# Implementation of Industrial IoT Laboratory for Sensors

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## 1 Introduction

Machining tools are conventionally categorized into two groups: Forming and chip-making machines. In forming processes such as forging, pressing, bending and shearing, a desired shape is obtained by deformation. When it comes to chip-making type machining processes, material is removed from a work piece in the form of chips. The main types of these machining processes are drilling, milling, boring, grinding and turning. Defects and errors in the final product may result from various factors starting from human errors, machinery and material characteristics/wear and tear, temperature and pressure and environmental conditions, etc. In order to achieve zero defects, minimum down time and setting time, an IoT based intelligent control and monitoring system are needed at the industry where process data acquired from sensor network is transmitted to controllers [1, 2].

Data captured from manufacturing lines can be logged to a cloud storage housed in a data center through an indexing server. Controllers should give the right response based on the current sensor inputs as well as from the analytics of historical data from cloud [3]. However, these are possible only through proper knowledge of sensors, and use of the sensors data in various analysis techniques to provide skills in these areas. It is essential to develop proper laboratories in the institute and generate data for the purpose of analysis. One such laboratory setup is visualized by the development and implementation of PLC, industrial PC (IPC) and hydraulic laboratories. The

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experiments connected in each of the laboratories can be accessed with the IoT controller/data logger by the remote user from different locations at any time [4].

In this paper, an attempt has been made to develop industry Internet of Things-based laboratory in the institute and bring the concept of practical learning in the areas of sensors and IoT.

### *1.1 Architectural Framework*

Monitoring the parameters such as temperature, pressure, position, etc., need integration of sensors or detecting devices to be put on the machine or on the object and ensure that they are maintained at required set levels throughout the production time/process time. In this paper, application of IoT to capture data, and use of analytics to understand the cause of variations is discussed. This approach can be a big game changer for precision manufacturing industries in terms of quality production and realization of six sigma level. Figure 1 gives architectural framework of such system.

### *1.2 Field-Devices Network*

Manufacturing industries employ huge number of devices, equipment, machineries which perform machining operations on workpieces using tools and support equipment. Devices could be I/O blocks, systems, readers, process instruments and drives, etc. All these machine-level operational and monitoring components could be made smarter by incorporating AI technique and smart control whose operations are triggered by control signals from remote terminal units (RTU's) or I/O modules. Thus, data from various sensors, i.e., analog/digital signals are communicated to control system through these RTU's transmit control signals from controller to actuators. These remote terminal units are basically channeling for data transmission to and from field equipment with embedded controllers. They control device management functions with device level protocols like foundation fieldbus, highway addressable remote transducer (HART), PROFIBUS-PA, and most of them have 4–20 mA analog current or 0–10 V.

### *1.3 Connectivity Network*

Operational data to/from RTU's across the plant should communicate with master controller. Master controller being the center of control, intelligence and co-ordination across the complete system should process these input data signals from

