

HMI Design Project

MIE 653

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Executive Summary

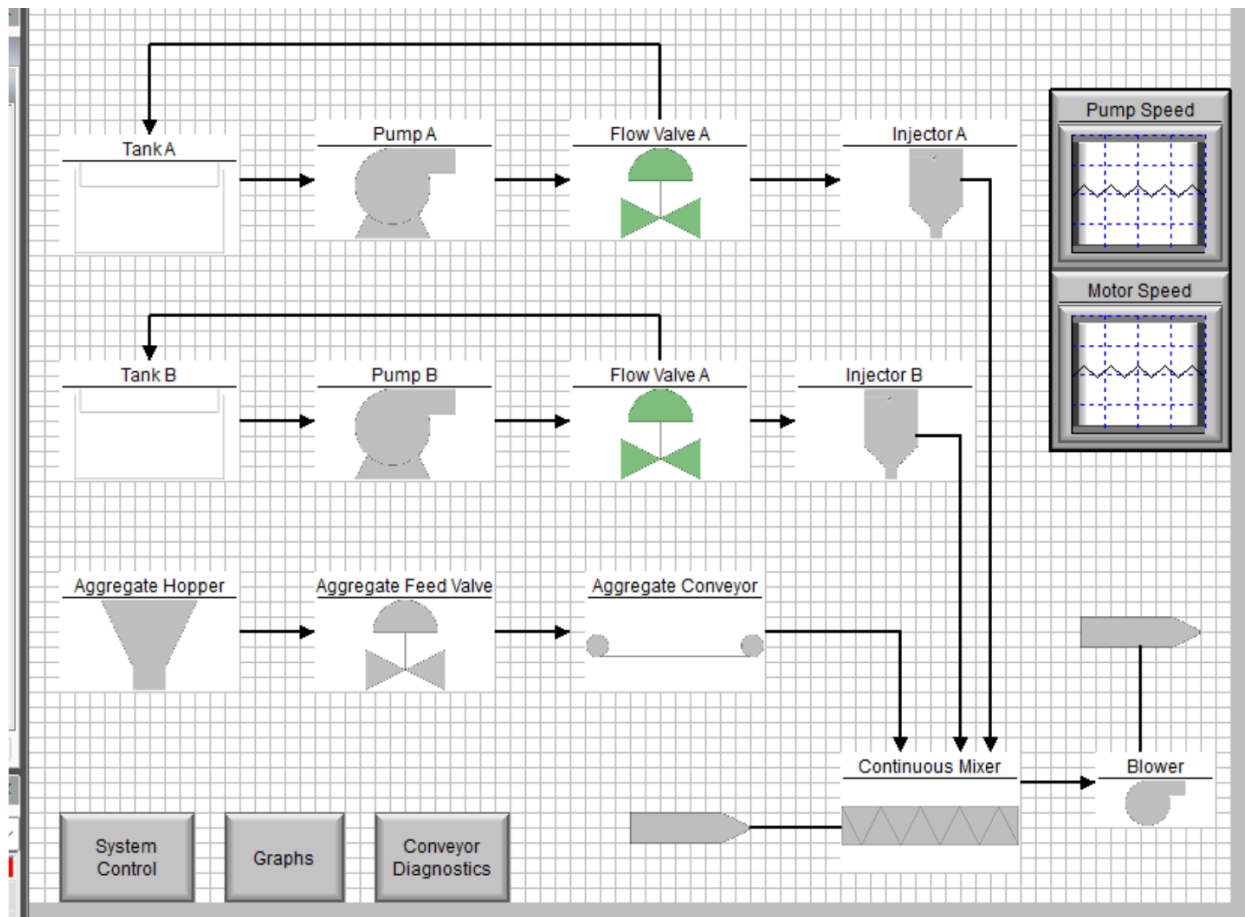
The porous panel process involves combining a solid aggregate material with two reactive fluids—resin and coreactant—to form an adhesive mixture that bonds the particles together. The process begins by feeding aggregate from a hopper into a continuous mixer via a conveyor belt. In parallel, resin and coreactant fluids are injected into the same mixer. When properly combined at the correct ratios, these components form an adhesive matrix that binds the aggregate particles, ultimately creating the porous panel structure.

Currently, the system's operational conditions rely on ensuring that the mixer's maintenance door is closed and the blower is active before startup. Control elements include pumps, valves, and injectors. These elements are primarily driven by the conveyor motor's operational state as a safety measure, ensuring that fluids only flow when the aggregate feed is active. The existing implementation limits the ability to fine-tune process elements due to a lack of additional push buttons and minimal sensor data beyond motor speed.

