INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

By Prof. S. Mukhopadhyay
Department of Electrical Engineering
IIT Kharagpur

Topic Lecture – 52
Course Review and Conclusion

Welcome to lesson number 40 the last lesson of this course. So we have come to the end of the journey and it is time to recollect the places that we had seen. So in the last lesson we will take a quick review of the codes all the lessons that you have taken and finally we will make some concluding comments.

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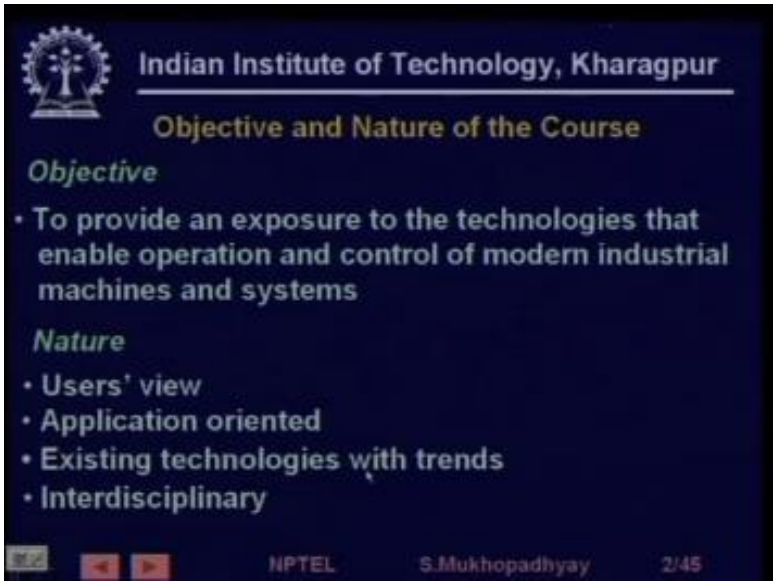

So let us recall the objective and nature of the course as we had stated it in lesson number 1. So the objective is to provide an exposure to the technologies that enable operation and control of modern industrial machines and systems. So in short I wanted it, so that if you go and visit a factory which produces something discrete manufacturing processes, steel plant, auto factory, you should be able to recognize much of the equipment and systems that you see and also be able to make out how they work right.

So that was the basic objective so as we stated in lesson number one that this is essentially a user's view, so you, we for a large body of technologies which are used in for automation in various types of industries we want to understand basically how they work and help in producing things rather than, you know contrasted to users view is the designers view. So we do not want to this is, this course is meant to be so in depth that you can start designing some of that equipment that would be an order of magnitude enhancement of depth and we have not attempted that here.

We said that we will keep it application oriented so whenever we, you know talk about a technology we will try to make it always talking in the context of its use, so how that does that help. We will mainly talk about existing technologies not very cutting-edge technologies but sometimes we will also try to capture the trends that are happening in industrial automation. And we said that this is going to be ending interdisciplinary kind of course in the sense that a lot of people although this is predominantly electrical in the sense that lot of the depth or the exposure that is expected in the electrical discipline is more than in the other disciplines.

But I guess still industrial automation technology is necessarily interdisciplinary and therefore of interdisciplinary interests. So it should, it will always be, you know it should be possible for somebody from mechanical or chemical to go through this course maybe with a little bit of extra effort in building up the background in some of the electrical parts. So that was the idea of the course that to provide a view towards the breadth of automation technology is used in to the variety of factories and to try to understand the basic operational issues in that. And that was in lesson one, and so that was a major objective of the course.

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Then in lesson one we you know we started the course in a very general note and try to define industrial automation. So we try to motivate, we try to basically see how, you know if we see that automation is I mean an industry is a systemic economic activity. So and its primary objective is to make profit then we try to find out how automation helps in making profit. And then we found that we introduced the concept of economy of scale and scope that, you know in and showed that in both respects automation helps.

We looked at the various types of production systems the various types of factories batch processes, continuous processes, job shops, various kinds and finally we categorize the classes of automation system fixed automation, flexible automation, integrated automation. So and try to discuss that which kind of automation is actually good for what kind of factories.

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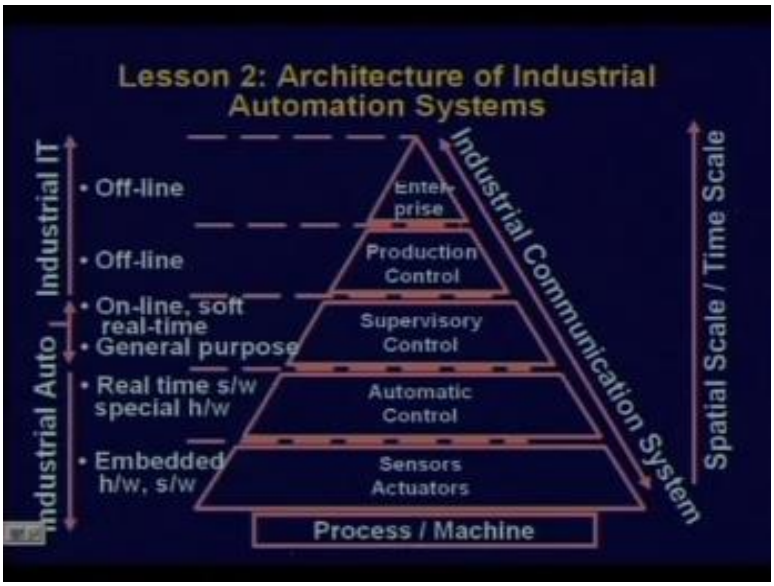

So and then we in the next lesson we took a look at the architecture of industrial automation systems and we introduced the automation pyramid and the levels of automation. So we talked about the levels 0 of sensors and actuators then level 1 of automatic control of various protections, alarms, then supervisory control, process monitoring, set point optimization, then production control scheduling, maintenance, management, inventory, then finally enterprise control where we basically finance, business, HID marketing.

And we said that all these for today's modern efficient factories all these have to be integrated and they must continuously exchange information from the field and decisions from the various parts in both ways right. And this must be enabled by some sort of an industrial communication system. So we also said at this point of time that in this course we are going to mainly concentrate on level 0 and 1.

And we said that is primarily industrial automation and the higher layers are more in the realm of industrial information technology and we are not going to cover that in this course.

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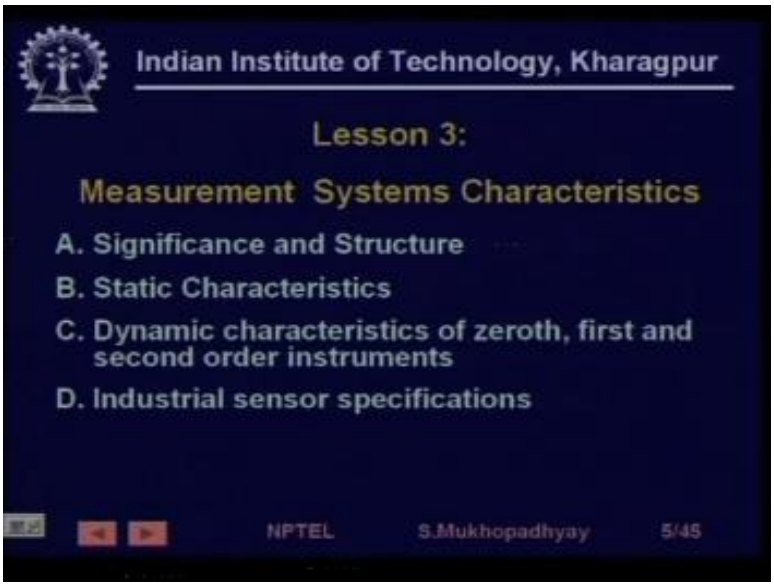

So we started with level 0 and we first talked about the sensing system. So we first took an abstract view of a measurement systems and found what are the typical structures, what are their typical static characteristics and dynamic characteristics by which you can describe the performance of any abstract instrument. We also looked at some, you know typical sensor specifications of industrial sensors then having done that having taken a look at an abstract sensor.

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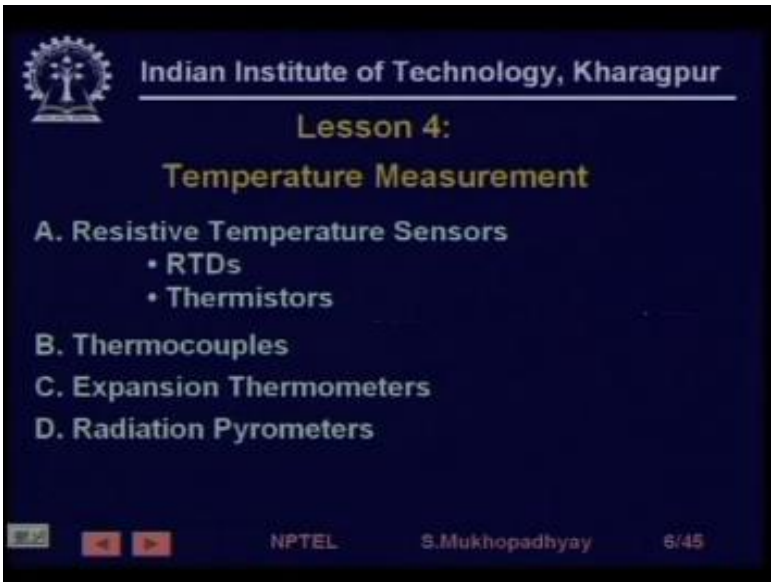

We started taking look at the exact I mean the individual sensors for the typical process variables which are measured and which are, you know controlled in an industrial environment like temperature. So we talked about various kinds of temperature sensors and of course, they are, you know signal processing circuits we talked about pressure force and torque sensors. So low pressure, high pressure, force measurement, strain gauges, torque measurement.

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And then we talked about position velocity and acceleration sensing, you know position velocity and acceleration, position velocity sensing is very important for manufacturing because, you know from the point of view of manufacturing accuracies. So we talked about position sensing for example, speed control is actually a very, very important function. So position and velocity sensing so we talked about position sensing various techniques, resistive inductive, capacitive.

Velocity sensing various electromagnetic sensing or optical sensing techniques, as well as acceleration sensing.

