Birla Vishvakarma Mahavidyalaya
Electronc Engineering Department

(Internship Project)

Development of IIoT Dashboards for Smart Manufacturing using ThingWorx

Presented By
Rishi Raman
21EL039

Under the guidance of
Industry Guide:Prof.Anishbhai A. Vahora
at
Centre of Excellence, Digital Manufacturing

Faculty Guide: Prof. TD Pawar
Coordinator: Prof. DL Vala
In fulfilment of the award of the Degree
Of
BACHELOR OF TECHNOLOGY In ELECTRONICS ENGINEERING

Acknowledgements

[I would like to express my sincere gratitude to **Prof. Vinay Patel**, **Prof. Anish Vahora**, **Prof. Jaydeep Sanandiya**, and **Prof. Mehfuza Holia** for their invaluable guidance and support throughout this project. Their expertise, insights, and constant encouragement have been instrumental in successfully completing this work. I truly appreciate their time and efforts in helping me overcome challenges and refine my understanding of the subject.]

Abstract

Development of IIoT Dashboards for Smart Manufacturing using ThingWorx

The rise of **Industrial IoT (IIoT)** has revolutionized real-time monitoring and automation in manufacturing. This project focuses on implementing an **IIoT-based monitoring system** using **ThingWorx and Kepware** for seamless data acquisition from industrial machines.

The **objective** is to enable real-time tracking of machine performance, including parameters like **cycle status, alarms, energy consumption, and operational conditions** across multiple stations such as **AS/RS and Turning Center**.

The **methodology** involves integrating **PLC data with Kepware Server**, which serves as a bridge between machine controllers and the **ThingWorx dashboard**. Various sensors, including **temperature, vibration, proximity, and energy meters**, provide critical machine insights.

Key findings include successful **dashboard development** for AS/RS and Turning Center, ensuring **real-time visualization and analysis**. The system enhances **machine monitoring, reduces downtime**, and lays the foundation for **complete IIoT integration** in digital manufacturing.

List of Figures

Contents

Chapter 1

Introduction

1.1 Problem Summary

Modern industrial automation systems generate vast amounts of real-time data that must be efficiently monitored and analyzed for better decision-making. Traditional SCADA systems lack flexibility, scalability, and advanced visualization capabilities. This project focuses on designing and implementing interactive dashboards in ThingWorx, connected via Kepware to collect real-time data from ASRS, Turning Centre, Machining Centre, Assembly Station, and Manual Inspection Station. The goal is to centralize monitoring, improve data accessibility, and enhance operational efficiency.

1.2 Aim and Objectives

1.2.1 Aim:

To develop an integrated ThingWorx-based dashboard system that provides real-time monitoring of various industrial stations by establishing seamless data communication with Kepware and PLCs.

1.2.2 Objectives:

- Design and develop individual dashboards for ASRS, Turning Centre, Machining Centre, Assembly, and Inspection Stations.
- Integrate Kepware with ThingWorx to acquire real-time data from industrial equipment.

- Create a central dashboard that allows navigation between different station dashboards.
- Ensure scalability by designing an adaptable and user-friendly interface.
- Optimize system performance to achieve fast data refresh rates and minimal latency.

1.3 System Overview

This system leverages ThingWorx, an IIoT platform, for data visualization and real-time monitoring. Data is collected from industrial machines via Kepware, which acts as a communication bridge between PLCs and ThingWorx dashboards. Each station has a dedicated dashboard, and all dashboards are accessible via a central dashboard that allows users to navigate between them.

1.3.1 Key Components:

- PLCs (Programmable Logic Controllers): Collect machine data (temperature, cycle time, errors, etc.).
- Kepware: Acts as an OPC-UA server to transmit PLC data to ThingWorx.
- ThingWorx Platform: Provides data visualization through dynamic dashboards.
- User Interface: Interactive dashboards for real-time monitoring and analysis.

1.4 Literature Review

To establish the relevance of this project, a literature review was conducted in the following areas:

- **Web & Research Publications:** Studies on **IIoT in manufacturing**, industrial **sensor-based monitoring**, and **ThingWorx applications**.

- **User Feedback:** Common industry challenges in **real-time machine monitoring** and **predictive maintenance**.
- **Market Research:** Existing **IIoT platforms** (Siemens MindSphere, AWS IoT, Azure IoT, etc.) compared to **ThingWorx**.
- **Patent Search:** Patents related to **IIoT-based industrial monitoring solutions** to avoid redundancy and explore innovation.

1.5 Tools and Technologies Used

1.5.1 ThingWorx

ThingWorx is an Industrial Internet of Things (IIoT) platform used for developing interactive dashboards and real-time data visualization.

Figure 1.1: ThingWorx IIoT Platform

1.5.2 Kepware

Kepware acts as an OPC-UA server, facilitating communication between PLCs and ThingWorx.

Figure 1.2: Kepware Industrial Connectivity

1.5.3 OPC-UA Protocol

OPC-UA is a machine-to-machine communication protocol for industrial automation, ensuring reliable data exchange.

Figure 1.3: OPC-UA Communication Protocol

1.5.4 Programmable Logic Controllers (PLC)

PLCs are used to control industrial machines and collect real-time sensor data.

Figure 1.4: PLC System

1.5.5 Sensors and IoT Devices

Various sensors are used to monitor parameters like temperature, pressure, and cycle time.

Figure 1.5: Industrial Sensors

Chapter 2

System Architecture

This chapter describes the overall system architecture, including hardware-software interaction, data flow, and dashboard integration.

2.1 Overall System Architecture

The industrial monitoring system integrates PLCs, Kepware Server, and ThingWorx for real-time data visualization. Kepware connects with PLCs using OPC-UA and transmits sensor data to ThingWorx for dashboard visualization. The system ensures seamless data acquisition, processing, and monitoring across multiple industrial stations.

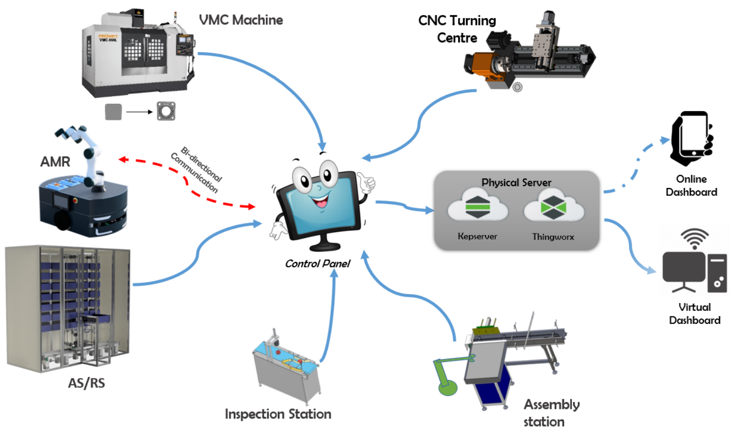

Figure 2.1: Overall System Architecture

2.2 Hardware Components

The system includes PLCs, sensors, and industrial controllers to capture real-time data. The PLCs act as primary controllers, sending data through Kepware Server to ThingWorx. Various sensors measure temperature, vibration, and operational parameters, ensuring real-time monitoring and fault detection.

Figure 2.2: ASRS system

2.3 Software Components

The software stack consists of ThingWorx, Kepware Server, and OPC-UA Protocols for communication. ThingWorx provides an interactive dashboard, while Kepware facilitates data acquisition from multiple PLCs. The OPC-UA protocol ensures secure and scalable connectivity between industrial devices.

2.4 Dashboard Design

The dashboards in ThingWorx provide an interactive monitoring system for multiple industrial stations. Each dashboard displays real-time machine status, alerts, and trends. The design includes a main dashboard with clickable sub-dashboards for ASRS, Turning Center, Machining Center, Assembly Station, and Inspection Station.

2.5 Data Flow and Communication

The data flow starts from PLCs, transmitting signals to Kepware Server via OPC-UA. Kepware processes this data and sends it to ThingWorx, where it is visualized through widgets and analytics tools. The real-time data pipeline ensures instant updates and alerts for operators.

