Developing Intelligent Piping and Instrument Diagrams (P&ID)

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Topics Covered in this Workshop

- Introduction to Intelligent Piping and Instrument Diagrams
- Current Intelligent Piping and Instrument Diagram Issues
- Standards for Instrumentation Symbols and Identification
- Intelligent Piping and Instrument Diagram Properties Data
- Data Integration with other Engineering Automation Tools
- Rules for developing Intelligent Piping and Instrument Diagrams
Intelligent Piping & Instrument Diagrams

- The current Work Process when developing a P&ID is for Process Engineers to make Sketches and send them to Graphics Designers to create the drawings.
- The adage that “a picture is worth a thousand words” seems to be the current accepted philosophy when developing P&IDs.
Intelligent Piping & Instrument Diagrams

- Over the years there has been a tendency to put less and less on P&IDs by using graphic symbols to represent instrument devices and components as well as the process interoperability and loop associations
- This practice was initiated to streamline and de-clutter the diagrams but required much interpretation by the users
The addition of a data layer to the P&ID has resulted in what is commonly called the Intelligent Piping and Instrument Diagram.

An Intelligent P&ID contains both graphic and meta data and is the source of all the information needed to develop the Process Equipment Sequence and the Instrument Control Schemes.
Multiple Standards for P&ID Symbols

- There are many different standards for the symbology used in the development of Piping and Instrument Diagrams.
- Standards serve a particular purpose or market, for example: ISO/IEC-14617 standards is used for PFD equipment while the ANSI/ISA-5.1 standard is for Instrument P&ID Symbols.
Piping & Instrument Diagram Legend Sheets

- Legend Sheets show all the Symbols, Identifications, Naming Conventions and Abbreviations used on the P&ID
- Additional Properties are assigned to the Symbols to add more information and Intelligence to the P&ID
- Most Properties are not displayed on the face of the Diagram
Out of Date Instrument Diagram Symbols

- Most Company Legend Sheets and Symbols are based on Standards that were out of date years ago while more recent Versions of Standards are available and should be used
- Updating the Legend Sheets and Symbols can be a costly effort but will enable the use of Emerging Technologies
Use of Abbreviated or Typical Symbols

- Abbreviated symbology used to de-clutter the drawing results in Implied Tag Instruments not being shown on the P&ID.
- Implied Instrument Tags cannot be represented in the intelligent P&ID database as they do not have a symbol in the body of a P&ID to attach the Tag Data properties.
Use of Tabular Data in Place of Symbols

- Creating One Typical P&ID for Duplicate Equipment, Trains or Units and using Tables or Tag Prefixes to Reference the Tags across the duplicate systems limits relationship to the Database.

- Using Tables to List Instruments Associated with each Loop instead of showing Symbols for each Tag does not provide enough detail to reflect the actual design conditions of the Control System.
Use of Complex Naming Conventions

- Trying to put too much information in the Tag numbering convention can overly complicate the Tag naming process.
- A simple ISA naming convention should be adequate to give each tag a unique ID and any additional information can be added as Data to the Properties of the Symbols.
Piping & Instrument Diagram Workflow

- Most P&ID workflows are focused on the graphics and visible part of the diagrams with little attention to the Data Properties.
- Intelligent P&ID workflows should direct attention to the data centricity capabilities of the P&ID and provide mechanisms for Data Input, Validation and Integration.
Emerging Instrument Technologies

- Instrumentation Technologies Have changed dramatically over the last few years but most Projects still use outdated Symbols on the P&IDs that do not represent current and emerging technologies.

- Different Instrument Systems and Wiring methods need to be correctly represented on the Intelligent P&IDs so that all of the information used to define the properties of the control networks are accounted for.
ISO 10628-1:2014

- ISO 10628-1:2014 “Diagrams for the chemical and petrochemical industry” does not contain instrument and control symbols but defines the physical sequence of process equipment and systems.
- This standard is used to create Process Flow Diagrams (PFDs) and represent only basic control points within the process.
- The PFD provides the basis for the development of P&ID and Control System schemes, with safety and operational information added during the design phase of a project.
PIP PIC001:2008

- PIP Piping Industry Practice - PIC001 “Piping and Instrumentation Diagram Documentation Criteria” has symbols for Process Piping and Equipment as well as Basic Instrumentation Symbology
- This standard can be used to create a complete P&ID and is the basis for most Intelligent P&IDs
- PIP PIC001 refers to ISA 5.1 as the basis for Instrument Symbols and the two standards should be used in conjunction for the most up to date representation of Control Systems technology
ANSI/ISA-5.1:2009

