Introduction to Industry 4.0 and Industrial Internet of things

Prof. Sudip Misra
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 19
Basics of IIoT: Industrial Sensing & Actuation

In the previous lectures, we have gone through the revolution of the industries, the industrial revolution, internet revolution, and at present the industrial internet revolution that the industries are going through. Now, we have also seen that parallel industrial IoT has become very popular. And when we are talking about whether it is the industrial internet or the industrial IoT. At the core, it is about sensing and actuation.

Sensing and actuation is very important and then comes issues of connectivity, communication, analytics, and so on. So, there are different sensors, when we talked about the introductory issues of different sensors, sensing and actuation. I have shown you different sensors that could be used for connecting with IoT. For Industrial IoT, there are certain specific requirements.

The sensors that are used in the industries are typically the ones, which have higher performance, are much more accurate, and are able to perform for longer durations of time. So, they are high grade, better performing, highly and normally scalable, and can work for longer durations of time. So, we need to now understand the specificfications of these different sensors and actuators being used in the industrial sector. So, industrial sensing and actuation is what we are going to cover in this particular lecture.

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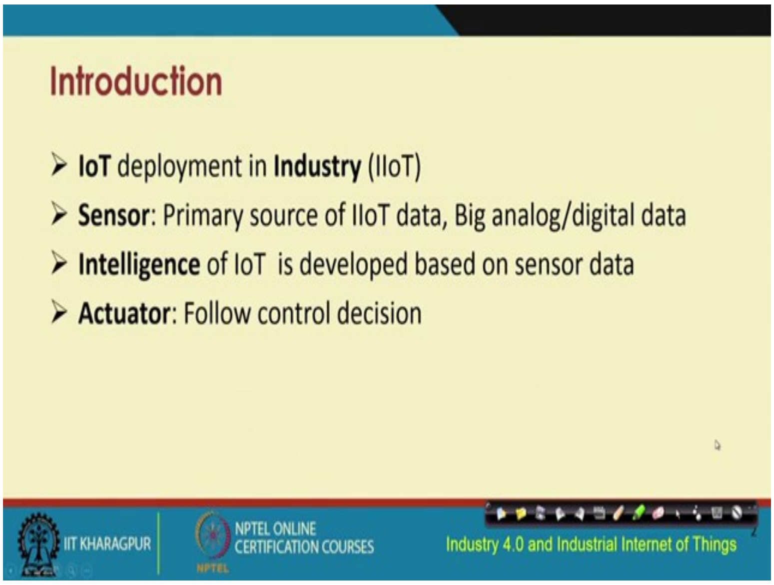

So, just as a recap when we are talking about IIoT, if we are talking about the same thing IoT, but considering industry-specific applications. And there are certain industry-specific requirements that are there, which will have to be catered to. But for IIoT as well, like IoT sensors and actuators are the core technologies.

These are the core components, which are used and these are the ones, which basically form the backbone behind the collection of all these different data and making different changes dynamically to the system. Sensors are basically the primary source of IIoT data. There can be different types of data, that can be sensed using different sensors, the sensors themselves can be analog or digital sensors.

And these sensors need to be deployed in the industrial scenarios typically are going to collect lot of analog data, digital data and not only lot of data, but data, which are big in nature. So, this big data that I talked about in a previous lecture so, all these big data properties are basically going to come if you are going to have industry scale sensors deployed and connected to one another and to different machines.

The data that are collected by the sensors will have to powered with; will have to be powered with intelligence. So, this data will have to be processed, to process in order to get information and knowledge out of the data from this processing. And followed by that followed by the processing, the analysis, that is done from the data that is collected in real-time in typical scenarios, some real-time actuation can also be done. And this actuation can be done following control decisions.

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There is a need of sensing for the industry. And these sensors that are used in the industry should help in promoting higher degree of automation, raising the productivity, improving the quality of these different products, quality of the processes, that are used for manufacturing, improving the overall safety and reducing the downtime of the machinery.

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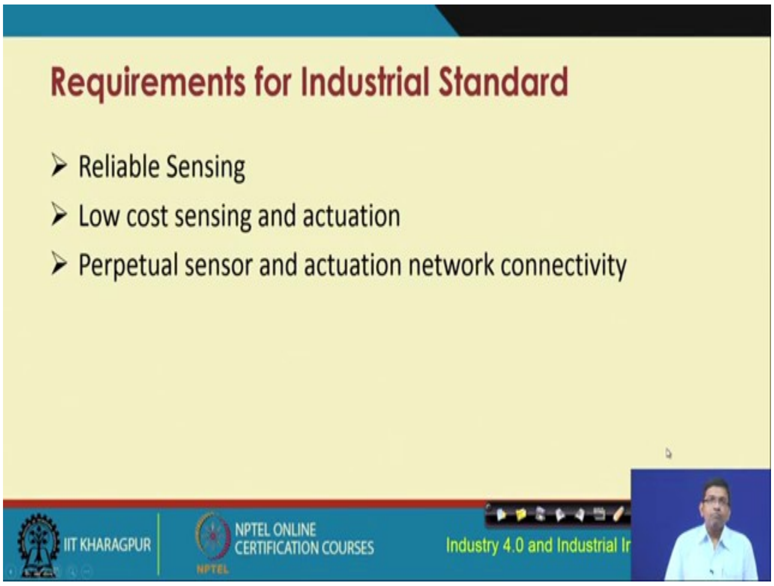

In terms of the requirements for industrial standard, it is required to have reliable sensing, low cost sensing and actuation, and perpetual sensor and actuator network connectivity. So, what is meant by these requirement is that we need to have low cost, but higher performing reliable sensors. Low cost because we are going to use large number of these different sensors, it should not happen that one sensor is so costly, that only you can use it for one machine. Because you have to now in the industrial internet or IIoT you have to internet work all these different machines and consequently these different sensors.

These sensors themselves if you want to replicate and scale up, you need to have these to be very cheap. Otherwise you cannot have multiple such sensors to be deployed in different machines, so they have to be low cost. High performing because, these sensors will have to perform for long durations of machine use under extreme conditions these sensors will have to perform.

And they have to be reliable, because not only they have to operate for long durations, but will also have to throw in data which can be relied upon; they have to be accurate and reliable. So, these are some of these requirements for industry related, industrial-related sensors being used.

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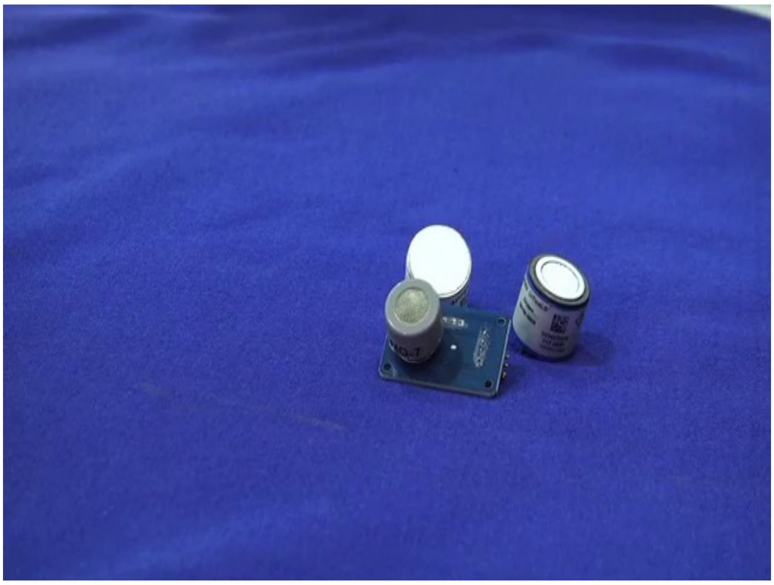

So, let me now show you some of these different sensors. So, here this is one type of; so, here I will show you three different sensors, these are three different gas sensors. So, this is the carbon monoxide sensor and then you have the methane sensor, this is the methane sensor, as you can see over here.

This is the methane sensor with three different pins at the bottom of it. And this one is an oxygen sensor, this is the oxygen sensor, here also you have three different pins for connectivity purposes. These pins are there for connectivity purposes. So, we have three different types of sensors, I just wanted to show you the samples of these.

