Industrial Automation & Control
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Lecture - 39
Higher Level Automation System

Welcome to lesson number 39 of the course on Industrial Automation & Control, this is a penultimate lesson and therefore, while we are ending the course we need to be aware of at least 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 1 which is automatic control and sequence control.

But as, we have discussed there are higher levels of automation systems, there is level 2, level 3 and conceive lily level 4, so in today's lessons, we will try to take a look at it is going to be a brief look. But, take it never the less take a look at, what makes level 2, 3 and 4, so that we have some idea about them and get a more complete picture, this is about industrial automation not so much, it turns out that the higher levels are more concerned with information technology and software. Other than, you know automation technology in hardware, so therefore they have not been treated in detail in this course, so here we go.

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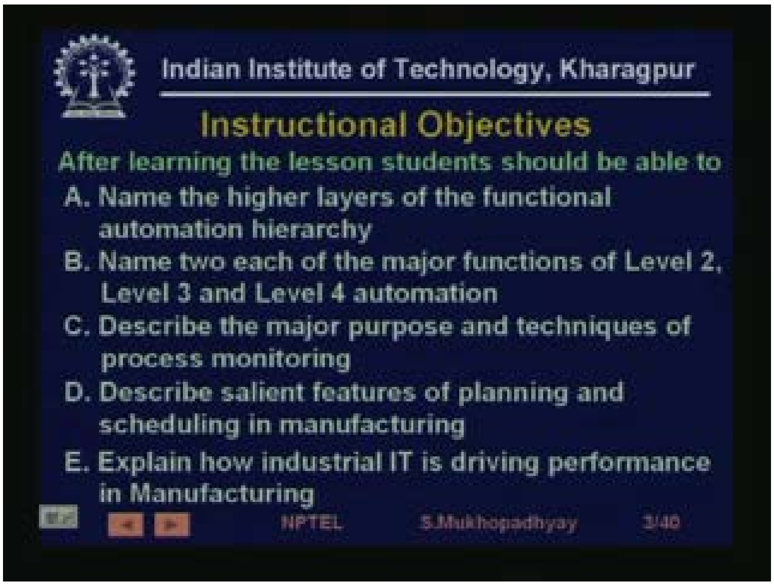

So, as usual instruction objectives and name the higher layers, so the student should be able to at least name the higher layers and name the major functions of each of the higher layers level 2, 3 and 4 automation. And describe the many of them, there are basic technologies which are involved in these are monitoring technologies, optimization technologies part of it gets manifested in planning and scheduling.

So, student should be able to talk about what is process monitoring, how it is done, why it is important, then planning and scheduling, what is planning and scheduling and how in the overall automated factory industrial information technology plays a role in coordinating integrating. These complex operations for achieving for squeezing out performance getting productivity efficiency to gain an edge of competitiveness in the market.

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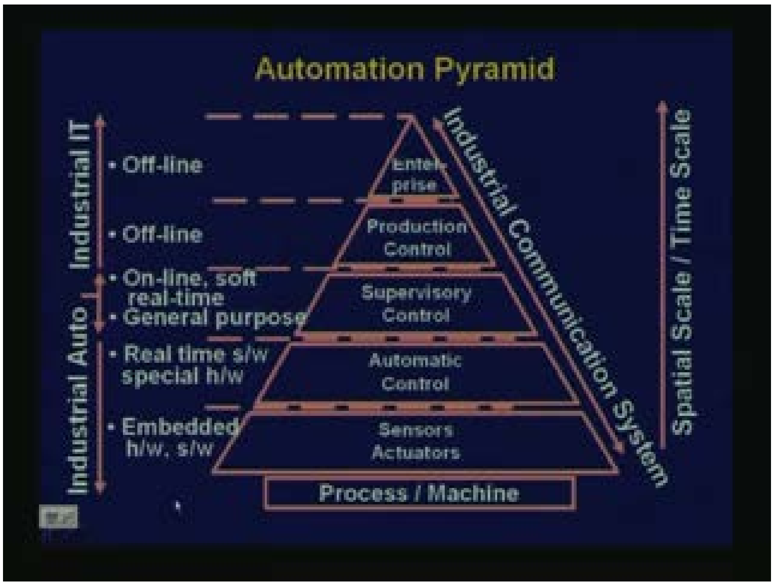

So, we first take a look at the automation pyramid, remember we had taken a look at this automation pyramid in the very early parts of the course. So here, as we said that this is the automation it can be viewed as a pyramid with the process machine, the basic equipment and the which is the ground and 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 we have mostly been concerned about these two layers, we will select thicker pen. So, we have mostly been concerned about these two layers and in this lessons we will take at 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 and they give reference commands or set points are to the lower layers has to what is to be achieved, they set the targets for the lower layers.

And therefore, all these information there is information passing back in forth, so there is in a communication system and we have already learnt about such a industrial communication system. Then, there is a special scale time difference among the layers, when the sensor and actuators look only at a part of machine. But, look at it in great time resolution as you go up, the layer of automation at those levels look at much bigger geographical areas first it talks about unit control, where one piece of equipment is looked at.

Then, you talk about group level control, where groups of equipment are looked at, then you can talk about shop 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 extend goes up and your time resolution or a time scale also goes up which means that you do not look at things in on minute time scale.

But, start looking at things in terms of hours, hours to days, days to weeks sometimes months, so when you are doing enterprise level planning and optimization you typically look at months of operation. While if you are looking at automatic control level, then you are taking typically at minutes level output, signals at levels of second to minute.

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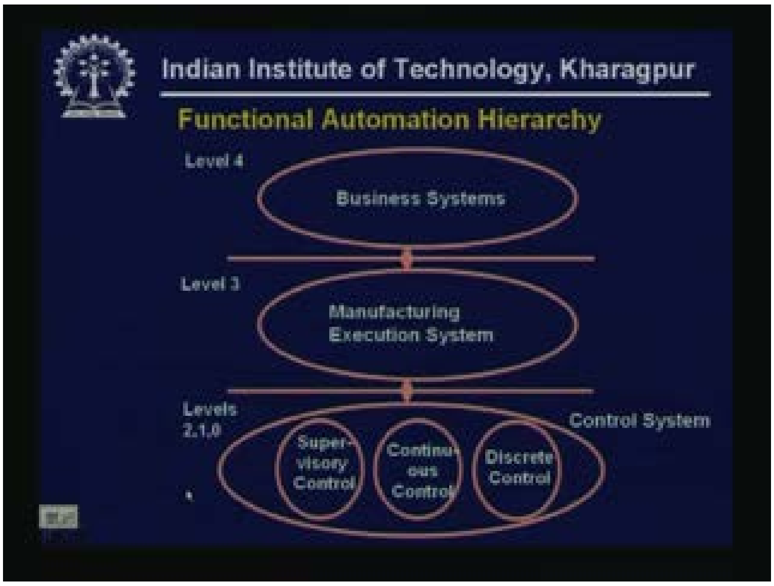

So, we see that this is the way complex automation systems are organized and functionally typically you will find that level 1 and 0 we have seen their levels 2, 1 and 0, actually basically constituted of control systems. So, they talk about physical dynamics, they talk about the physics of the process, heat transfer, mass transfer, signal value, so they are one kind of technologies, so they have been clubbed level 2, 1 and 0, they are all control technologies.

Beyond that you have level 3 or the sometimes the systems which or the computing systems which support these performance here and do the kind of computation that are required are called manufacturing execution systems. Systems, which actually plant production take a check at resources, track I mean how a particular order is being produced, take care of quality, etcetera.

So, such systems are the manufacturing execution systems, so they actually it 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 etcetera. And on the other hand, they actually produce they take this targets from the business systems and they translate them into engineering targets exactly in terms of schedules of production which machine to be used at what time.