- The latest version of ANSI/ISA-5.1-2009 Instrumentation Symbols and Identification has significant changes over the previous version ISA-5.1-1984 (R1992)
- This standard has been updated to include new and evolving Instrument Technology, Control Systems and Computer Networks
- This standard addresses only the graphic layer of the documents and does not address the Data or Attribute layer of Intelligent P&IDs but the symbols are easily adapted to add data properties links
Clause 3 added Definitions:

- Analog
- Application Software
- BPCS
- Communications
- Computer Control System
- Data Link
- Detector
- Discrete Signal
- Field Instrument
- Hardware
- HLCS
- Software
Some additions to Clause 4, “Identification letter tables”:

- **C** – “Close” Modifier
- **D** – “Deviation” Modifier
- **G** – “Gauge” Function
- **O** – “Open” Modifier
- **R** – “Run” Modifier
- **S** – “Stop” Modifier
- **W** – “Probe” Function
- **X** – “Accessory Device”
- **Z** – “SIS” Variable Modifier
ANSI/ISA-5.1-2009 – Clause 5

- **column A - DCS - BPCS**
  - Primary Shared Control System (DCS)
  - Basic Process Control System (BPCS)

- **column B - PLC - SIS**
  - Alternate Shared Control System (PLC)
  - Safety Instrumented System (SIS)

- **column C - Software**
  - Computer Functions and Software
  - High Level Control System (HLCS)

- **column D - Hardware**
  - Discrete Primary Elements
  - Discrete Transmitters
  - Discrete Switches and Indicators
  - Discrete Transponders and Relays
  - Discrete Hardware Controllers
  - Discrete Final Control Elements
  - Discrete Control Valves
ANSI/ISA-5.1-2009 – Clause 5 Tables

- Table 5.2 is a new table for Measurement Notations, Descriptions and Functions to be used with symbols

Note: Several new technology functions (e.g. OP-MH = Orifice Plate Multi-hole, LSR= Laser, GWR = Guided Wave Radar, etc… )
Table 5.2.3 - Primary element symbols with several new symbols for special orifices and measurement technologies

Note the Concentric, Eccentric, Quadrant and Multi-hole Orifice Plates
Table 5.2.5 - Measurement symbols for auxiliary and accessory devices

Note the addition of “Probe” function for sample probes connection
**ANSI/ISA-5.1-2009 – Clause 5 Tables**

- Table 5.3.2 - Line symbols for instrument-to-instrument connections with new symbols or signal types

Added Wireless, Fieldbus and Smart or Serial signals
ANSI/ISA-5.1-2009 – Clause 5 Tables

- Table 5.4.2 - Final control element actuator symbols with new positioners and partial stroke testing device symbols

Added Valves with Positioner to eliminate the use of I/P Transducer
ANSI/ISA-5.1-2009 – Annex A

- Annex A has expanded Tables for Allowable Loop, Tag & succeeding letter combinations for instrument functions

Added Function modifiers FF = Ratio, FQ = Total, FS = Safety & FZ = SIS
ISA now recognizes over unique 1000 Instrument Type identifiers
Annex B, “Graphic symbol guidelines” (Informative), is a new informative clause that replaces the examples formerly given in Clause 6, “Drawings,” to provide some limited assistance in the application of the symbols in Clause 5. These examples are more generic and limited in nature than the previous ANSI/ISA-5.1-1984 (R 1992).

Note the use of “FC” Field Controller for Fieldbus VFD.
Symbol Attribute Connection to Database

- The standards when applied to the Legend sheets define naming conventions that define the mechanical, electrical, process, Piping Lines and instrument systems.
- The naming conventions give unique Tag Names to the symbols and elements on the P&ID.
- On Intelligent P&IDs the Tag Name text is placed in the Symbols as CAD Attributes that are associated to the Database Tables as Key Fields.
- The P&ID Database has separate tables for each type of Symbol.
- Additional columns in each table allow the placement of additional properties added to each Tag Name.
Intelligent P&ID Properties Data Tables

- The quantity and content of the Data Tables in the database will very depending on the Software Provider but the User Interface to the database will usually be similar.
- Navigating from Table to Table can be done from an explorer type interface or by clicking in an element in the graphic to expose the Properties of that Tag.
- The Properties can be shown on a browser type interface with rows and columns or a dialog box with data displayed vertically in a window.
- Most Intelligent P&ID Software also provides a Command Menu of user functions to allow the engineers to access the data for editing.
Intelligent P&ID Properties Editing