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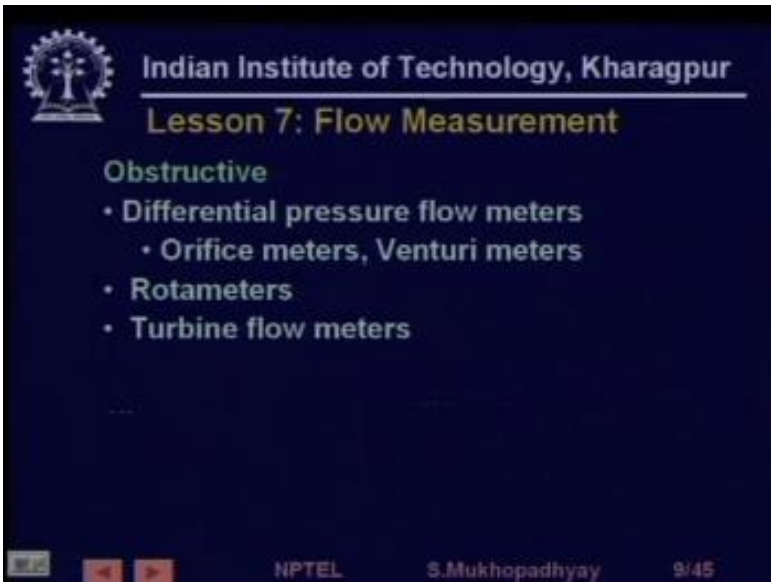

Then we took a look at flow measurement, flow measurement is, you know very one of the most widely measured and controlled variable in especially in process industries flow because as you have said that, you know for temperature control you have to do flow control for example, steam flow control, for a level control you obviously have to do flow control because level is nothing but flow integrated.

So for pressure control you also have to do flow control because pressure is also, you know in away flow integrated. And then flow control is obviously flow control, so the major variables pressure level flow temperature all these in many cases come back to flow control and flow control implies flow sensing. So flow measurement is actually a very important component of process control. So we talked about various, the obstructive methods of measurement including you know. –

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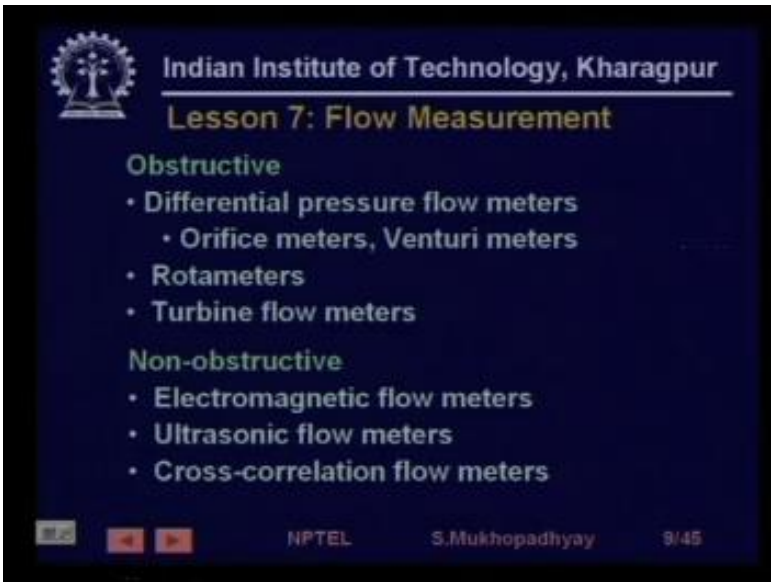

Differential pressure flow meters like orifice and venture, rotor meters, turbine flow meters we also talked about non-obstructive methods the electromagnetic flow meter ultrasonic flow meters cross-correlation flow meters and things like that.

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After flow measurement we took a look at signal conditioning the signal conditioning today is electronics is giving us this feature the signal conditioning is very important and there are some typical you know for instrumentation there are some typical signal conditioners which are used with large type of large number of sensors so we talked about deflection bridges both resistive capacitive then various types of amplifiers you know voltage amplifiers current amplifiers voltage controlled current amplifiers charge amplifiers.

So we took a look took looks at varied kind of amplifiers then filtered filters are very important for you know removing noise so filters active and passive filters then phase sensitive demodulation demodulators I mean many cases the raw signal out of the sensor comes in a modulated fashion for example LVD or strain gauge bridges so it what needs to extract or demodulate the actual process variable that one is interested in so that requires the phase sensitive demodulator circuit so we reduce that. Then various other kinds of circuits like sample-and-hold multipliers and multiplexers we talked about.

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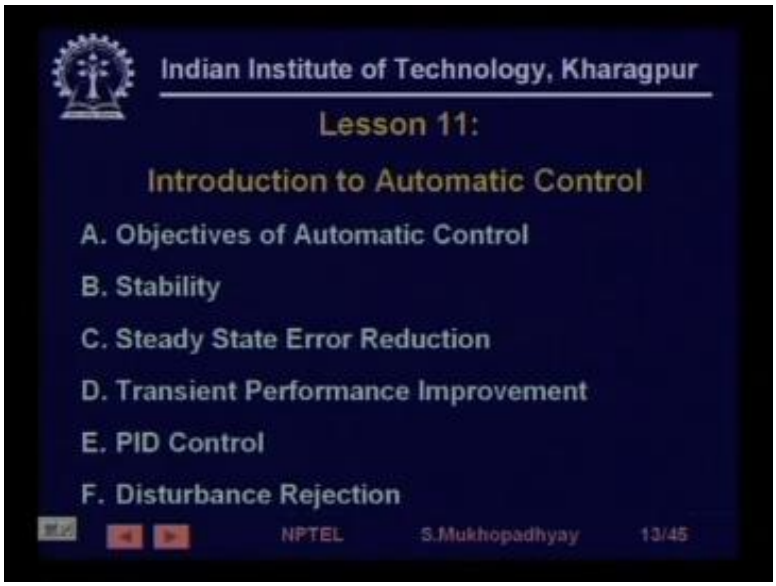

Then we took a look at measurement noise and errors you know measurement noise and errors are as so how does noise get coupled to a sensor as we have seen as you will see that noise is actually very important because noise reduces measurement accuracy it also creates problems when a sensory that is giving feedback to a to a process control loop so if there is noise in the sensor then as you have seen that the whole process control loop will start oscillating noise can also give you noise and errors can also give you other kinds of example quality control problems.

They can give you dimension errors so there we need to understand how noise gets coupled in circuits and some of the techniques and precautions to be taken and then still we have to live with noise and we have to characterize it so we have to know that the performance that that we are getting out of our measurement systems to what extent it is certain and to what extent it is uncertain.

So we need to know characterize we need to build a model of measurement errors so that we can specify our the quality of our products so this is so we talked about measurement errors and then we talked about that each individual you know typically a system consists of subsystems so even measurement systems have various subsystems so there can be a primary sensor there can be a

secondary sensor then there are signal conditioner than a signal processor now each of them have their individual noise characteristics so these noises are generated and they get propagated through the system.

And so we also discuss that if noise is propagated how does it how does a fine how does it affect the final readings of the instrument finally in today's automated environments the sensors are typically connected to the data acquisition systems which are connected to the computers so that you know these process variables which are the which is the final reality in the field and which is the real story about the production process.

So that we can one can measure it sense it analyze it monitor it control it so all that is should a done by computers so one of the first things is to get these process level signals into the computer and that is done through data acquisition systems so we took a look at the architecture of data acquisition system what they are made of and how they you know get the data into the computer.

So we started with sampling then we talked about analog to digital conversion and finally we talked about the interface with the computer and the software which let us a human being or a computer program see the data analyze the data for control purposes this come this has completed so you see that we started with an abstract measurement system then we took looks at some specific you know the major process variables of measurement then we took a look at the typical signal processing circuits that are used for instrumentation and measurement then we took at look at the noises and the uncertainties and the measurement errors and finally we took at to look at the data acquisition systems which gets the data into our computer.

So we have after that now the ones that a time is in the computer we need to we came to the second module of the course which is on which is on automatic control so we have come first we have covered sensing then we have come to automatic control and in automatic control the first in the beginning we you know talked about the basic purpose of control and what are the what are this typical performance issues like stability like you know steady-state errors like transient performance.

What is the goal of a controller and then we talked about the sources which you know create problems in control like you know disturbance so having understood this general concepts we first took up.

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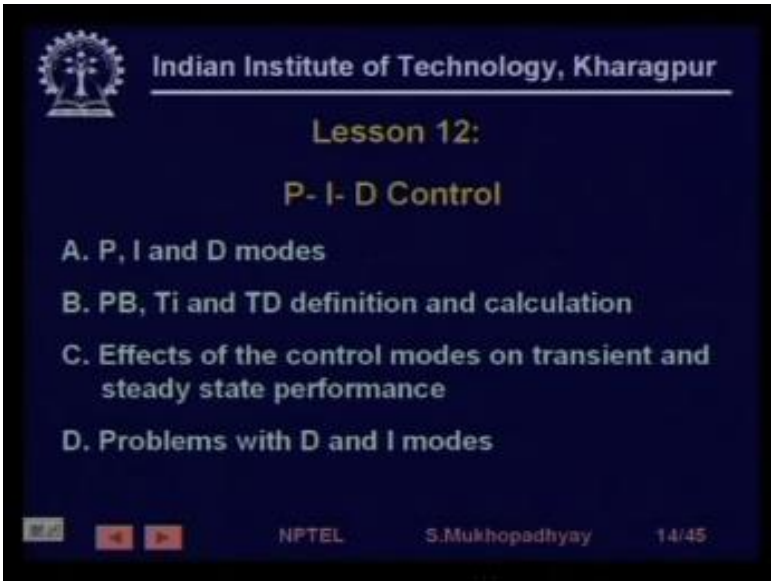

PID control which is which is he still people say that even with so much advanced controls about you know 80 to 90% of all industrial controllers a PID so it is important that that the PID controllers are looked at thoroughly so we talked about the basic PV P I and D modes then the various parameters like process proportional band integral time and derivative times the effects of these changing this these parameters on the transient performance of the plant and the steady state performance there are some problems with D and I modes and how to circumvent them.