And once these are now give I mean handed on to supervisory control system, then the supervisory control system can act according to that schedule and actually do I mean execute the steps that are required to do the physical manufacturing. So, functionally you can have I mean if you see the nature of technologies then you will find that this is one nature of technology which are essentially business system. So, enterprise the source planning etcetera.

On the other hand, these systems are still related to the engineering equipment,, but look at them as behaviorally and just I mean model them in terms of their functionality and their some performance parameters and model the manufacturing process just like a sequences of operations. While the actual physical entities are handled at the control system levels, so this is the way it goes, so we are going to talk about the supervisory control manufacturing execution and to some extend to the business system today.

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So, if you brief look at the various levels the highest level you have a enterprise level systems or business systems were you talk about finances human resources, you talk about documentation. You talk about long term capacity planning, whether you need to looking at the order or looking at the market whether you need to set up a new plant or you need to acquire a sudden kind of machine.

You what kind of production goals, you want to achieve and these are the kinds of things that are actually done 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 a in a course.

But, it is good to know that this is what the business system does it, it actually finds out basically it is directly interface to the market and it actually finds out that, what should be the kind of production resources and production schedules. So, that profit can be made, below that is level 3, so once this enterprise level comes with comes out with the orders and provides schedules of various, I mean the capacities which are going to be available.

Then, the manufacturing level actually sits down and says, so now I have to makes so many pieces of these over such time with such kind of resources. So now, how I am 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 of a particular machine and then give it for maintenance. So, all this is done at the manufacturing level.

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So typically, once you have done that then the exact production sequence and when what will be produced, so you have a kind of schedule. Now, you can send this schedule there now everything is fixed up, so now you actually physically produce according to this schedule. So, then the supervision level actually takes this and firstly, it makes the production that it actually find out the configurations of these machines as they have to be configured for a particular manufacturing and they actually run this machines according to this download the configuration then give the proper commands. So, such that the machine actually starts producing and they also supervise the overall production process they actually optimize and deploy control strategies.

So, they actually manage the whole production automatically sometimes it is done manually. So a many case, it is done manually that is using operator, so they these systems visualize view the operator view of what is happening in the plant. They also store process data for future use they do lot of documentation, which can be used later on for quality tracking purposes for process improvement purposes.

They actually they actually commands several units in an every coordinated fashion such that best volume and quality of production can be reached. So, the coordinate individual groups of machines and they give them appropriate set point, so that you get products of certain quality and of certain volume and they also handle plant emergency is shut downs failures accidents etcetera. So, they actually manage the production process.

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Below that you have the actually automating control in this case referred to as unit control and below that you have the field level where you will sense a data acquisition, since we have done this in detail I am not going to spend time on this.

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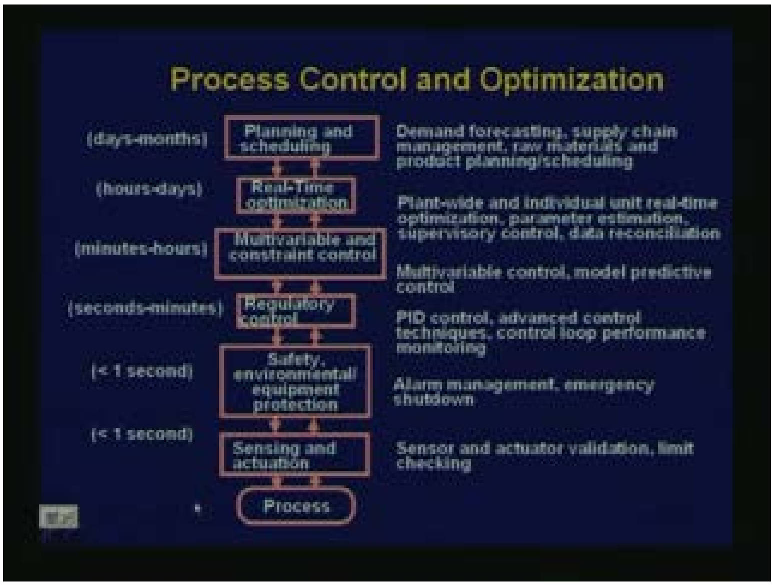

So, this is the picture with shows that in a typically in a process control situation not a discrete manufacturing scenario the kinds of technologies that are use. So, you have a also time scales that I was talking about so you have at the bottom level, you have these sensing and actuation protection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

Then, you have what they call regulated control or which we call automatic control. So, this is kind of level 0, then some of it is actually level 1 and then this as we said that you need to give very good set points to these automatic PID loops So, that is again computed by multivariable control models, where you consider the interaction among the various variables you do what is known as model predictive control is a is a very modern technology which is used for using number process plants.

So, you have talking about set giving set point which hold for typically for over the minutes hours kinds of horizons. And then you have real time optimizations where real time optimization is also done at the level of multivariable and constraint control. So, you have real time optimizations for actually for various kinds of… So, and then or finally, on top of that you have the planning and scheduling modules which again as I said that that decide, what is to be made and typically work on days, month’s week’s kind of time period. So, this is a diagram which shows the various kinds of technologies there are used.

For example, for planning scheduling you have to do demand for costing, you have to do supply chain, if want to know that, what sort of what should be big schedule. Then you have to know, what kind of order as a 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 in a raw materials and product plan in scheduling. So, they at this various stage is you use different kinds of techniques and there are very advance software tools today available which actually help plant manager take this decisions.

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So now, we start talking about the various levels and we start with from level 2, so level two is supervisory control, so the major functions of supervisory control are the following, so you first of all optimal set point computation. So, supervisory control is typically concerned about a group a one machine or a group of machines and they have to be their 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 typically let us I mean supervision system will let us say they if you take a steel plant, then you have a blast furnace feeding to the steel melting shop of the basic oxygen furnace and then basic oxygen furnace feeding to the continuous cast. 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 it 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. So, the molten steel supply situation depends on the basic oxygen furnace, so you see that these set points. Firstly, the continuous caster casting speed specification has to be given based on some there are some other considerations also like for example, that there is a phenomenon call break out were if you do not give the proper cooling set point. I mean cooling system control and the proper caster speed.

Then, sometimes I mean molten metal can actually come out of the come out of the slab and then you have to stop production and there is a lot of problems. So, there are other technical considerations, but there are also considerations related to coordination among the different units, so all these is done by the supervisory control layer.

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

Similarly, if process reconfiguration and tuning sometimes it happens that you need to retune your controllers, because a process slowly changes or because there may be some problems with the raw material quality or there may be some problem with some is power source like let us say the pressure source. We have low pressure problems, in such cases sometimes you may have to retune your controller such that it gives optimal performance in terms of quality, efficiency, energy efficiency and sensor.

So, the direct result of monitoring is reconfiguration tuning as in 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 inside about the things that happening in the plant which may be quite for aware from the control room. So, there is a process visualization system man machine interfaces which have to be provided.

And similarly process event management, I mean something treats some alarm goes some pressure level shoots up. One has to find, one has to activate strategies is shutdown 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.

So, such things have typically handled at level 2, these are the functions of the supervisory control.