- Since the Database contains ALL of the intelligence of the P&ID it is important that the data be input and managed by the engineers that are responsible for that Data
- Piping and Mechanical Engineers should edit and manage the Piping Line and Equipment Databases to support the graphics provided by the Process Engineer
- Control Systems Engineers should have access to the Instrument Tag and Loop data tables for editing
- Using pick lists and rule based editing mechanisms will add consistency and validation to the edited data
- Management of change is important as the P&ID is the primary source document for all engineering
Intelligent P&ID Mechanical Equipment Data

- All Equipment shown on the P&ID including Tanks, Vessels, Towers, Exchangers, Heaters, Pumps, Motors and Rotating Equipment should have a defined Naming Convention and be associated to Tables in the P&ID Database
- Different Types of Tagged Equipment require different Properties
- In addition to the Tag Number and Description, properties should include Process Design Conditions, Materials of Construction, Trim, Etc…
- Rotating Equipment should also include Sizing Data and Power Requirements
- Additional Equipment Properties may exist depending on the Piping Line connection requirements
Intelligent P&ID Piping Line Data

- Piping Line numbering convention should be defined to set a unique Tag for each line for association to the Line number database table.
- Piping lines have some unique properties that need to be considered in the data dictionary:
  - Lines often show on more than one P&ID as they pass through Off Page Connectors (OPC).
  - Piping Line Size and Line Class Spec are important integration properties.
  - Lines are often divided into segments.
  - Line Process Design Conditions are needed properties for integration to other Software.
Intelligent P&ID Process Conditions

- The Process Design Conditions define 1.3 times the Maximum Operating Pressure and Temperature of the Process.
- These Design Condition Parameters are applied to all lines and Equipment that comes in contact with the process on a P&ID.
- Additional Process Operating Conditions are required to Size and Select other P&ID elements.
- Process functions such as Flow, Level, Pressure and Temperature are common measured variables defined by the Operating Conditions.
- The Control System manipulates the Process Operating Conditions as defined on the P&ID to meet the required Instrument Control Scheme.

<table>
<thead>
<tr>
<th>Operating Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed composition (%)</td>
</tr>
<tr>
<td>Feed temperature</td>
</tr>
<tr>
<td>Feed rate</td>
</tr>
<tr>
<td>Distillate rate</td>
</tr>
<tr>
<td>Reflux rate</td>
</tr>
<tr>
<td>Bottoms rate</td>
</tr>
<tr>
<td>Isobutylene conversion</td>
</tr>
<tr>
<td>Bottoms ether purity</td>
</tr>
<tr>
<td>Distillate ether purity</td>
</tr>
<tr>
<td>Overhead Pressure</td>
</tr>
<tr>
<td>Condenser temperature</td>
</tr>
<tr>
<td>Temperature of top reactive section (stage 3)</td>
</tr>
<tr>
<td>Temperature of bottom reactive section (stage 5)</td>
</tr>
<tr>
<td>Temperature of middle stripping section (stage 8)</td>
</tr>
<tr>
<td>Reboiler temperature</td>
</tr>
<tr>
<td>Reboiler duty</td>
</tr>
</tbody>
</table>
Intelligent P&ID Instrument Data

- The P&ID Instrument Data Properties include the Loop and Tag Names, Service Descriptions, Signal Types, Process Operating Conditions and additional Monitoring or Control data.
- The Instruments, especially Control Valves, have the largest number of Data Properties of any the P&ID elements.
- The Symbols used on P&IDs should convey a minimum Data set such as Device Type, Signal Type, System Type and Measurement Technology. All these Attributes need to be reflected as Editable Data.
- Sufficient Instrument Data should be loaded into the P&ID Database that Instrument Indexes and I/O lists can be created directly from the P&IDs.
Intelligent P&ID Reports and Exports

- Most Intelligent Piping and Instrument Diagram software have provisions for generating reports from the database.
- The Report generators also have the ability to Export in other File Formats using Open Database Connectivity (ODBC).
- Typical Reports and/or Exports from the P&ID database are:
  - Instrument Lists and Indexes
  - P&ID drawing Lists
  - Electrical Load Lists
  - Inline Device Lists
  - Piping Line Lists
  - Equipment Lists
  - I/O Lists
- The Exports are used for Integration.
P&ID Integration with other Automation Tools

- In a Data Centric Engineering Environment the Integration of data between each Discipline Automation tools is essential.
- The Intelligent P&ID is the source for most of the data that initializes the other Engineering Automation Project databases.
- Several mechanisms are used to pass data between tools.
P&ID Integration with other Software Methods

- The most popular Integration method is to Export Data from a source application and then import it into a destination application using Excel or XML as a neutral file format.
- Many software applications integrate data use Application Programming Interfaces (API) to directly link the two databases.
Intelligent P&ID Integration Data Sets