And these are industry-grade sensors these have higher performance, higher efficiency, they are very reliable. And they are relatively cheap, but they are much more reliable than the low cost ones, lower cost ones that are available in the market. So, for example, for instance, this sensor I will show you one by one, this is the methane sensor.

So, this methane sensor; basically continuously measures that how much is the methane concentration in the environment in which it is operating. And the operating temperature of this methane sensor is quite broad spectrum; from roughly about minus 20 degrees centigrade to about plus 55 degrees centigrade, this methane sensor can work. It can work in different hazardous environments such as nuclear power plants, underground mines, and so on.

It also can be used for different safety critical environments for designing different safety critical environments. And it has a sensitivity of about 24 ± 4 milli volts per percentage methane. So, this is highly sensitive to any kind of methane concentration change, so the is this methane sensor.

Now let us look at this sensor, which is the oxygen sensor. So, this oxygen sensor is basically a electrochemical sensor, the composition is the way it is fabricated it is a electrochemical sensor. And it can detect different it is highly accurate and can detect any changes in the oxygen concentration.

It is also quite rigid, quite robust, it can work under different extreme conditions, different extreme environmental variations, and so on, and temperature variations. And also it has the output signal, which is about 0.1 ± 0.02 milli-ampere in the air ok. So, this is this methane sensor so this is this oxygen sensor. And then we have this normal, carbon monoxide or general gas sensor, which is highly sensitive to changes in different gases such as carbon monoxide.

And the detecting range for carbon monoxide for this particular sensor is about 20 ppm to 2,000 ppm. So, this can be used in cars in different industries for monitoring the concentration of carbon monoxide and so on. So, these are all industry grade sensors. And as you have seen that these sensors are highly accurate, they are very much sensitive, and sensitive to the changes in the gas that they are supposed to sense.

And they are quite robust and can operate in broad temperature ranges, under different varied environmental conditions and so on. So, these are some of the higher level specific requirements for serving industrial applications.

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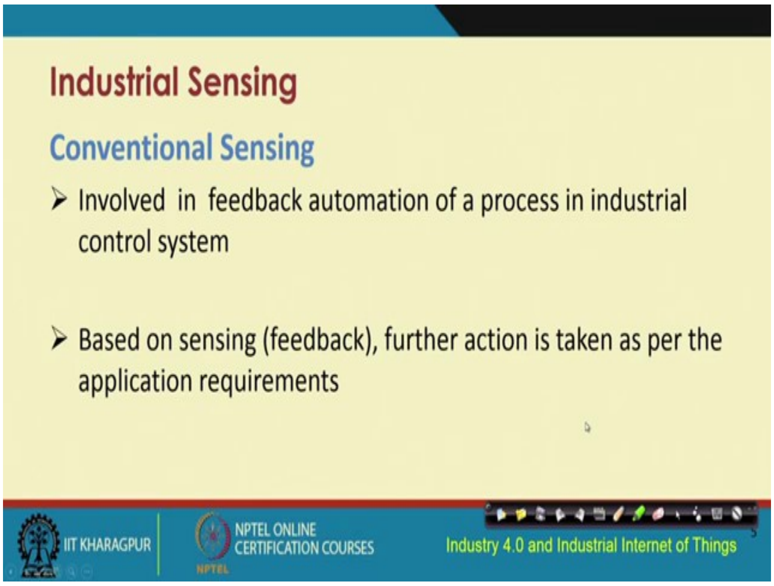

Now let us go ahead and look at sensing, in further detail, industrial sensing. So, when we talk about industrial sensing there are these conventional sensors that have been there since long. Again sensors have been there for decades, but then now recently they have become even more popular in the recent years, with the popularity of IoT and IIoT.

So, conventional sensing it involved getting some kind of feedback, automation of a process, in an industrial control system. And it was based on some sensing or then getting some feedback for taking some further action to serve certain specific application requirements. And these conventional sensors have been there since long as I just said.

But the way you are evolving these sensors making them much more intelligent connecting them to the internet getting value out of the deployment of these sensors in a big scale and making processes much more efficient, in the industries, is what has made IIoT much more exciting.

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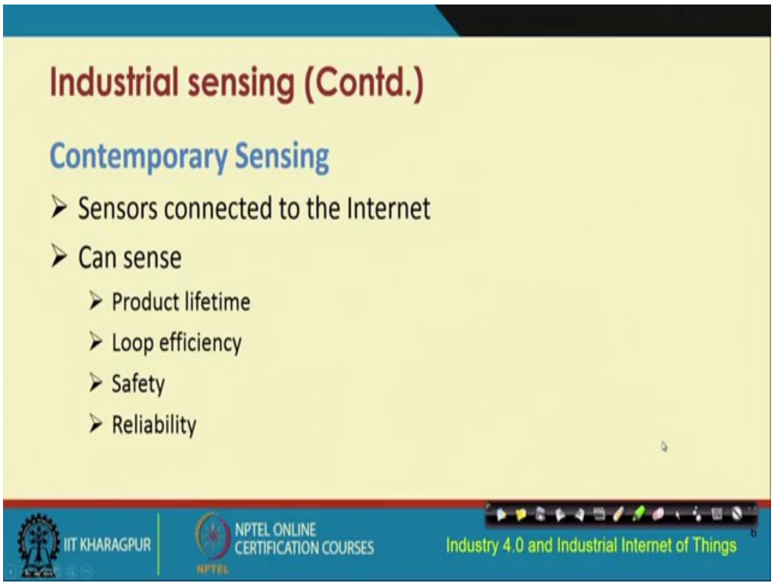

In contrast, to the conventional sensors the contemporary ones the recent ones. These can be connected to the internet. So, it is possible to connect these sensors to have industrial internet or industrial IoT applications. These contemporary sensors are much more intelligent. They can sense product lifetime, loop efficiency, safety, reliability these are some of these different properties.

But it all depends, which sensor is supporting and type of application. And who has what type of attractive properties it all depends on the type of sensor. Typically, what happens is the more you make these sensors much more competent, intelligent, robust, the price also increases. But at the same time it should not be too expensive to be not being able to use easily in most of the IIoT applications.

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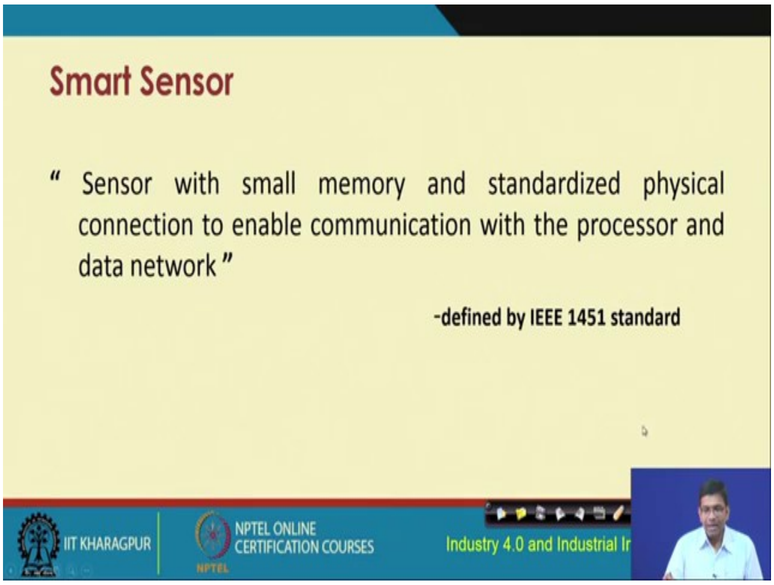

So, smart sensors are the ones, which have small memory and standardized physical connection to enable communication with the processor and data network. And this is as per the IEEE 1451 standard, this is a smart sensor and we are talking about the definition of a smart sensor having some kind of small memory and connectivity, attached to it.

