Introduction to Industry 4.0 and Industrial Internet of Things
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Lecture – 26
Key Enables of Industrial IoT: Sensing – Part 1

In this module, we are going to go through, some of the Key Enablers for Industrial IoT, and the basics of which we have already gone through in the previous lectures. But we need to understand these key enablers, in little bit more detail and so we will start with the Sensing. So, sensing is I would say that it is the most important element in industrial IoT in smart applications, and so on. So, we will start with sensing and try to understand how these sensors work and what is the utility of these sensing elements in the overall smart IoT, Industrial IoT applications?

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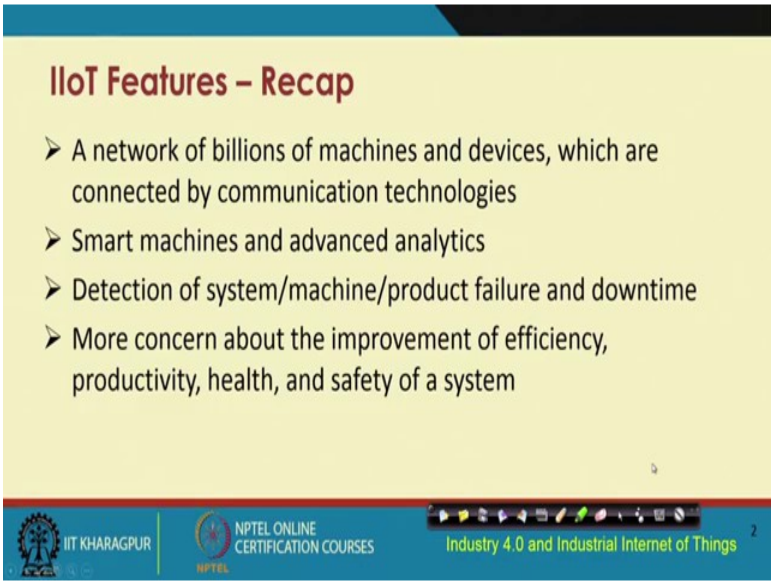

So, if we take a recap of the IIoT features, we have in IIoT we are talking about large number of industrial machines, connected machines, having different sensor nodes devices, and so on. These sensor devices are connected themselves, through different communication technologies. So, basically these different sensor devices are connected to one another, which in turn makes these different machines, the host machines connected to one another.

And the smart machines basically, which have these different sensors produce lot of data, which are typically analyzed either locally or, off site, maybe in a cloud or, in a data center or, something of that sort, and intelligent inferencing is made and based on which, maybe there is some actuation that is performed.

So, here basically we are talking about smart machines, smart objects and so on. So, these smart machines are also smart because they can detect by themselves, if there is any failure at point of time, or in the production line, if there is any failure in any point in the production like line and also if there is any, machine downtime or, production downtime or anything like that. So, everything will have to be detected on their own by these different smart system, smart machines in these industries.

We are talking about improvement of efficiency, productivity, health, safety, etcetera of the systems. So, how can this be done and autonomy, autonomously, automatically, basically these things are going to be detected, whether any machinery or, any parts of the machines are defective or, anything is going wrong or anything like that. So, everything has to be detected on their own. So, how it is possible the core element for making it possible is the sensing element. We need to understand these sensors, in more detail.

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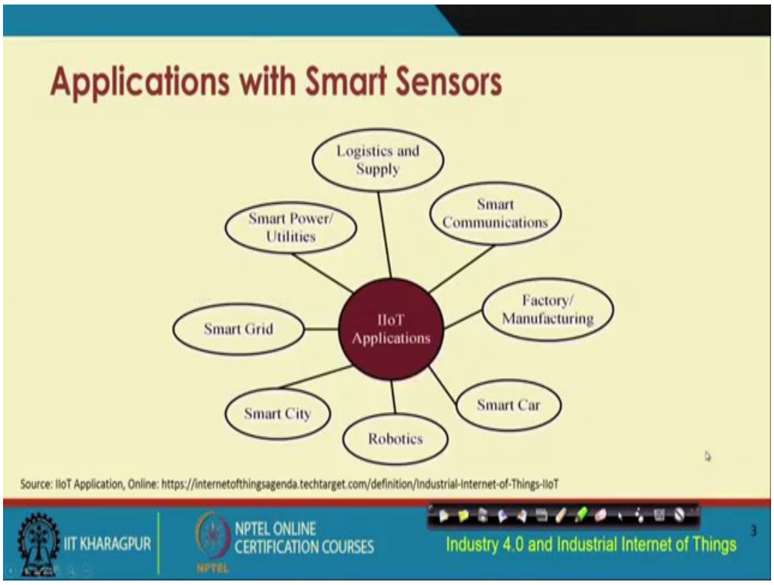

So, before we do let us take a recap also of the different applications of these smart sensing elements. So, smart sensors basically drive different IIoT applications in the power, sector utility sector, so smart power or utility, smart logistics and supply, smart communication, smart factory, smart manufacturing, smart car, smart robotics, smart cities, smart grid, everything basically this smart component is primarily due to the existence of these smart sensors embedded in these different machinery devices and the system, as a whole.

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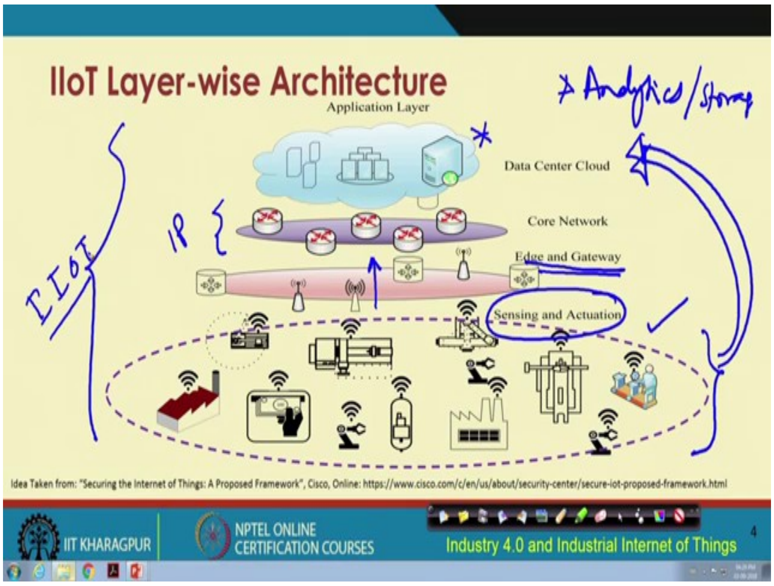

So, we need to understand this part in more detail so, if we look at the IIoT, if we look at holistically. This smart sensing element, the smart sensors are basically at the very bottom. So, we have these different smart sensors and actuators in the bottom most layer.

These smart sensors basically, what they do they send the sense, and the sensed data are basically sent to some data center or some cloud or something like that for further analysis. So, before these are sent the data basically the sense data will pass through some kind of gateway device. These are the gateway devices, through which this data is going to pass through, and then it is going to go through the four backbone network maybe the IP network or, something like that and then finally, the data will reach the data center where all the different analytics are analytics and storage are performed. This is sensing and actuation, which is the most important part behind driving IIoT, and the smart manufacturing, smart factory applications.