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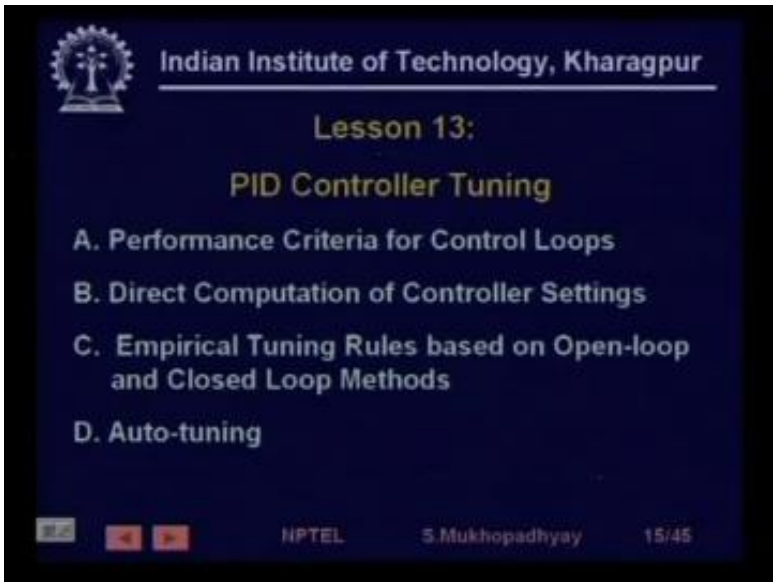

Then we talked about PID controller tuning so these gains have to be properly said that you have good response and you're because the response of the control loop is as you have said is directly related to a number of quantities like you know like mainly product quality the energy efficiency raw materials that you are consuming and things like that so it is very important to have control loops well tuned so that efficiency of production can be achieved so we looked at various methods of tuning starting from you know direct computation of an analytical computation based on models.

Then empirical tuning which are based on experimental results and finally we took a look at auto tuning so auto tuning is that the controller itself examines the input output signal and then decides and then from there it decides the best controller parameters for this process and then downloads it into the control I mean basically sets the PID controller parameter as those values so we out human intervention and we describe the method using you know relay control systems. So after PID controller tuning.

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We took a look at various different control structures which give great advantages in certain system in a very common industrial situations in control like we started with feed-forward and ratio control feed forward control is typically can give you very good performance in the face of disturbance if disturbances is measurable we also look at ratio control which is a kind of feed forward control.

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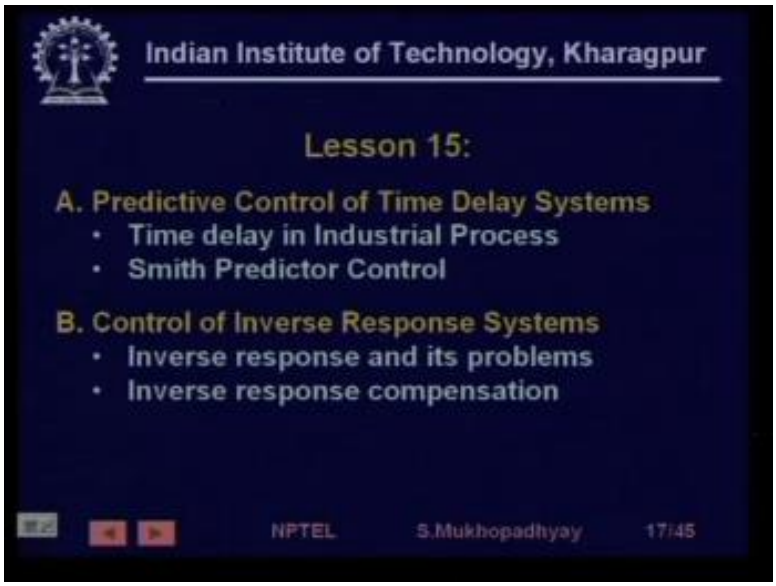

Then we took a look at typical techniques to control process time delays which are which are very common because of you know material flow times etc… in process systems and also non minimum phase systems where which are also some not uncommon and for example in a Drama level control so in such situations some special control structures are actually required for effective control of the process so we looked at these two particular kinds of processes namely time delay Systems and inverse response processes and then found introduced some particular control structures which are used for controlling this.

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Then we looked at some special control structures which use multiple sensors that is multiple measurements in a loop or multiple actuation points. So in particular first we looked at cascade control and explained that how it can give you much improved performance than in non cascade control if some intermediate variables can be measured, similarly we took a look at selective control selective control to the control where you know you typically used for controlling spatially distributed equipment something like you know boilers.

Or furnaces, similarly multi actuator control where the same there is only one variable being controlled but that may be controlled using several actuators. So typical case will be let us say HVAC control that is heating ventilation air conditioning control where the same room temperature is controlled but when it is below ambient it is controlled using a different equipment or some kind of a chiller or air conditioning. While if it is to be maintained above ambient then you use heaters.

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Similarly we can use the change control so that this is this is this is pitch range control and then we can use override control you know sometimes you operate a plant for let us say let us say I mean from time to time your plant operational policy can change so sometime you can you can operate for a maximizing production sometimes you can operate for minimizing some energy condition.

Some emergency condition or four from the point of view of safety, so there can be you know various ways of controlling. So I mean sometimes you can control using there may be two valves and you can operate either one of them sometimes so in such a case I mean the when one control policy actually at times overrides the other and then writes a different actuator but the same control variable is being controlled.

In such case we have override one true. So in other words we first looked at PID in depth and then we looked at certain very special control structures which gives significant benefit.

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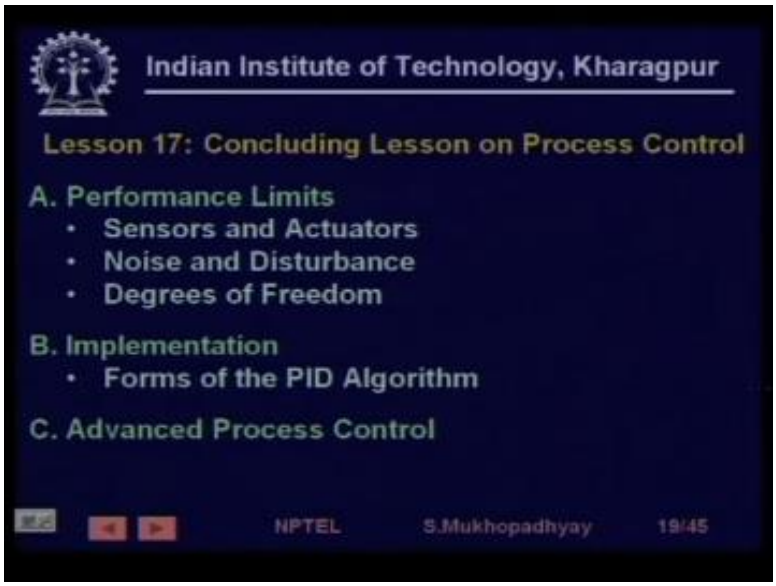

And finally we took a look at you know some the factors which limit performance typically the characteristics of sensors the characteristics of actuators in all actuators have their rate limits as well as position limits so even if you so if you think a very large input can be given to a plant it actually cannot given for actuator limitations and it is from fun it is for these reasons that the so-called theoretical responses cannot be obtained. So these constraints put a limit on the performance of the control loop.

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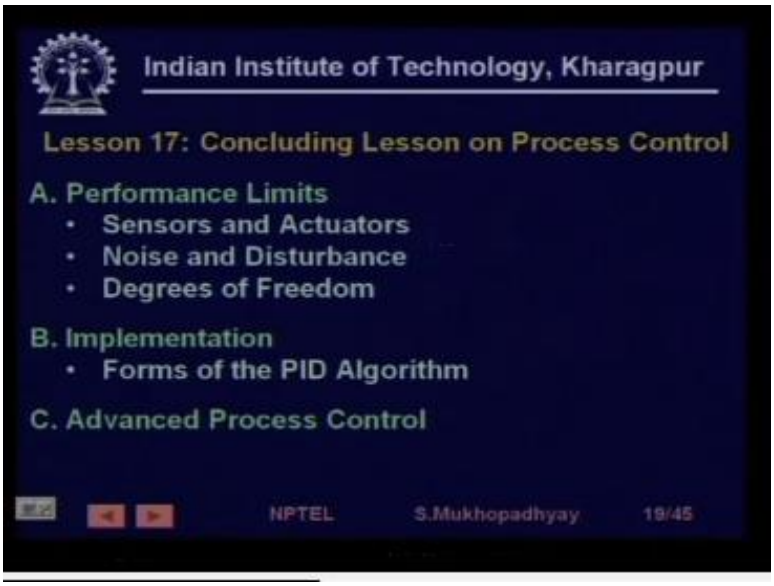

And similarly we have we have limitations on sensors and we also have limitations on the process dynamics or in other words degrees of freedom that is things are related and we cannot have we cannot all the time it is not possible to have absolutely independent control, so that is how much of independent control you can actually achieve depends on the degrees of freedom.

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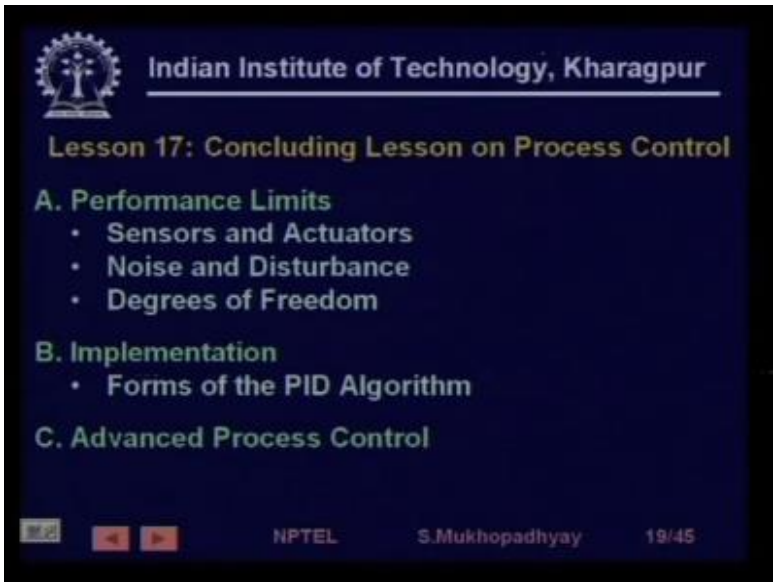

So these are some of the factors that actually limit you know control performance of industrial systems then we talked about the implementation and in specifically we talked about how the PID algorithm can be implemented in various ways and how they are practically implemented in the commercial industrial controllers and finally we talked about a little bit about advanced process control that is in fact we have not in this control module we have not talked about some of the advanced process controls that are slowly being introduced.