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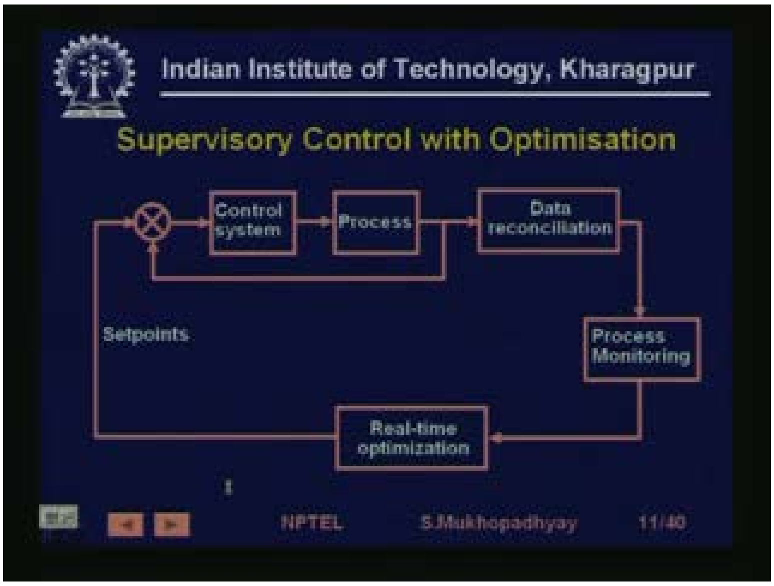

So essentially, when you are giving a set point there is an element of optimization involved in this, so that is shown here that this is your this is your automatic control loop So, this is your automatic control system this is your set point this is the set point and this is your system close loop system.

So, you always try to find out that so first of all you get is the data from the process and you actually reconciled that is you they may contain noise some sensor they may be inconsistent, because of various reasons. So, first you before making taking decisions you recon ciliate the data that this all the signals make sense, according to standard mass balance energy balance equations of the process.

So, once you do that, then you have here you have good data good and valid data, now based on that you may like to compute various kinds of 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, what is the magnitude of the control input that, what is the input energy that have been consumed, what is the agility 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 the of process operation or cry can be computed and based on that you get an ideas to whether your process is working fine.

Or whether it needs a new set up new set point that is another cycle of real time optimization will have to be done to generate new set point. So, this is typically the way in which the supervisory system is always looking at the plant and then doing I mean carrying out optimizations based on set points.

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Now, these optimizations can be done in various ways and I mean finally, you want to minimize cost of production and cost of production generally per unit. And you as we 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 things. Firstly, there are quality constraints, you cannot produce things too fast, because then they are going to they may be of may not be of adequate quality. Then, there may be production volume constrains that you do not know how much even, if you can meet the quality constrained how much you can produce can actually depend on the your equipment capacity, how many it can actually produce or can it can be restricted by the market, because you do not want to produce things which would not sale.

So, typically if you go to I mean this, what I always find that if you go to sweetmeat shop or some food shop around 9 o'clock in the evening you will find that many of the items have been finish. So, they actually schedule their production in such manner that towards the end of the day it get's exhausted, so I mean they would not produce more, because food is perishable item and they want to they want to produce more than they can sell. So, sometimes when your production can be also constrained by the market.

Similarly, where you have very energy intensive processors or were energy is the is main bottle neck like in a let us an aluminum refining plant say in aluminum refining plant actually works on electrolytic principles and it is highly energy guzzling and it works an electric energy. So, it is exactly have very clean plant we were literally 100 of 1000 of amperes actually flow through those aluminum pots.

And these here, I mean in a such plant production can sometimes be actually limited by energy, because it may be I mean, because that that amount of electrical energy, some of it typically aluminum plants have they are captive generations by… But sometimes they may also draw power from the grid and in which case in especially in developing country likes 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

So, it is similarly minimizing waste if through effluents, so that can be again it can be for example, you typically optimize fuel air ratio to safe calorific value of un burnt hydrocarbon you do not want carbon monoxide. It actually escape in to that atmosphere because that can be burnt further and you are actually if you escaping carbon monoxide then you are actually loosing calorific value of fuel that you were using that is number 1. Number 2 is that sometimes you may be restricted by environmental considerations like you cannot dump acidic or basic effluence into the into rivers. So, there can be what I am trying to say is that in a typically in a industrial scenario you can have various kinds of optimization criterion.

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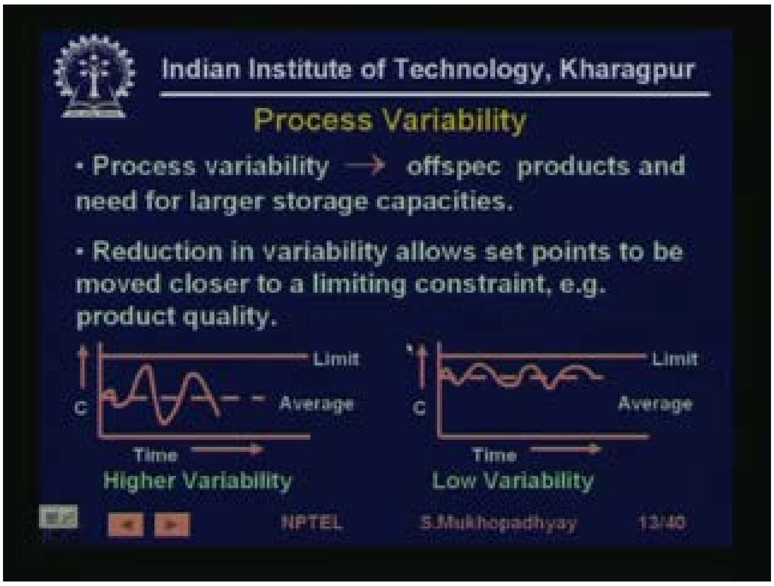

Second thing which is important for a production is that process variability that is typically you want to maintain a certain set point you are holding and, but still the process signals of the process final product parameter. Let us say a steel strip thickness coming out of a rolling mean. You have the same roll gap, so you want that a steel bar comes of a certain width and when it gets rolled it should come out with a certain level of thickness. So, you have will accordingly you have set roll gap, so this gap between the two rolls you have sets your set point is fixed.

But, it turns out that there can be a normal variation seen I mean there can be quite a bit variation seen roll gap, depending of other factor for example, the temperature of the bar which is the entering. So, if the bar is heated to the appropriate temperature it will get rolled easily, if the bar is not heated, if the bar has cool down little bit, because it was waiting to be rolled for some time. So, it is temperature has fallen down.

Then, it will become considerably harder to roll and therefore, the dimension reduction may not be appropriate. So, such things can give a lot of process variability and once you want for the product to sale, you need a certain quality finally.

So, in the case of sometimes, if you are storing in tanks as we have said that is a storing in tanks and if you have widely fluctuating product quality. Then, you actually need a large tank such that all these variations where when they get when they actually come to the tank and finally, gets mixed, then they come to an average quality.

So, if you may have small tank, then; obviously, integration over a smaller time of a sinusoid will still give variations, so if want to reduce variation you will need to have large tank. On the other hand in the case discreet manufacturing you now each pieces actually different, so it is not that if manufacture more length of steel plates, then you can tolerate certain kind of variations, I mean variations on one part will not the cancel the other.

So, in such a case you have to for example, suppose railway wheel, it has to have a certain amount of weight. Now, when your cutting an ingot, you are first cutting an ingot and then shaping, the ingot in the in the form of a wheel. Now, you when you are cutting the ingot if you cannot cut precise amounts of material, then what is going to happen is that, you will always places, because you do not becomes of less volume or weight, then the it will be totally rejected.

So, you will try to places safe and you will actually set your limit higher, so you will cut more material, then finally that additional material will have to be machined and you are not only going to waste material again, but you are going to waste machine time. So, if you have high variability generally you do not have good performance of process.