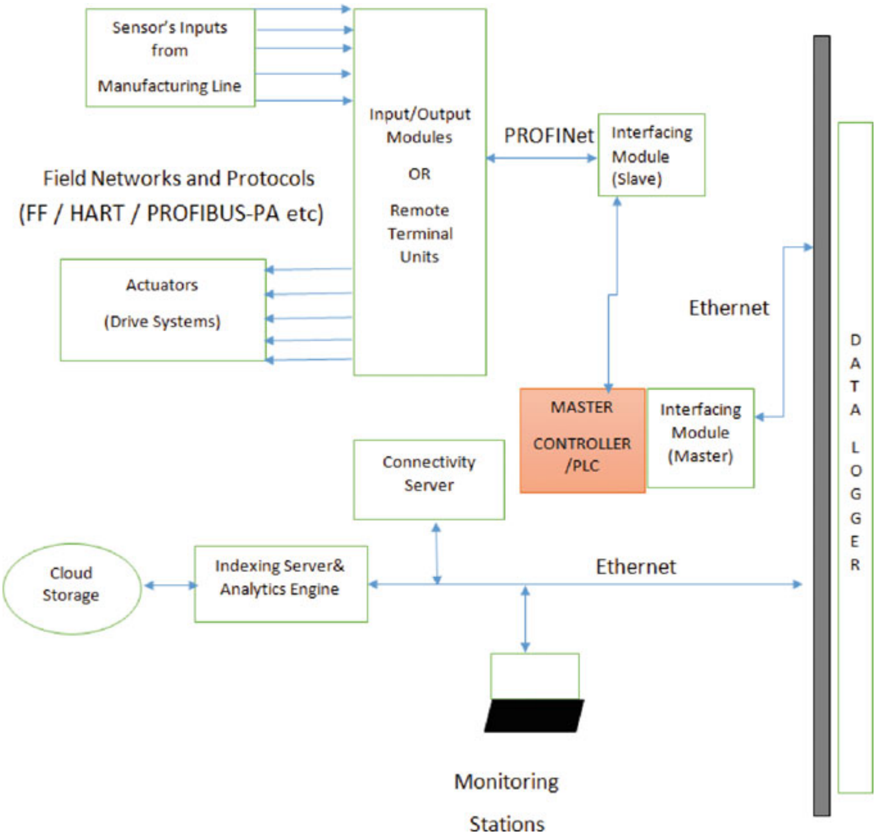


**Fig. 1** Architectural framework

sensors and give out responsive control signals on real time basis. Every set of operational data processed by controller is logged to cloud infrastructure. Hence, response given by controller for any input signal should also consider analytics of data logged previously, ensuring self-learning and improvisation.

Data transfer from RTU's to ethernet network switch would require interfacing modules, as communication from RTU's, all through the plant should be using protocols which are rugged and match industrial standards. PROFINET is an ethernet-based industrial communication protocol, which utilizes physical interface RJ-45 ethernet jack. PROFINET cables contain robust shielding and are designed to function well in harsh environments with less than 1 ms, making it ideal for high-speed applications. In order to provide similar kind of experimentation at laboratory setup in the institution, different types of sensors and actuators were connected to Siemens ET-200SP which intern links to PLC with single cable. These kinds of arrangement create a flexible link between the sensors, actuators and PLC. Student can program PLC and realize the input/output operations of sensors/actuators as per requirement.

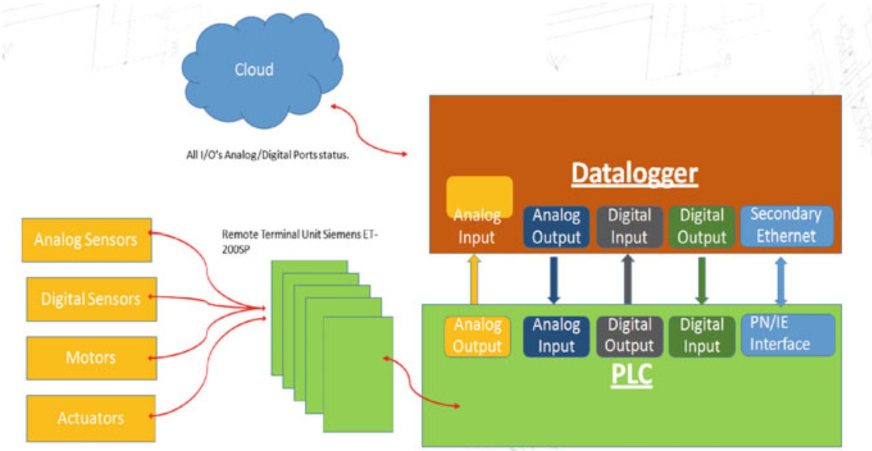


**Fig. 2** Connectivity network between sensors, clouds, data logger, RTU and PLC

PLC in turn connects to a data logger and communicates the outputs to a cloud server using message queue telemetry transport (MQTT) protocol, JAB Hibernate is used to communicate with database and http-based protocol for data transfer from server to web application and http REST APIS protocol for data transfer from server to mobile applications. Figure 2 shows connectivity network between RTU, PLC, cloud, data logger and sensors.

## 2 Cloud Infrastructure, Configuration and Monitoring Network

In order to configure, program and monitor the control activities of the system, servers and client machines are configured with software tools, which can support building, debugging, configuring and downloading the logic to controller.

This software should ensure proper and distinct access for operator functions (Switch ON/OFF on HMI), engineering functions (Building Topologies, Designs, I/O Tags and Logics) [5], monitoring functions (SCADA Tools, etc.) and analytic functions (where ML based algorithms are developed, debugged, triggered and monitored), etc. These server/client workstations should link to ethernet switch, while connecting to cloud infrastructure at another end. Also, a connectivity server system is required, which runs few critical services depending on operating system of server/client nodes.