So for example we have not talked about model predictive control or nonlinear model predictive control you have not talked about internal model controls or others other kinds of control like state feedback controls we have not talked about decoupling so there are there are there are several topics that we have not talked about but still we talked about the major common control structures.

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Having talked in terms of the continuous controls we shifted to logic controls you are also equally important and equally prevalent in industrial manufacturing which basically control sequence of operations of machines and generate you know there they are often sometimes used for protection sometimes used for supervisory control where you know several sequences of control modes are executed.

Sometimes they are used for generating alarms as they are most more commonly used in discrete manufacturing.

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So we first took a brief look at the theory of you know any control is actually based on models so we took at take a look at some discrete event system models which and then try to introduce and captured from the you know industrial sequence control problems in terms of this experiment systems model.

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Then we introduced the programmable logic controller or the PLC it is a it is the either the class of equipment which sell in the market which carry out most of the sequence control and then we introduce the programming languages for this logic control which are used as peas in PLC's so namely the relay ladder logic.

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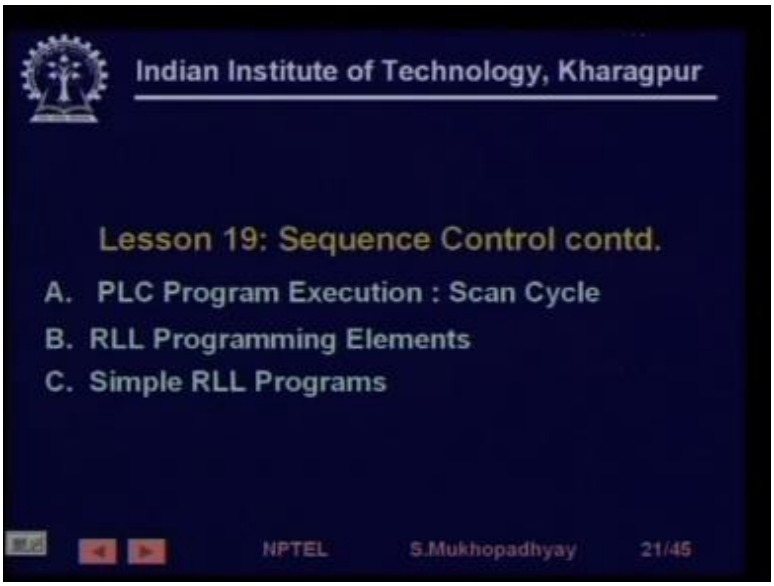

Then we explain how PLC's work how they you know how they get data compute outputs and then finally download into the field we also introduced the RL programming elements as the basic programming elements and started discussing simpler level programs.

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Then we talked about other RLL program features various kinds of statements arithmetic data move and program control operations and other some other some other Mike I mean macro operations which are basically a collection of fixed collection of elementary operations.

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Finally we introduced a systematic method by which these PLC controllers can be PLC programs can be written for some for some industrial control problems.

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So we model the process of the state machine and then based on that state machine we discussed how we can write a relay ladder logic program.

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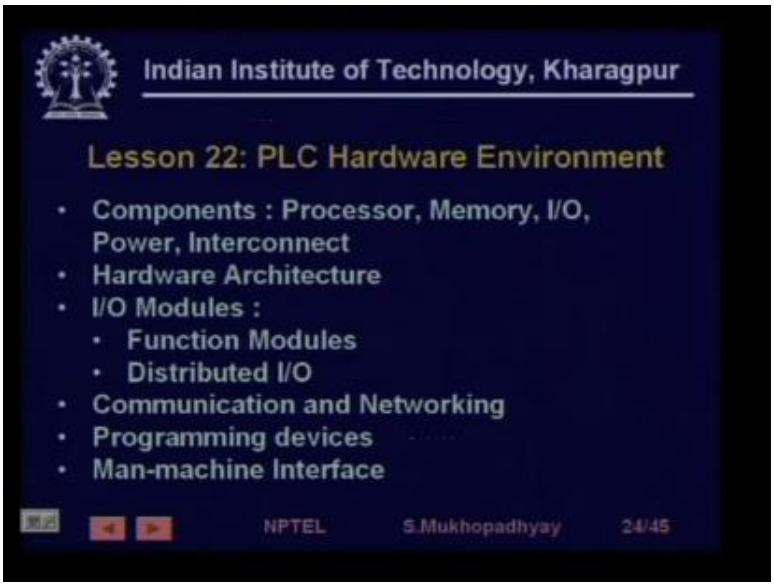

In the last lesson we talked about the PLC hardware environment the exact the kinds of processors the specifics typical specifications of processor memory I/O the buses bus extension various kinds of special purpose I/O modules like function modules distributed I/O modules various kinds of communication and networking modules like you know industrial Ethernet then the devices that are used for programming PLC’s.

Developing programs and then downloading and finally you know man-machine interfaces like which are which can be connected with PLC's.

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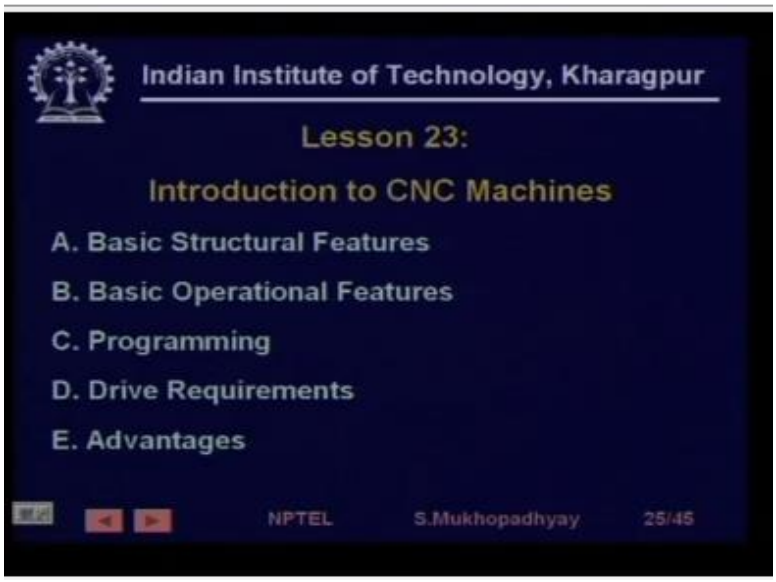

So this completes our logic control module and we come to one of the application areas namely CNC machines which are typically used for money for discrete manufacturing all over the world, so we looked at the basic structural features and the basic operational features of CNC machines and how they are their program that is how the various cutting operations can be specified so that the machine can operate by itself.

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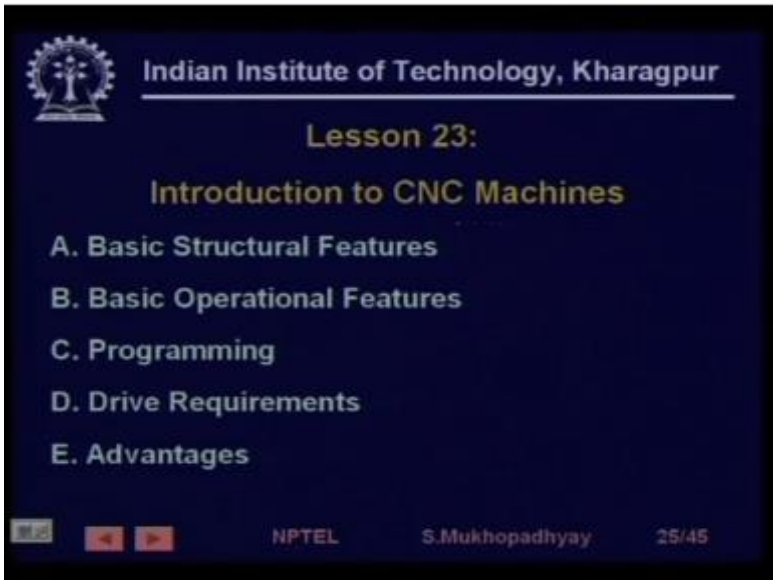

We also look at the typical kinds of you know actuation requirements for these machines and also take a look at the huge advantages that these machines can sometimes give you.

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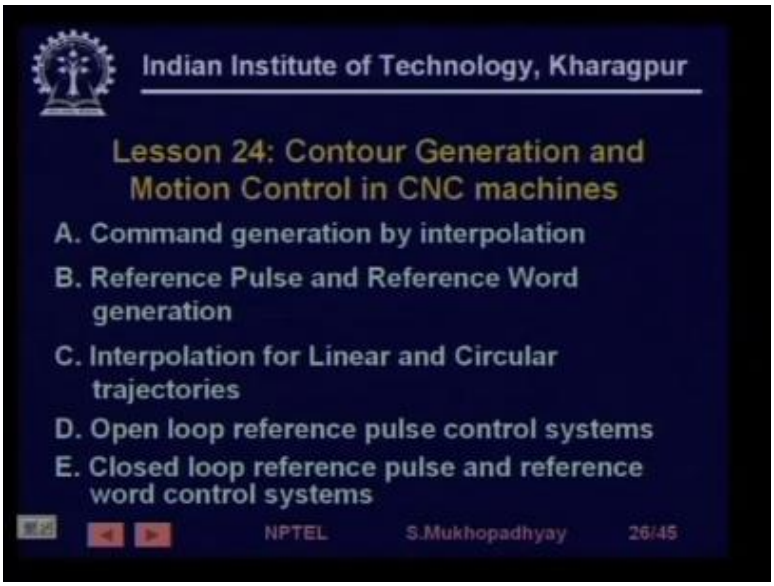

In the next lesson we took a more detailed look at how the you know in a CNC machine they are basically you have to create when you have to have when you are doing manufacturing actually removing metal by this hearing, so relative motion between the between the job and the tool has to be created.