2.6 System Scalability and Security

The system is designed for scalability, allowing the addition of new stations without affecting performance. Role-based access control (RBAC), data encryption, and OPC-UA security features ensure a secure industrial environment while preventing unauthorized access.

Chapter 3

Dashboard Design and Development

3.1 Introduction

In this chapter, we will discuss the step-by-step approach to designing and developing the dashboard. The process involves creating a project in ThingWorx, configuring data sources via Kepware, designing mashups, adding widgets, and configuring the layout and functionality of the dashboard. The dashboard serves as the central monitoring tool for various stations like ASRS, Turning Centre, Machining Centre, Assembly Station, and Manual Inspection Station. The design process is carried out in a systematic manner, ensuring all necessary data is displayed and monitored in real-time.

3.2 Creation of PLC Tags

3.2.1 Steps to Create Tags in CODESYS

1. Open CODESYS and load the PLC project in which tags need to be created.

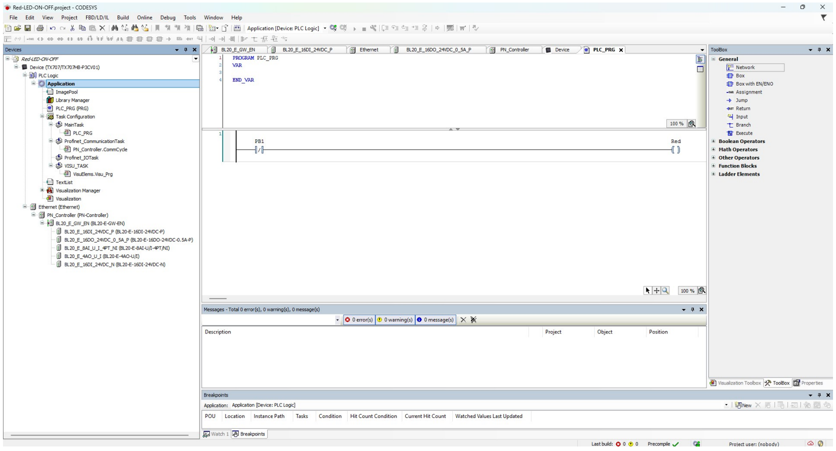

Figure 3.1: Codesys Interface

2. Ensure that the development environment is connected to the physical PLC. Record the IP address of the PLC, as it will be needed during the configuration phase.