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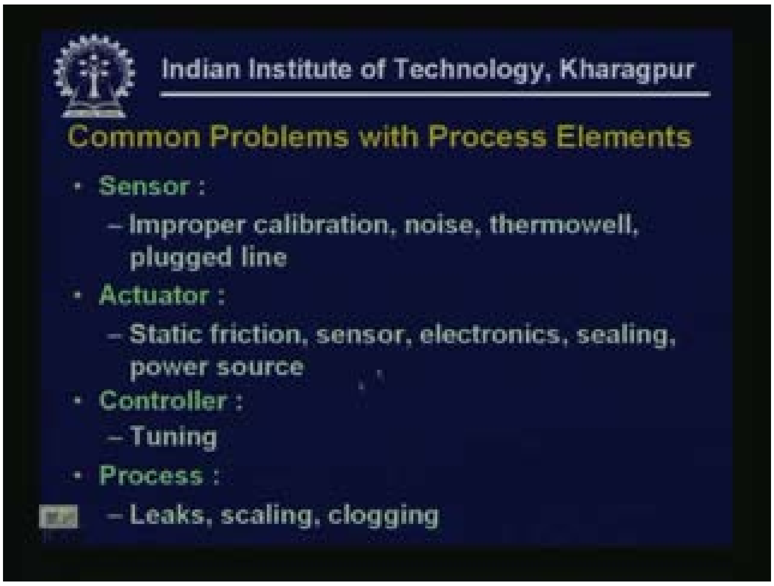

And, variability big variability generally comes for various kinds of problems in process like commons problems which occur like for sensor, they may have improper calibration, improper calibration will directly result in dimension inaccuracy.

If you have noise, then because of noise feedback things there will be perturbations in the output. Similarly, thermo wells when they get plugged the actually can inside quite bit of time constant. And therefore, especially when you have shifting set points, then the process will not track the set point well as we have learnt.

Similarly, plug lines means all, the sensor will actually sense, so you are sensing a pressure sensor and you have a line, which actually connect the process to the meter and sensor the pressure. Now, this line if it is plugged, then the pressure will not be properly sensed and the sensor will give bad reading. And, sensor readings as we have seen earlier that sensor reading, sensor errors in control system directly affect the output, so if you have any problem with the sensor it is going to be directly transferred to your output.

Similarly, you could have actuator problems, various kinds of problem like friction due to lack of lubrications, then actuator also have sensors. So, there may be problems there may be problems of electronics or problems of sealing, sometimes fluids will leak say hydraulic systems or problems of power sources. For example, suppose you have pneumatic actuator and if you have less air pressure or you have hydraulic actuator and your hydraulic pump pressure has fallen. So, such problem will give problems in the actuator, these are very typical problems.

Similarly, controller may be badly tuned and similar and of course the process can develop leaks it can develop scales on heat transfer equipment things can get clogged. So, all sorts of all these kinds of problems can occur and these problems generally make the performance of the control loop inferior. So, one needs to all the time check, whether the control system is actually performing adequately, so that is the basic job of process monitoring.

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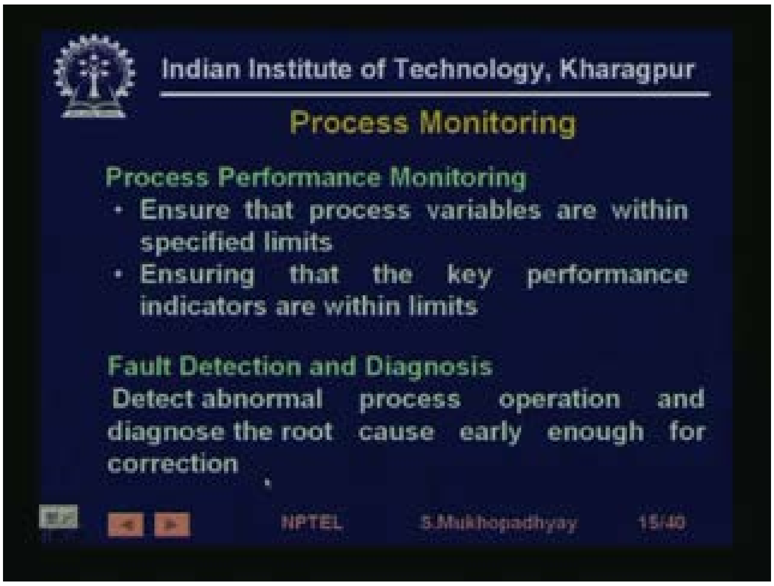

So, you have process monitoring, so the basic job of process there are you can divide process monitoring into two ways, one is performance monitoring. On the other one is is failure detection and diagnosis.

So, when you are doing performance monitoring, then you are ensuring that process variables are within specified limits. So, no limits are being crossed quality will be and you are also ensuring that that other key performance indicators. For example, energy being spent or compositions of waste compositions etcetera or scrap the amount of scrap or the amount raw material that you are consuming per unit product this could be key performance indicators or the loop dynamic performance these are within limits.

So, well you are doing performance audit and monitoring and you are trying to look for better optimization opportunities, but as such the plant is operating. Contrasted to that you have a situation, where they were something goes wrong something breaks. So, there are abnormal process operations and then you have to diagnose the root cause early enough for correction, so that it can be corrected and the operation does not get jeopardized.

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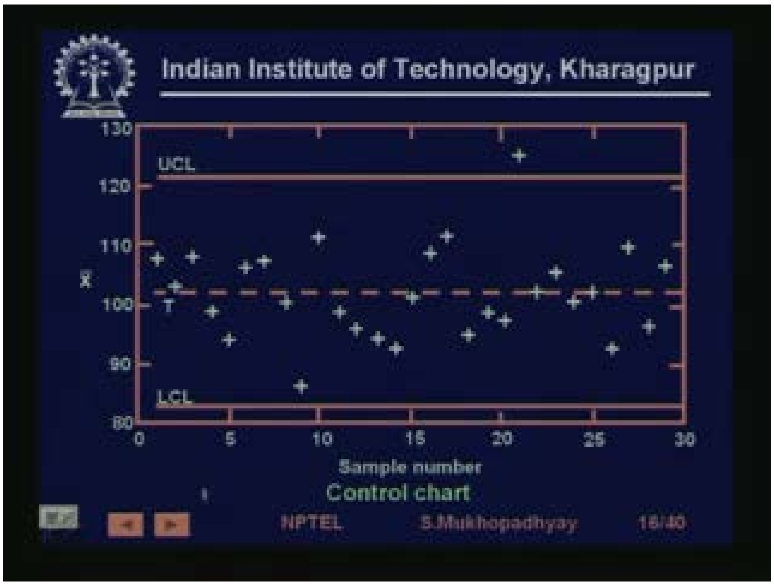

So, these are the two kinds of functionality, main functionality for process monitoring process variability check this is the standard control chart. So, you takes lots and then you from this lots actually calculate means mean values and then you plot the mean values and you continuously try to see. So, you have decided some upper control limit and some lower control limit and you try to see the how that whether the mean values are actually contained within that. In some cases they may go out if they go out that is cause for concern if they go out too often and they are cause for really cause for concern and you need and you now that your process variability has increased.

So, the process is not being able to follow a particular kind of I know output properties, but the output property is varying and there is lot of variability. So, which means that something has gone wrong? So, you need typically you check process variability using such charts.

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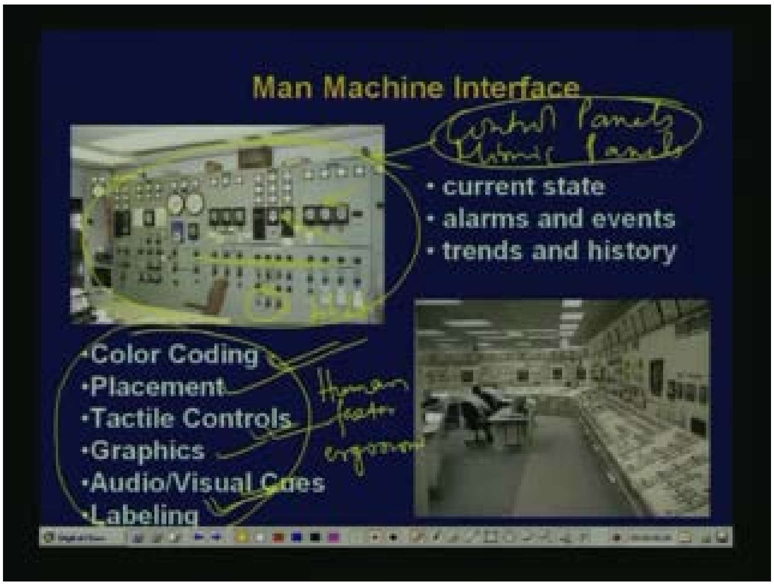

Often process monitoring, why we are showing this diagram is that, in many many cases process monitoring is actually done by expert operators. So, there is always a question of having man machine interfaces and there are lots of issues in their designs like for example, previously older.