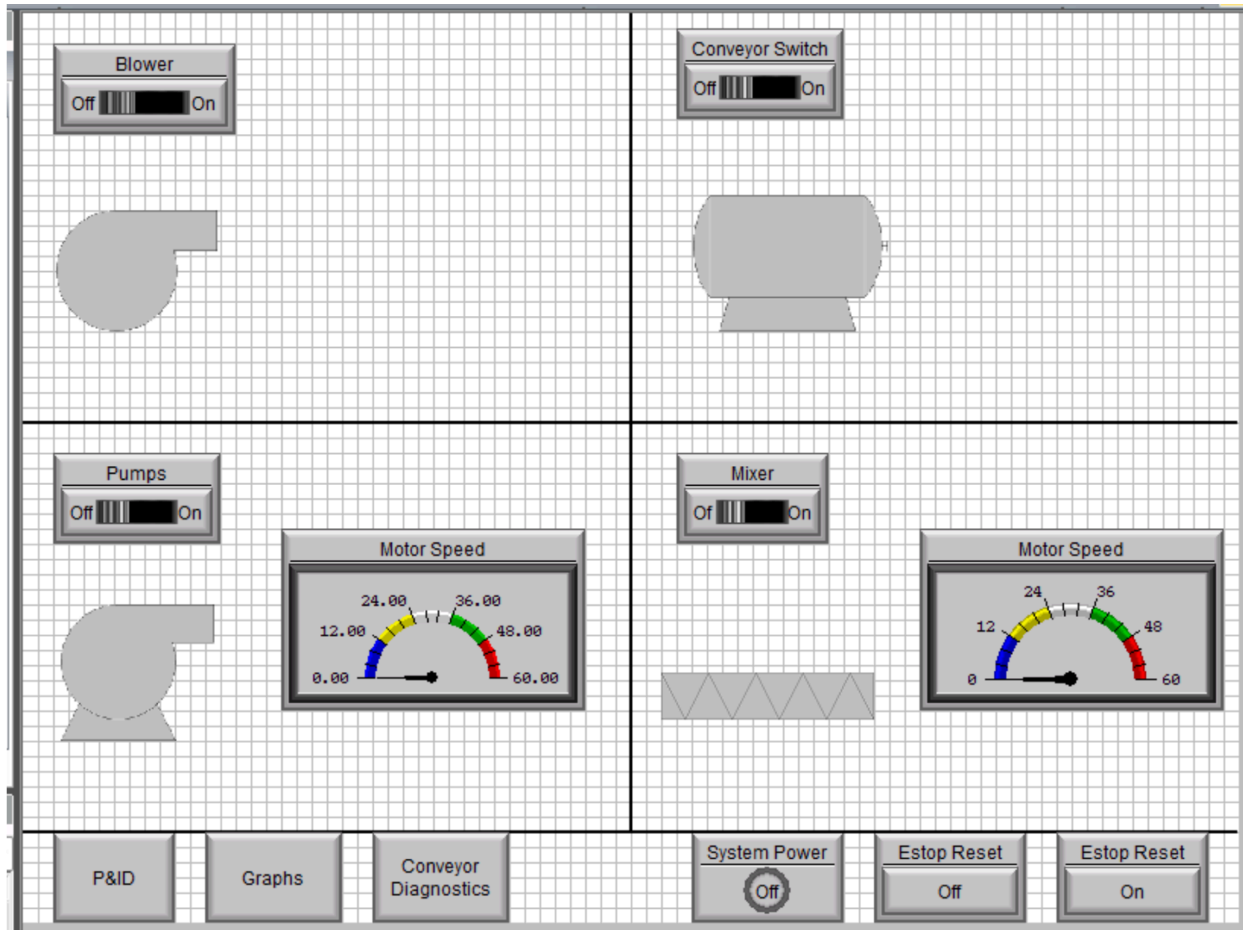
The Human-Machine Interface (HMI), developed in Logix 5000 with guidance from the ISA-101 standard, aims to streamline and automate the porous panel process, reducing reliance on physical, hard-wired controls. While the current HMI allows for full control of the process, it lacks control limits and advanced sensor data that would ensure stable and repeatable operation. By refining the HMI, operators can more easily manage the fluid injection parameters, monitor system performance, and avoid potential process upsets. Key recommendations include adding more comprehensive sensors (such as flow meters, level sensors, and pressure transmitters) and implementing automated control limits and alarms to maintain the process within acceptable operating ranges.