# 3 IoT Sensors for Industrial Applications

## *3.1 Experiment on Digital Sensor Using PLC and Data Logger*

Sensor applications and few characteristic experiments can be conducted using the developed laboratory. In this section, digital sensors such as inductive, capacitive, etc., are considered and one of them is operated using a PLC to demonstrate an application of an industry. In this example, an inductive sensor is connected to the PLC and to the data logger to detect the conductive materials, and result is pushed to the cloud as 0 or 1 in value column no.-5 through ethernet. Table 1 gives the port name and corresponding digital outputs. Figure 3 shows connection of data logger to PLC.

**Table 1** Process parameters when data logger connected to PLC

| Time and date | Port | Port no. | Sensor name | Value | Type (V) |
|---|---|---|---|---|---|
| 2020/10/27, 16:17:35 | Digital Input | DIO | Q1 | 1 | 0–24 |
| 2020/10/27, 16:17:30 | Digital Input | DIO | Q1 | 1 | 0–24 |
| 2020/10/27, 16:17:25 | Digital Input | DIO | Q1 | 0 | 0–24 |
| 2020/10/27, 16:17:20 | Digital Input | DIO | Q1 | 1 | 0–24 |
| 2020/10/27, 16:17:15 | Digital Input | DIO | Q1 | 1 | 0–24 |

**Fig. 3** PLC connected to data logger

### 3.2 Experiment on Analog Sensor

Balluff position sensor is used to measure the linear distance. As the sensor is moved from 0 to 500 mm, the values of voltage change are recorded through the data logger. The same is shown in Table 2. Column 5 shows the voltage values varying from minimum value of 1.54 V to maximum value of 3.83 V. Figure 4 shows the sensor connected to the data logger for conduction of the experiment manually by moving the sensor actuator rod. The output is shown as graph in Fig. 5 (Fig. 6).

**Table 2** Process parameters when Balluff sensor connected to data logger

| Time and date | Port | Port no. | Sensor name | Value |
|---|---|---|---|---|
| 2020/10/19, 16:30:20 | Analog | AIO3 | Position sensor | 3.83608 |
| 2020/10/19, 16:30:30 | Analog | AIO3 | Position sensor | 3.0428 |
| 2020/10/19, 16:30:40 | Analog | AIO3 | Position sensor | 2.15304 |
| 2020/10/19,16:30:50 | Analog | AIO3 | Position sensor | 2.1852 |
| 2020/10/19, 16:31:00 | Analog | AIO3 | Position sensor | 1.56344 |
| 2020/10/19, 16:31:05 | Analog | AIO3 | Position sensor | 1.54736 |

**Fig. 4** Balluff sensor connected to Data Logger

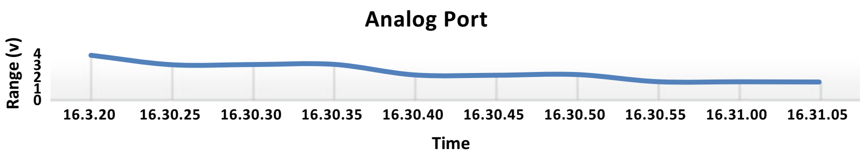


**Fig. 5** Graph shows the voltage reading of position sensor over time

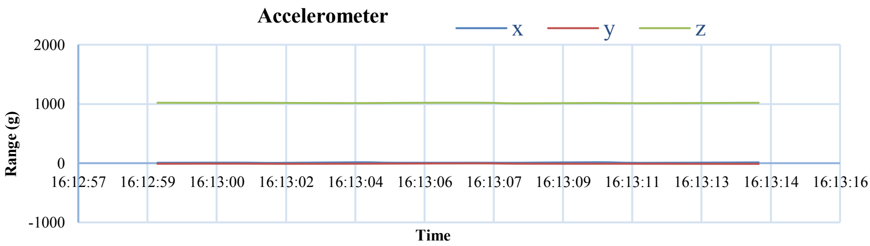


**Fig. 6** Graph shows the accelerometer reading (g) in *x*, *y* and *z* direction over time

## *3.3 Experiment on XDK Sensor Without Data Logger*

It is an IoT sensor used to measure multiple parameters with a single device. This is used to log various parameters such as ambient temperature, atmospheric pressure, light intensity, acceleration of the body in three directions, humidity, angular velocity, strength and direction of magnetic field and rotation of the body in degrees. Based on the industrial application requirement, any of these parameters can be monitored, and data is logged as shown in Table 3. Based on the data obtained, process is controlled.