So for that the job has to move and the tool also has to move so typically what happens is that one of these motions is rotational and the other motion is translational so in any case there are precise you know position control speed control requirements on these on these actuations or this drives so that the part dimensions are good and the part surface finishes are good so to understand how these motion commands are generated and how the motion control is actually carried out this position control in the CNC machines.

In lesson 24 we looked at various kinds of command generation strategies like by interpolation then we took basically two kinds of control system.

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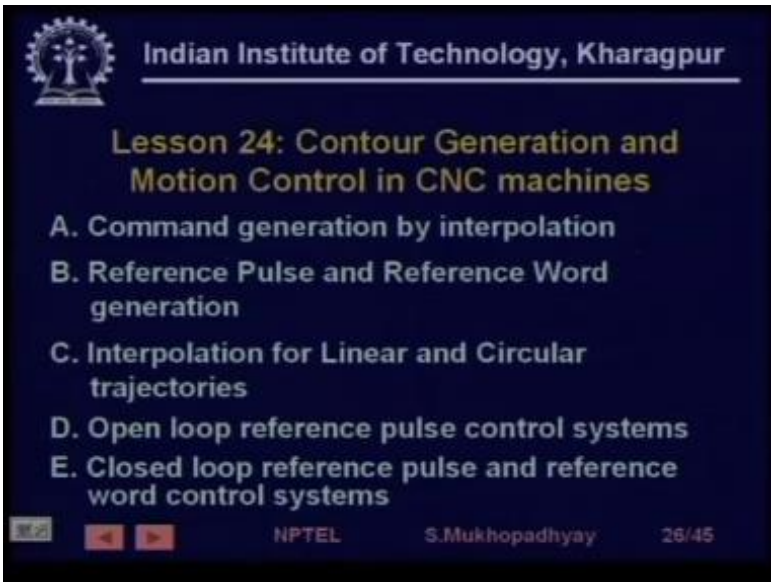

Called reference pulse and reference watts systems and how to generate them and we actually took at take a look at one open-loop reference pulse control and closed-loop reference pulse and reference word control systems so the.

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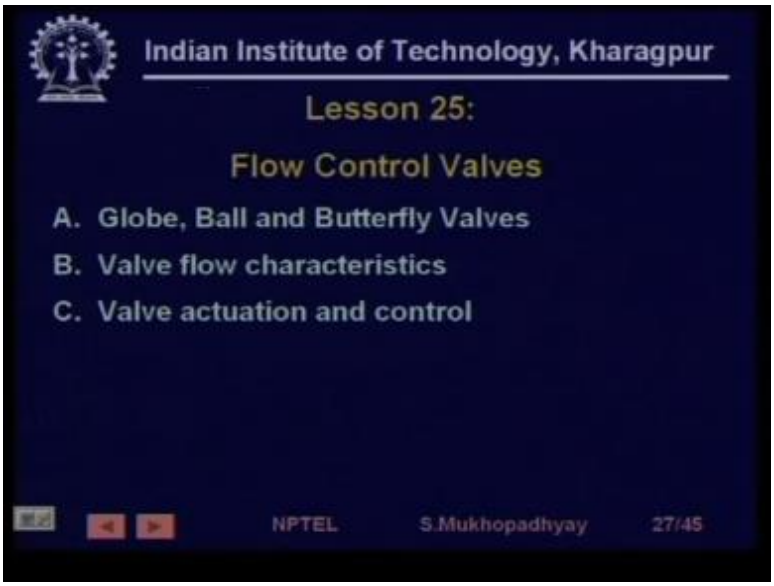

After that we took a look at flow control valve flow control valves are very, very common and important elements in factories so we looked at three major kinds of Valve's globe ball.

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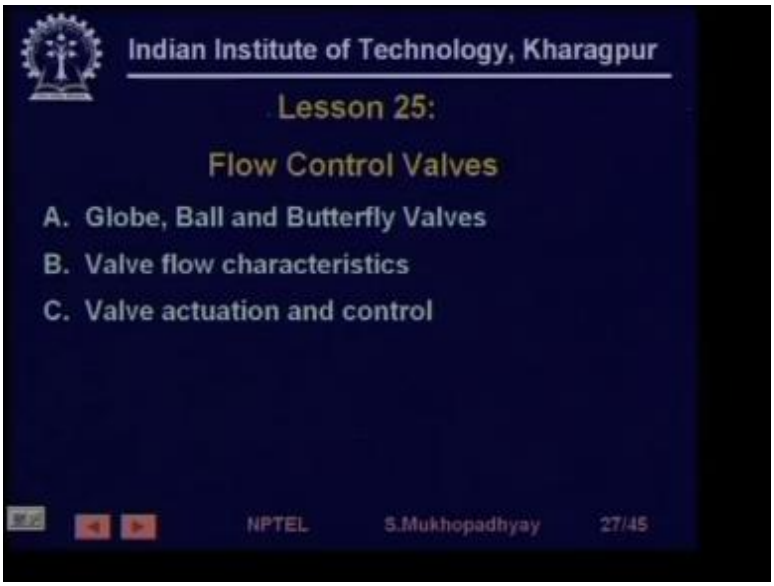

One butterfly valves and we took a look at the flow characteristics their constructions and how the valves are moved and how the valves are moved precisely for example we took a look at you know valve positioner and what advantage these this position is give you after flow control valves we took started taking a look at hydraulics and pneumatics so first we took a look a hydraulics where we understood the basic principles Pascal's law then major hydraulic system components and then we took look you can look at the components one by one that is we took a look at pumps and the motors.

We took a look at the hydraulic valves both you know Direction control valves as well as servo valves and then we finally look at the final actuated control element or hydraulic cylinders.

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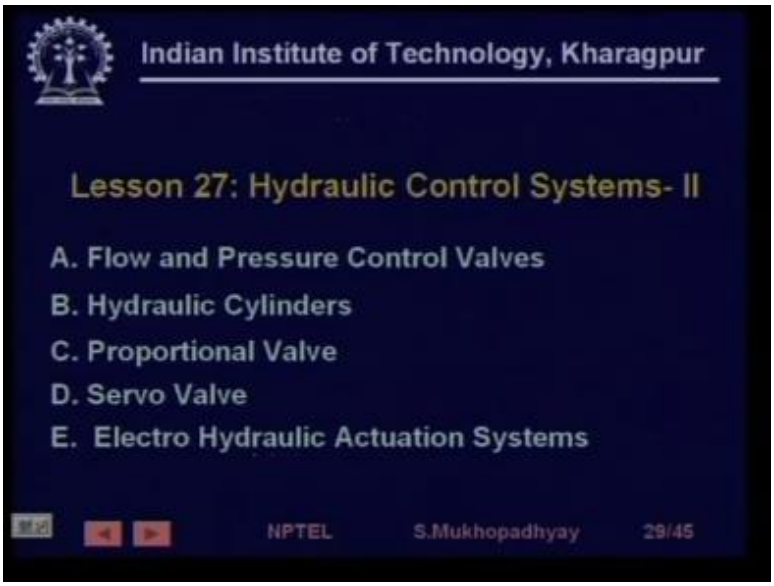

Then in the next lesson week actually continued this and we took a look at flow and pressure control valves and previous really we mainly took a look at direction control valves now we took flow and pressure control valves hydraulic cylinders then two kinds of valves which are used very much in controls that is an analog flow control so they are the proportional valve and the servo valve so and then finally we took a look at an electro hydraulic actuation system.

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In lesson 28 we took a look at various typical industrial hydraulic circuits and so how these techniques can be applied for industrial purposes.

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Then we came to pneumatics is very similar to hydraulics but there are slight differences so we took a look at system components again compressors pneumatic valves and their accessories.

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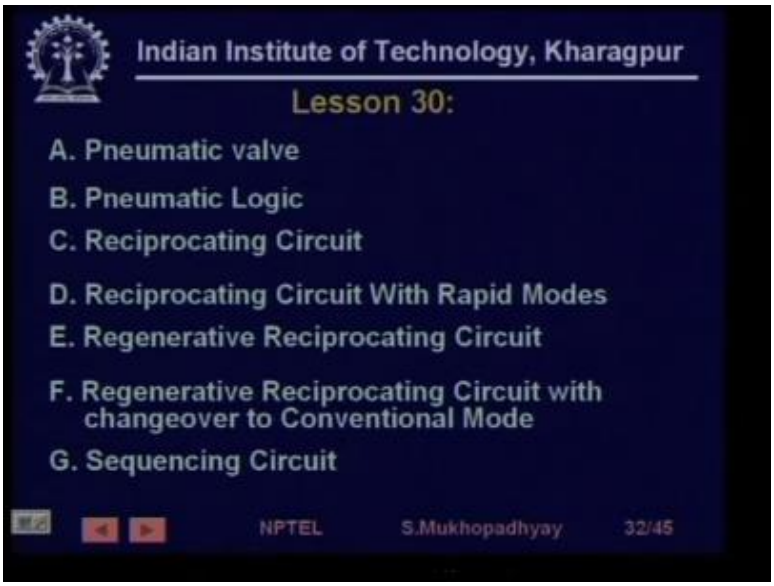

And finally we took at look took a look at pneumatic logic various kinds of reciprocating and then various kinds of typical pneumatic circuits like reciprocating circuits reciprocating circuits with rapid retracts reciprocating circuits with regeneration so that you know the pressure energy is not wasted and then various kinds of sequencing circuits after that.

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We took a look at electric actuators but before taking a look at electric actuators we first understood that why it is a definite trend in the among the industrial control or drives that people are going for variable speed drives now variable speed drives what so what is the basic advantage of variable speed drives and showing that variable speed drives can be huge very significant energy savers so we first took a look at actually compared you know fans and pumps are the predominant devices which are driven by motors.