This is a typically looks like a power plant power substation is a powers the here is the bus, here is the bus, here is the various feeders. This is a probably some sort of a machine, so you have these are various meters then you have relays at the back and things like that. So, you see that these are called control panels or mimic panels sometimes.

So, previously you used mainly such man machine interfaces where the so you have big meters and they are. So, now, the design of these has to be such that it is easily problems see an operator looks at 100 of these meters into. So, they have to be properly color coded, so that this an operator can from a distance he can quickly make out what is the source of the problem, their placement more important thing should be in front of the operator.

Then, the various controls should be such that the operator can very closely operate it, so you have various kinds of joysticks and other controls, whether the operator can conveniently give manual control commands. Of course, graphics audio visual clues alarm enunciations, so some lights glowing some hooters and proper labeling that is each variable should properly labeled, so the that operator can quickly make out situation.

So, there is a lot of these are called human factor engineering human factor engineering sometimes referred to as ergonomics. So, they have lot of such thoughts going to the design of such man machine interfaces. On the other hand if some modern interfaces many of it will be often will be for example, you can see here, that apart from these the operators will have computers. So, there will be you know VDU or CRT based displays which will also show these are the modern kinds of man machine interfaces.

Typically a man machine interface shows to the operator these three things, it is shows the current state of the process. It shows alarms and events and it lets the operator compare performance against trends and history, so these are the kinds of information that a modern man machine interface based on computers makes available to the operator.

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So, it these are the major functions of man machine interface data acquisition and display, then measure and processing it calculates the various derive values that it does not always produce raw data to the operator. Because that the raw data does not is sometime require further processing to give more meaningful operation information to the operator for effective plant of operation management.

So, such measurement processing will go on and so measure and processing, then events and alarms it will clearly show the events and alarm their sequences then etcetera. So, how the things are happening, what when which signal has reached some high or low level, so all these things all the sequence of events, then happening in this a system it lets the operator.

See it maintains the history data base and log generate logs and reports. It also takes the operator commands and applies to the plant. And finally it integrates with the higher layers of automation like for example, in this cases which may be a manufacturing execution system. So, these are the main function of…

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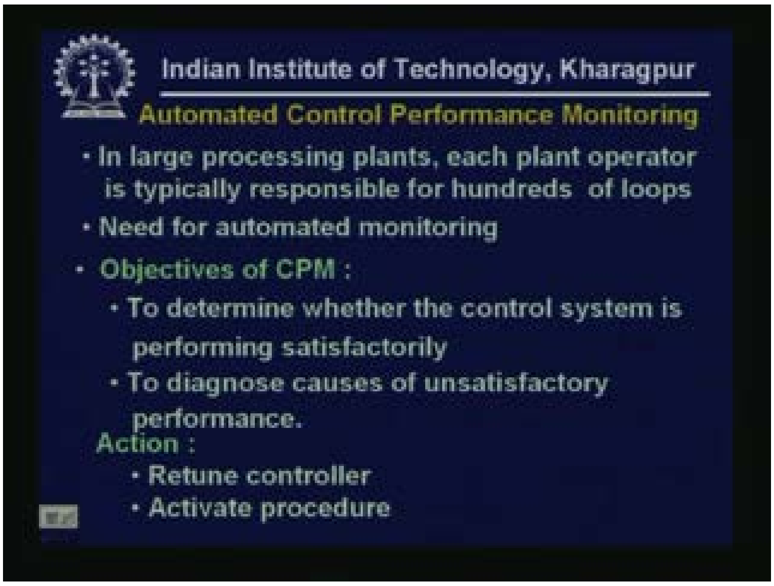

Now, it turns out that as we as we have seen from the previous picture that there are 100 and sometimes may be close to a 1000 variables and loops that the that the operator may be require to monitor. So, there is a need for it is very difficult in this there is a need for automated monitoring and therefore, purely manually monitoring requires lots and lots of experience and even, then operator errors a not cannot be ruled out and have occurred in various situations. Just like they occur in aircraft accidents, aircraft accidents also the pilot has to see a whole lot of signals and take very time critical decisions.

So, the control performance monitoring automated control performance monitoring as actually basically tries to determine whether the control system is performing satisfactorily. If not, then to diagnose causes of satisfactory performance and then finally, it generates action which could be retuning of controllers or it could be activating special shutdown or emergency procedures. So, this is the basic idea of performance monitoring.

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Now, if you want to monitor if you want to basically determine whether something is going wrong, then just a moment man machining interface then so we have seen this one. So, whatever saying is that if you want to find out, whether a plant is working perfectly then you need to do two things.

Firstly, you need to check with the benchmark something weather is good enough, so for first of all you have to determine, so you have to first of all look at some quantity. So, what are the quantities that you are going to look at to understand, whether the plant is performing properly? So, you need to select some response parameters or some performance indicator and then you need to check, whether it is value is ok.

So, you need to define, what is ok and what is good enough, so that is called bench mark. So, what should do is; so you could be have various kinds of benchmark, for example you could have response parameters like rise time, settling time, overshoots offsets integral error criteria. So, all these could serve as benchmarks.

So, if you have a too high or overshoot, then that that is something wrong and one of the reasons could be that the loop delay has increased. For some reason may be may be the may be the sensor thermo well has accumulated some materials. So, the sensor lag is increased, and therefore you are you are getting too much overshoot, because a overall loop phase has increased.

Similarly, you could calculate sudden signals and we will see what this will little more detail if you have model of the process I mean dynamic model, which could be described in various mathematical terms. Then you could generate a residual that is you could you could generated signal that as long as the system and the model are the close enough then that is signal will be is going to be small. If the system deviates from the model, then this the signal will go up and then you can try to look that model you can try to look at residual.

What you can look at you can even look at historical data; you can look at data saying that and which that this is satisfactory performance. So, you can always compare, so suppose some maintenance was done in the plant and immediately after that that the plant was working fine. So, if you have historical operational data stored with that you can always compare with that and that can also serve with a benchmark.

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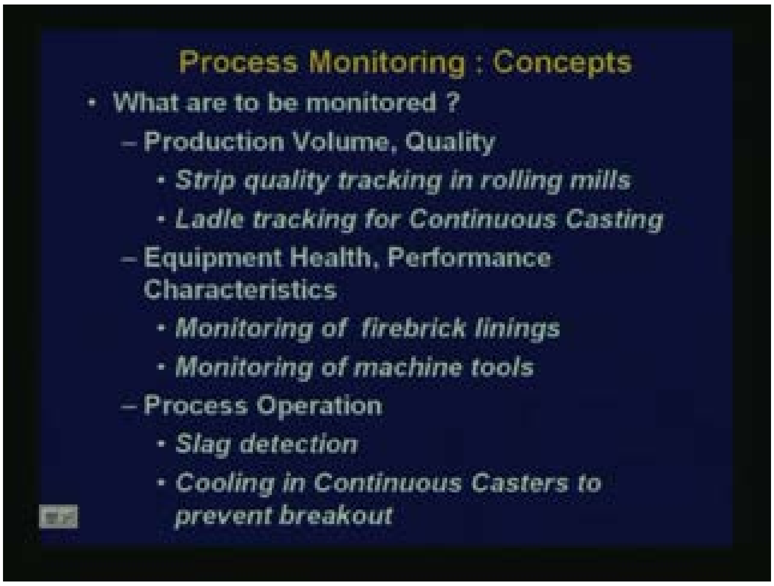

So, there are various ways that this process monitoring can be done; you can try to monitor various things like production volume, production quality. For example, you can strip quality tracking in rolling mills or ladle tracking for continuous casting, because so that you can achieve a certain amount of certain number of heats in a continuous caster.