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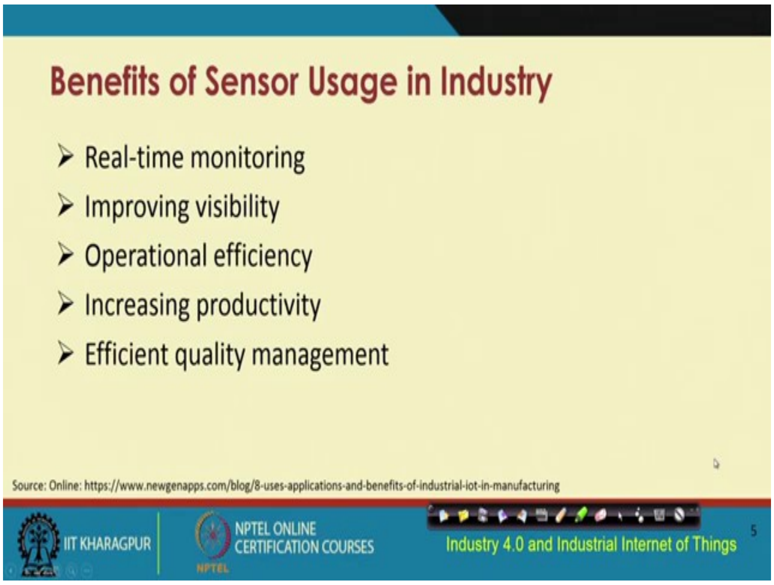

So, what are the benefits of sensor usage in the industry with smart sensors we would be able to do real time autonomous, monitoring of different machine parts, different processes, manufacturing processes, everything can be done in real-time monitoring, can be done in real-time. Then second utility is basically improving the visibility of what visibility of the machine status, in the device status and so, on improving visibility, operational efficiency will also be improved with the help of use of different sensors likewise increasing productivity, improving quality, efficiency, quality management, efficiency.

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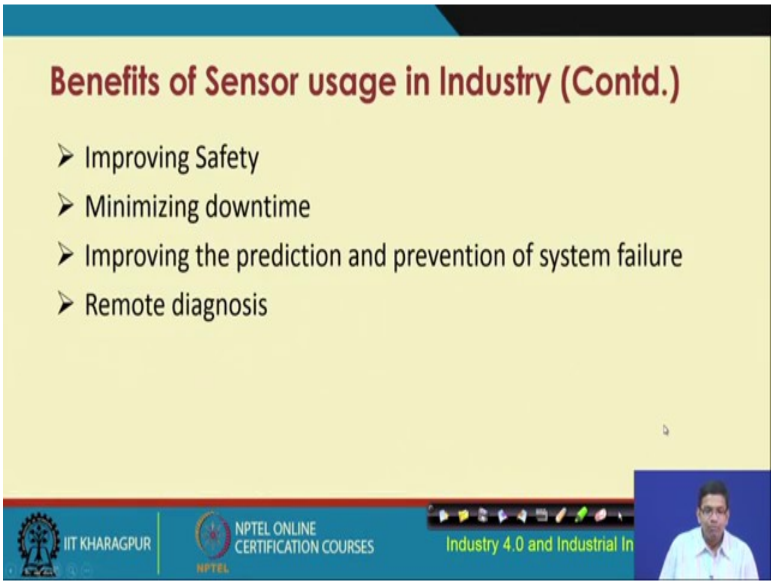

And then improving safety, minimizing downtime, improving the prediction and prevention of system failure, remote diagnostics, all of these things can be done, in a much more efficient manner, with the help of use of these different sensors or, smart sensors.

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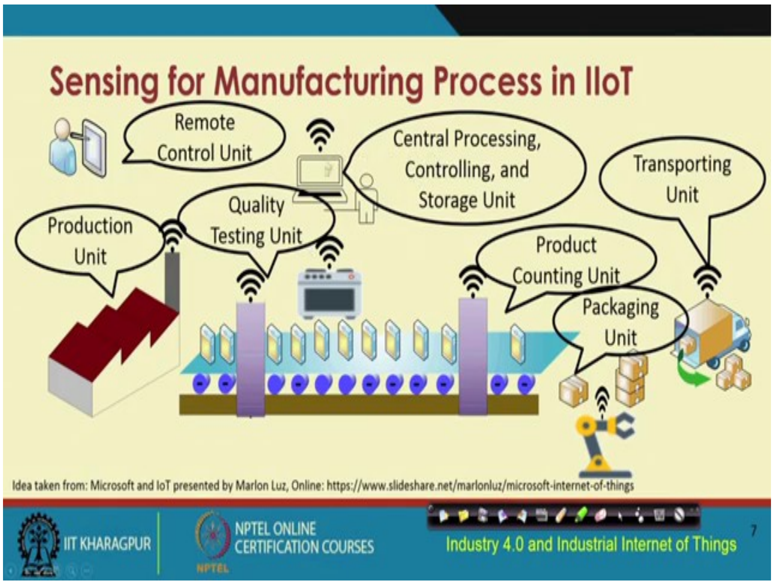

So, let us try to look at the sensing holistically in a, smart manufacturing plant, let us say that we have a manufacturing plant, and we want to look at how these sensors, play a role. So, we will start one by one with all these different elements. So, let us say that in this figure as you can see this is the smart, this is the central processing controlling and storage unit. So, let us say that this is the central processing controlling and storage unit, which is basically the central controller.

Then we are also the processing not only the processing, but also the storage take place then we have, the remote control unit, this is sort of like the control station from which the production processes over here are all going to be monitored. So, this is the remote control unit so, basically this is the place from where the controller or the user is going to start the process with the switching on or, off of any button for instance, so, this is the remote control unit. Then we have this one is the production unit, we have the quality testing unit.

Basically after production the different manufacture parts, let us say, that these are the manufactured parts or manufacture products. These manufactured products will go through a conveyor belt. The quality testing is going to be done over here. Let us assume, then the parts will get quality tested and move forward and finally, it will it is going to come over here and we are going to have the counting of these different units of product taking place over here.

Counting will take place here and then after counting, the packaging takes place, we have a robotic arm or robotic device, which is helping in this packaging and finally, the units that are manufactured are going to be boxed or packaged and transported. So, the smart logistics, are going to come into picture from this point on.

So, what did we that these are the different components of a smart manufacturing plant. And these different components as you can see these are all these have different sensing units in them and not only sensing units, but these units they can also talk to each other. They can sense and they can send the information to somewhere, and typically in this case this information is sensed and sent all these different information from all these different units are going to be sensed and sent to this central processing unit or central controller or the storage unit, over here.

So, either it is going to be sent directly or through multi-hub communication maybe through this particular node which is a intermediate node, which is going to collect all this data from all these different points in the manufacturing plant, and send it over to the central processor.