So we found out that if the system load has a certain amount of variation then having a variable frequency although it is capital intensive it is actually more expensive and more capitalist win has to be invested but you know this capital cost structure is actually coming down as the cost of power electronics is coming down and on the other hand the cost of energy is going up so it now really makes a lot of sense to have variable speed drives since they can save lot of energy and we so basically from a pump or fan characteristic as to how a variable speed drive can make significant saving of energy to the extent of seven sometime 50 60%.

Or 100% having convinced ourselves about the requirement for variable speed drives we took a look at first DC motor drive which is.

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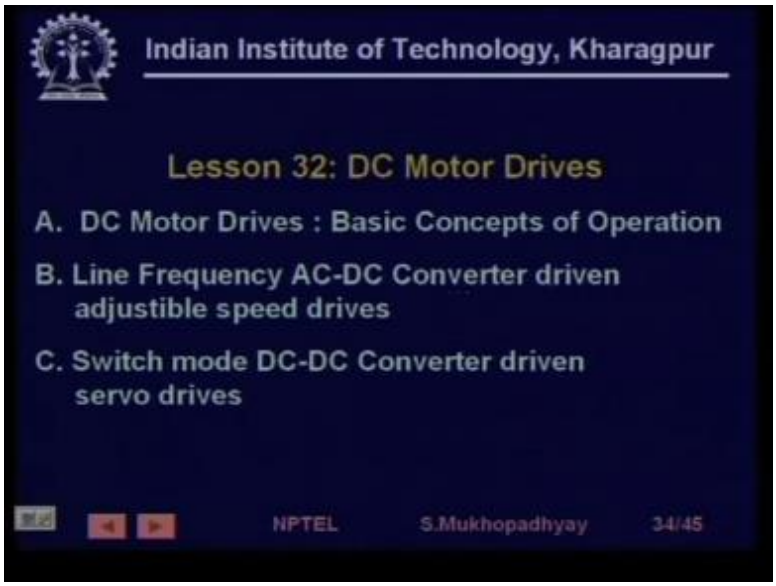

The most common and so we understood the basic concept of operation of DC motors and then we took two things to two different kinds of DC motor drives one is the line frequency AC DC converter drive there is rectifier which is used for adjustable speed drives you know adjustable speed drives are and servo drives are two different things in adjustable speed drives feed seed speed can be changed but generally the drive is operated for significant amount of time at a particular speed reference.

While in survives the speed continuously keeps changing so we the kinds of power electronic drives that you use for adjustable speed drives and servo drives are different so we took a look at two different kinds of drives one with the converter one with an rectifier AC DC.

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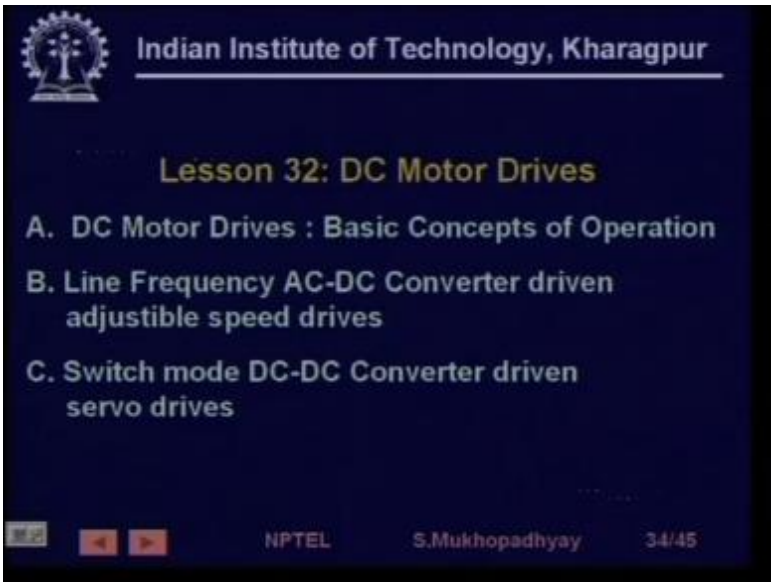

Converter and another with the DC – Dc converter.

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So we went on this is a continuation lesson number 33 of these switch mode DC- DC converters and then we also you have seen thin since these are used for BLDC drives we also took a look at brushless DC drives.

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Which are essentially AC motors then we took a look at induction motor drives and may in the case of induction motors we mainly concentrated towards the adjustable speed drives induction what is are generally not used for server types also they can be but they are much less used for servo drives generally DC and nowadays more BLDC drives are being used.

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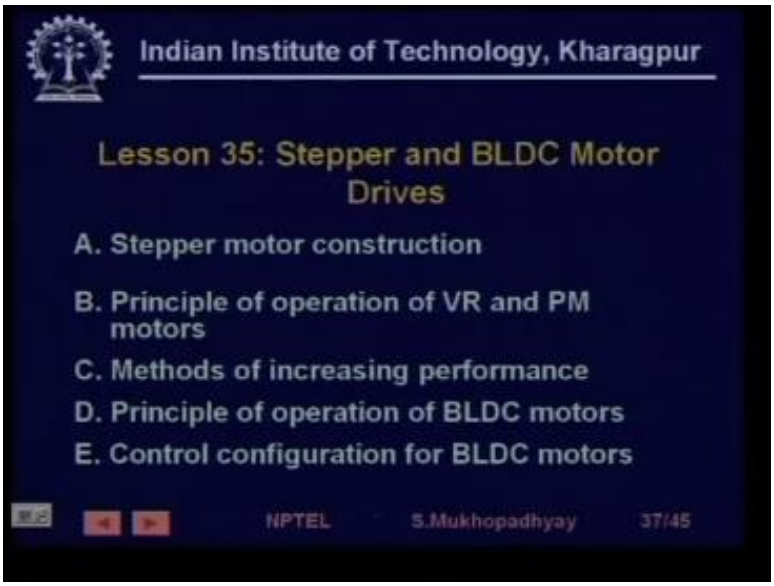

So then we look last we took a look at two kinds of motor drives one is one of stepper motors which are used for various which are very simple very simple and cheap drive electronics and are used for non critical applications and for smaller applications having smaller power ratings and then we also took it took a more detailed look at BLDC drives which are becoming very, very popular basically because of the magnet and improvements in magnet technology then we so this 0 completes actuation and then it turns out that electronics is making sig.

Very significant inroads into all areas of Technology and also into industrial automation so now what is happening is that most of the industrial automation devices like sensors actuators valves they are they have they are having electronics on the field or electron is embedded in them so they are all becoming you know microprocessor control devices which have which are which give previously I mean huge capability to these you know elect mechanical or electromechanical devices.

So now you know you can have a you can have a flow control valve which, which has electronics on it which can do all sorts of signal processing auto-calibration it can. It can send values, it can monitor his own failures, it can calibrate itself, it can even connect on a network so

all this is possible because every device is getting is having I mean computing and electronics technology embedded in them. So we thought that you know it is a good thing to take a look at the basic embedded system technology, because it is so becoming so common and all pervasive in all aspects of our life, and also industrial automation.

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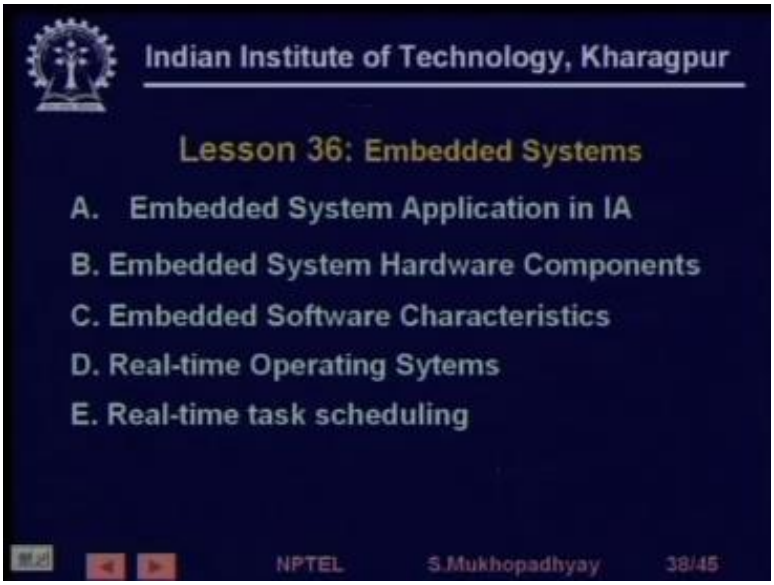

So we took a look at you know embedded system embedded systems and understood is basic hard types of hardware components and basic software characteristic the kind of software that are used in that, then we took a look at you know many of these systems are actually operate for example, a CNC machine, a CNC machine has various at least 3, 4 processor it has axis controllers it has PLCS it may also have you know front-end processors which manage the man-machine interface.

So all these if this multiprocessor complex systems generally work under you know some sort of a real-time operating system. So we took a look at real-time operating systems and their features and the one of the essences of real-time operating systems that there are several time critical tasks contain I mean which are in parallel executed in the system, so how to schedule them which one will be computed after what, whether they can be interrupted in the middle or not

under what conditions so these are one of the major aspects of real-time computing which is a feature of embedded systems used for industrial automation. So we took a look at this real-time task scheduling the basic principles of it,

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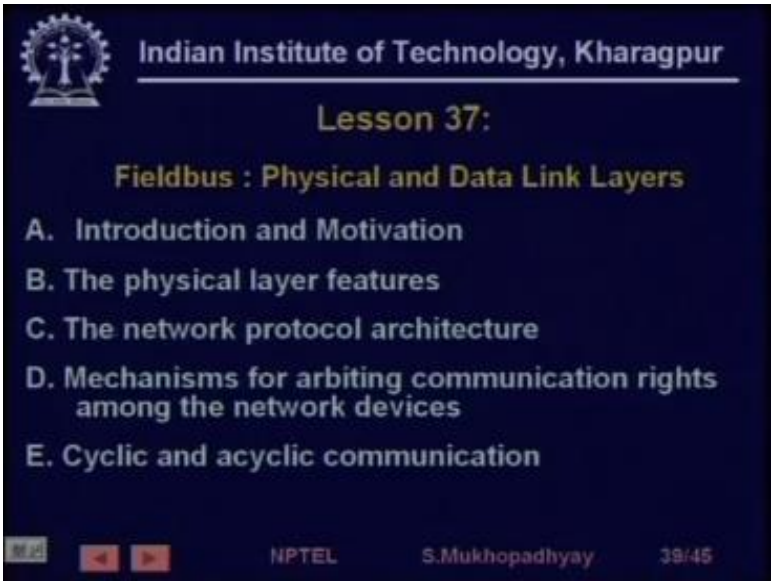

Now once you have this embedded devices with this embedded electronics and embedded processors in them then the that is I mean the whole new world of opportunity is open up. So now since you have processors on each of these devices this device should be able to communicate with each other and there is very significant benefit that can arise out of this communication I mean a much more significant coordination would be possible and you know optimization would be possible lot of data can be acquired, knowledge can be gained, operations can be always kept in a very tuned manner by you know continuous adaptation so all sorts of you know documentation can be made, so all sorts of benefits can accrue if these intelligent automation devices can be made to communicate.