3. In the project tree, right-click on **Application** and select **Add Object**.

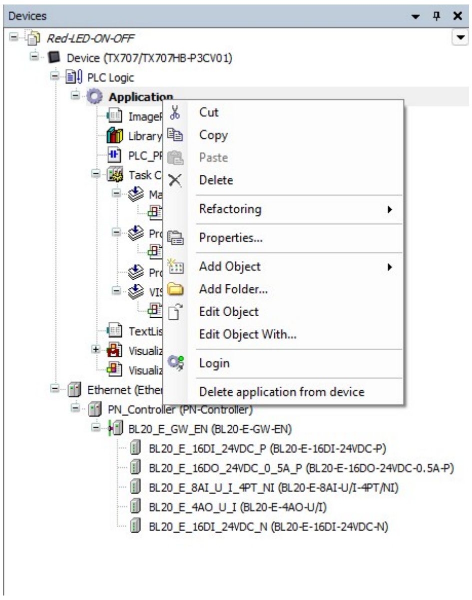

Figure 3.2: Add object

4. Choose **Symbol Configuration** and click **Add**.

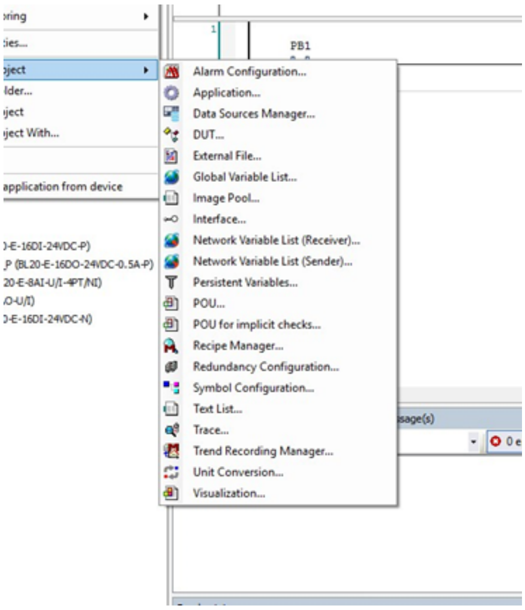

Figure 3.3: Symbol Configuration

5. A list of variables (tags) used in the PLC program will appear.

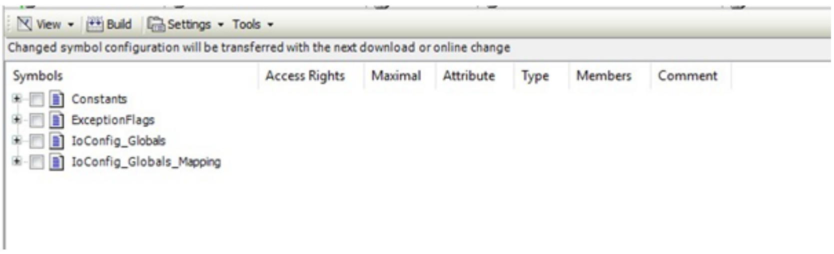

Figure 3.4: List of Tags

6. Select the tags that are to be exposed to ThingWorx by ticking the corresponding checkboxes.

7. Click on the **Build** option to compile the project with the selected tags.

8. Typically, the exported tags will be located in the file path `IO_config_global_mapping`.

9. Once the build is complete, click **Login** and then **Start** to run the PLC program.

10. Ensure that the PLC remains actively connected to CODESYS throughout this procedure.

3.3 Configuration of Kepware Server

3.3.1 Establishing Connection to the Server

1. Open the **ThingWorx Kepware Server 6 Configuration** application.

2. Navigate to **File** → **New** to create a new project.

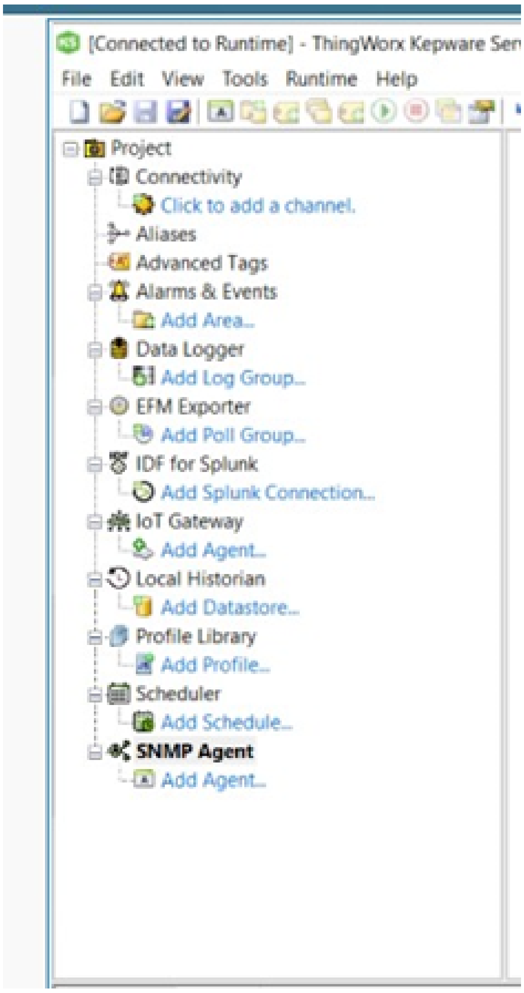

Figure 3.5: Kepware Homepage

3. Click on **Click to add a channel** under the Connectivity section.

4. From the drop-down list, select **OPC UA Client** and proceed by clicking **Next**.

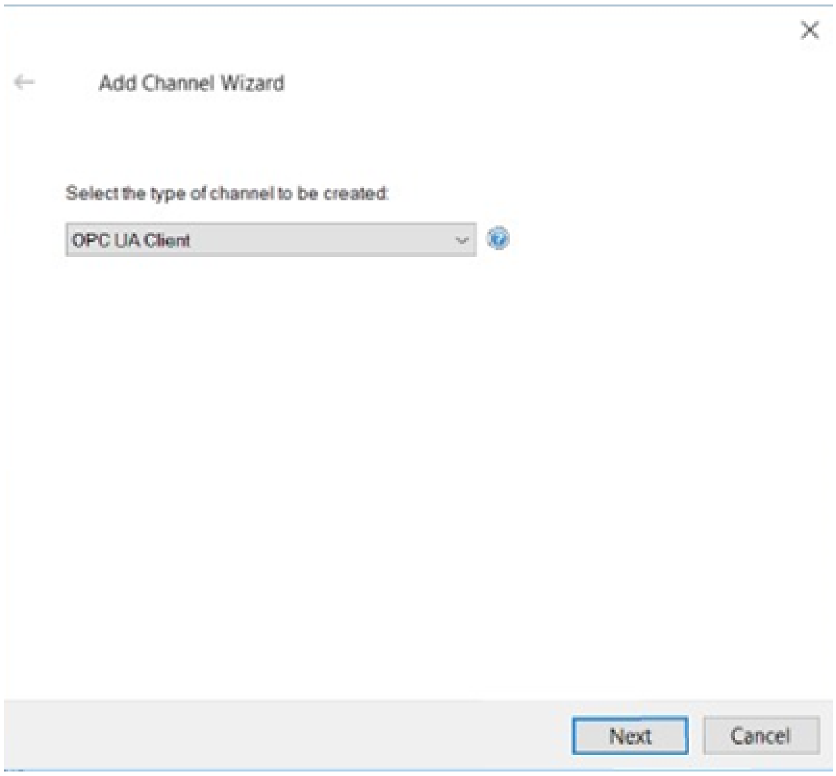

Figure 3.6: Configuration Window 1

5. Enter a suitable name for the channel (e.g., `Turck PLC`), then continue.

6. On the Server Endpoint screen, replace `opc.tcp://localhost:49320` with the IP address of the PLC, e.g., `opc.tcp://10.10.14.93:4840`. Set the **Security Policy** to **None**.

7. Click through the subsequent prompts (**Next** → **Next** → **Finish**) to complete the channel setup.

8. Under the newly created channel (e.g., `Turck PLC`), click **Click to add a device**.

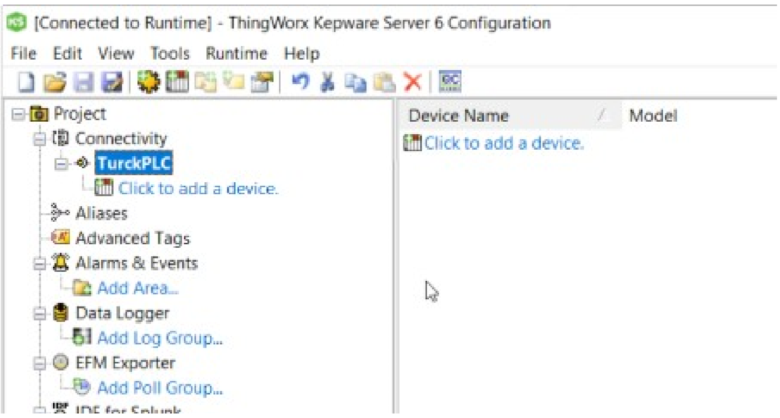

Figure 3.7: Add new device

9. Provide a device name such as `TX707` (corresponding to the PLC model number), then proceed.

10. Continue clicking **Next** until the **Select Import Item** screen appears.

11. Expand the node: `DeviceSet` → `Turck/ARM/WinCE TV` → `Resources` → `Application` → `GlobalVars` → `IoConfig_Global_Mapping`.

12. Select the desired tags (e.g., `PB1`, `Red`) and click **Add Items**.

13. Confirm the selection by clicking **OK**, then proceed to **Finish**.

14. Navigate to the same path in the project tree or click on **Quick Client** to view real-time tag values.

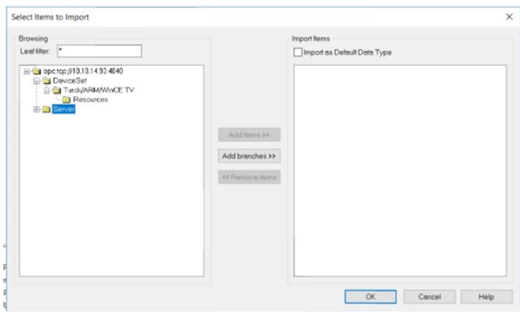

Figure 3.8: Import Tags

3.4 Designing IIoT Dashboard for AS/RS System using ThingWorx Platform

3.4.1 Hardware Used

The following hardware components were utilized in this project:

- Omron PLC (NX102-9000)
- Load Cell
- Limit Switches
- LEDs

3.4.2 Procedure for Creating the Dashboard in ThingWorx

1. Launch the ThingWorx platform and navigate to the **Browse** tab to create a new project.

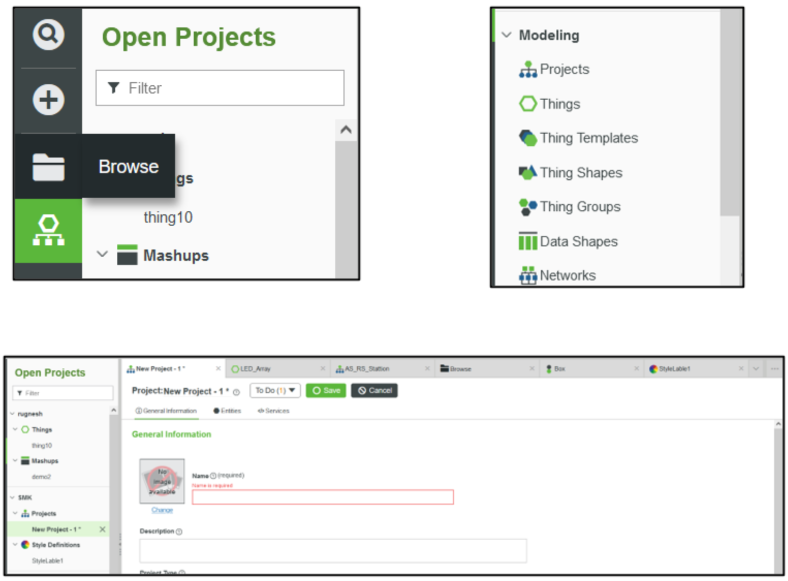

Figure 3.9: New Project in Thingworx

2. After creation, the project will appear in the workspace.

3. Add **Things** to the project. These represent physical devices, systems, or components (e.g., LEDs, sensors). The data fetched via the Kepware server will be associated with these entities.

