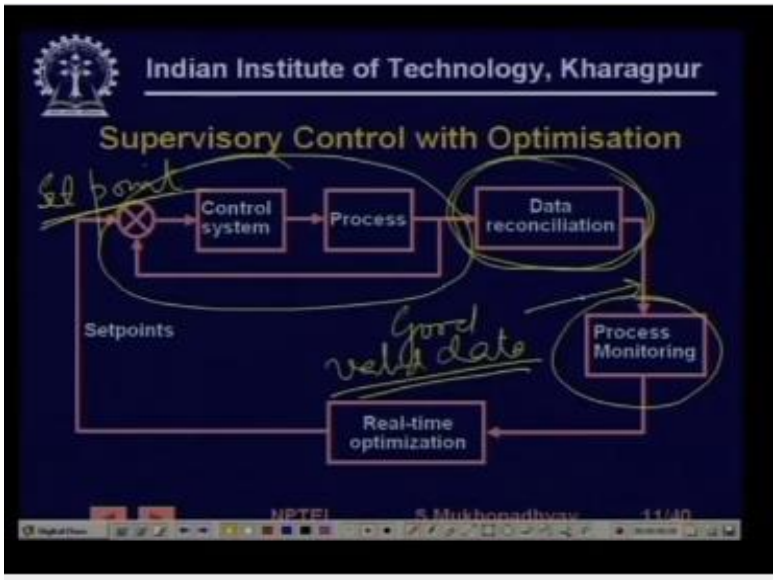

Good data good and valid data, now based on that you may like to compute various kinds of you know performance indicators of the process, what is the kind of, what is the production volume, what is the deviation from quality, what is the for example say well what is the magnitude of the control input that, what is the input energy that have been consumed, what is the unity of the plan, what is the dynamics that if there is a set point change, what is the process variability. So various things various features of process operation or can we can be computed and based on that.

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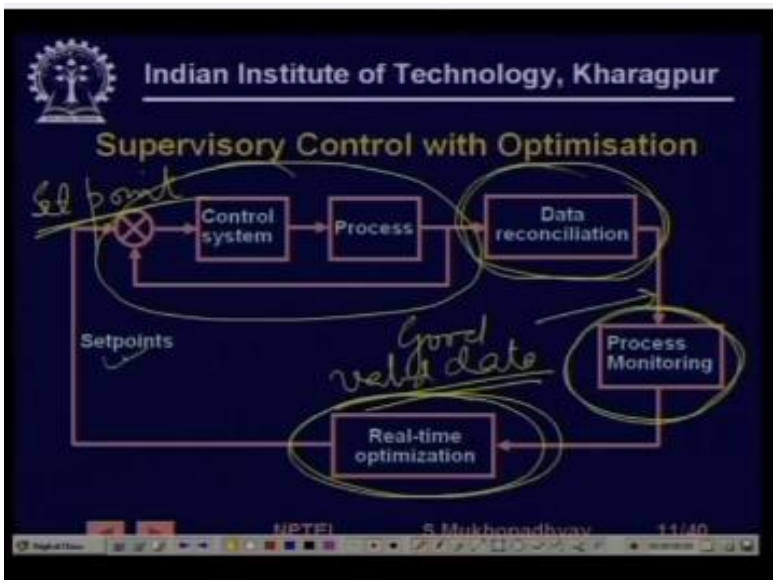

You get an idea as to whether your process is working fine or whether it needs a new set of new set points that is another cycle of real-time optimization will have to be done to generate new set points. So this typically the way in which the Supervisory system is always looking at the plant and then being and carrying out optimizations based on set points.

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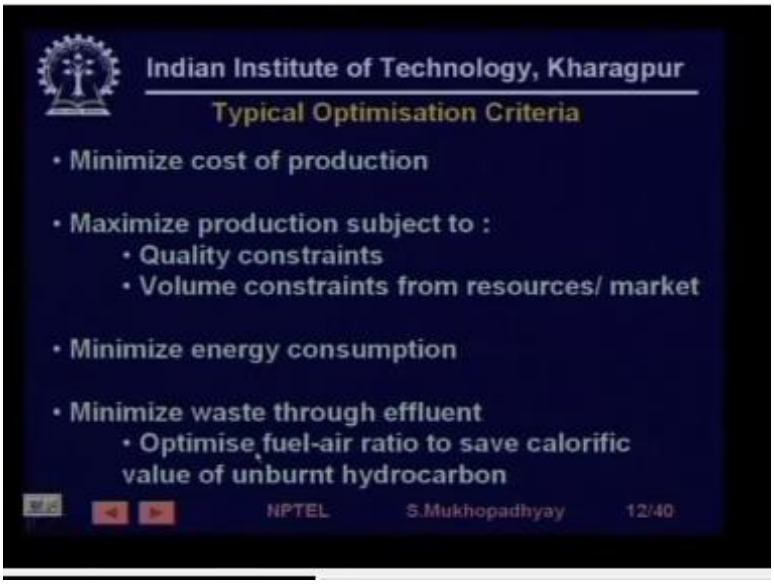