Design

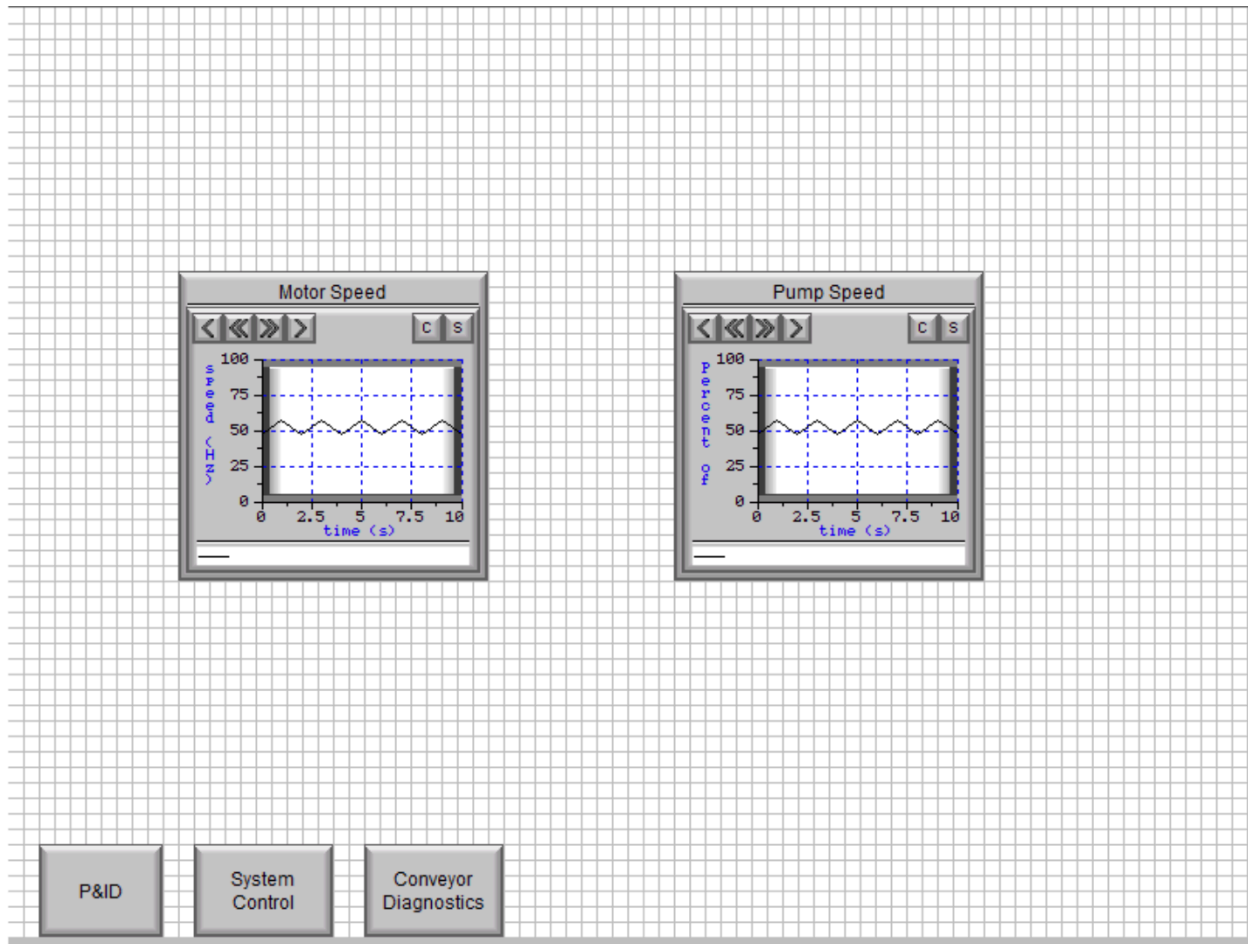
HMI Screenshots



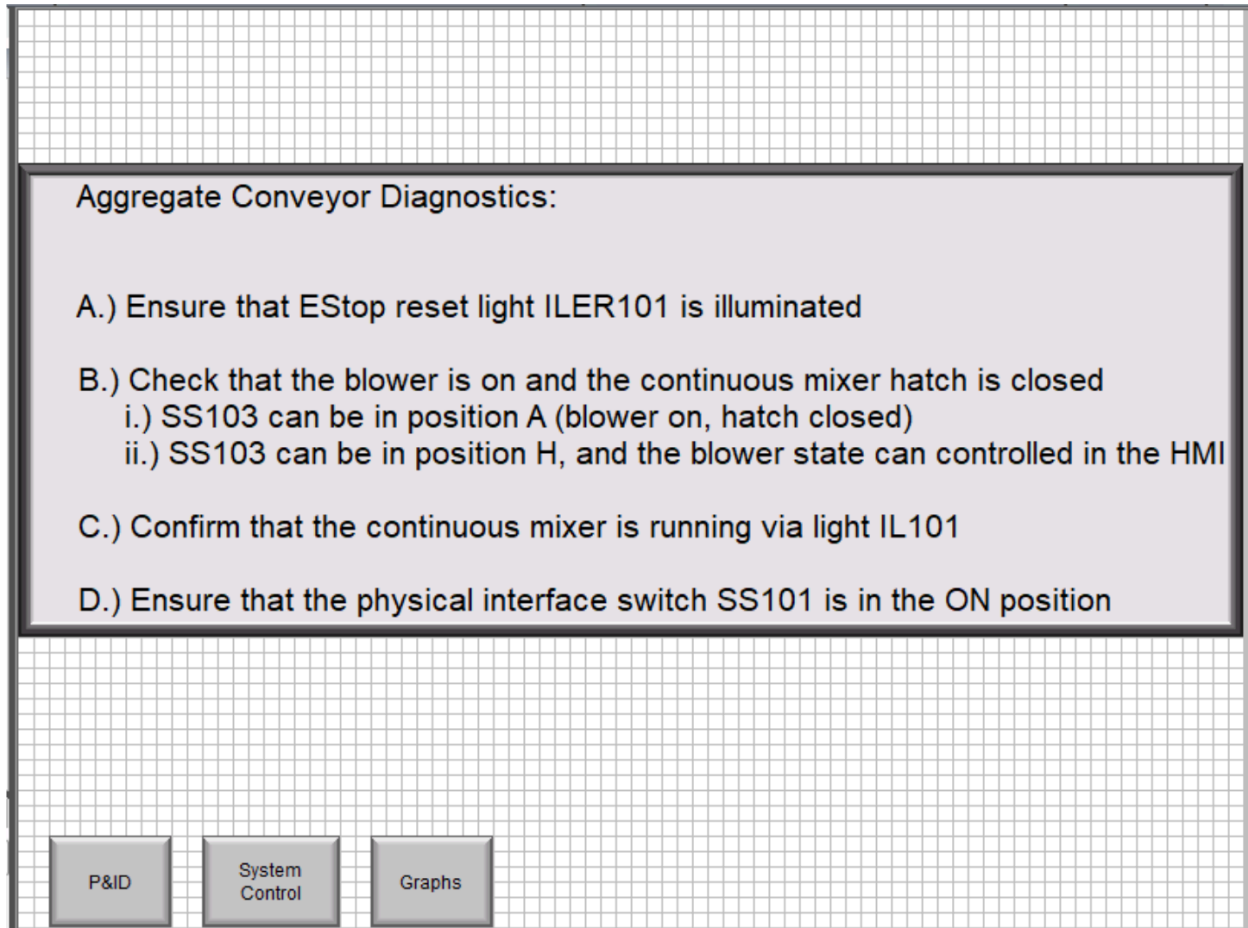
- **Figure 1: Process Overview Screen (Level 1)** – Provides a top-level diagram showing the continuous mixer, hopper, conveyor, fluid injection lines, and blower. This screen includes indicators for mixer door status, blower operation, and the conveyor motor state.



- Figure 2: Aggregate Conveyor Subsystem Screen (Levels 2-4)** – Offers insight into the conveyor motor, pumps, pump speed, motor speed, continuous mixer, and blower. Furthermore, the Estop Reset (blue light) can be controlled, but the Estop can not be controlled



- **Figure 3: Control Graphics and Trends Screen** – Displays process variables over time. Operators can monitor trends in conveyor speed and hypothetical fluid flow rates.



- **Figure 4: Diagnostic & Maintenance Screen** – Contains instructions for operation of the conveyor, and diagnosis steps that can be performed if it is not working.

Operator Navigation and Functionality

Operators access the HMI through a main menu that guides them to multiple functional areas. Navigation follows a hierarchy that simplifies drilling down into system components. At the top level (Level 1), the operator sees an overarching process overview—a simplified flow diagram that summarizes each major subsystem. Access to Levels 2-4 can be seen in the bottom left of the screen, where each layer reveals more granular details of the physical components involved.