So it is from this concept that now people are saying that this, these devices all should be on a network. So and one of the very emerging and very prominent network standards for the

industrial automation market is the field bus. So in the, in this lesson and the next the in lesson number 37.

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The field was protocol network protocol was looked at so it like all network protocols this is also organized in terms of you know various kinds of layers, I mean you know in a network data is the whole soft data basically goes to gets transformed here the top level you are generating information and when you are sending it down finally it is becoming 1ones and 0s, and it is at the destination those 1s and 0s are being received and they are being processed in various ways, so that finally you get back the information.

So this is actually carried out through as layers of software, so we have first talked about so we started discussing and we in this lesson we talked about the physical and the data link layer the various features and the network protocol architectures and also the mechanism of our biting communication rights, you know one of the problems of having a bus is that the bus is electrically shared and therefore people cannot I mean the devices only one device can talk at a time.

So there is a need to understand who is going to talk when, so there are elaborate rules have been formulated for that otherwise when somebody is talking or some device is transmitting data on the network if another device starts transmitting the I mean some different data on the same network then the data can be get corrupted. So we took a look at some of these models of you know are biting communication rights on the buses and taking a look at how that actually turns out for cyclic and acyclic communication.

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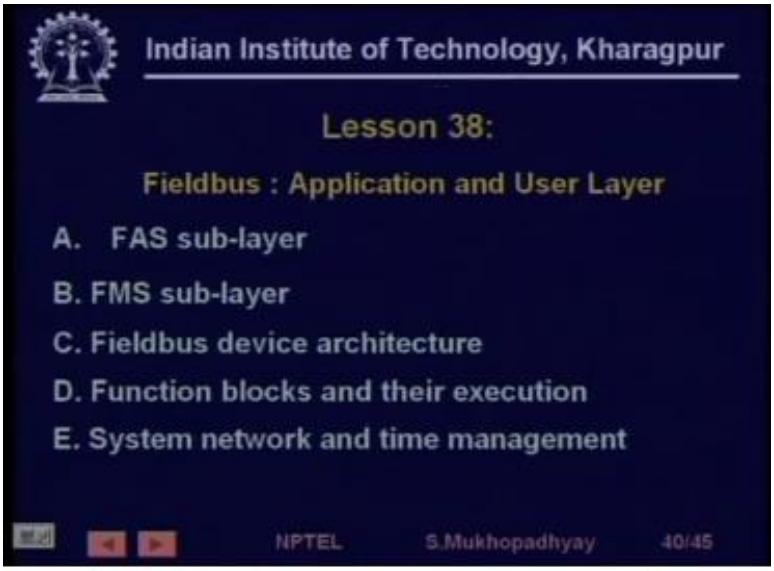

Once the basic so this you know any will ensure that the basic data packets at the low level they can get transmitted reliably from one point to the other, and then you have to talk about the application and the user layers.

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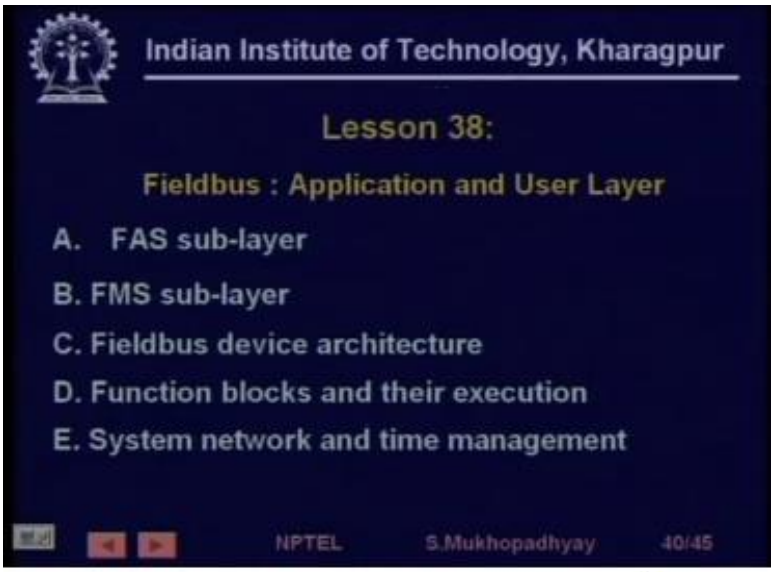

So how that is, when one device looks at another device how it comes to know that what is the how that device is made of what is it doing the interpretation of the variables that one device is sending to the other so all these issues are dealt with at the application on the user layers and we mainly discussed the function blocks which is the abstract model for any field bus device, and we also discussed the issue of you know obtaining synchronization throughout the network so doing network management and being doing time management over the network.

This more or less completes you know so if you go back you have seen that we have discussed sensors that were in the first module then we have discussed controls both analog controls as well as sequence controls and then we discussed various types of actuators, so we discussed flow control valves, we discuss hydraulics, we discuss pneumatics and we discuss electrics that is basically motor drives and we also discussed that how these can save lot of power.

So then finally we discussed the electronics which give makes them intelligent and makes them and enables communication among them. So once you have all these devices this level 1 and level 0 devices on the network, so all their data are available then it would be possible to do

system wide coordination and system wide optimization, and in fact it is precisely this which is done at the automations are at level 2 and level 3.

In absence of this electronics and communication typically this these optimizations and these co-ordinations are done at a much slower scale basically by the operator so this was operators just take looks at those values and then they operate the process. But once these data are available on the computers over the network then there are possibilities of doing much faster and much more pervasive coordination among in the factory. So actually that is what is to be done, that is what is done in the case of in level 2 and level 3 automations.

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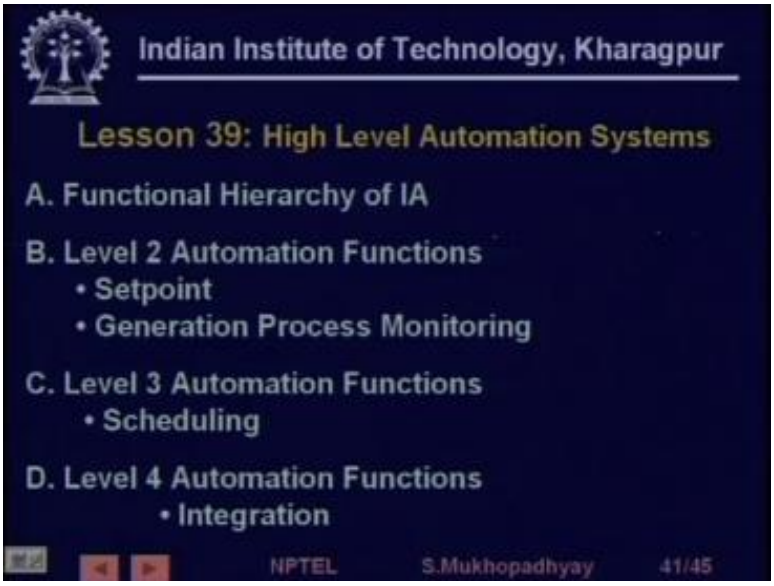

So in the last in the penultimate lesson in very in brief we actually talked about the higher layers as we said that we are not going to discuss the higher layers in great depth, because of various reasons because firstly it takes time to cover only you know level 0 and level 1 so we do not have enough time. Secondly higher layers are often very domain dependent while level 0 and level 1 technologies are domain independent and they apply to a wide variety of plants.

If you want to do if you want to know how to up to do set point optimization then you can you have to only talk about set point optimization for either a distillation column or a boiler or whatever, so they become very process specific and therefore difficult to discuss in a force.

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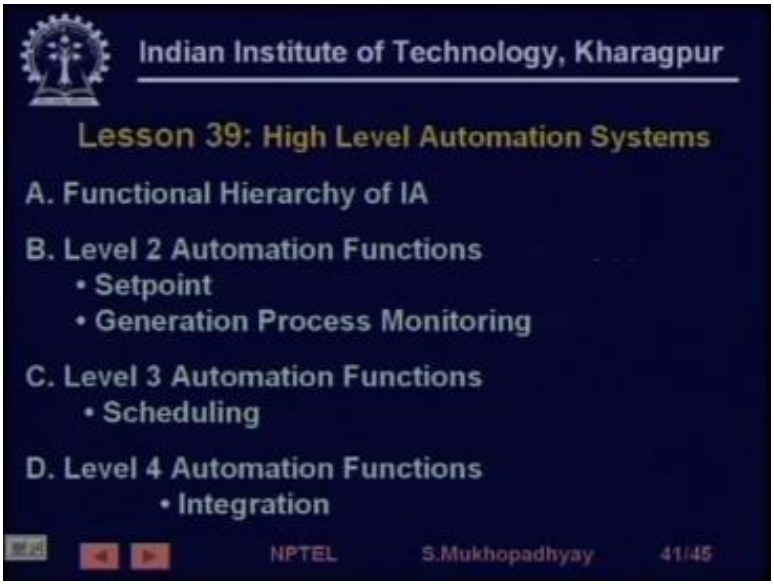

So in this lesson, in the last lesson last penultimate lesson the basic features of you know supervisory control and manufacturing management were discussed. So we talked about level 2 automation function size like that set point optimization and process monitoring so one they have they actually this is wrong it should be it should be set point generation and process monitoring this is a typo.