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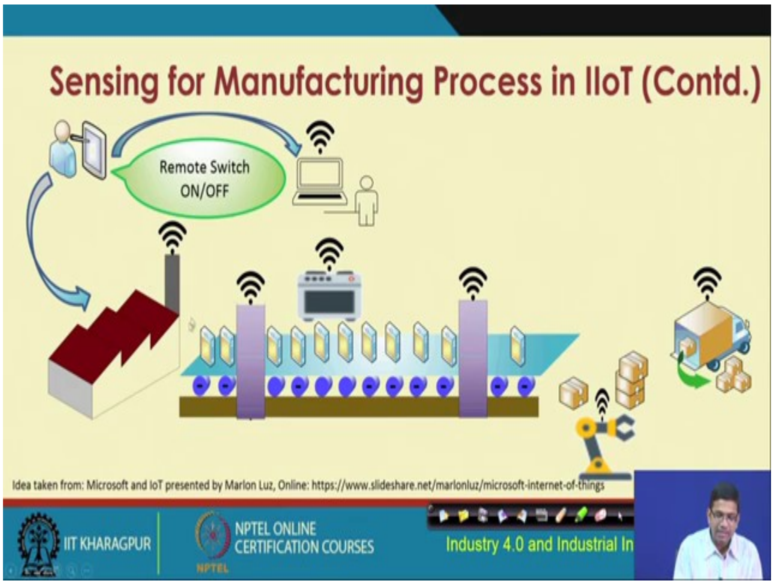

So, we have this remote switch on or off, which basically starts the process or switches of the process and that is from that central controller where the user is sitting and then let us say, that it is switched on. So, you turn on the process so, once it is switched on that data is sent to the central processing unit and it is also sent to one signal is sent unit signal is sent to that factory, the production plant it is sent. So, the production process starts from here.

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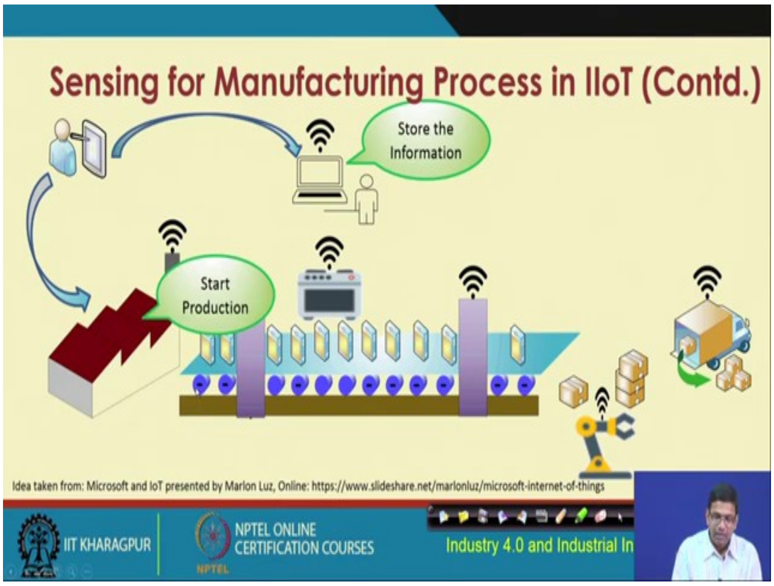

So, if then that all these data that are sensed and sent are stored in this central processing unit like this.

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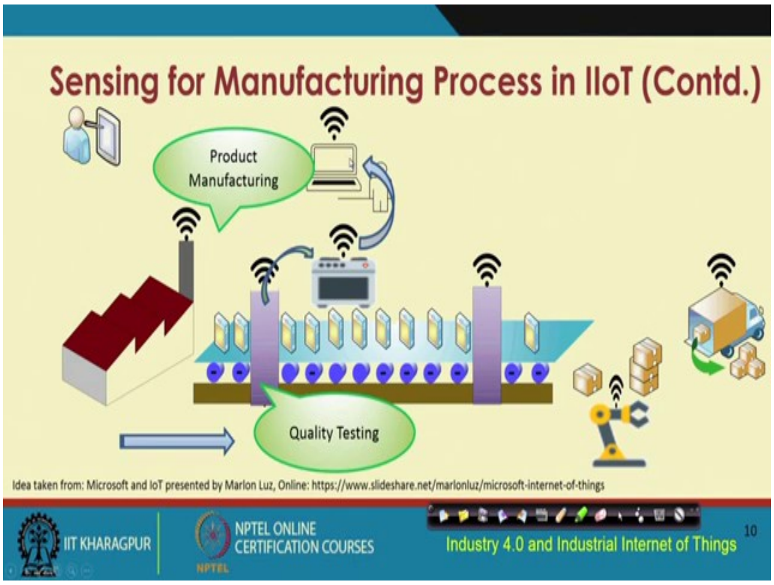

So, the production starts, manufacturing starts, and then each of these manufactured units are going to be produced, and put on the conveyor, for further processing. So, the next step on is basically to quality test; test the quality of these manufactured products, unit by unit.

So, this unit is going to do this quality testing, and then this data is going to be sent from here in this particular scenario, as you can see from this point it is going to be sensed and sent over here. And this is sort of like an intermediate hop current kind of like an aged device, which is going to collect all these different data, and then either it will process partially over here or fully this data, is going to be sent to the central processor.

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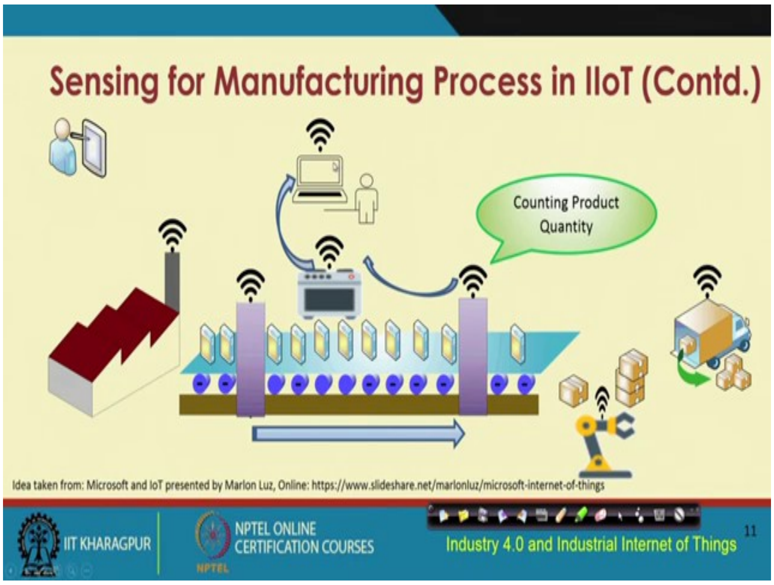

Then the product moves on comes to this particular point, where the counting of the number of units of production, the units, which have been not only produced, but tested over here this counting takes place counting of these products takes place. And then this data again is sensed is sensed and is sent over here to that intermediate node, this intermediate node again sends it to the central processor for further processing and storage this information.