- **System Control Screen (Level 1 Overview):**
On this screen, operators can see the state of the: pumps, valves, motor, mixer, and blower; they can also see the current conveyor and pump trends. This screen provides information about the normality of the process, and can be used for quick diagnosis of issues.

- **Aggregate Conveyor Subsystem Screens (Levels 2-4):**
When the operator selects the conveyor subsystem from the main overview, they enter a screen dedicated to aggregate handling. These sections are not comprehensive due to the limited number of sensors provided.
- **Level 2:** Control for the blower, pumps, conveyor, and mixer
 - **Level 3:** Conveyor belt and pump speeds
 - **Level 4:** Diagnosis options for a nonfunctional conveyor belt
- This hierarchical approach ensures that operators can quickly identify where an issue might arise, reducing downtime and improving process understanding

Four-Level Hierarchy and Process Division

The porous panel process up to the casting stage was structured following a four-level hierarchy to align with good HMI design practices and to comply with guidelines derived from ISA-101:

1. **Level 1: Process Overview**
The entire process of feeding aggregate, injecting resin and coreactant, and mixing is depicted. The operator sees a simplified diagram of the system, providing quick insight into all aspects of system operation.
2. **Level 2: Conveyor Subsystem Overview**
The focus narrows onto the aggregate transport. This level displays the conveyor motor, mixer, pump states, and blower system. Operators can now see a visual representation of the max speed for the pumps and motor via a dial interface.
3. **Level 3: Component-Level Controls**
Currently the level three screen shows the graphs of the pump and motor output over time. This is also shown in the first screen. Ideally, with the addition of more sensor data, this screen could be populated with other graphs and control limits, if desired.
4. **Level 4: Detailed Diagnostics and Maintenance**
The final level is the most granular and is intended for troubleshooting and maintenance. Here, operators and maintenance personnel can see troubleshooting steps for operation of the conveyor in the event that the aggregate mixture is not working correctly. In the future, this could be updated with a series of diagnostic scenarios, however the system is currently too simple for major improvements.

ISA-101 Usage and References

The design process referenced ISA-101, a standard that guides the design of HMI for process automation systems. Key aspects of ISA-101 that influenced the design include:

- **Consistent Layout and Navigation:**
Screens were designed with a consistent layout, color coding, and navigation bar. This ensures operators can quickly find what they need regardless of the subsystem they are viewing.

- **Use of Hierarchical Navigation:**

By breaking the process down into hierarchical levels—from an overview down to detailed diagnostics—the operator is never overwhelmed with unnecessary detail. Instead, they can drill down as needed, aligning with ISA-101's emphasis on user-centered design and hierarchical presentation.

- **Context-Appropriate Alarms and Indications:**

Although not fully implemented, the plan is to follow ISA-101 guidelines by placing alarms at appropriate hierarchical levels. For example, a Level 1 screen might show a general alarm indicator, while deeper-level screens specify what component triggered the alarm.

- Alarms are practically useful when there are desired setpoints for the system. It was not considered necessary for the motor speed, since it has a dedicated controller. However, as system complexity increases alarms could prove necessary.

Challenges and Limitations in the Current Implementation

Currently, the HMI can control all aspects of the process—conveyor operation, valve control, and fluid injection—via on-screen elements. However, several limitations must be addressed in future iterations:

1. **Lack of Control Limits and Setpoints:**

Currently, the system lacks predefined control limits (e.g., maximum motor speed, minimum fluid flow rates, recommended operating pressures). Without these bounds, the operator may inadvertently run the system out of specification, affecting product quality and safety.

2. **Minimal Sensor Data:**

The system currently relies solely on motor speed feedback. Additional sensors—such as flow meters for the resin and coreactant, load cells or scales for the aggregate, pressure gauges, and level sensors—would provide valuable information. These data points could be displayed on the HMI to help operators optimize process conditions and detect anomalies early.

3. **Manual Valve State Indication:**

The HMI does not currently show manual valve states. Operators and maintenance personnel must rely on physical inspection or secondary documentation to know whether a manual valve is open or closed. Integrating these states into the HMI is critical for ensuring safe and accurate operation.

4. Reliance on the Conveyor Motor as a Master Control:

Currently, the start/stop state of the conveyor motor dictates the operation of the fluid injectors and valves. While this ensures safety by stopping fluid injection if no aggregate is flowing, it limits flexibility. Ideally, operators should have independent control over each subsystem (with interlocks for safety) rather than funneling all logic through the conveyor motor state.