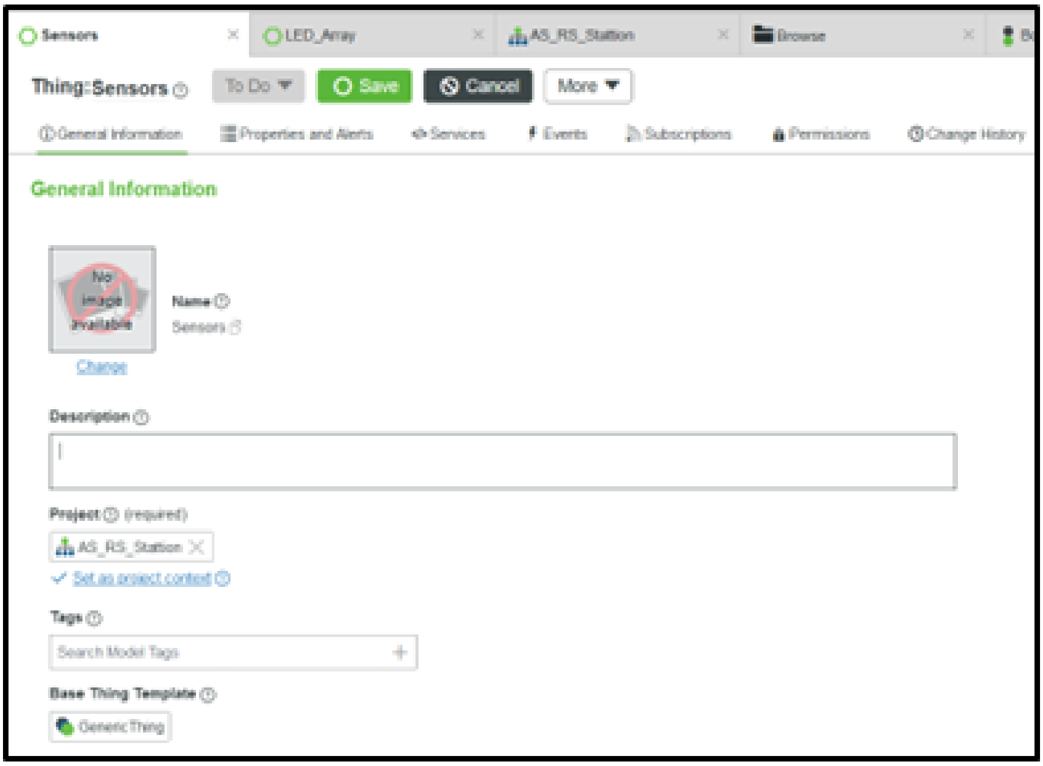

Figure 3.10: New Thing

4. Create two separate **Things**:
   - One for LEDs (used for indicating slab positions)
   - Another for sensors such as load cell and proximity sensor
5. For each Thing, define the required **Properties**. For instance, an LED will have a binary state (ON/OFF), which can be represented using the Boolean base type.

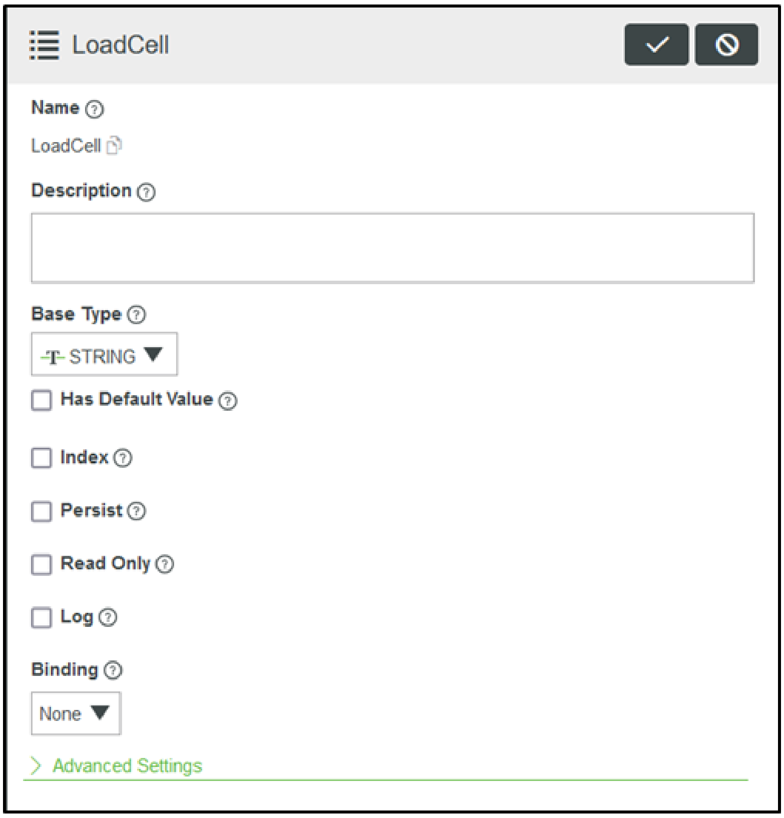

Figure 3.11: Properties

6. Once the Things and their properties are defined, create the dashboard structure using a **Mashup**. Select **Mashup** from the **Browse** tab under the Visualization section.

7. Choose the **Static (Legacy)** template for easier positioning of widgets and interface elements.

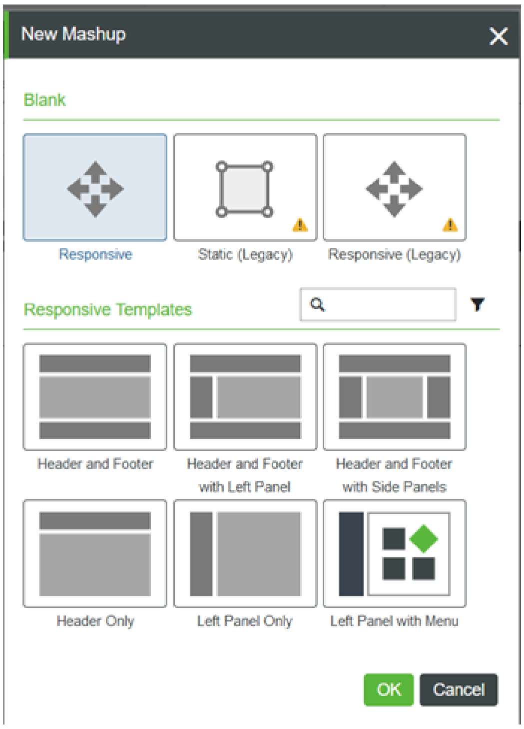

Figure 3.12: New Mashup

8. Set the **Canvas Size** (e.g., HD 1280x720) according to display preference.

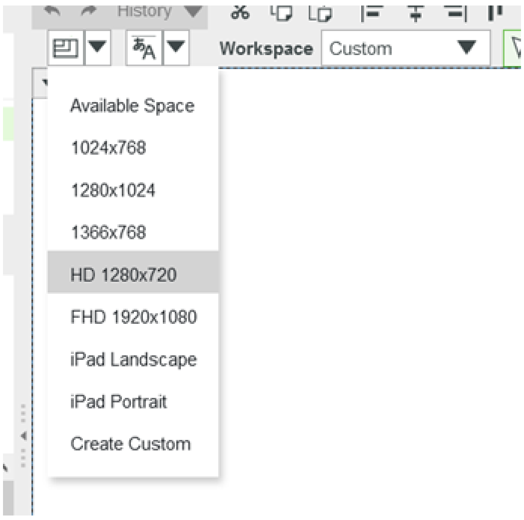

Figure 3.13: Canvas size

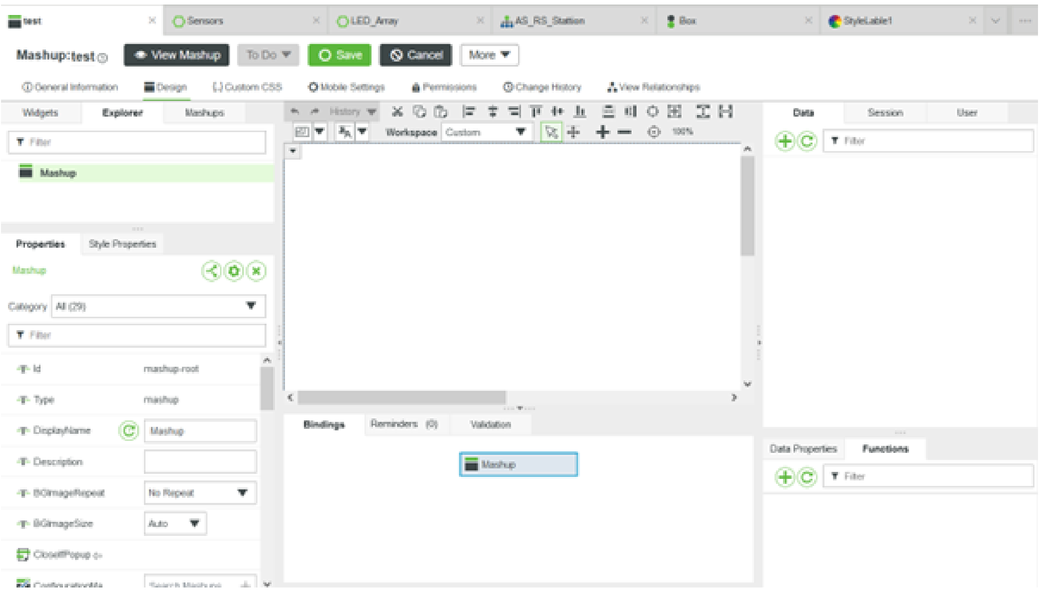

Figure 3.14: Mashup Interface

9. Add various widgets to the mashup. Start by adding a shape widget and customize its position and size using properties like height, width, left, and top.