This was actually a problem for our steel industry that they were not having enough number of heats.

Similarly, you can have equipment help were perform characteristics like you can actually monitor machine tools whether they have got one out you can have firebrick linings check firebricks linings of furnaces. Similarly, you can check monitor process operations like detect when you are pouring metal where when slag is going to come or not and etcetera. So, you can monitor various kinds of quantities.

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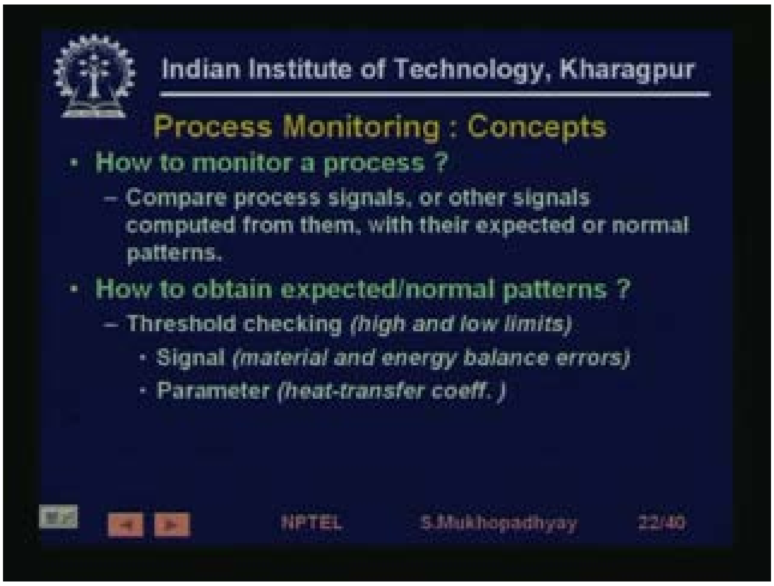

So, as you as I said that a how do monitor a process, you compare a process signal or some other signal derived from them with their expected or normal patterns. So, expected or normal pattern you have to calculate, how to obtain expected normal patterns; either by checking threshold high and low limits, which we have already set or by checking material and energy balance errors.

So, for example, if that the mass of material which is going out is some sort of mass of fluid which is going in the mass of fluid which is going out are not matching, then there could be a leak in the equipment. You can check certain parameters like heat transfer coefficients if a tube develops scales, then the heat transfer coefficient is going to fall or you can also sometimes check sensor failures by physical redundancy you have more of sensors. So, you check whether their radius is tallying, so that if one of them is not tallying then that that sensor is faulty.

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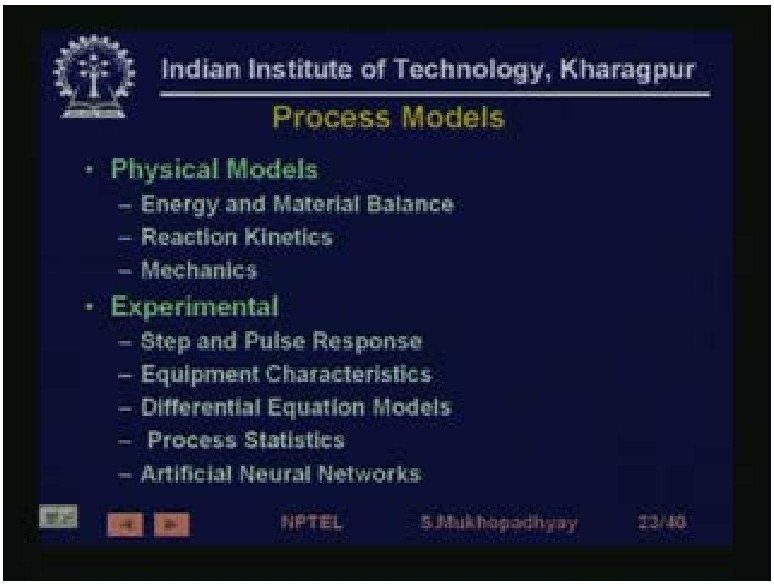

So, you can have several such ways of monitoring the process signals, so you have continuously look at that process signal which are acquiring and then using various kinds of physical models or various kinds of experimental models which were mathematical models. You can do computation, which can tell you whether the behavior of the process is as expected in terms of performance.

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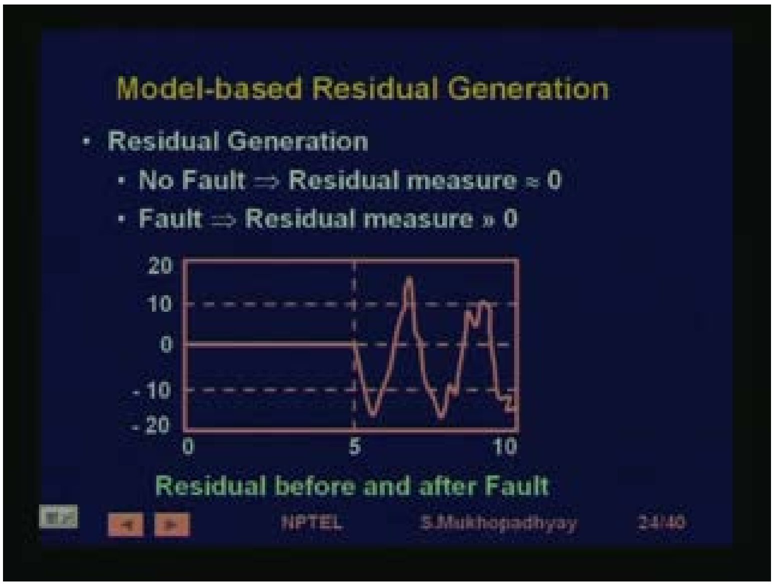

So, I will skip this little bit, this says that the residual signal model base residual should be calculated such that when these no fault, then the residual going to be very small. The moment there will be a failure this residual will grow up and so looking at the residual you can determine whether there is a failure in the plant.

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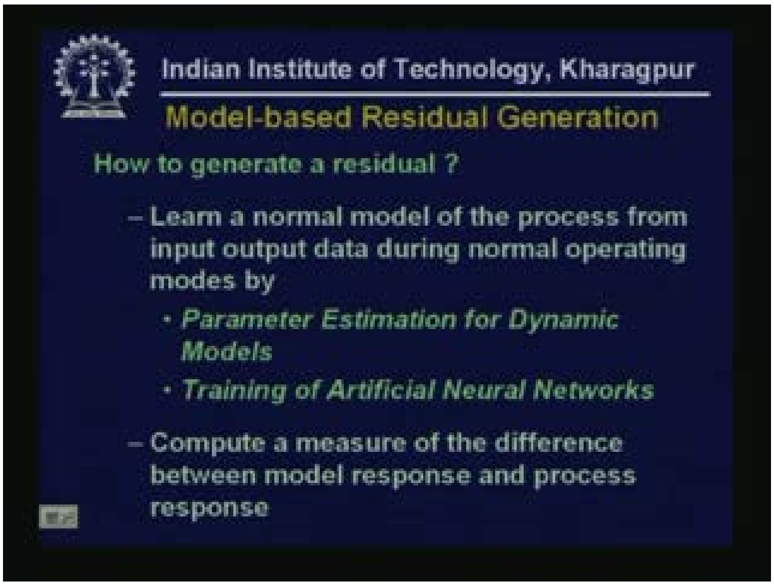

So, residuals can be generated by various kinds of signal processing algorithms, so we do not have to discuss them.