5. Physical vs. HMI Controls Redundancy:

The conveyor can be turned on/off from both the physical interface and the HMI. While this adds a layer of safety, it can also create confusion if not clearly indicated. Enhanced communication and visual feedback on the HMI would help reconcile any discrepancies and ensure operators know the true operational state at all times.

6. Lack of Additional Controls

There are some components in the system which were programmed to depend on the motor state. These include the injectors, flow valves, and mixer. Because of this, it would not be practical to individually control these components because of the way that the system was programmed.

Conclusion

The current HMI for the porous panel process provides a consolidated, graphical platform to control and monitor the system's key components. Following ISA-101 guidelines, the HMI design uses hierarchical navigation and consistent layouts to enable operators to move from a top-level overview down to detailed component-level screens. This approach ensures that operators can easily identify the status of the mixer door and blower, control the conveyor motor, and consequently drive resin and coreactant injection. In essence, the HMI delivers the intended functionality: enabling control of the process and offering an intuitive interface compared to traditional physical controls alone.

However, several critical improvements remain to be implemented. The lack of control limits means that, as the system grows in complexity, operators may have difficulty maintaining the process within safe and optimal parameters. Similarly, the absence of comprehensive sensor data reduces the operator's ability to monitor and optimize the process fully. Future enhancements should include integrating more sensors—such as mass flow meters, load cells, pressure transmitters, and level sensors—into the HMI. These sensors will allow the development of automated control loops, alarms, and operator guidance tools that maintain the process within established quality and safety limits.

Another area of focus should be adding more granular control elements and on-screen push buttons so that the operator can manage individual valves and devices without relying solely on the conveyor motor's state. Improving the display of manual valve positions would also help ensure that operators have a complete picture of the system's state, enabling quicker troubleshooting and safer operations.

Recommendations for Future Development

To enhance the usability and functionality of the HMI, the following recommendations should be considered:

1. Implement Control Limits and Setpoints:

Define acceptable operating ranges for critical parameters (e.g., conveyor speed, fluid flow rates, temperature, pressure). Incorporate alarms that warn the operator when these limits are approached or exceeded. These limits can also form part of automated control loops to maintain stable operations.

2. Add Comprehensive Sensor Data:

Install additional sensors to provide real-time feedback on aggregate mass flow, fluid flow rates, pressures, levels, and temperatures. Display these values on the HMI with trending capabilities, so operators can quickly identify anomalies, predict issues before they escalate, and adjust parameters proactively.

3. Enhance Manual Valve State Integration:

Update the HMI graphics to reflect the open/closed status of manual valves. Incorporate color coding and symbols to indicate valve states clearly. Offer drill-down screens so that operators can quickly find which valves are open or closed during maintenance or troubleshooting.

4. Introduce Specialized Push Buttons and Local Controls:

Add dedicated push buttons and toggle switches on the HMI for critical components, such as individual fluid valves or pump start/stop. This will reduce dependence on the conveyor motor state and improve the operator's ability to fine-tune the process.

5. Refine Navigation and Consistency:

Maintain consistent screen layouts, navigation bars, and color schemes throughout the HMI. Provide “breadcrumbs” or clear hierarchical indicators so operators can easily return to a previous screen or identify where they are in the system’s navigation structure.

6. Support Operator Training and Documentation:

Include context-sensitive help or documentation directly in the HMI. This could be ISA-101-compliant tooltip windows or an accessible help menu explaining alarm conditions, process variables, and normal operating procedures. Proper documentation will reduce training time and improve operator confidence.

7. Monitor and Adjust Alarm Strategy:

Once control limits and new sensors are integrated, configure alarms following ISA-101’s best practices. Ensure that alarm conditions are meaningful, prioritized, and displayed in a way that directs the operator’s attention to the most critical issues first. Avoid alarm floods and ensure that alarms guide operators toward corrective actions.

8. Improve Code Structure

The code structure makes control of components such as the injector and valves mostly impractical. It may be advisable to refactor the code to allow the control of these components in the fluid system for more precise system control and troubleshooting

Final Assessment

The HMI, in its current form, provides a good starting point for controlling the porous panel process. By following a structured, hierarchical approach, referencing ISA-101 guidelines, and offering basic functionality, it grants operators a single interface for start/stop operations and basic monitoring. With planned improvements—adding sensors, implementing control limits, refining navigation, and integrating manual valve states—this HMI can evolve into a robust, reliable, and user-friendly interface that not only controls the system but also ensures that it operates within optimal parameters, ultimately improving efficiency, product quality, and safety.