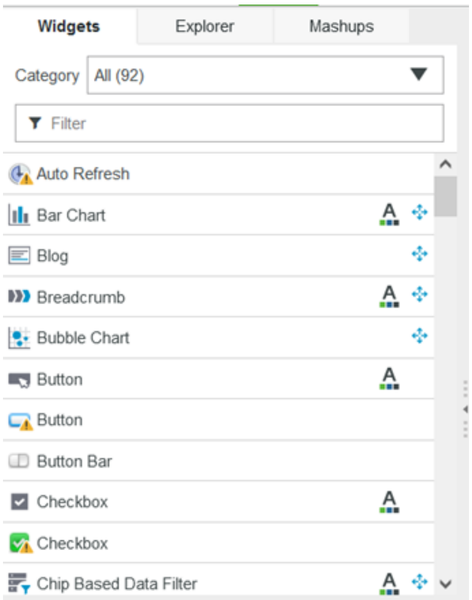

Figure 3.15: Widget Tab

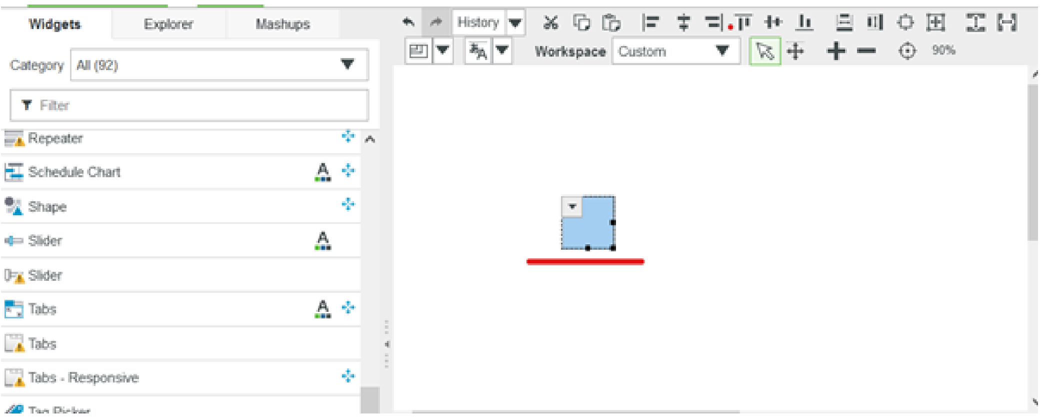

Figure 3.16: Adding Shape Widget to Canvas

10. Utilize label widgets for displaying textual values and adjust visual settings under the **Style Properties** tab.

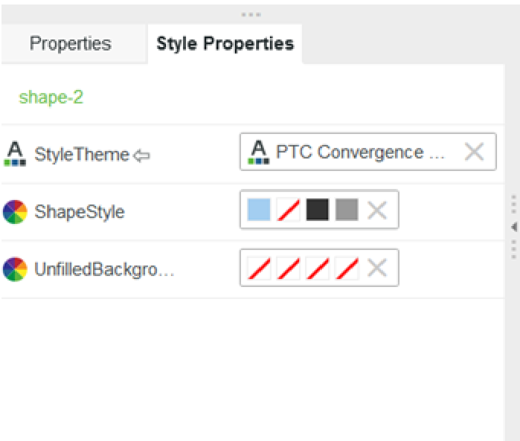

Figure 3.17: Style Properties

11. To preview the dashboard, use the **View Mashup** option. At this stage, the visual layout is complete, but data binding is still pending.