- Regardless of the Integration method it is necessary for only specific data be exchanged between applications
- Certain Key Fields (Usually Tag Names) must be correlated between the databases to establish record matching
- Then additional properties mapped to the Key fields will integrate
Intelligent P&ID Integration Data Mapping

- The property fieldnames and data tables between Integrated databases usually do not match so it is necessary to create a Data Map to define the correlation of the data sets.
- Intimate knowledge of both data structures is necessary for mapping and in some cases data may need redefinition.
P&ID Integration with 3D Modeling

- Equipment Lists and Piping Line Lists from the Intelligent P&ID are the building blocks of the 3D Model
- This data centricity between the 3D Model and the P&ID should be maintained to facilitate Change Management, Model Reviews and Hazard and Operability studies (HAZOP)
Legend Sheets for Intelligent P&IDs

- Following are a few simple Rules and Practices to take full advantage of Data Centric Intelligent P&ID and Legend Sheets:
  - The Legend Sheets need to be based on the latest standards
  - Naming Conventions for all Key Tag entities should be defined on the P&ID Legend Sheet
  - Be sure all the Primary Symbols defined on the Legend Sheets have attributes linked to the database
  - Update the Legend Sheets as design develops to show actual usage of symbols and tag naming
  - The Legend Sheets need to address naming conventions and symbology for Emerging Instrument Systems
Provide for New and Emerging Technologies

- Instrumentation Technologies Have changed dramatically over the last few years but most Projects still use outdated Symbols on the P&IDs that do not represent emerging technologies.

- Different Instrument Systems and Wiring methods also need to be represented and Identified on the P&IDs.

- Instrumentation Systems
  - Basic Process Control Systems (BPCS)
  - Safety Instrumented Systems (SIS)
  - Equipment Protection Systems (EPS)
  - Burner Management Systems (BMS)

- Emerging Wiring Systems
  - Conventional 4-20 ma Instruments
  - Smart Digital Instrument Systems
  - Bus Based Instrument Wiring Systems
  - Wireless Instrument Systems
Do Not Take Drafting or Data Shortcuts

- The Piping and Instrument Diagrams and Intelligent P&ID Database are the most important source documents on any project.
- The P&ID is the wrong place to try to save time or money when developing the content of the Process and Control Systems.
- Every Tagged Element needs to be shown on the face of the P&ID so they will have a record in the database.
- The P&ID Data layer properties define all of the engineering requirements of a project so do not think of the Intelligent P&ID as simply graphics.
- The owners of the individual types of data need to be the ones editing and validating the content of the P&ID Graphics and Data.
- To get multiple disciplines involved in the content of the P&ID new work processes will need to be developed.
Develop Data Centric P&ID Work Processes

- Most work processes for developing P&IDs are focused on the Graphics layer of the documents with little regard to how the data properties are populated or validated.
- The P&ID Database contains information from several disciplines so members of those departments should be defined in the Data Centric Work Process.
- A typical Data Centric Work Process:
  - Process Engineering is responsible for overall Graphics and Process Data.
  - Piping, Mechanical and Instrument Engineering are responsible for their respective data properties.
  - It may be necessary for other entities to have input to the database (e.g. Plant Operations or Safety Engineering).
- Make provisions for Data Integration.
Expand the Intelligent P&ID Data Integration

- The primary reason to have Intelligent P&ID software is to create a data source for other Automated Engineering Applications.
- Most Intelligent P&ID software solutions have interfaces that allow the data to be formatted and exported to other tools.
- The extent of the Integration will depend on the quantity and quality of the Data in the Database.
- Some common Integration data sets:
  - Equipment Lists with Properties
  - Piping Line Lists with Properties
  - Instrument Lists with Properties
  - Electrical Load Lists with Properties
  - Process Design Conditions
- Integration is out of the box with most Intelligent P&ID Software packages.
Intelligent Piping & Instrument Diagram Tools

- There are many providers of Intelligent P&ID Software:
  - AutoCAD P&ID
  - AVEVA P&ID
  - CADISON P&ID Designer
  - CADWorx P&ID
  - COMOS P&ID
  - MEDUSA4 P&ID
  - OpenPlant PID
  - Plant-4D P&ID
  - PlantSpace P&ID
  - SmartPlant P&ID
  - SolidPlant P&ID

Autodesk
AVEVA Group plc
CADISON
Intergraph
Siemens
CAD Schroer
Bentley
CEA Systems
Bentley
Intergraph
SolidWorks
Developing Intelligent Piping and Instrument Diagrams

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