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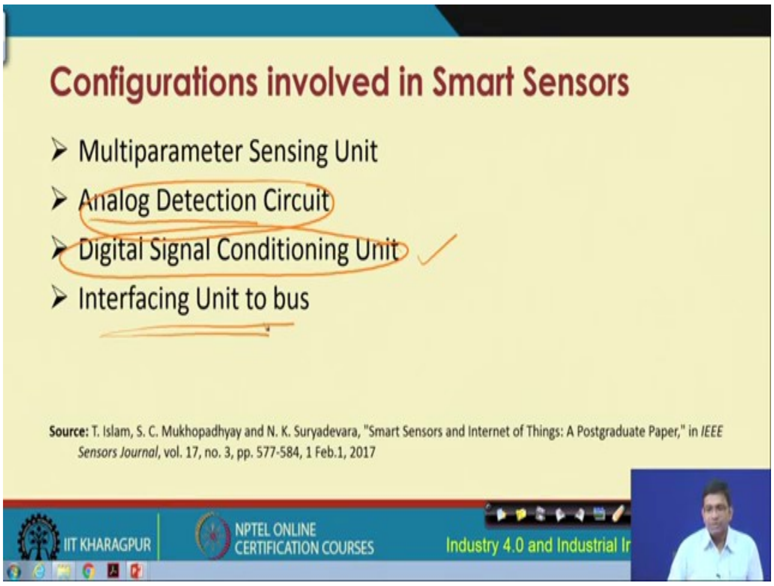

So, the configurations that are involved in the smart sensors are it is possible to have a multi parameter sensing unit. Multi parameter sensing means different parameters in the same sense, through the same sensors it is possible to measure multiple parameters. So, same sensor can be used to measure multiple gases for example. Then we have the analog detection circuit, digital signal conditioning unit, and interfacing unit to the bus. These are the different components, which will be used to configure the smart sensors. So, what is this multi-parameter sensing is what I just said, but what is this analog detection circuit. So, most of these sensors basically, analog sensors.

But in order to connect them to the internet. And to get and to perform multiple intelligent stuff you need to convert this analog signal into digital data. So, this analog detection circuit is required, then you need to have some digital signal conditioning unit, this digital signal conditioning unit will, after the analog signal is collected and then you want to digitize you want to have digital data out of the signals you need to digitize it. So, before you digitize you need to do some kind of conditioning. So, conditioning of the analog signals and this conditioning is done through different means.

For example, amplification filtering of the signals and then digitize. So, this is basically the work of the digital signal conditioning unit. And then you have the interfacing unit to the overall bus. So, this interfacing unit will help you to connect these different sensors to the information bus.

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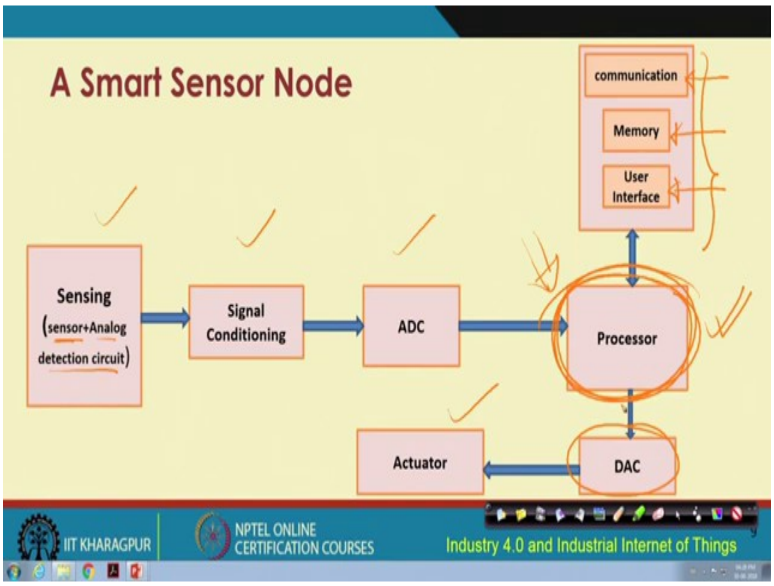

So, let us look at the architecture of a smart sensor node. A smart sensor node has the sensing unit, which again has a sensor, an analog detection circuit. There is this signal conditioning circuit or component that is there. And this signal conditioner will basically do the things like amplification, filtering of unwanted stuff.

So, signal conditioner, then you have the ADC, the analog to digital converter and the processor. So, processor is the one, where all this processing are taking place all these computations different algorithms can be executed at this processor. So, this is basically very important in a smart sensor node and intelligent sensor nodes. Intelligence come through algorithms, and these algorithms can basically be executed at this processor.

Interface with different components such as the communication unit, the memory unit, and give some user interface components. So, all of these finally, based on the processing some kind of actuation would have to be made. So, for that the actuators will be, will have to be invoked, will have to be started and this DAC Digital to Analog Converter sits in between to help in the process.

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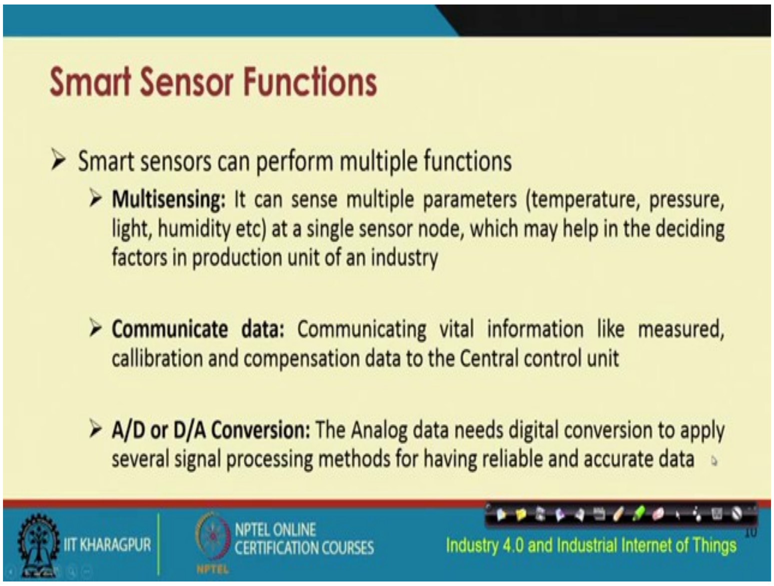

Smart sensors can perform multiple functions. Multi sensing as I told you before it is about sensing multiple parameters such as temperature, humidity, light, pressure, and so on. In a single sensor node, communicating the data that is measured, calibrating the data, and then compensating the data. And sending it to the central control unit is the next important function of a smart sensor node.

And then the other component is the AD or DA converter, Analog to Digital, and Digital to Analog converter. The analog data needs digital conversion to apply several signal processing methods. Because unless you make it digital, digital signal processing methods cannot be applied. So, digital signal processing methods will have to be applied for having reliable and accurate data.

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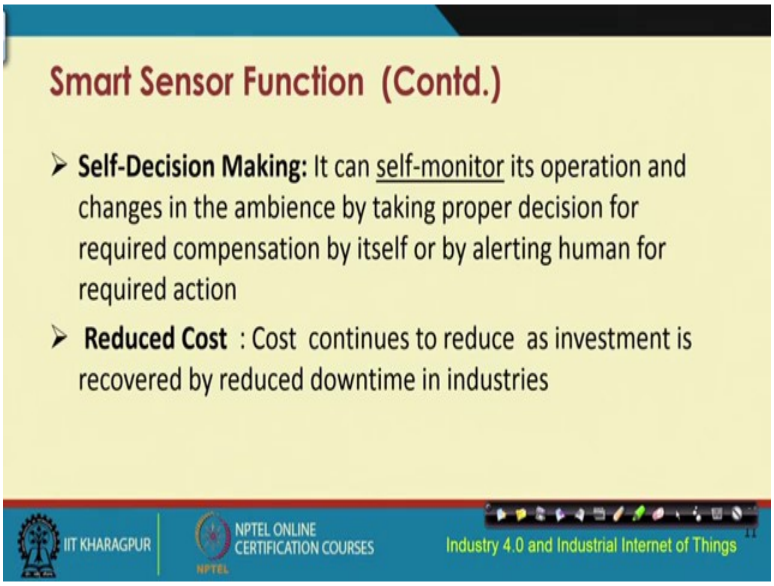

So, the next important function is the self-decision making. Because it is a smart sensor, an intelligent sensor, it has to do things on it is own. So, it has to self-decide, it can self-monitor, and based on the ambient conditions, it can make certain decisions on its own. And this would be possible with the help of the processor that is inbuilt into this smart sensor.