**Accelerometer**—It measures the acceleration of the body in three different axes, i.e., *x*, *y* and *z*. Column 2 of Table 3 shows the values for *x*, *y* and *z* directions.

**Gyroscope**—Gyroscope is used for measuring angular velocity. It is measured in terms of (rad/s). Column 3 of Table 3 shows the values for *x*, *y* and *z* directions (Fig. 7).

**Table 3** Process parameters of XDK sensor

| Time and date | Accelerometer | Gyroscope | Temp | Pressure | Humidity |
|---|---|---|---|---|---|
| 2020/10/28, 16:13:14 | 13, −12, 1019 | 610, 1220, −448 | 33 | 1 | 34.23 |
| 2020/10/28, 16:13:11 | 6, −10, 1013 | −3417, −4638, −4150 | 29 | 1 | 34.59 |
| 2020/10/28, 16:13:10 | 16, −10, 1016 | 3906, 2685, 1953 | 29 | 1 | 34.58 |
| 2020/10/28, 16:13:08 | 7, −9, 1011 | −366, 2075, 2075 | 29 | 1 | 34.59 |
| 2020/10/28, 16:13:07 | 8, −3, 1020 | 3540, 7934, 5371 | 29 | 1 | 34.58 |
| 2020/10/28, 16:13:05 | 7, −7, 1018 | −1220, −1831, 1708 | 29 | 1 | 34.58 |
| 2020/10/28, 16:13:04 | 15, −9, 1014 | −4150, −1220, 1708 | 29 | 1 | 34.6 |
| 2020/10/28, 16:13:02 | 5, −11, 1018 | 1098, 3295, −3051 | 29 | 1 | 34.59 |
| 2020/10/28, 16:13:01 | 9, −8, 1018 | −1708, −2319, 3906 | 29 | 1 | 34.59 |
| 2020/10/28, 16:12:59 | 7, −10, 1020 | −1708, 1708, 5493 | 29 | 1 | 34.6 |

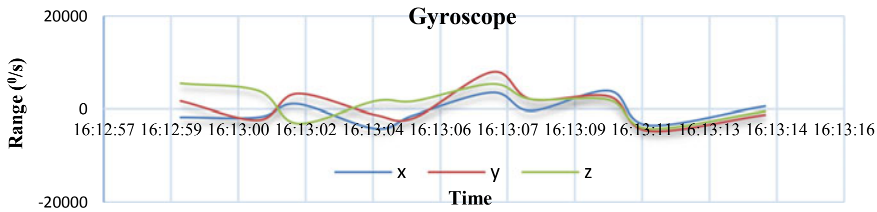


**Fig. 7** Graph shows the gyroscope reading ($^0$/s) in *x*, *y* and *z* direction over time

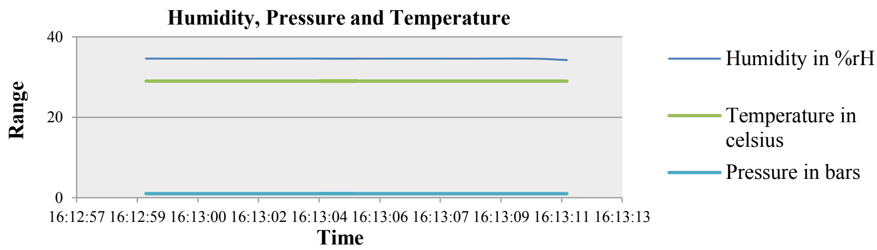


**Fig. 8** Graph shows humidity, temperature and pressure readings over time

Columns 4, 5 and 6 of Table 3 indicate the values of room temperature, atmospheric pressure and humidity obtained at the time of conduction of the experiment. Also, other parameters such as magnetometer reading, rotation and light intensity may be recorded (Fig. 8).

## 4 Conclusion

In the project, IoT laboratory with suitable data logger from Hydac India was used along with Siemens and Delta PLC to conduct various experiments related to sensors. This has enabled the institute to have a separate lab of 2 credits on IoT applications related to sensor which is designed and conducted. The system so developed to enable the student login from anywhere through the internet and conduct the experiments as per the data logger availability. However, on every experiment completion, data logger is to be released by a lab supervisor to enable the same data logger to the others.

To avoid this, a program is proposed such that auto release is done after the completion of the experiment. All the experiment conducted is satisfactory and recorded either in table or graphical form as per the laboratory requirement along with student registration details for proper validation process.

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