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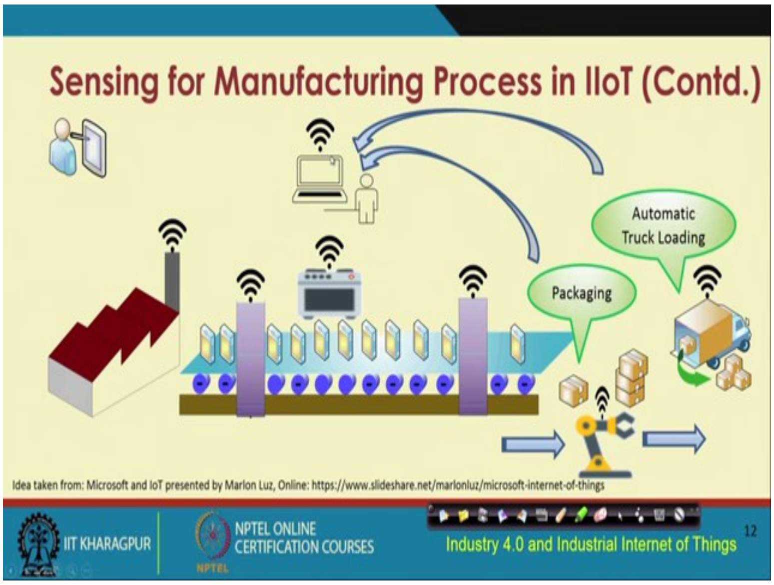

Then the product moves on further, it is packaged and that information again is sent directly not over here, as you can see over here, this is showing that it is sent directly to the central processor. In the previous example all these units, were sending it to that intermediate node and this intermediate node, in turn was sending it to the central processor and over here, this packaging unit, whatever information it has it sends it directly to the central processor. And as I was telling you that there are two ways of doing this thing.

So, one way is basically, that you send it to some intermediate node, and which is not far off from the point of sensing, and that basically is this example shown over here and once it is done the advantage is that you can have quicker response to the sensed data in terms of processing, but because not typically these intermediate nodes are not well-equipped to do lot of processing, they are not very high power computational devices typically. So, partially they can do some processing, but then the rest of the information they will be sending it to the central processor like the data center or, cloud or, whatever, for further processing.

And in this case, in this example the alternative was to send it directly to the central processor, and this is what this packaging unit is doing sending it directly to the central processor instead of taking help of this intermediate node and that is also an alternative. So, there are advantages and disadvantages of doing both. The product moves on further, after the these are packaged and automatically the products are loaded on the trucks or any vehicle, that is going to carry these products the packages are loaded on the truck and that information is also sent to that central processor.

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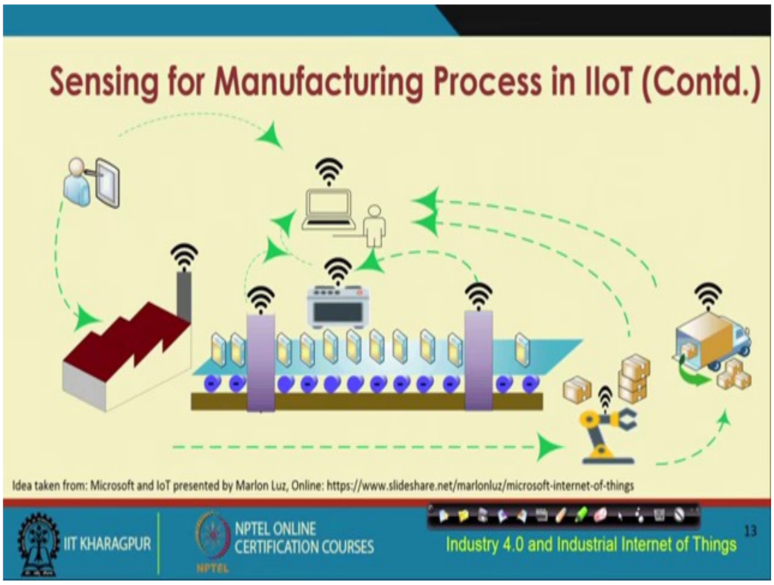

So, overall this is how this these arrows basically show you where the sensing and then the communication took place the sensing took place at all of these different points, but then these green arrows will show you how those sensed data are going to flow through this through this manufacturing plant to the central processor, this is what is shown over here.

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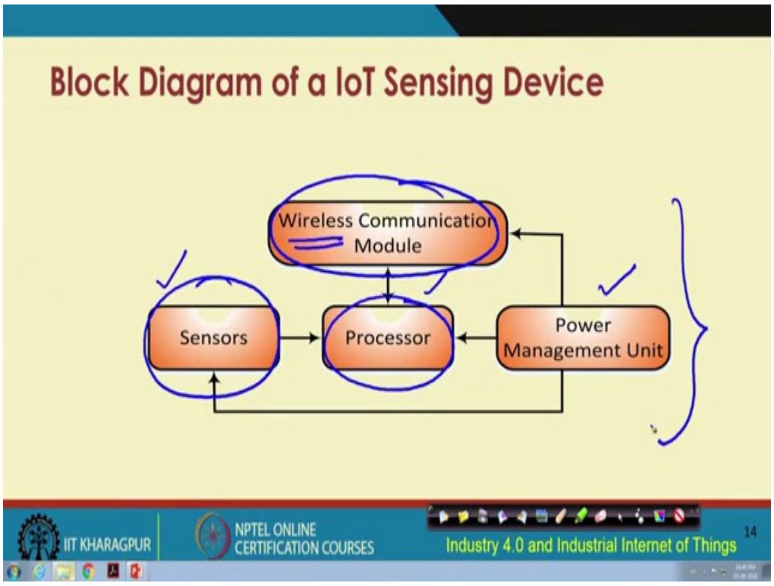

So, going back we have seen that these sensing devices are very important. So, these sensing devices have the sensor, which will which is actually the element, which is sensitive to these changes of environment or any other thing, that they are supposed to sense. So, these sensors are the central ones, then, we have the other components, the processor, the power management unit like battery or whatever processor is the one, who will do a little bit of processing and then for communication, typically, it is the wireless communication module. But it is not necessary that it has to be wireless, but typically, it is wireless in IOT, but it can be wired as well or, it can be a mix of both wired and wireless communication. So, this is the typical structure or the block diagram of an IoT sensing device.

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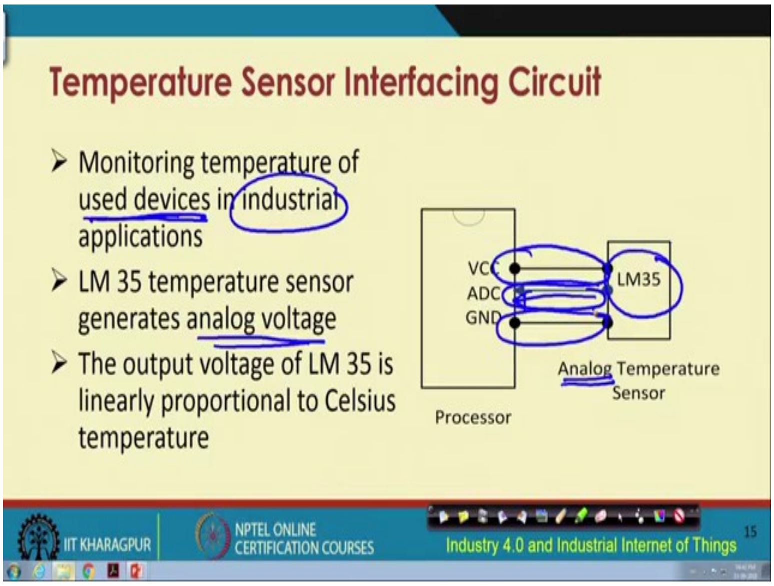

So, let us look at each of these sensors one by one so, we will start with the temperature sensor. So, there are many (many) different types of sensors that are used in the industries and temperature sensors are the common once temperature sensors are required to see or, to monitor, whether certain parts of the product that is being manufactured the temperature of it stays below a certain threshold or a certain compound compartment, a chamber in the factory is staying below a certain temperature threshold.