Now these optimizations can be done in various ways and finally you want to minimize cost of production and cost of production generally per unit and you as you have talked about in our first beginning slide that if you want to make more profit then have to cut down on the cost and I have to increase the production, now increase the increasing production how far so that can be limited by typically by two kinds of you know things.

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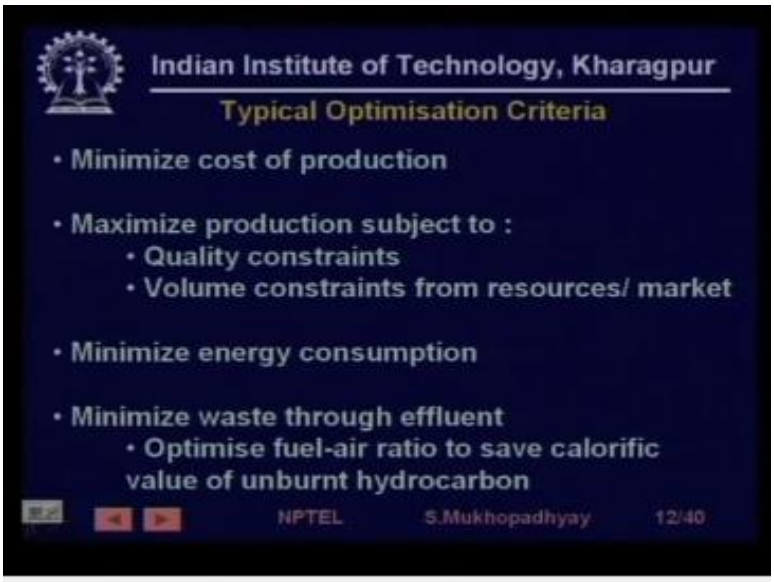

Firstly there are quality constraints you cannot produce things too fast because then they are going to do they may be of may not be of adequate quality then there may be production volume constraints that you cannot you do not know how much even if you can meet the quality constraint how much you can produce can actually depend on your equipment capacity how what is this what is how many it can actually produce.

All it can be restricted by the market because you do not want to produce things which would not sell right. So you know typically if you go to a if you go to I mean this what I always find that if you go to a sweetmeat shop or some food shop around you know 9:00 0'clock in the evening you will find that many of the items have been finished, so they actually schedule their production in such a manner that towards the end of the day it gets exhausted.

So I mean they would not produce more because food is a perishable item end and they do not want to they want to produce more than they can sell, so sometimes volume production can be also constrained by the market. Similarly where you have very energy-intensive processes or where energy is the main bottle neck like you know in a let us say is an enemy and aluminum refining plant.

Say an aluminum refining plant actually you know works on electrolytic principles and it is it is highly energy guzzling and it works on electric energy sites that way a very clean plant whether you know literally hundreds of thousands of amperes actually flow through those aluminum pots and these here the you know I mean in such a plant production is can sometimes be actually limited by energy.

Because it may be because that amount of electrical energy some of it typically aluminum plants have their captive generations but sometimes they may also draw power from the grid and in which case in especially in developing countries like Hours there may be constraints on that so in such a case a energy consumption will be a very critical optimization criterion for you know giving set points.

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So similarly, minimizing waste through if through effluents so that can be again it can be for example you typically optimize fuel air ratio to save calorific value of unburned hydrocarbons you do not want carbon monoxide to actually escape into the atmosphere because that can be burned further and you are actually if you are escaping carbon monoxide then you are actually losing calorific value of the fuel that we are using that is number one.

Number two is that sometimes you may be restricted by you know environmental considerations like you cannot dump acidic or basic effluents into the into reverts, right.