And then you have the reduced cost, the most important function I would say of a smart sensor. Because if cost is not reduced then, it is not possible to replicate and scale up to build to have more copies of these different sensors and replicate it further.

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So, let us consider the example of the milk processing unit. Let us say that you are talking about a smart milk packaging unit. And let us talk about the sensing in a smart milk packaging unit much more specifically.

So, in a milk packaging unit you need to install the sensors in line with the outlet tab. Then there would be some impellers, which would be attached to the sensors. These impellers would spin, when the milk moves. So, impellers I think most of you have already seen that it is something very circular and has some grooves blades and so on, on its surface.

So, when some fluid such as milk will flow then it is going to rotate accordingly. So, impeller spins when the milk moves and sends the electrical signal to the control unit. And the controller would interpret the amount of fluid flow and stop, when the threshold is reached.

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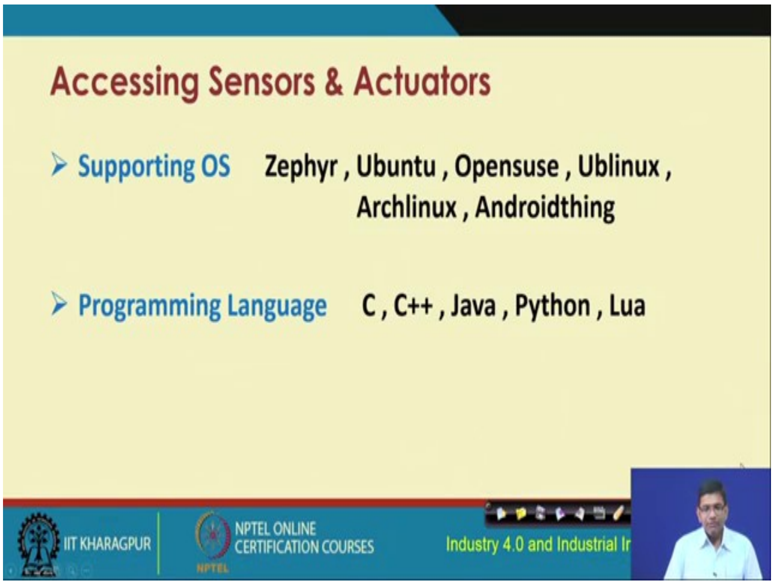

So, there are different sensors which would sensors and actuators industry scale which would support different operating systems, such as the ones that are mentioned over here. Zephyr, Ubuntu, Opensuse Ublinux, Archlinux, Androidthing, these are some of the different operating systems that are used in the smart sensors and actuators.

The different programming languages that are used for applications of smart sensing and actuation are C, C plus plus, Python, Java, Lua, and many other languages are also coming up in the recent years for use in the smart sensing and actuation environments and programming those environments.

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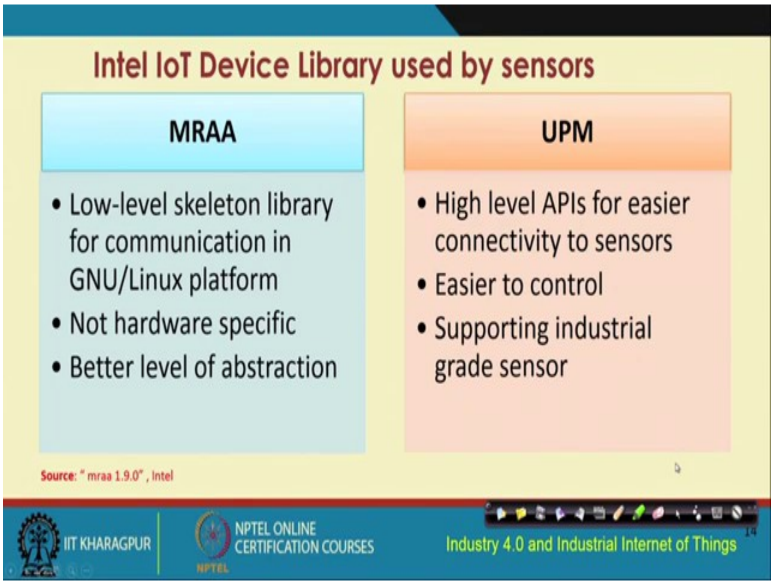

So, different device libraries are also available for the programming purpose. Intel IoT device library is one such library and there are different components in it. One is the MRAA component which is a low-level skeleton library for communication in the GNU Linux platform.

There is another component, which is basically, which provides high level APIs for easier connectivity to the sensors. And also UPM helps in control applications. These UPM MRAA together they help in supporting industry grade sensing.

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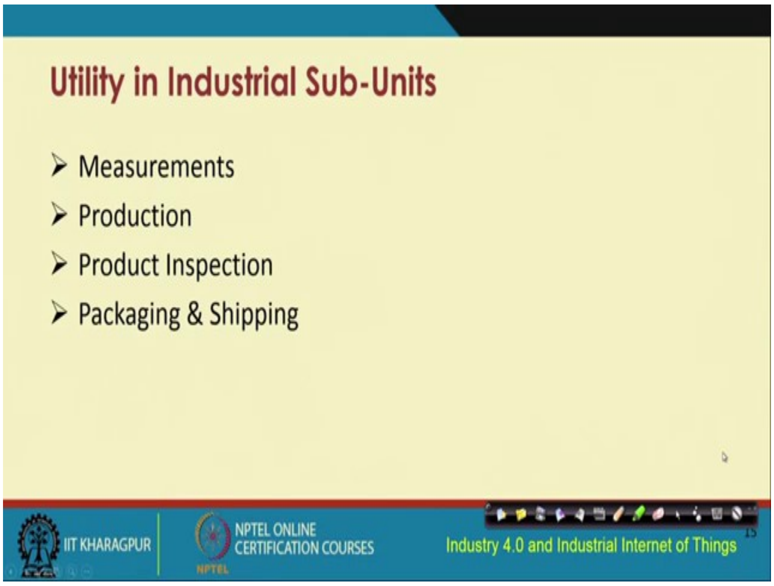

So, utility in industrial subunits measurement production, product inspection, packaging, and shipping, these are some of these utilities of industrial sensors and their use, in different industrial subunits.

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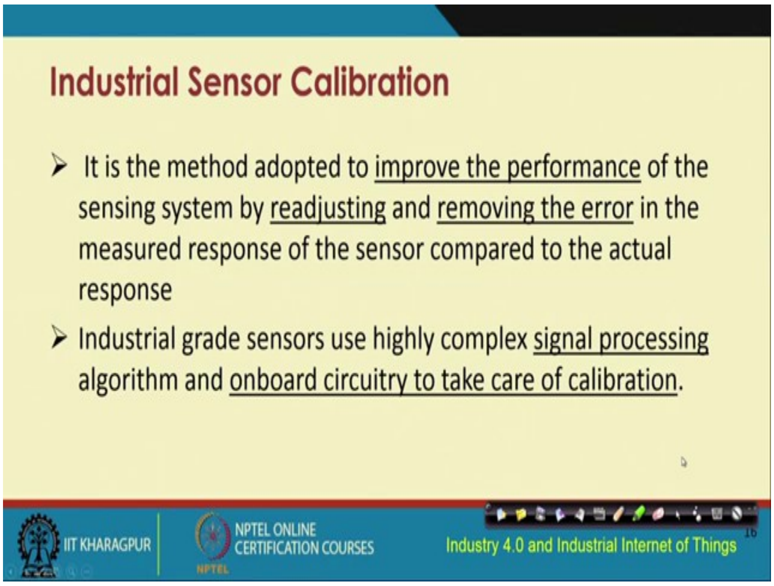

Calibration of any sensor is very important. Calibration has to be done in order to improve the performance of a sensing system through different adjustment, readjustment removal of errors, and so on this calibration can be done. And calibration has to be done because certain sensors would not behave the same way with passage of time. So, you have to calibrate and you have to re-calibrate a sensor. Industry grade sensors use highly complex signal processing algorithms and on-board circuitry to take care of calibration.