Then we talked about level three automation functions where we talked about basically planning scheduling and basically planning and scheduling so how the various we did not go into much depth though then on top of that we have so we have level two systems and level two systems which are still with the controls then level some bit of level two and basically level three systems are generally decide in a different type of computer and the their computing and techniques are completely different. So they are called manufacturing execution systems and then in level four we have business systems.

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Which do which employ technologies like why chain management enterprise resource planning and therefore and basically they generate long-range plans they generate market projections they actually decide how I mean how much order has to be taken what are the commitments deadlines and then they pass it on to the manufacturing execution systems which in turn then decide that with the available equipment manpower raw materials how exactly production should go so besides that all the production deadlines are made.

And then these production sequences and detailed production sequences are passed on to the supervisory controller which then actually gets about producing so this is the way it goes on so in the last lesson we discussed this higher level automation functions so that brings us to the end of this lesson.

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And so having discussed what is what has been cause covered we should also take a look at what has not been covered at least we should be aware of some of the things that we have not covered which were if you are also relevant so for example as we have said that we have mainly concentrated on level 0 and 1 so level 2and 3 have not been covered in detail that is the first thing but even in level 1 and 0 and 1 there are certain parts which could have been covered but could not be covered.

You know you have to always leave out certain things for example we did not take a take a detailed look of look at metrology or which are widely used for a quality control we did not take a look at analytical instruments which are used for process product composition testing we did not look at look in great depth on instrument standards and calibration similarly in terms of control as we said that we while we look at the PID controllers.

And some of the standard process control architectures there are some advanced controls which are coming and which are gradually becoming gradually also being applied in processes and manufacturing we did not discuss them like non linear model predictive control the PLC treatment was also kept more or less you know the standard technique that PLC of several

programming languages this so we did not discuss all of them we only discussed the relay ladder logic in detail and then the sequential function chart in some detail.

So in other words what I am trying to say is that in case somebody is interested one can one can go ahead and read other supplementary or advanced level material for knowing the latest in these fields which is which would be the which beyond what has been covered in this course.

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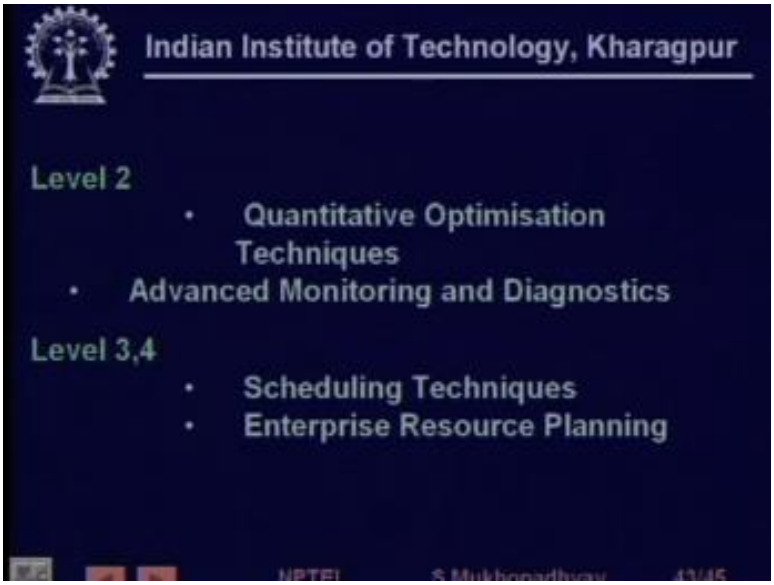

Similarly level 2 we did not discuss various kinds of quantitative optimization techniques linear non linear programming we did not discuss advanced monitoring and diagnostics techniques some of which have just started becoming being applied they are quite advanced we did not deal with you know as I said level 3 and 4 we hardly talked about it and there are very detailed scheduling and optimization techniques available with for example enterprise resource planning can be a course in itself. So having said that I would make the final concluding comments of this course.

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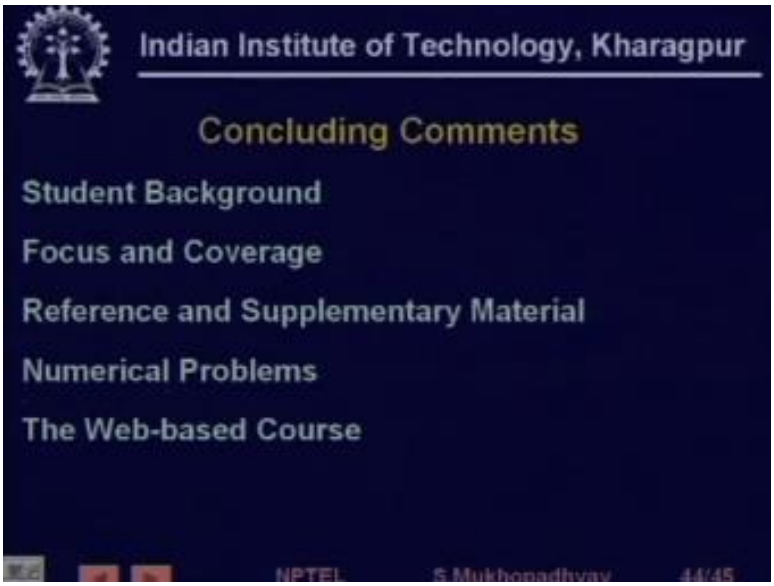

This course was thought of because such a course actually is rare you have you really have you do not have books or materials which discuss this I mean the industrial automation technology is all within one covered so that was one of the main motivating factors of having this course and this course it was also felt that can be useful for a various kinds of student backgrounds of students from engineering undergraduate students from mechanical chemical electrical etcetera. So the major focus and coverage was kept.

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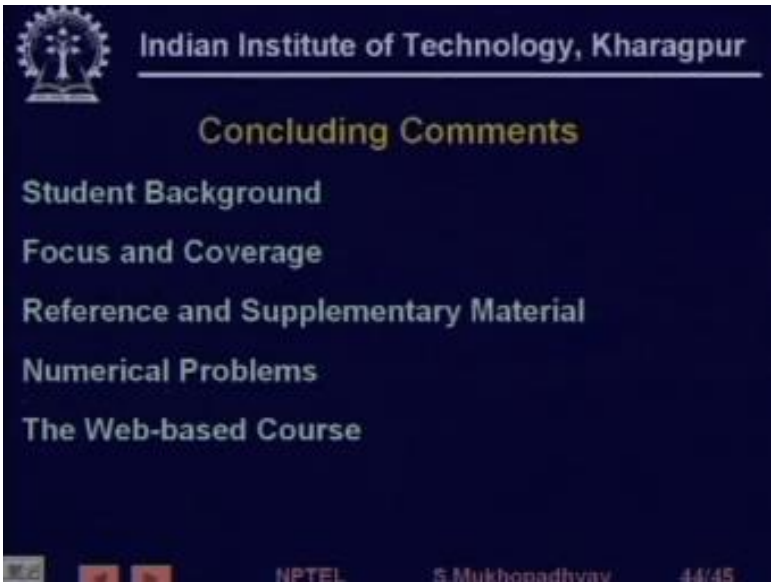

Suitable for the major focus on coverage was kept suitable for the for the under graduate levels we have just discussed what has been covered reference in supplementary materials have been used from a variety of sources several texts internet my own class notes and books so because it is simply because in fact they were but in all while have I mean we are not within the limits of this course it has not been possible to it would not have been possible to cite all of them.

So I we have left out left them out altogether but in all cases while we have I have certainly referred to various kinds of material I have tried to you know present them in my own ways so that way the presentations in many cases I mean in all cases are original we have not been able to give again because of you know short we have not been able to discuss numerical problems so in fact one has to find out numerical problems from individual modules like for example numerical problems and control can be found from process control books.

Similarly drives maybe from power electronics and raise books and things like that another thing is that under the same NPTEL program and associated web-based course has also been developed by myself and Prof. S. Sain of IIT Kharagpur.

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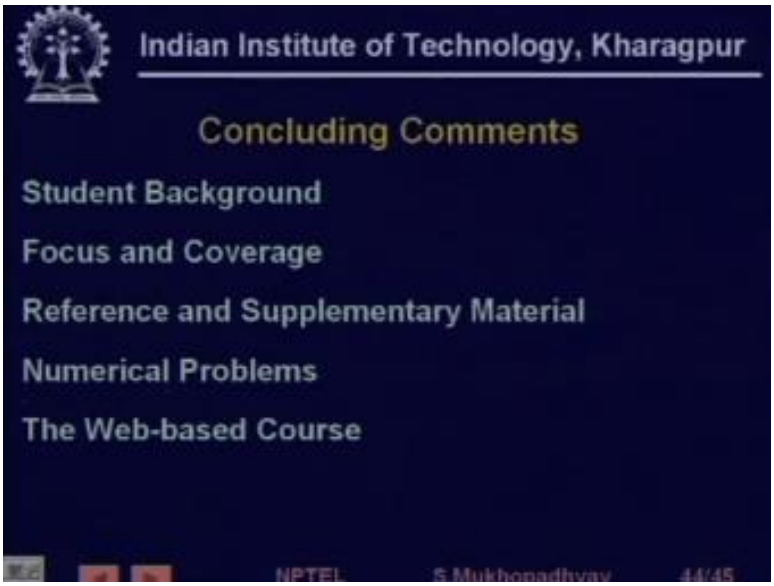

And we will be able to give some of these refer to I mean address some of these problems of numerical problems questions answers references in those web courses so that is all for today I hope this course would be useful and well yes after recording these courses I am right now teaching these courses in my own classes using the same set of slides and I have discovered a few errors.

So while in the final version some of these errors will get removed I am sure that some of them might still stay various kinds of errors I hope there are no major errors so in case there are errors and if you declare if you find them and you can inform me I will be get full but I will apologize in advance for any errors that may be present here but I always feel that you know if one can correct an error in a particular part of any learning material he probably learns that part of the material the best. So there you are this is the end of the course, thank you very much and bye, bye.