So, temperature monitoring is very common it is very much required in most of the smart factories and manufacturing plants. So, we have the example of a temperature sensor which is the analog variant, the analog temperature sensor. So, we can have analog temperature sensors, we can have digital temperature sensors. This variant, this model, LM 35 is it a is an analog temperature sensor, that generates analog voltage.

So, this temperature sensor could be used in industrial applications, to check the temperature or to monitor continuously monitor the temperature of the different devices that are being used in the manufacturing process. In this example, this LM 35 produces some output voltage; some output voltage, which is linearly proportional to the Celsius temperature, which is proportional to the Celsius temperature.

So, we have in this case this LM 35 comes with three different pins one is this voltage one the VCC, ADC is for Analog to Digital Conversion, and then we have the ground. So, let us look at each of these components over here.

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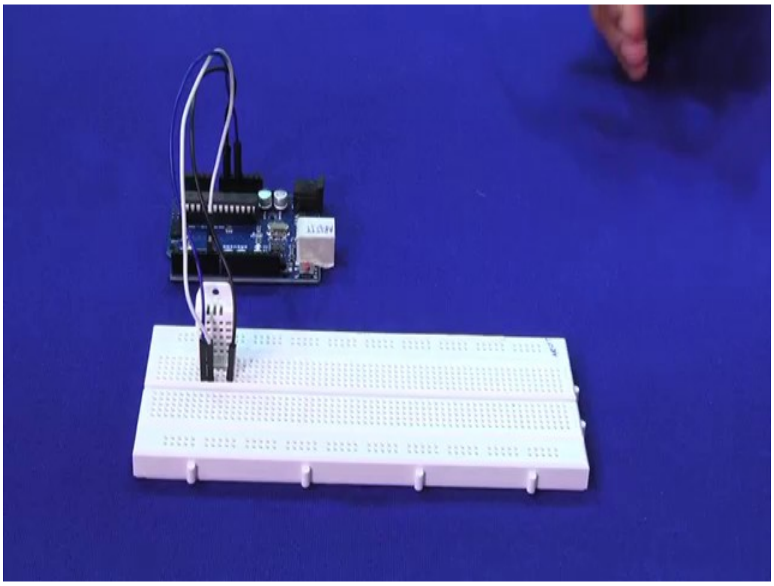

So, this is an example of a temperature sensor not the LM 35, we do not have the LM 35 model, but this is the one we are using this temperature sensor as you can see and so, I told you that it has three different pins. So, one is basically the ground, the second one is for actually sending the signal, and the third one is for sending the highest voltage, typically, it is the 5 volts. It can be 5 volts or 3.3 volts in this case for this particular sensor it is 5 volts.

So, this one this blue-coloured wired is basically the one, which is connecting to the 5 volt. This is the microcontroller to which the sensor is getting connected. This blue colored one is connecting to the VCC 5 volts. Then we have this ground this ground is the black colour wire. So, the black color wired is put on the is connected to the ground of this microcontroller and then we have this white colored one which basically sends the signal the temperature value the actual temperature value is sensed and is sent through this particular wire. So, this is how it is going to look like if you connect these sensors to the microcontroller's, this is how it is going to look like.

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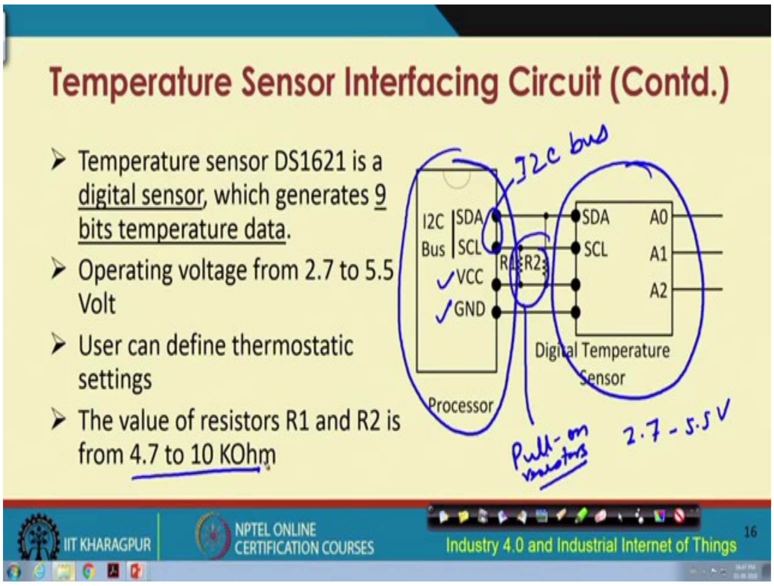

As I was telling you that temperature sensors are very important I have shown you an analog temperature sensor, but we could also have digital temperature sensors. The functioning of a digital temperature sensor is bit different from the way, the analog sensors work. This is an example of a digital temperature sensor, the model is DS1621 and this particular sensor will generate 9 bits of temperature data and this sensor digital sensor operates in the range 2.7 to 5.5 volts.

So, the user can define the thermostatic settings using this particular sensor and as you can see over here, it is connected to this processor or the microcontroller this is this microcontroller unit and we have the ground, the VCC, and these are basically the ports on the I2C bus. This SCL is basically for clock synchronization and this DA is the one that will carry the data the data acquisition for data acquisition. So, this is for the I2C bus these ports are there and these registers are the one, which do the pull-on.

So, we have these pull-on registers, which basically help in this connectivity process in a certain way. So, I am not getting into the details of these pull on registers, but these pull on registers are required and they operate in the range 4.7 to 10 kilo ohms.

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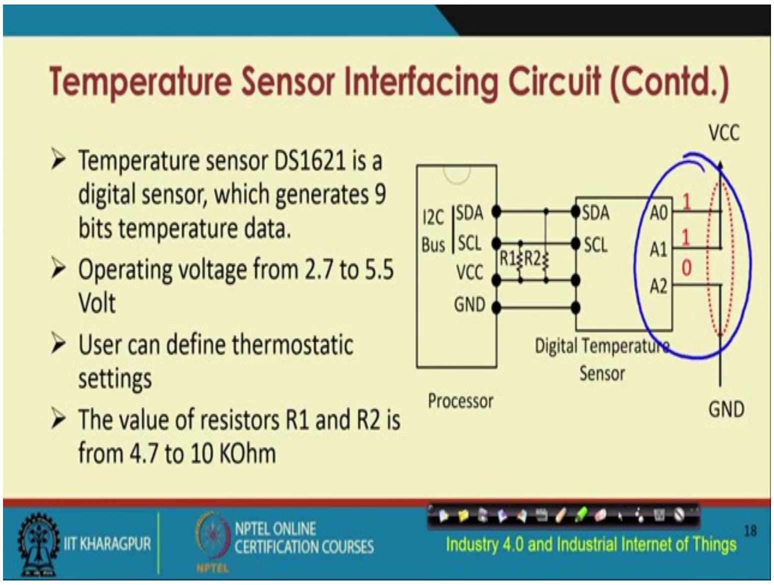

So, we have then this output produced from these digital sensors in this manner. So, these are the different outputs which can be. So, I told you that the outputs are basically generated as 9 bits of temperature data and these are the last three bits, that are shown over here, and we can have a combination of all of these, it could be 000 or a permutation basically permutation 011, over here it is 011. These are basically the different sense, I mean each of these 000 will correspond to one type of sensor connect connection to one of these sensor device, then 011 for another one.