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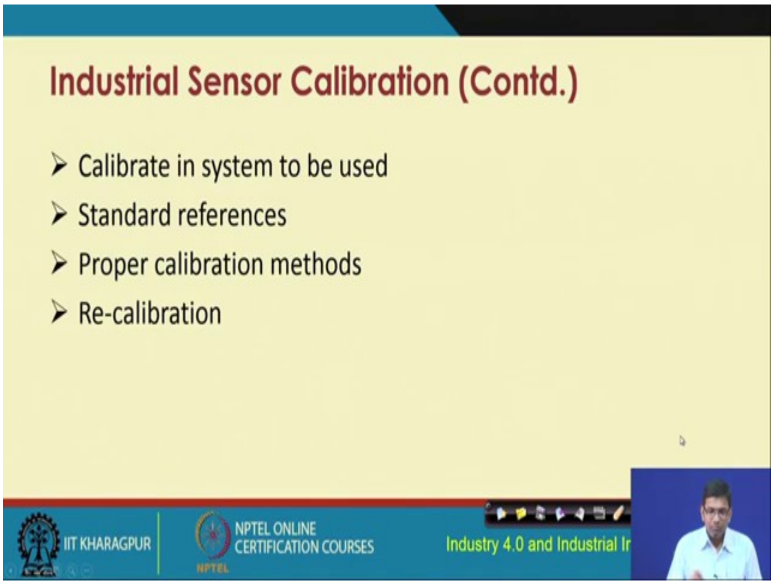

So, it is required to calibrate the sensors in a system. And it is also required to have some kind of standard reference against which the calibration is going to be done. Because if you do not know what the sensor is supposed to do and how much the actual measurement should be, then you cannot do the calibration, if you do not have that kind of standard reference.

Standard difference has to be there. Then proper calibration methods will have to be used and if required sometimes what happens is certain sensors do not behave the same way over passage of time. So, they will have to be recalibrated.

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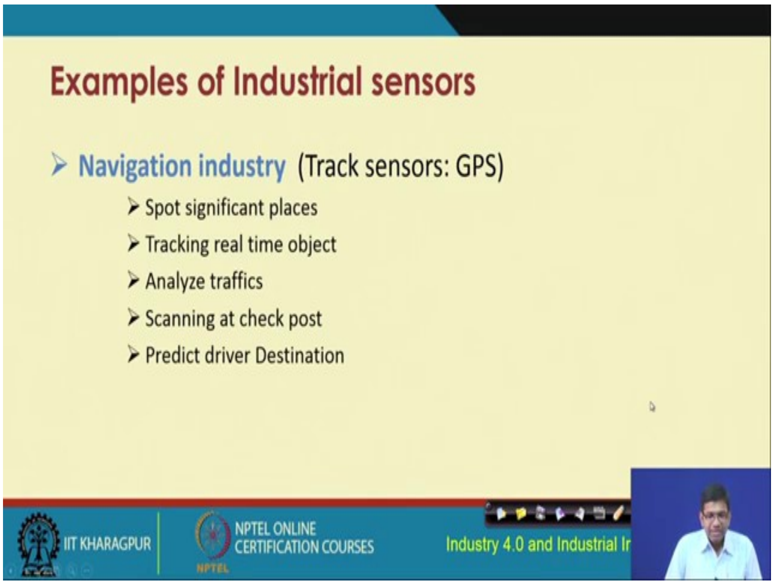

Examples of industrial sensors, industrial sensors can be used in the navigation industry, for tracking and so on. GPS based sensors are the ones that can be used in the navigation industry for tracking purposes, tracking of shipments, tracking of logistics, tracking of trucks.

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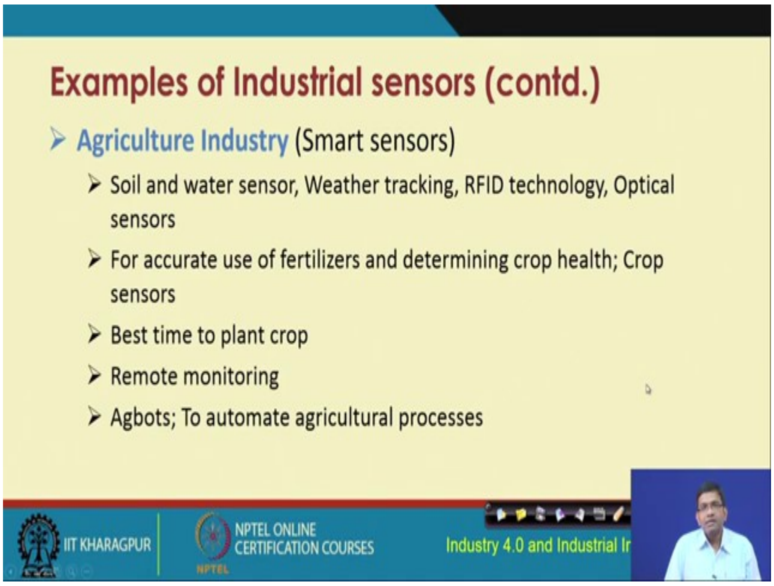

In the agricultural industries, smart sensors can be used for monitoring the soil condition, water condition in the soil, soil, moisture, water level in the soil, different weather parameters, then different other parameters such as the fertilizer content, the nutrition content of the soil to be used by the plants. So, this is this agricultural use of smart sensors.

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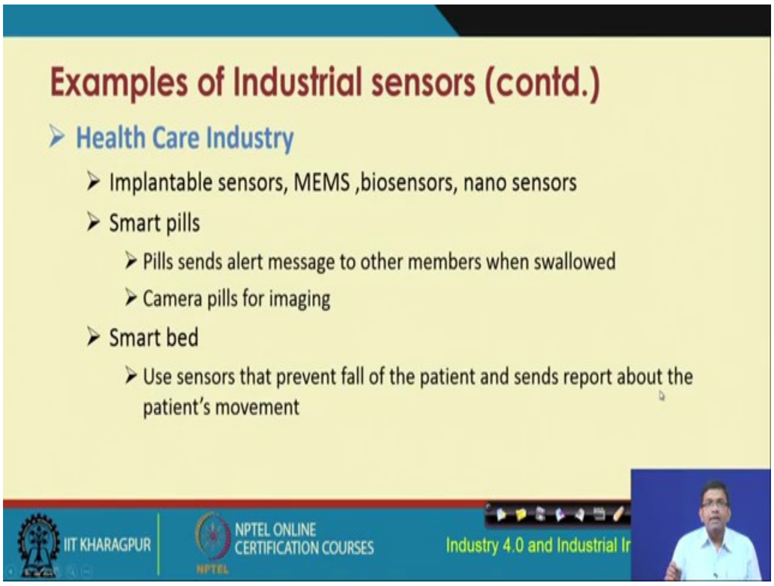

In healthcare industry as well different sensors, such as the regular ones for example, different biosensors like this pulse oximeter sensor, body temperature sensors could be used. Similarly, ECG, EMG, EEG different sensors the traditional, conventional ones could be used. But now there are some smarter sensors for healthcare purposes that have also come up. There are smart pills which basically can be swallowed and these pills go to the human circulatory system.

And they send, they sense the human physiological parameter that they have been designed to sense and then basically those physiological parameters wirelessly they are going to send those parameters to the doctors for further monitoring. Smart beds in the hospitals also use sensors that prevent the patient from being falling down and sending report about any kind of movement, suspicious movement of the patients.

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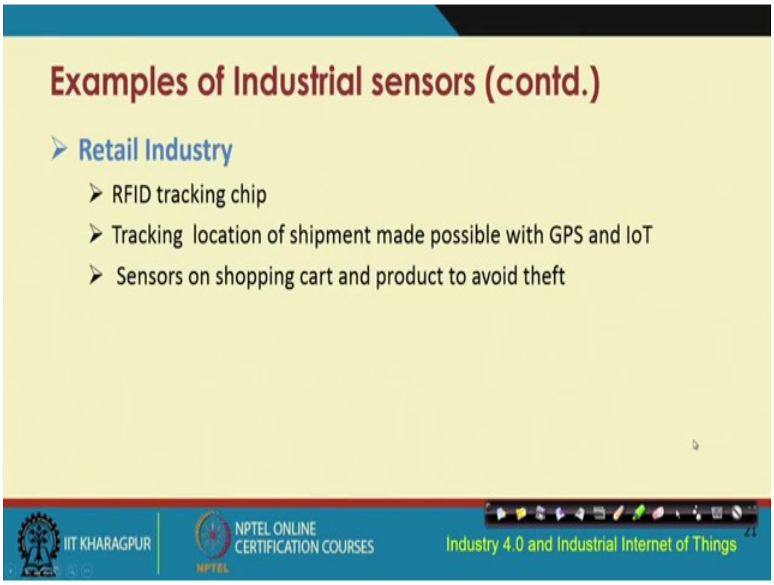

In the retail industry, also industrial sensors are used, for example, RFID tracking chips, tracking location of shipments made possible with GPS and IoT, sensors on shopping cart are also deployed. And by doing so it is possible to avoid theft of different products from the supermarkets and so on.