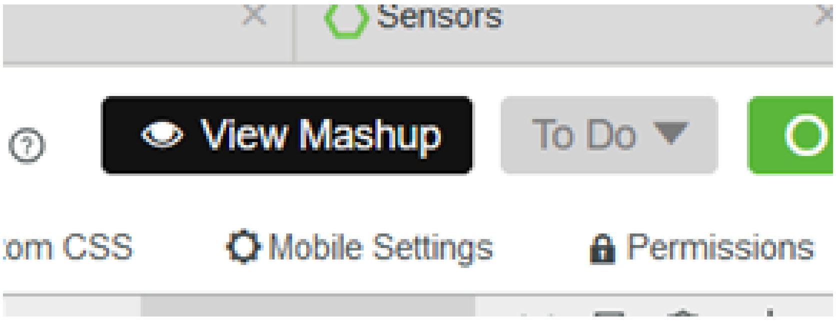

Figure 3.18: View Mashup

3.4.3 Binding Data to Widgets

1. Begin the data binding process by clicking the (+) icon to add data sources.

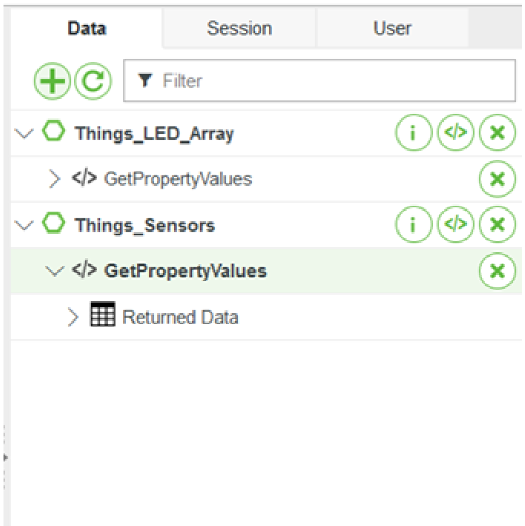

Figure 3.19: Add Data Sources

2. Select the Things created earlier and choose the service **GetPropertyValues**.

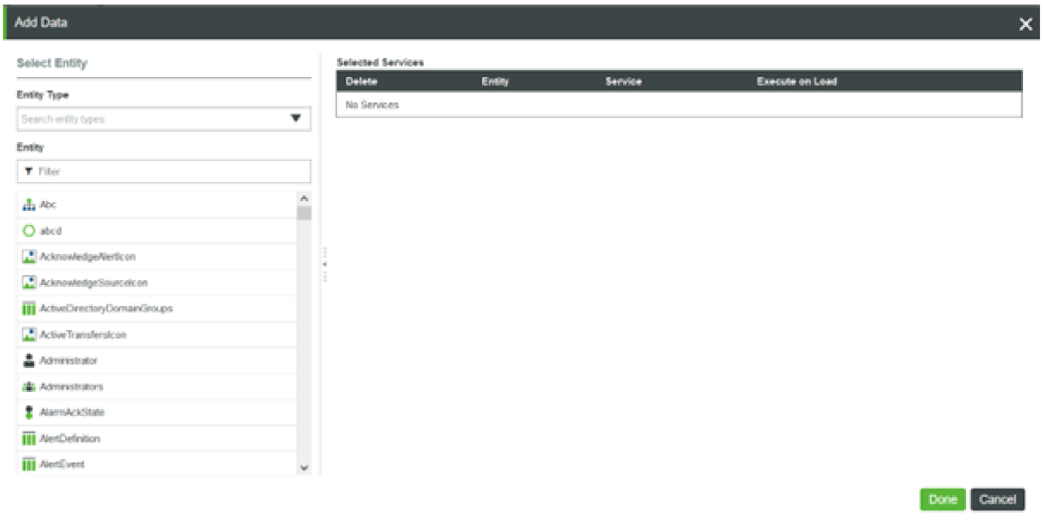

Figure 3.20: Things Created

Figure 3.21: Get Property Values

3. Drag and drop the desired properties onto their corresponding widgets to establish the bindings.

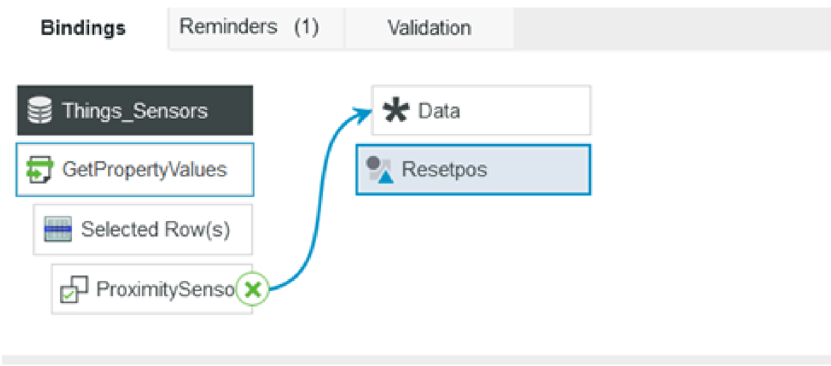

Figure 3.22: Binding Data

4. Confirm the binding setup in the **Binding** tab to ensure that the correct values are linked.

5. Finally, integrate the system with the Kepware server using the appropriate application key to enable live data flow into the dashboard.

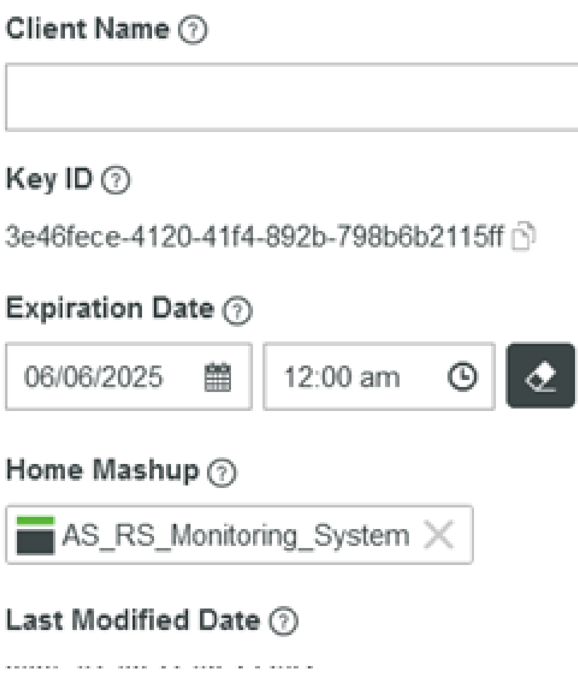

Figure 3.23: Application Key

Chapter 4

Design of Various Work Stations in the system

4.1 Automated Storage and Retrieval System (ASRS)

4.1.1 Introduction

Automated Storage and Retrieval Systems (ASRS) are computer-controlled systems that automatically place and retrieve loads from defined storage locations with precision and efficiency.

4.1.2 Working Principle

ASRS uses robotic shuttles, conveyors, and cranes to move materials between storage locations and workstations, minimizing manual intervention.

4.1.3 Components

- Storage racks
- Container Weight
- Homing Limit

4.1.4 Applications

ASRS is widely used in warehouses, manufacturing plants, and distribution centers to enhance productivity and space utilization.

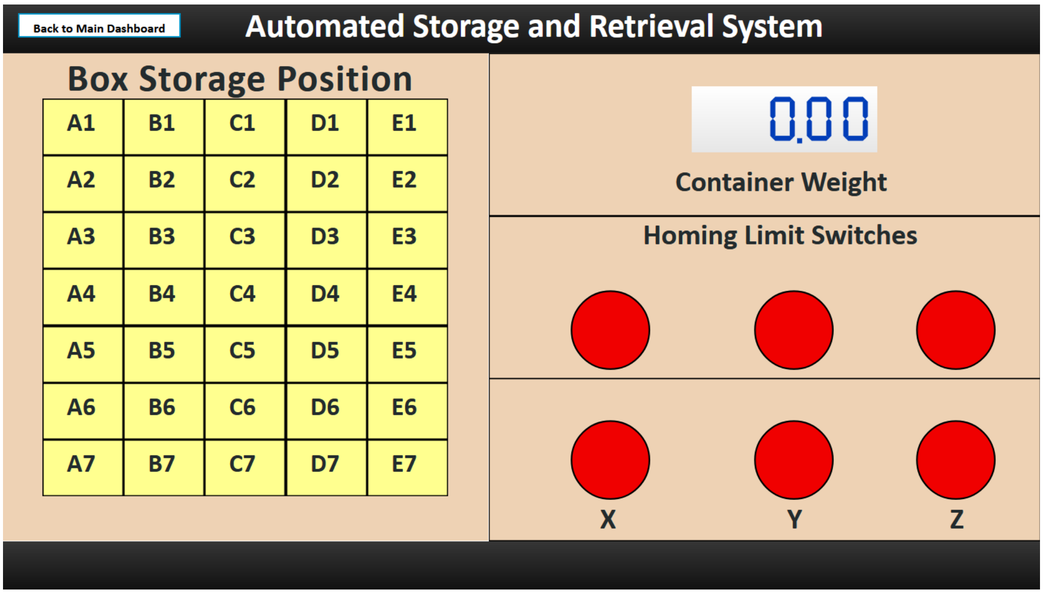

Figure 4.1: ASRS Dashboard

4.2 Turning Centre

4.2.1 Introduction

A Turning Centre is a CNC-controlled machine used primarily for shaping metal by rotating the workpiece against a cutting tool.

4.2.2 Working Principle

The turning centre holds the workpiece in a chuck and rotates it while cutting tools remove material to shape the final product.

4.2.3 Components

- Servo Motor Position
- Speed
- Pneumatic Chuck
- Temperature and Vibration
- Energy Consumption

- Tower Light
- Safety Curtain
- Tool Number

4.2.4 Applications

Turning Centres are used in industries like automotive, aerospace, and manufacturing for precision machining.

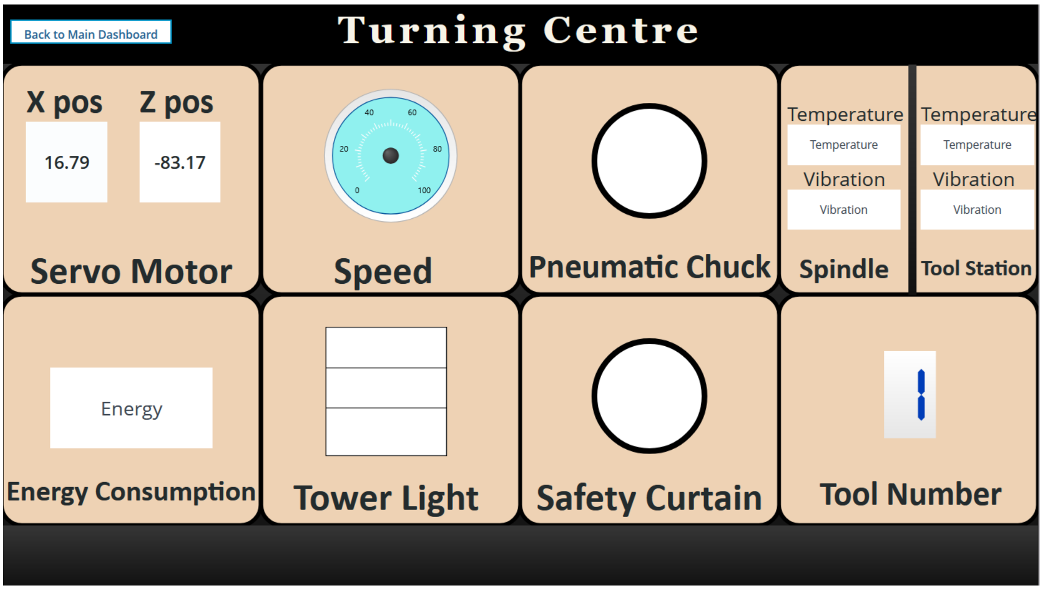

Figure 4.2: Turning Centre

4.3 Machining Centre

4.3.1 Introduction

Machining Centres are advanced CNC machines capable of performing multiple operations like milling, drilling, and tapping.

