HMI, PLC and SCADA Fundamentals for Industrial Automation

This document provides a practical and technical introduction to Human Machine Interfaces (HMI), their integration with Programmable Logic Controllers (PLC), and the role of SCADA systems in industrial automation environments. Examples, basic formulas, and best practices are included.

1. HMI Fundamentals and Screen Navigation Design

An HMI (Human Machine Interface) is the graphical interface that allows operators to interact with machines and industrial processes. A well-designed HMI improves usability, reduces human error, and increases productivity and safety.

Key HMI Components:

- Process screens (overview, detail, maintenance)
- Navigation elements (buttons, menus, tabs)
- Status indicators (lamps, colors, icons)
- Input controls (numeric input, sliders, selectors)

Screen Navigation Design Principles:

- Use a hierarchical structure: Overview → Area → Detail
- Keep navigation consistent across all screens
- Minimize the number of clicks to reach critical information
- Use standardized colors (e.g. red = fault, green = running)

Example: A main overview screen shows the entire production line. From this screen, the operator can click on a conveyor to open a detailed screen with motor speed, current, and alarms.

2. Connecting HMI to PLC (Tags, Variables, Addressing)

Communication between HMI and PLC is based on shared variables, commonly called tags. The HMI reads and writes PLC memory areas using industrial communication protocols such as Modbus, Profinet, EtherNet/IP, or OPC UA.

PLC Memory Areas (generic):

- Digital inputs/outputs (BOOL)
- Analog inputs/outputs (INT, REAL)
- Data blocks or registers

Tag Definition Example:

```
Motor_Start : BOOL → PLC address %M0.0
Motor_Speed : REAL → PLC address %DB10.DBD0
```

Scaling Formula (Analog Value):

```
Engineering Value = (Raw_Value − Raw_Min) × (Eng_Max − Eng_Min) / (Raw_Max − Raw_Min) + Eng_Min
```

Example: A temperature sensor provides a raw value from 0–27648 corresponding to 0–100 °C. If Raw_Value = 13824, then Temperature = 50 °C.

3. Alarms, Trends, and Data Visualization

Alarms notify operators about abnormal or dangerous process conditions. Trends and charts help visualize process behavior over time.

Alarm Types:

- High / Low process alarms
- Fault and diagnostic alarms
- System and communication alarms

Alarm Priority Example:

```
Priority 1: Emergency stop activated
Priority 2: Motor overload
Priority 3: Maintenance warning
```

Trend Example: A real-time trend displays motor current (A) and speed (rpm) over the last 60 minutes to detect abnormal behavior.

4. User Management and Basic Security

User management controls who can access and modify the HMI and process parameters. Basic security is essential to prevent unauthorized operations and accidental changes.

User Levels Example:

- Operator: start/stop machine, view alarms
- Maintenance: reset faults, manual controls
- Engineer/Admin: configuration and parameter changes

Security Best Practices:

- Use strong passwords and role-based access
- Log user actions (audit trail)
- Automatically log out inactive users

5. Introduction to SCADA Systems and Data Logging

SCADA (Supervisory Control and Data Acquisition) systems monitor and control industrial processes at a supervisory level, often across multiple machines or sites.

Main SCADA Functions:

- Centralized monitoring of multiple PLCs
- Alarm management and historical storage
- Data logging and reporting

Data Logging Formula Example:

```
Average Value = (Σ Process_Value) / N
```

Example: A SCADA system logs energy consumption every minute. Daily and monthly reports are generated to analyze efficiency and reduce costs.

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