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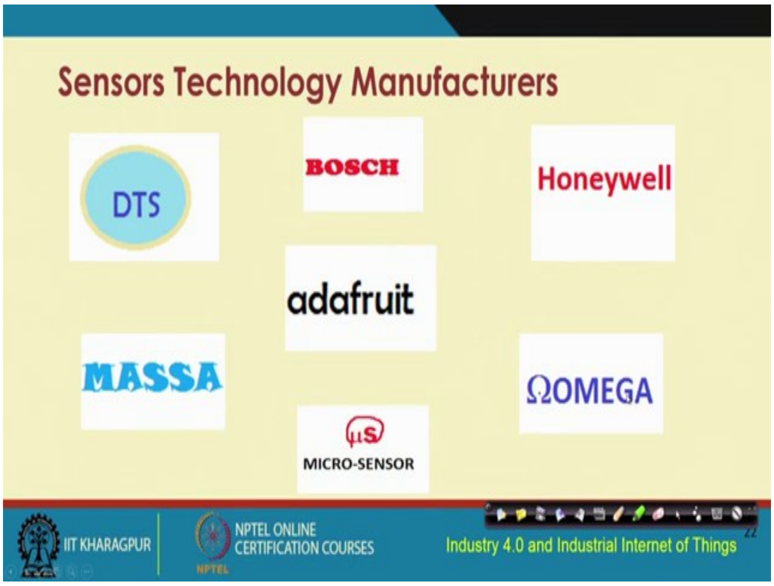

So, there are different players of these sensors, sensor manufacturers are there who develop different (different) types of sensors. You have the DTS, Bosch, Honeywell, OMEGA, these are some of the common sensor manufacturers. Like this, there are different other sensor manufacturers globally, that produce different types of sensors.

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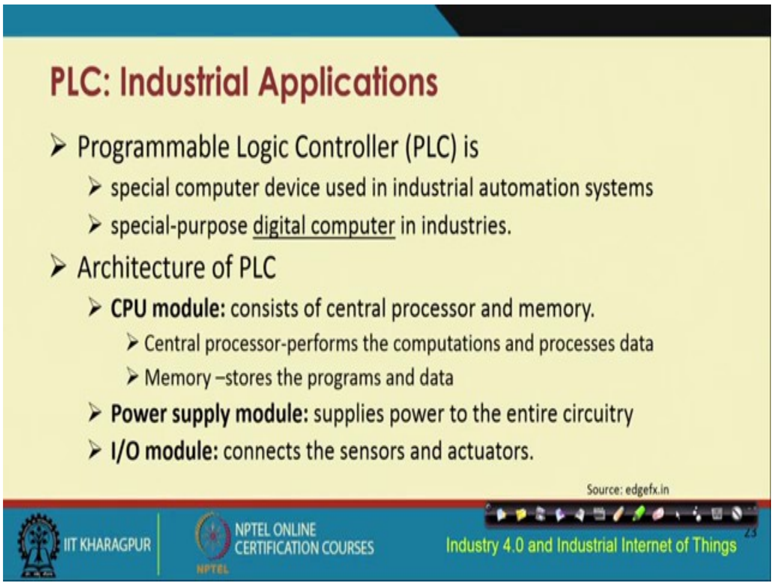

Now, when we talk about sensing at the same time we also need to talk about actuation. And in industry actuation is very important, use of PLC is very important to serve actuation platforms. PLC stands for Programmable Logic Controller and these programmable logic controllers are some kind of special purpose digital computers that have certain special capabilities.

Special capabilities for automating the industrial processes, industrial machinery, and so on. So, these PLC's are quite widely used in the industries to automate, for automation purposes and these PLC's could be extended further to be able to serve the industrial internet and IIoT requirements. So, a typical PLC has three different modules.

The CPU module which consists of the central processor and the memory, and then you have the power supply module, which the name says it all, it supplies power to the entire circuitry, and the input output module which basically connects the sensors and the actuators. How this PLC's work?

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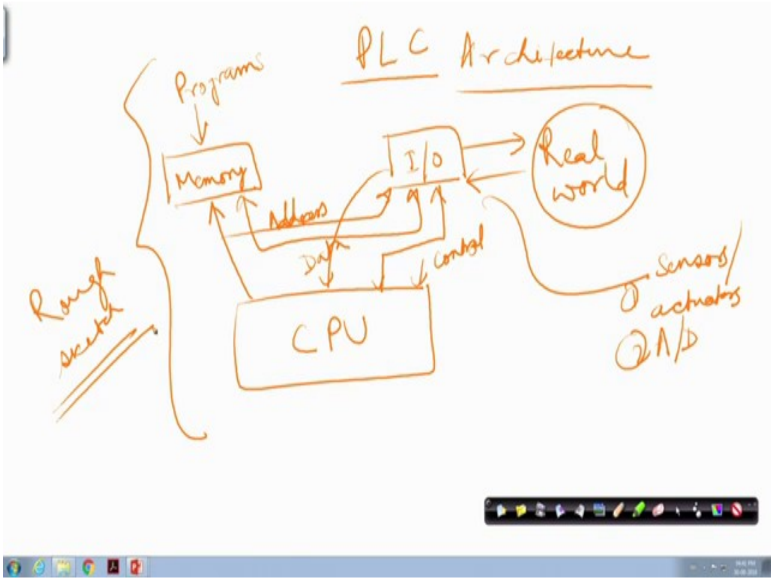

So, we will talk about the architecture of a typical PLC system. So, a typical PLC system has memory, and the input over here are different programs, which run these PLC’s. Then you have the central processing unit and the input and output. Through this input-output, there is interaction with the real world.

So, this input output component in fact, for the interaction with the real world connects two different sensors, actuators, which can sense different parameters. And these could be of analog or digital type. Basically the interaction happens between the CPU to the memory. The memory to the input-output, and also between the input-output and the CPU.

All of these things are interconnected and they are going to send data. First of all we are going to send this memory is going to send the address. The data could also be sent from the input-output to the CPU. And also it is possible to control the CPU’s by sending suitable control signals.

And these control signals can come from take input output. So, this is at a very, it is a rough sketch of the different components in the architecture of a typical PLC. Now, let us go little further and talk about the different, the most important thing that happens in a PLC.

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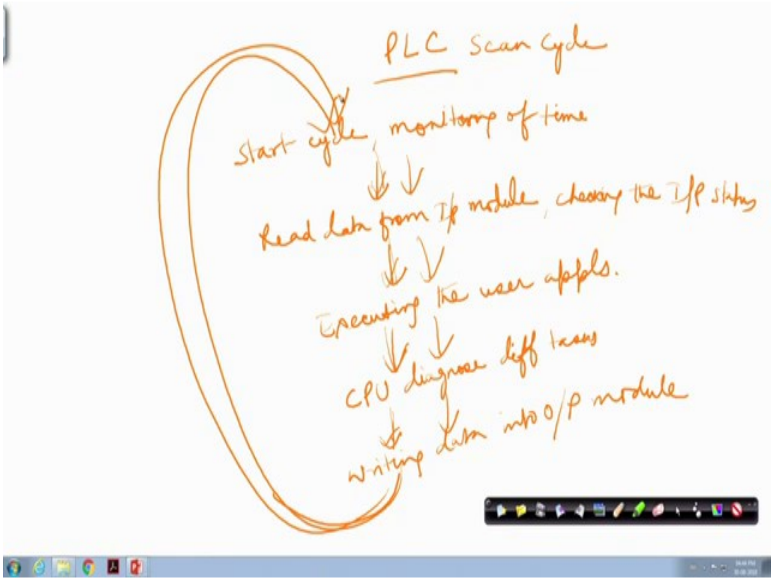

PLC basically in most of these machines PLC goes through different loops. There is something called the scan cycle, PLC scan cycle. So, in the scan cycle, basically this looping happens. So, you have first of all the starting of the cycle and monitoring different parameters; monitoring different parameters such as time.