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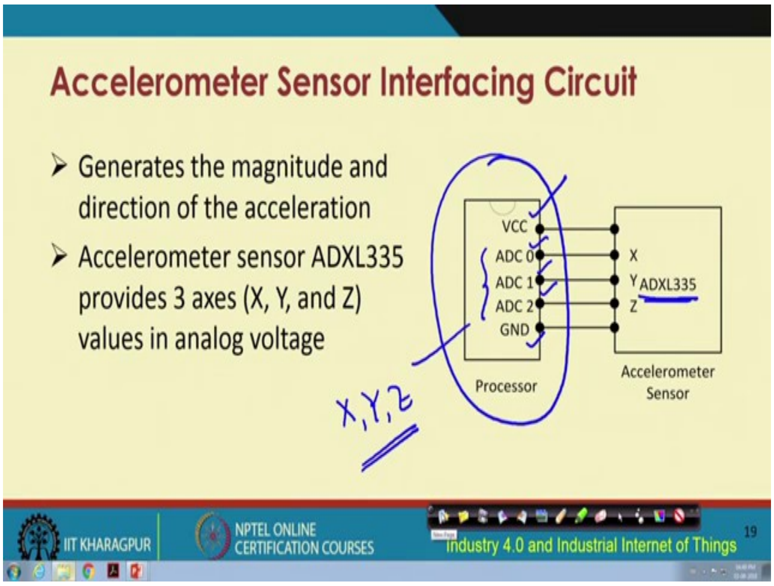

Then we will have a look at another very commonly used industrial sensor, which is the accelerometer sensor, and this is this accelerometer sensor that is shown over here the this is basically how this ADXL335 accelerometer sensor looks like and these are the different pin configurations. These accelerometer sensors are connected to a microcontroller in this manner, the first one corresponds to this VCC the maximum voltage of operation.

Then you have these ADC's, ADCI so, 0 ADC 0, 1, 2 and the ground and these are the ones, which will be responsible for actually carrying the data and why we have 3 ADC's over here? Because accelerometer data come as X, Y and Z coordinate values and these analog voltages will have to be; will have to be captured in this processor in this manner through these different ports 0, 1 and 2.

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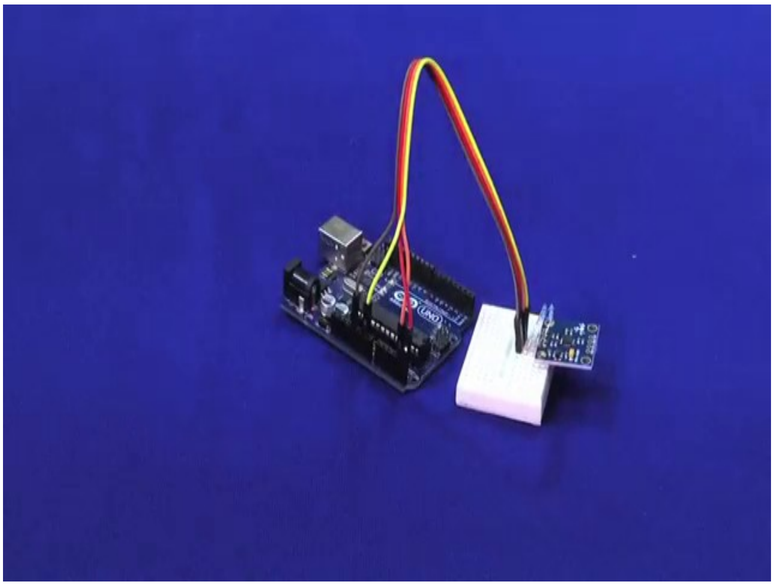

So, let me show you the example of an accelerometer sensor over here, this is an accelerometer sensor; this is an accelerometer sensor it is little small. So, you not be able to see it very well, but I think this will give you a fair enough idea, if I tell you about how this pin configuration works. So over here as I was telling you that we need so, we have 4 wires over here, unlike the previous analog temperature one so, we have 4 wires. So, we have 4 wires and we have 2 registers, these are those pull-on registers, that I was telling you earlier. These are the 2 pull on registers, you can see these blue colored ones these registers. So, what are these pins corresponding to what do they correspond to?

So, the blue colored one sorry that the. So, these two the blue and sorry the yellow, and the gray colored ones they are the ones, which basically connect the ground and the VCC; ground and the VCC. The red and the orange colored ones are the ones, which are getting the accelerometer values. So, you cannot see over here very well because it is very small in size, but what I would like to impress upon you is you can get any of these different sensors look at their pin configuration, if it is a open hardware you can get easily get access to these pin configurations. And from these pin configurations you will come to know, which pin basically connects to which port of the microcontroller. So, this is then what you do is basically you connect the sensor to the microcontroller in this manner; this is the accelerometer sensor.

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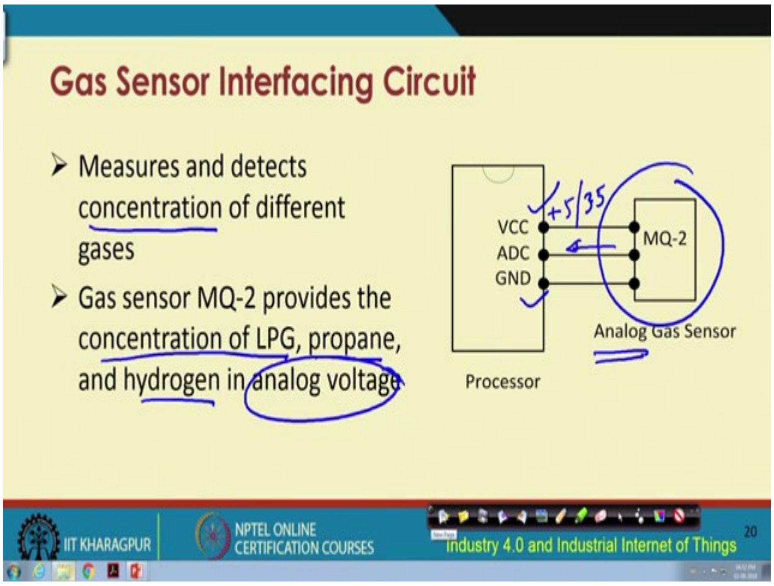

Then, we have another sensor which is also very common for industrial use which is the gas sensor and there are different (different) variants of gas sensor; this MQ-2 is a very commonly used gas sensor for industrial applications. It is a analogue gas sensor here we have three pins only; one is the maximum voltage the VCC then we have the ground; ground is basically like 0 volts, this is like your plus 5 or plus 3.5 volts, and then you have this ADC any ADC is the one, which is actually carrying the signal about what has been sensed in that gas sensor.