4.3.2 Working Principle

These centres use rotating cutting tools to remove material from a stationary or moving workpiece.

4.3.3 Components

- Tool magazine
- Spindle
- Worktable
- CNC control panel
- Coolant system

4.3.4 Applications

Used in precision manufacturing for producing automotive, aerospace, and industrial components.

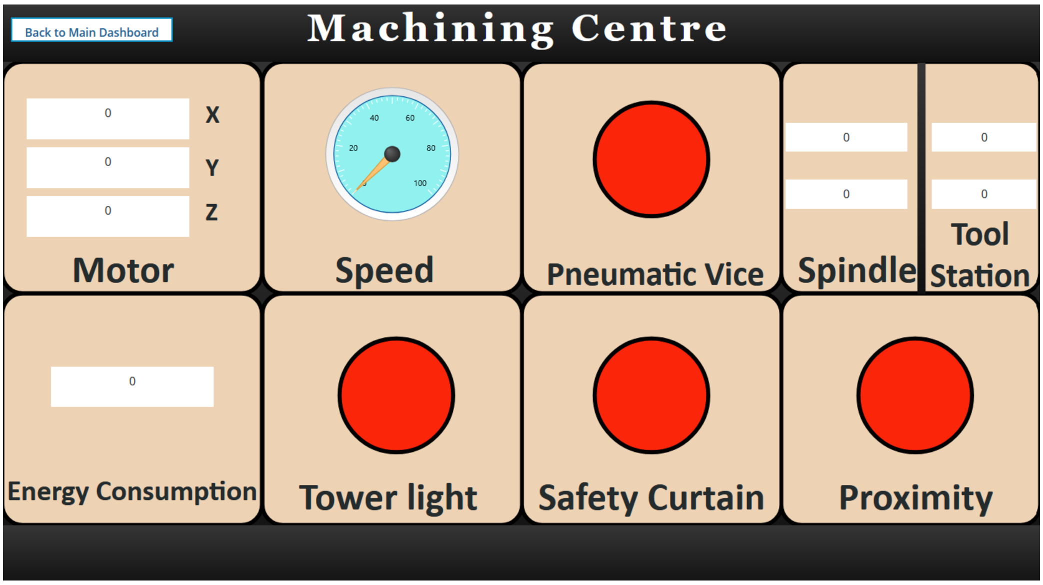

Figure 4.3: Machining Centre

4.4 Assembly Station

4.4.1 Introduction

An Assembly Station is a workstation where various components are systematically joined to form a final product.

4.4.2 Working Principle

Automated or manual systems assemble parts using robotic arms, fixtures, and fasteners to ensure accuracy.

4.4.3 Components

- Stroke Length
- Housing

4.4.4 Applications

Used in industries like electronics, automotive, and appliance manufacturing for mass production.

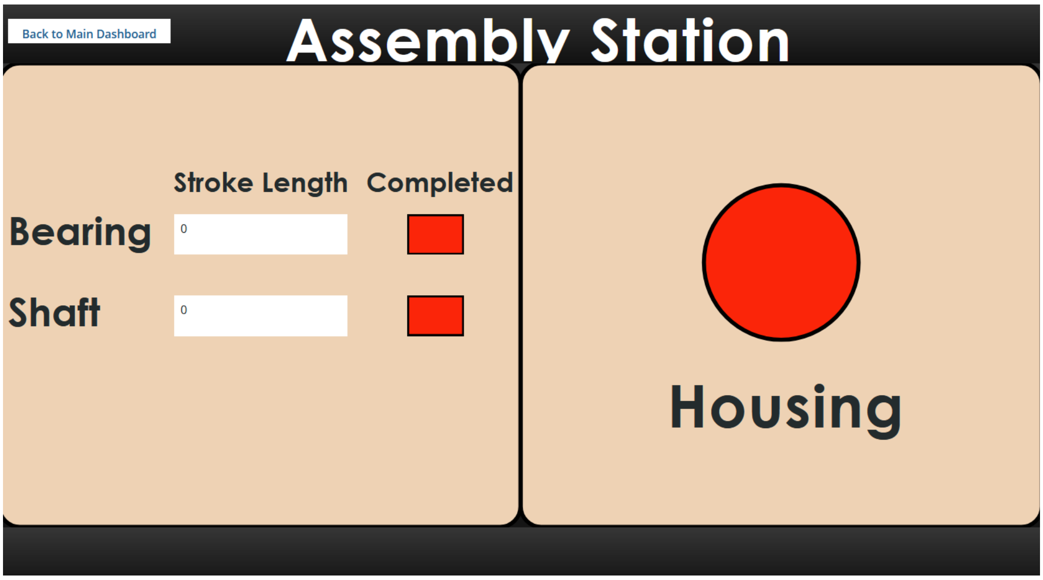

Figure 4.4: Assembly Station

4.5 Manual Inspection Station

4.5.1 Introduction

Manual Inspection Stations are used for quality control, where workers examine products for defects.

4.5.2 Working Principle

Operators visually or instrumentally inspect components to ensure they meet quality standards.

4.5.3 Components

- Bore Diameter
- Shaft Diameter and Length

4.5.4 Applications

Used in quality assurance across various industries, including electronics and precision manufacturing.

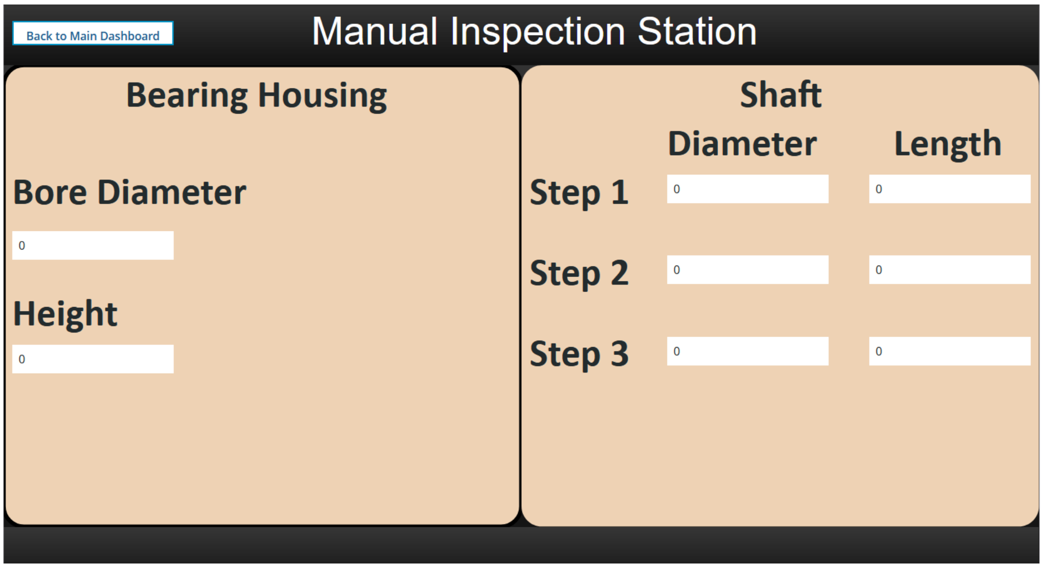

Figure 4.5: Manual Inspection Station

Chapter 5

Implementation and Development

This chapter covers the detailed implementation of the system, focusing on the design and deployment of dashboards, data integration, and communication setups used throughout the project. The process of development and integration was carried out in a systematic approach, where each component was individually configured before being integrated into the whole system.