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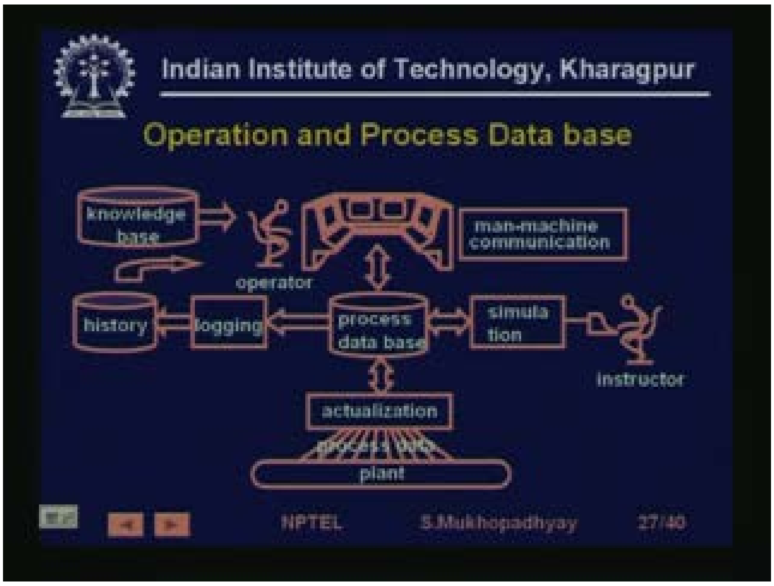

Those will skip this and before, I leave this level two we were discussing level 2 and I like to say that all these both optimization of set points as well as process monitoring require a lot of knowledge. So, you have to have good process data bases and you also have a good knowledge base, so that you can actually perform this computation. So, this operation and process data bases are very, very, very important components of supervisory control.

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Now, you come to level three automation, basic functions are material and production tracking, so how the production is actually taking place with respect to a certain order. Material handling and production procedure, how the material will actually move from one machine to another machine, what will be the sequence first milling, then turning then boring or what. So, the actual production procedures, then resource management an allocation, how many machines you have, which how many you are going to allocate to what batches and what orders.

Production dispatching for, so finally when you determine them, then finally dispatching these to the lower level for actual production data collection and quality assurance. So, assure that from the data that you have got from the supervisory control level as well as from I mean quality shop ensure that you have you are meeting quality standards which have which have required. And finally, overall performance analysis the plant or it is in terms material consumption energy consumption costs pursued costs etcetera. So, all these are typically done at the manufacturing automation levels document management.

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Document management is very important part of modern standards. So, for all these things showed all these doing all these you have manufacturing execution system which have computer system which let you do all that. So, basically this is exactly, what is being said that the manufacturing automation system this I also said earlier that the manufacturing automation system actually sits between the business system and the shop floor automation. So, it takes the business system requirements and targets, and then generates in turn generates the targets which can be then sent over to the shop floor automation system which is going to actually meet those targets in terms of volume and quality, and you know efficiency of production.

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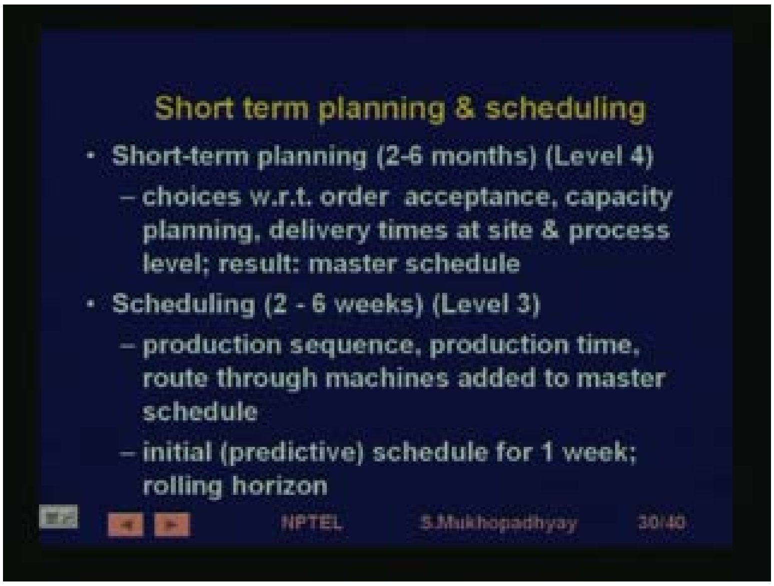

And that, process is actually basically short term planning and scheduling, so in short term plan planning, you planning is something which you do in the business system typically that is in level 4. And so you make choices with respect to order acceptance capacity planning delivery times at sites etcetera. And then you take this short term plans and then you further augment them with actual production sequences production times root through the machines etcetera and then you also elaborate them kind of week by week day by day. So, you have much more detailed schedule. So, these are the differences between basically scheduling is also planning, but over an longer horizon and with respect to the equipment which you are going to the deploy.

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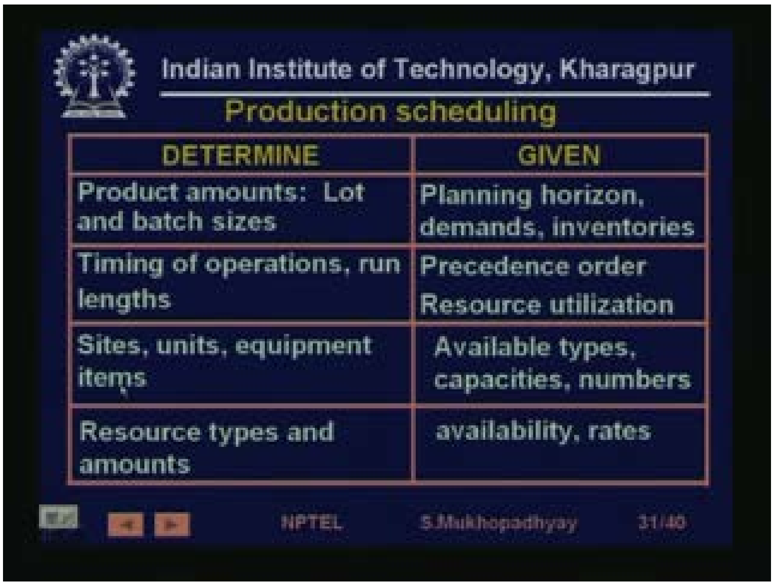

So, typically this is production scheduling, so you want to determine production amounts; that means, lots and batch sizes and you are given the planning horizon and the demands and inventories. So, how much is going to be required, how much you can stored over what time you should plan if you are given these, then you product you plan the lot and batch sizes. You can plan timings and operation the run lengths that is each set of batches how you are going to run them and that you need that you can actually determine if the precedence order in which the machining has to be done and the resource utilization. So, similarly you can determine this how you are going to at which sites you are going to produce this using which unit which equipment items etcetera. So, this is what you essentially do, in production scheduling.