So, this gas sensor basically measures and detects the concentration of the different gases and this has been made in such a way to monitor the concentration of LPG, propane and hydrogen in the form of analog voltage. So, like before let me show you the example of a gas sensor.

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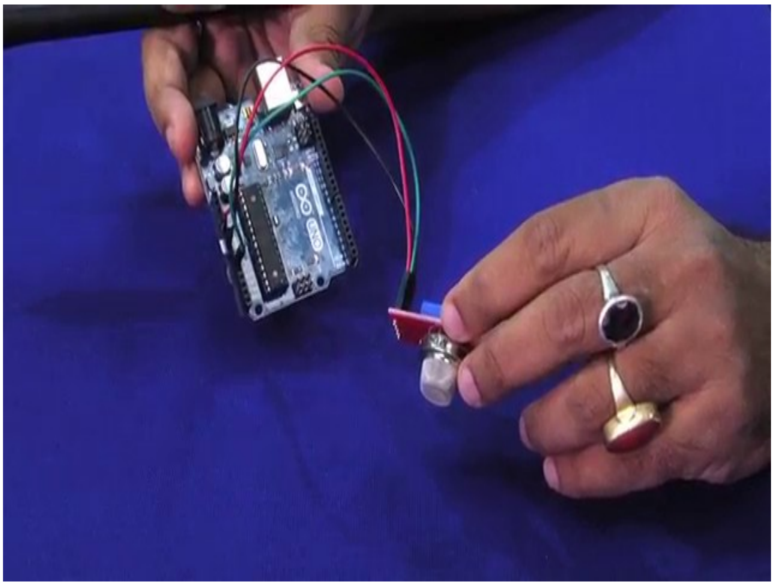

Let us show you let me show you the gas sensor. So, this is the gas sensor, this is a gas sensor, and this gas sensor basically like the previous sensors as you can see has 3 pins 3; pins, 3 ports. So, this you need to know as I told you that which pin basically corresponds to what.

So, the red one basically corresponds to this VCC, this red wire is connecting to the VCC which is the port for 5 volts. Then you have there is another pin over here in this particular sensor the way it has been made, there is a digital output which we are not connecting because we are interested in the analog variant of it which is the analog output. And this analog output is connected, through this blue colored where sorry the green colored wired from this sensor to this microcontroller and this is the one through which actually the signal about the gas concentration is coming.

And then, we have the ground this ground is basically the one, which is connected using the black wire. So, this is how you connect the different sensors you connect to the microcontrollers. So, I have shown you 3 examples; the first one was the analog temperature sensor then I have shown you the example of the accelerometer sensor, and how it connects to the microcontroller and this one is basically a gas sensor, and how it connects to the microcontroller?

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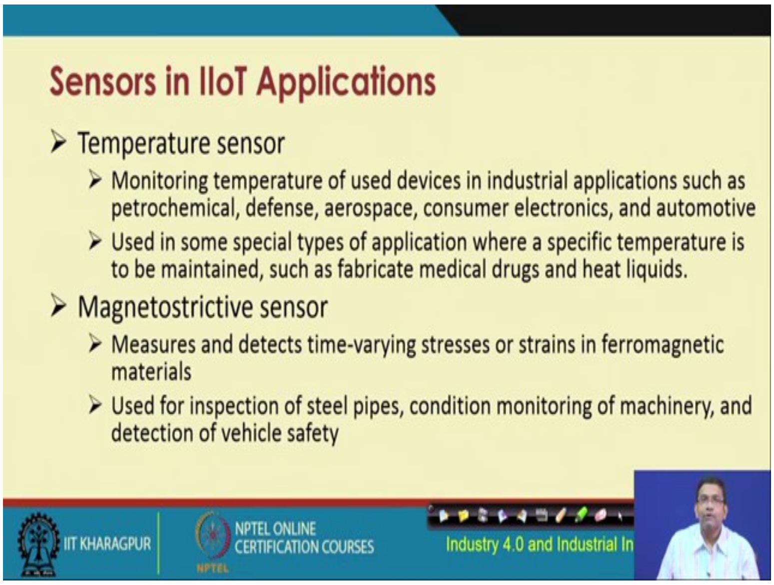

So, temperature sensors are used in industrial applications such as petrochemical, defense, aerospace, consumer electronics, automotive, and so on, and these are very important. Pharmaceutical industries also use a lot of these temperature sensors for monitoring the heat of the temperature of the liquids. Apart from temperature sensor, there could be magnetostrictive sensors, which basically measure and detect the time varying stresses or, strains in ferromagnetic materials. These are typically used for inspection of steel pipes, condition monitoring of machinery, and detection of vehicle safety.

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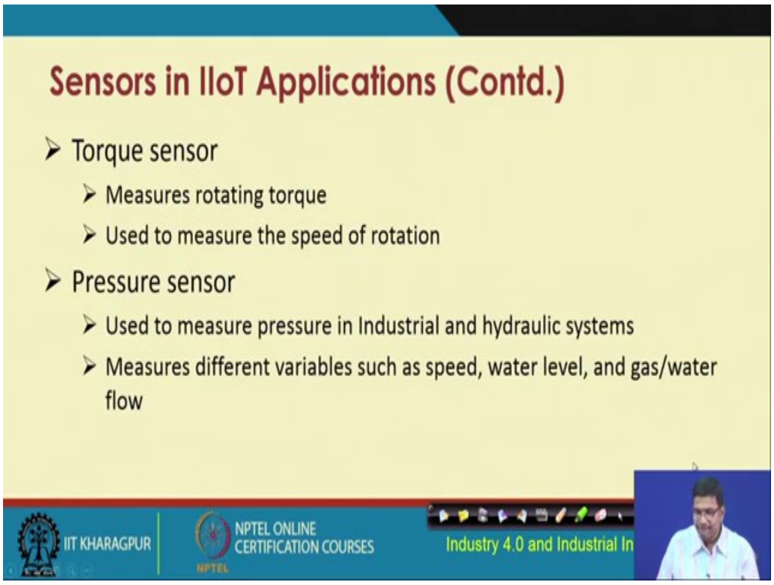

Other industrial sensors are like torque sensor, pressure sensor, vacuum sensor, acceleration sensor, speed sensor, PIR sensor.

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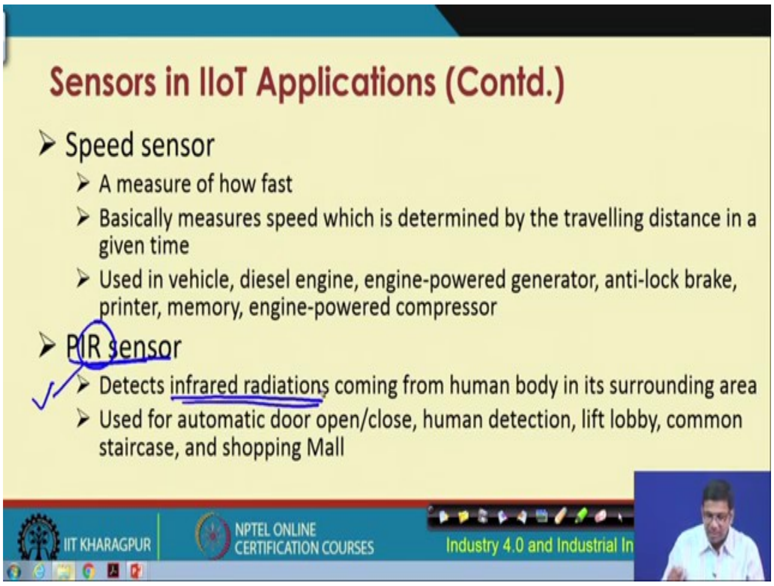

PIR sensor basically detect the infrared radiation coming from the human body in its surrounding area it is used for automatic doorbell, close closer, human detection, then the elevators in the lobbies, then common staircase, and shopping malls. PIR sensors are very commonly used, IR actually stands for infrared. So, these are basically based on infrared radiation.