Then you have reading the data from the input module, the input module and checking the input status. The next thing in the cycle is executing the application, the user applications. Then you have the CPU basically diagnosing different tasks. Finally, writing the output, basically the data into the output module.

And it is called a cycle because these activities will have to be done. And after they are done you go through another pass, when the machine, until the machine continues to operate. So, this cycle so basically it goes through this side these all these tasks and again repeat from the start. This is how the PLC scan cycle looks like. This loop is very important in PLC’s and they continuously, they keep on doing the stuff to continuously do whatever they are designed to perform.

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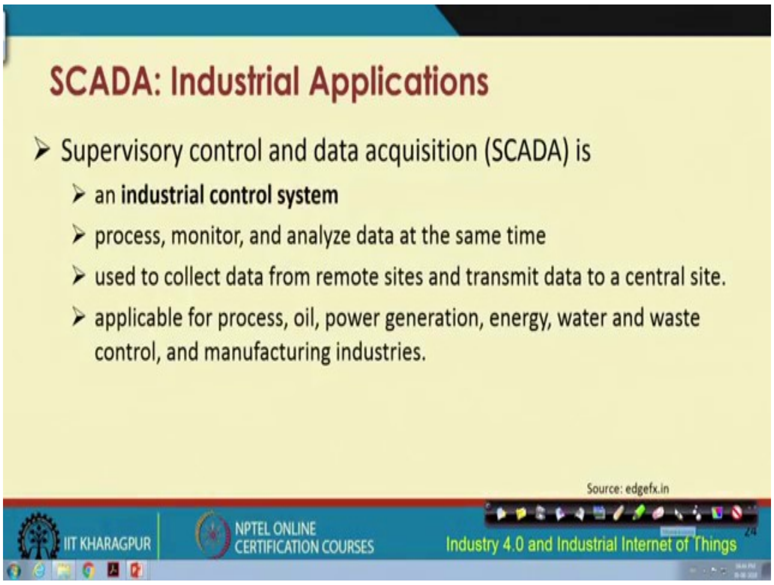

So, let us now again go back and look little further. So, these PLC's are very important in something known as the SCADA systems. So, SCADA is very important in industry applications. SCADA basically stands for Supervisory Control and Data Acquisition. And it is basically an industrial control system, an advanced industrial control system, which can do many different things such as; processing, monitoring, analyzing data, all at the same time can be done, with the help of industry grade SCADA systems.

These systems basically would collect the data from different sites, different locations. And transmit the data to the data acquisition system for further processing. So, typically water industries, oil industries, power generation industries, they all use SCADA based systems.

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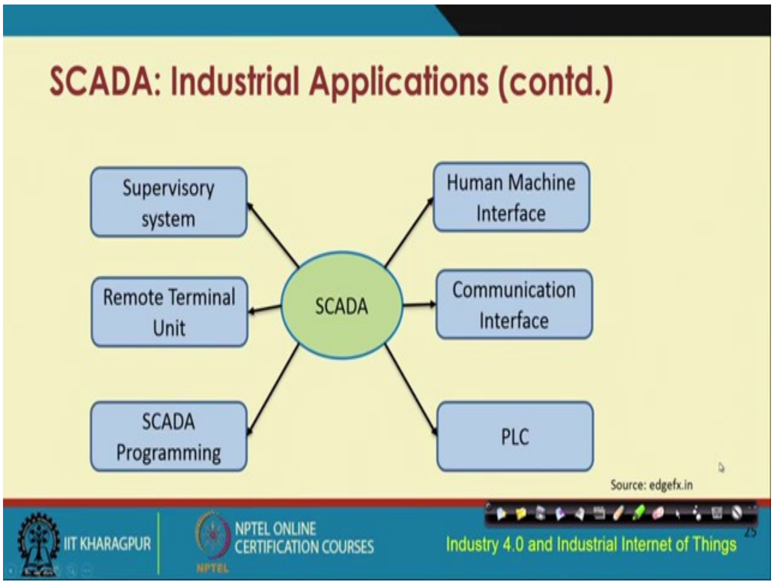

SCADA has different components. So, there is a supervisory system, there is a human machine system, there is a remote terminal unit component. There is a communication interface system or component, the SCADA programming is another one.

And the last one is this PLC that I talked about before, the architecture of which the rough sketch of the architecture of which I have shown you. And we also talked about this PLC cycle, which continues to operate the tasks are continuously done in the cycle as these PLC machine keeps on operating, until the machine keeps on operating.

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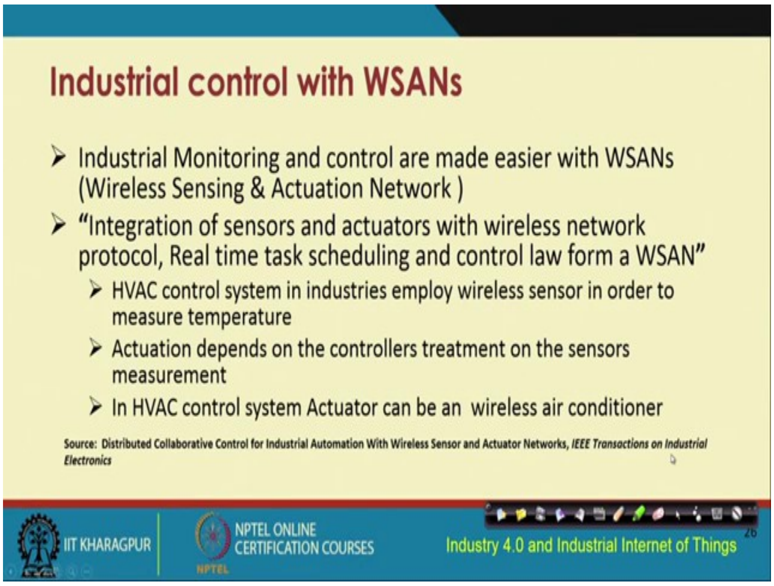

So, industrial control can be done with the help of all of these different technologies, different sensors, different actuators, based on PLC's SCADA and so on and there are different sensors and actuators that are used.

We have a wireless sensor and actuator network in the industry scale connecting different machinery, working in order to perform the different monitoring activities of these different machines systems, humans, and humans talking to machines. So, all these different interactions can be monitored, controlled, and so on.

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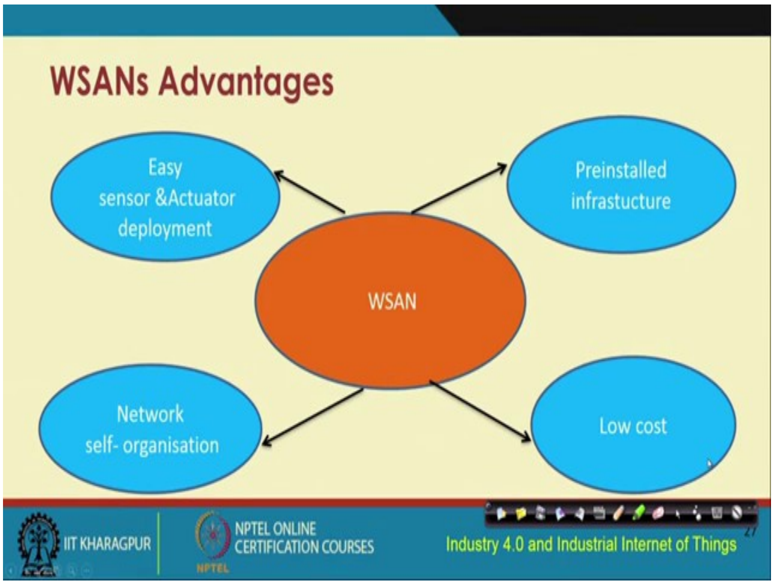

The advantage of use of wireless sensor and actuator network; is that it is not so difficult as we have seen so far. Sensors are common, once you get the sensors, once you get hold of the actuators, it is not so difficult to deploy the sensors and actuators. So, once you have deployed the sensors and actuators you can have these sensors being networked to be able to talk to each other.