5.1 Dashboard Development in ThingWorx

The development of interactive dashboards in ThingWorx aimed at visualizing real-time data from various stations in the production line. The dashboards are designed with widgets such as gauges, charts, and tables that display machine status, energy consumption, and sensor readings. The design process involved creating different mashups for various production stations like ASRS, Turning Centre, and Assembly stations. The goal was to create an intuitive interface that allowed operators to monitor and control the production process effectively. Each mashup was tailored to display only relevant data for its specific station, reducing clutter and ensuring that users could focus on the information that mattered most.

5.2 Kepware Server Configuration

The communication between industrial controllers and ThingWorx was established using Kepware Server. Kepware enabled the integration of OPC-UA and Modbus protocols to connect with PLCs. A series of tags were created in Kepware, mapping real-time data from PLCs to corresponding fields in ThingWorx. Additionally, secure communication channels were set up to ensure a reliable data transfer between the devices. The configuration process required configuring data points from multiple sources and aligning them with specific parameters within the ThingWorx environment. This was crucial to ensure seamless integration and data integrity, which allowed for real-time data updates.

5.3 PLC and Sensor Integration

PLC systems were configured to monitor various parameters such as temperature, vibration, and proximity from sensors installed across the production stations. These parameters were crucial for assessing machine health and operational conditions. The data from these sensors was transmitted through the PLCs and sent to the ThingWorx platform for processing. Programming the PLCs to send the data in a timely and accurate manner was essential for the system's success. Once the integration was completed, the system was able to provide real-time insights into the operational status of the machines, helping operators make informed decisions.

Chapter 6

Testing and Validation

This chapter discusses the various testing strategies and validation techniques used to ensure that the system meets the desired performance and accuracy standards.

6.1 Functional Testing

Functional testing was carried out to validate that each component of the system worked as expected. The integration between the PLCs, Kepware server, and ThingWorx was thoroughly tested to ensure seamless communication and accurate data transmission. Each of the dashboards was tested to check whether they displayed the correct data from the sensors. Testing also involved simulating different operational conditions, such as sensor malfunctions or communication delays, to assess the system's response. This helped in identifying potential issues early on and correcting them before the system went live.

6.2 Performance Testing

Performance testing focused on ensuring that the system could handle a large volume of data without any significant delays. This involved measuring the response times of the system when receiving and displaying real-time data, as well as evaluating system performance under stress conditions. Data transmission rates were monitored, and the system was subjected to heavy loads to ensure it could handle increased sensor input without slowdowns. The results indicated that the system performed well within the acceptable limits, providing reliable data even when the number of stations was increased or sensor data grew more complex.

6.3 User Acceptance Testing (UAT)

User acceptance testing (UAT) was conducted to assess how well the system met the expectations of the end-users. Operators and technicians participated in UAT, providing valuable feedback on the usability and effectiveness of the dashboards. They tested features like real-time data viewing, data accuracy, and system responsiveness. Feedback from this phase was used to improve the user interface and optimize some of the workflows. Issues such as the arrangement of widgets and data filtering were addressed, making the final product more intuitive and aligned with operational needs.

Chapter 7

Results and Discussion

This chapter presents the results of the implementation and testing phases, along with an analysis of the findings and their implications for the project's objectives.

7.1 System Performance and Reliability

The system exhibited excellent performance during the testing phase. The integration of the PLCs, Kepware server, and ThingWorx platform allowed for smooth communication and efficient data transfer. The system was able to display real-time data from all monitored stations, with very little latency. Data refresh rates were within the expected range, and the system maintained high reliability with minimal downtime. Stress tests indicated that the system could handle large amounts of data from multiple sensors without significant lag or errors. This proves that the system is both scalable and robust, making it suitable for long-term industrial use.

7.2 Data Accuracy and Visualization

Data accuracy was a key focus throughout the project, and the final system provided reliable information from the sensors installed at each station. The ThingWorx dashboards effectively displayed real-time data, ensuring operators had access to up-to-date information. The visualizations, including gauges and charts, offered an easy-to-understand representation of machine health and operational performance. These visualizations helped operators identify potential issues early, such as equipment malfunctions or performance degradation, enabling timely intervention. The high accuracy of the data and the clarity of the visualizations contributed significantly to the effectiveness of the system.

7.3 User Feedback and System Usability

User feedback was gathered during the UAT phase, and it provided insights into the system's usability. Operators appreciated the real-time data updates and the simplicity of the dashboards. They found the system's interface intuitive, which made it easy for them to navigate between different stations and monitor operations. However, some users suggested enhancements in data filtering and more customization options for widgets. These suggestions were valuable in refining the interface further. Overall, the system was considered user-friendly and met the operational needs of the factory floor.

Chapter 8

Conclusion and Future Work

This chapter summarizes the outcomes of the project and outlines the steps for future improvements.

8.1 Summary of Findings

The project successfully implemented a real-time monitoring system using ThingWorx and Kepware. By integrating multiple production stations, such as ASRS, Turning Centre, and Assembly stations, with PLCs and sensors, the system was able to monitor various operational parameters effectively. The dashboards in ThingWorx provided real-time insights into machine status and other critical parameters, aiding operators in making informed decisions. The system passed all functional, performance, and user acceptance tests, indicating that it meets the project objectives.

8.2 Challenges Faced

During the development of the system, several challenges were encountered, including issues with data synchronization between multiple PLCs, the need for precise mapping of sensor data to dashboard widgets, and the integration of different protocols within Kepware. These challenges were addressed through rigorous testing, collaboration with experts, and continuous optimization of the system. Despite these hurdles, the team was able to develop a solution that meets the original goals of real-time monitoring and visualization.

8.3 Future Work

For future improvements, the system could be enhanced with features like predictive maintenance, allowing it to anticipate machine failures based on historical data and sensor inputs. Further, adding more complex analytics and artificial intelligence to process and interpret the data could lead to more advanced insights. There is also potential to scale the system for larger factory environments with more stations and sensors. Future work could also focus on improving the user interface based on continued feedback and making the system even more intuitive and responsive.

Bibliography

[1] Smith, J., et al. (2022). *IIoT-Based Real-Time Monitoring for Smart Factories*. IEEE Transactions on Industrial Informatics.

[2] Johnson, R., Lee, K. (2021). *Kepware-ThingWorx Integration for Real-Time Industrial Monitoring*. Journal of Industrial Automation.

[3] Patel, V., et al. (2023). *Addressing Latency in OPC-UA-Based Industrial Monitoring*. International Conference on Smart Manufacturing.

[4] IBM Corporation. What is the Internet of Things (IoT)? `https://www.ibm.com/topics/iot`, 2022.

[5] PTC Inc. ThingWorx Industrial IoT Platform. `https://www.ptc.com/en/products/iiot/thingworx`, 2021.

[6] Madhuri, K., and Prasad, S. IoT-Based Smart Monitoring and Controlling System using ThingWorx. In *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, 2019.

[7] Kepware Technologies. Kepware: Industrial Connectivity Platform. `https://www.kepware.com/en-us/products/kepserverex/`, 2022.

[8] Singh, R., and Sharma, R. Implementation of Industry 4.0 Technologies in Smart Manufacturing. *Journal of Manufacturing Technology*, 20(3):45–52, 2020.

Appendices

A. Design Documents and Architecture

- Overall System Block Diagram (System → PLC → Kepware → ThingWorx)
- Individual Station Flowcharts (ASRS, Turning Centre, etc.)
- Dashboard UI Wireframes / Design References

B. ThingWorx Dashboard Details

- List of Mashups and Their Purpose
- Description of Widgets and Data Bindings
- Screenshots of Completed Dashboard Interfaces

C. Configuration Files and Setup Details

- Kepware OPC UA Tag Configuration Summary
- ThingWorx Entities Export (if exported as .twx)
- Connection Setup Details (PLC to Kepware, Kepware to ThingWorx)

D. Publications / Patents

No publications or patents have been filed at the time of this report.