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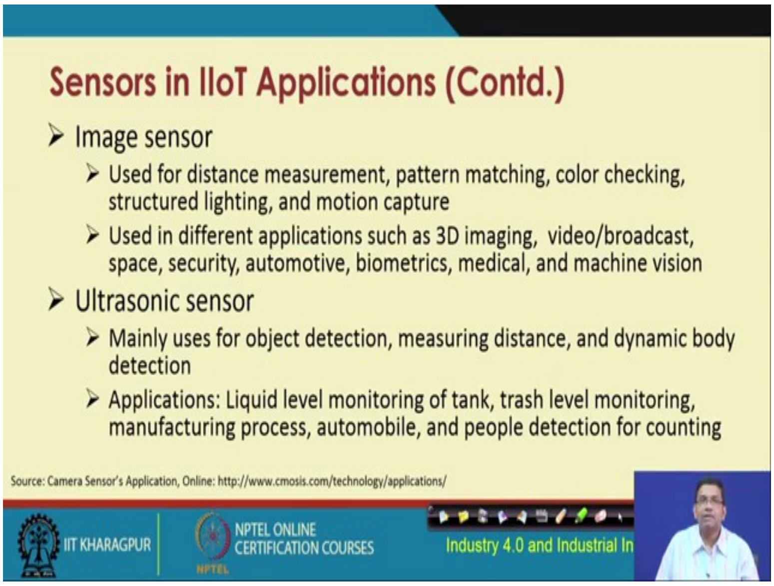

The we could also have other types of sensors like image sensors, ultrasonic sensors like based on sending ultrasound, sound waves are sent these are ultrasonic sensors are also commonly used for object detection, measuring distance, dynamic body detection, liquid level monitoring of tanks, trash monitoring, manufacturing process, automobile, people detection.

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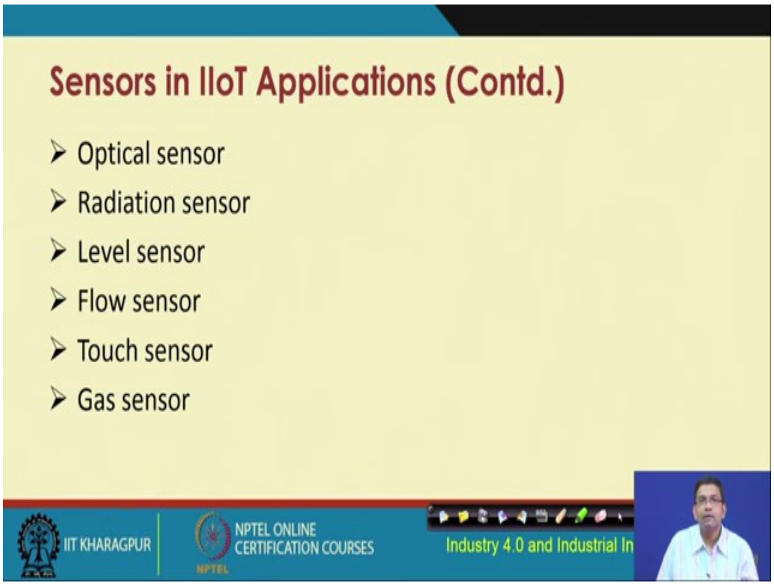

Other sensors are also possible different (different) other sensors for industrial applications like optical sensor, radiation sensor, level sensor, flow sensor, touch sensor, gas sensor, and so on.

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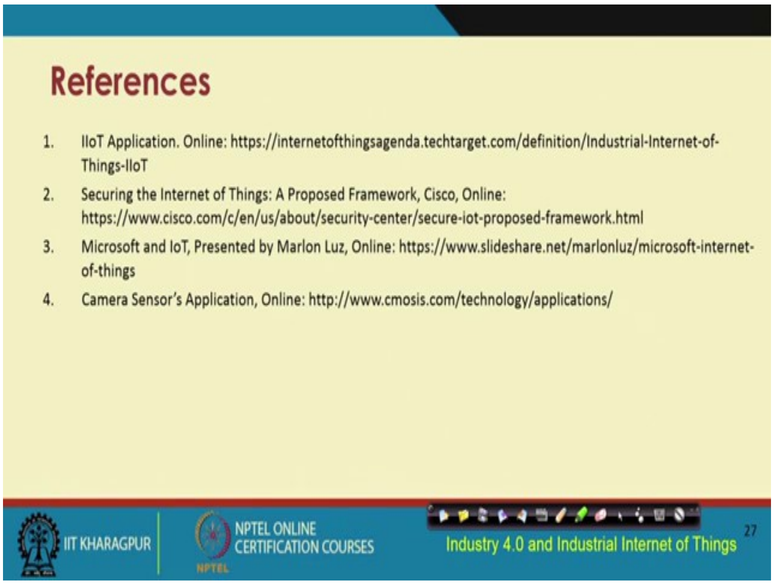

So, in this particular lecture we have seen the use of these different types of sensors for making smart applications in industrial scenarios. We have looked at the pin configurations of 3 types of sensors--analog temperature sensor, then accelerometer sensor, and third is the gas sensor, and each of these different sensors, they are pin configuration and how they connect to the microcontrollers, open hardware microcontrollers that also we have seen. And this is the small building block, which will be required to be expanded further; extended further in larger scale to build smart factories, smart applications in smart factories and so on.

Here are some of these references that you could go through there are many others on smart sensing and this is a topic by itself sensors are a topic by itself. So, you could basically find lot of literature on these different sensors, the way the sensors are made and so on. There are people who work solely on sensor fabrication and for one type of sensor fabrication it may take several months to several years for fabricating a single sensor for the first time.

If you are trying to come up with a sensor for the first time, depending on the type of sensor being made the complexity of it. It could take several months to several years to come up with the design of a particular sensor. And these are some of these common sensors that I have shown you which are readily available in the market.

So, you do not need to really worry about the designing of a particular sensor, the manufacturing of it, the fabrication of it, because that is a completely different ballgame and we really unless we are very much interested, and we dig deep into each of these, we will not be able to master the sensor fabrication. So, easily it’s a completely different story altogether.

With this we come to an end of it the part 1 and then in part 2 basically we will go through the in more detail we will take up one of these different sensors the gas sensor and how you produce the gas sensors. So, how what is done? So, I will show you how the working principle of a gas sensor is.

Thank you.