To self-organize the system, the communication platform, the network. And there is some pre-installed infrastructure, that could also be used. And overall this wireless sensor and actuator network technologies are low cost. So, that is why holistically this well is sensor an actuator network technology in the industry scale are low cost.

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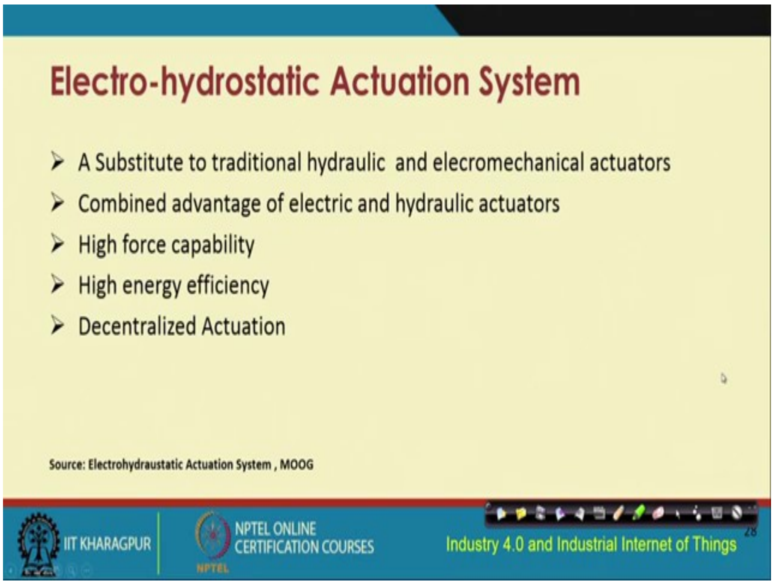

So, in terms of these different actuators could be used electro-hydrostatic actuation system. We have seen different actuators in the introductory lecture, we have seen different types of actuators being used. Many of these could be used for different purposes in the industries.

But there are some industry specific actuators that are at the higher end and could be used to serve industry applications. So, this electro-hydrostatic actuator is a substitute to the traditional hydraulic and electromechanical actuators. They have some combined advantages of both the electric and hydraulic actuators as these name suggests.

So, essentially these electro-hydrostatic actuation systems by combining the advantages of their electric and hydraulic counterparts together can have higher force capability, higher energy efficiency, and decentralized actuation.

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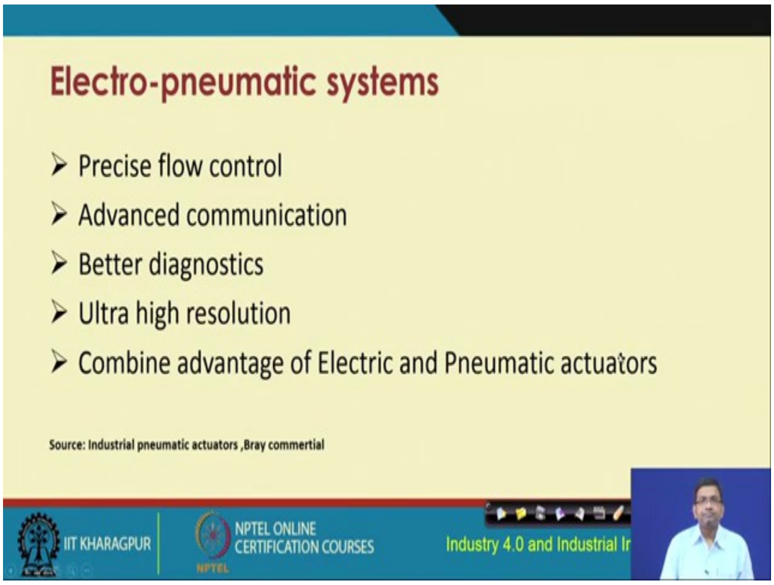

Then there are the electro-pneumatic systems, which have precise flow control, advanced communication capabilities, improved diagnostics than the previous traditional actuators. And ultra-high resolution and combined, they also have the combined advantages of the electric actuators and the pneumatic actuator.

All these actuators are typically the hybrid ones, which will combine the electric pneumatic and different other capabilities mechanical actuators. So, all of these capabilities combine together, becoming much, making these actuators much more advanced, much more powerful and accurate.

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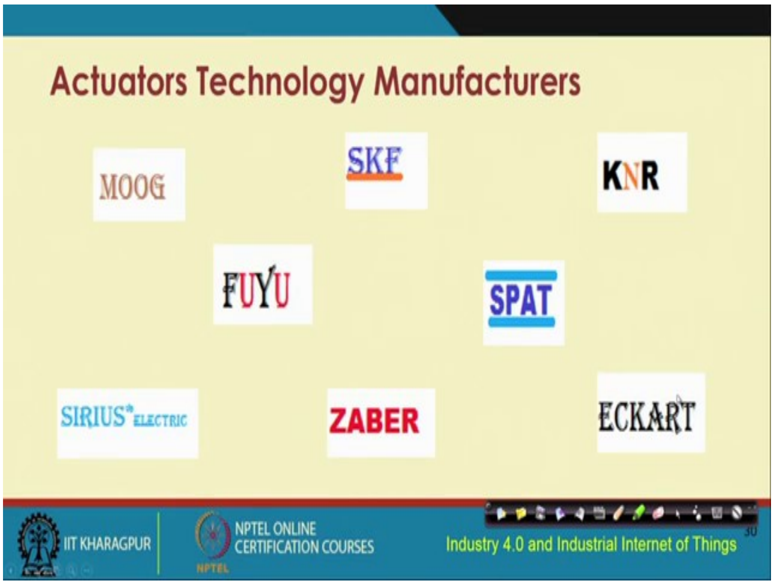

These are some actuator manufacturers.

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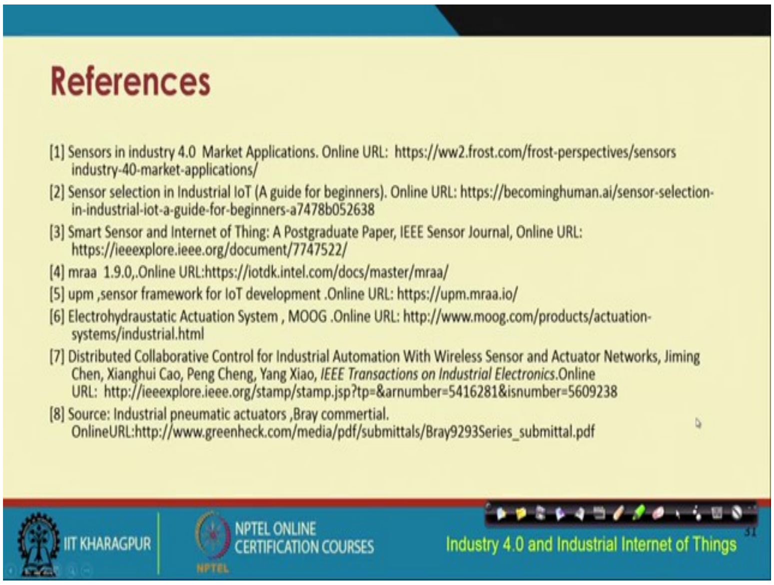

So, with this we come to an end of industry skill sensing and actuation lecture. And what I have done is I have shown you these different types of industry-scale sensors that could be used. I have also talked about PLC, SCADA and the corresponding architecture. Here are some of these references, which will help you to dig further deep into each of these that I have talked about, if you are interested further.

And so remember one thing that industry grade sensors and actuators have higher requirements, but at the same time, they have to come in lower cost. Unless you have low cost sensors and actuators, even in the industries nobody is going to pay for them to deploy them.

Because if the cost of these sensors and actuators in the industries are going to be higher, then the cost of the products is also indirectly going to be increased and that is not something that any of the industries would readily want to have. These are different references and with this we come to an end of this lecture.

Thank you.