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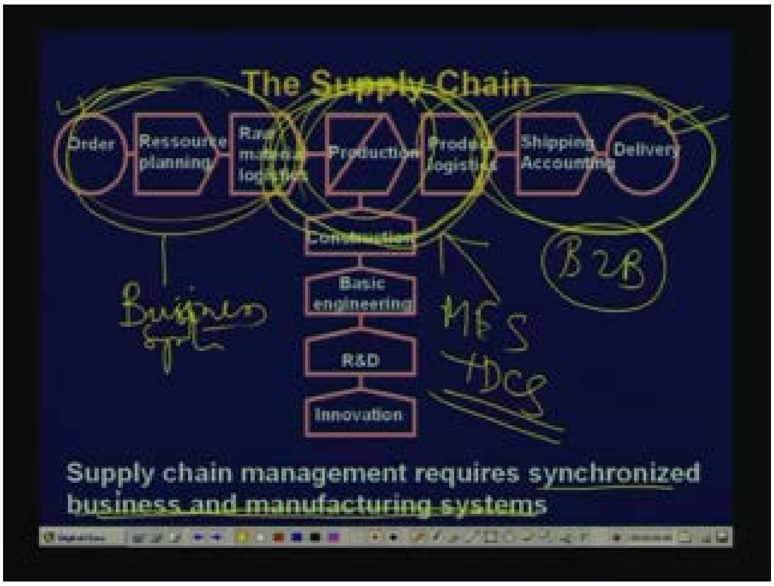

Now, it you take a finally, we have we are going to take we have to take a when we go to higher you have take an integrated view of the business and that is sometimes modeled as a supply chain. So, you have on the one hand you have the orders and based on the orders you have to do resources planning and you have to actually make your raw material logistics that is how you are going to procure the materials that you are going to transform to fine finished products.

Similarly, you have to create the facility for production, which can come from R and D basic engineering and then construction, so you have to do capacity planning you have to do actually manufacturing resources you have to put together. So, once you bring the raw material and the manufacturing resources, then you can actually do production, here you can do production.

So, this is the place why you do production and then you have to your finally, it has to start with the order and it has to end with the delivery and all these DCA supervisory control actual work in only this part. There is these parts are still managed by the enterprise or the business systems which take the product and finally, I mean ensure that the order to delivery sequence actually takes place.

So, this is an; obviously, if you manage want to manage the whole supply chain, then it requires actually basic coordination between these system which are sometimes call business systems. And, these are the MES and the DCS, manufacturing execution system and the distribution control systems distributed control systems and these are the B 2 B systems. So, these system; obviously, require synchronized business and manufacturing systems, so this is essence of feed that they have to be synchronize and they have to be integrated for ultimate coordination.

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So, that is why you need to; so as we have told we do not need to elaborate this that. So, the enterprise level system typically decides on the business part long term planning finance human resource and sets production goals capacity plans etcetera.

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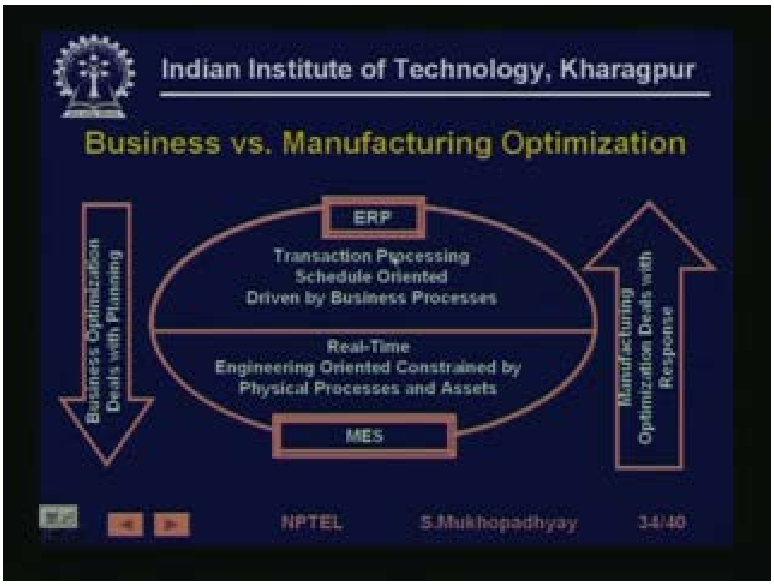

So, basically they all they are also trying to do optimization, they are also trying to do planning. So, at that level you do, what is known as enterprise resource planning and then these enterprise resource plans have to be finally, taken up by the manufacturing execution plan and then actually if they have to optimize them.

So, that you get the response, so the ERP system actually says that, what can of response is desired and the manufacturing execution system creates plans for lower level system such that such response can be generated. So, then need to obviously be very integrated.

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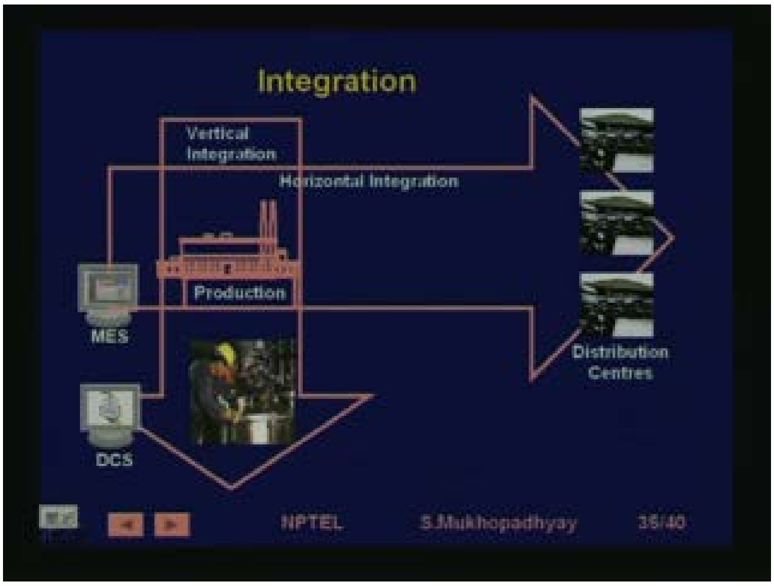

As a integration can actually be in both directions, that is there can be vertical integration right from the enterprise systems, down to the automatic I mean supervisory control automatic control. So, that vertical integration down to the machine that actually produces it and they also required horizontal integration in the sense that you need to integrate your activities over different sites between warehouses factories, so that is special integration at that is that is called horizontal integration.

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So, you need integration on both sides, we will skip these because you are running out of time. So finally, I would like to common that for making all that happen you need actually a lot of intelligent automation and therefore, you need a lot of deployment of industrial technologies.

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Finally lessons review. So, in this lessons we have talked about the basically the in brief we have tried to scan the three levels; level 2, level 3, and level 4 automation.

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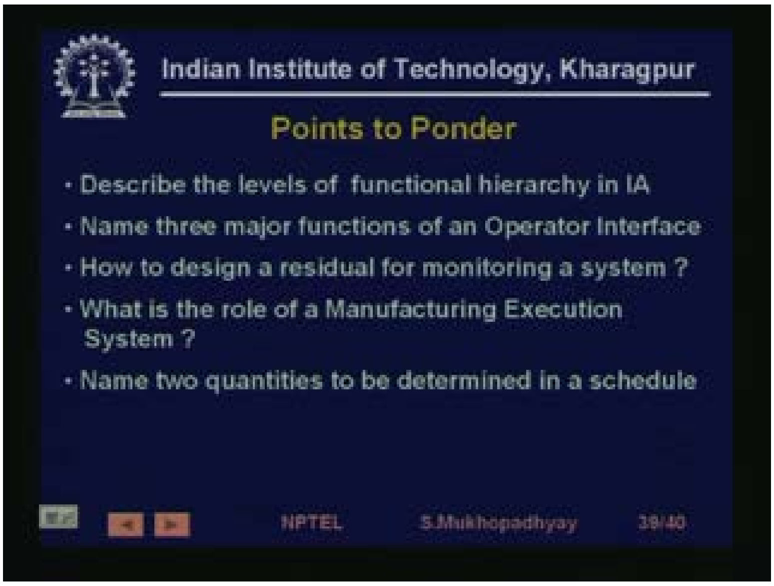

And finally, you have some points to ponder you can describe the levels of functional hierarchy name three major functions these basically describe how to generate residuals etcetera, so that is all for today.

Thank you very much.