Integrating PI, P&ID, and Business System Data into a Unified Knowledge Graph Using DeepIQ

Abstract

Industrial operations generate large volumes of data from historians, engineering systems, and business applications. Yet these datasets are typically trapped in separate silos, limiting analytics, optimization, and digital-transformation efforts.

This whitepaper demonstrates a simple but complete example of how to use DeepIQ to create a knowledge graph that integrates:

- PI AF hierarchy and time series data (from OSIsoft PI),
- P&ID-derived connectivity and topology,

The result is a semantically rich, queryable model that links operational data, engineering context, and business intelligence into a single digital twin.

Business systems such as SAP and Maximo contain rich operational, maintenance, and transactional data. DeepIQ enables users to ingest this information and seamlessly integrate it into the unified knowledge graph. Since this topic is covered extensively in other DeepIQ whitepapers (1 and 2), it is not discussed in detail here.

Overview of DeepIQ Integration Architecture

DeepIQ provides a unified low-code/no-code environment for industrial data integration and knowledge graph creation.
Using its modular workflows, users can ingest, transform, and harmonize data from multiple sources into a connected data model.

Key Components

DeepIQ's integration architecture brings together industrial, engineering, and business data through a set of modular, interoperable capabilities. These components work in concert to ingest, enrich, align, and connect information from diverse sources into a unified, semantically consistent knowledge graph.

- **DeepIQ P&ID Extraction Workflow:** Utilizes proprietary Generative AI models to extract entities and relationships from engineering drawings with industry-leading accuracy.
- **DeepIQ PI Ingestion Workflow:** Connects to PI AF to extract both hierarchical structures and live time-series data.
- **DeepIQ Transformation Workflows:** Standardize, harmonize, and align entities from PI and P&ID sources into a unified schema.
- **DeepIQ Knowledge Graph Builder:** Links all extracted and transformed information into a common data model, enabling exploration, analysis, and visualization of the connected knowledge graph.

As depicted in Figure 1, DeepIQ's architecture enables seamless integration of disparate industrial data sources into a unified model.

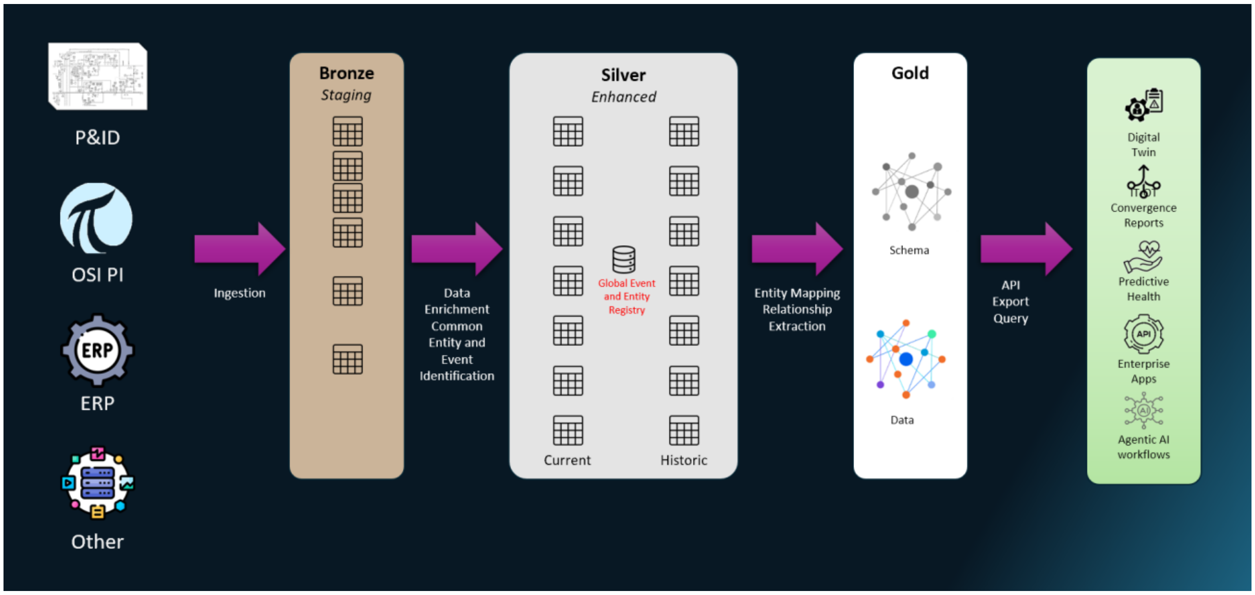


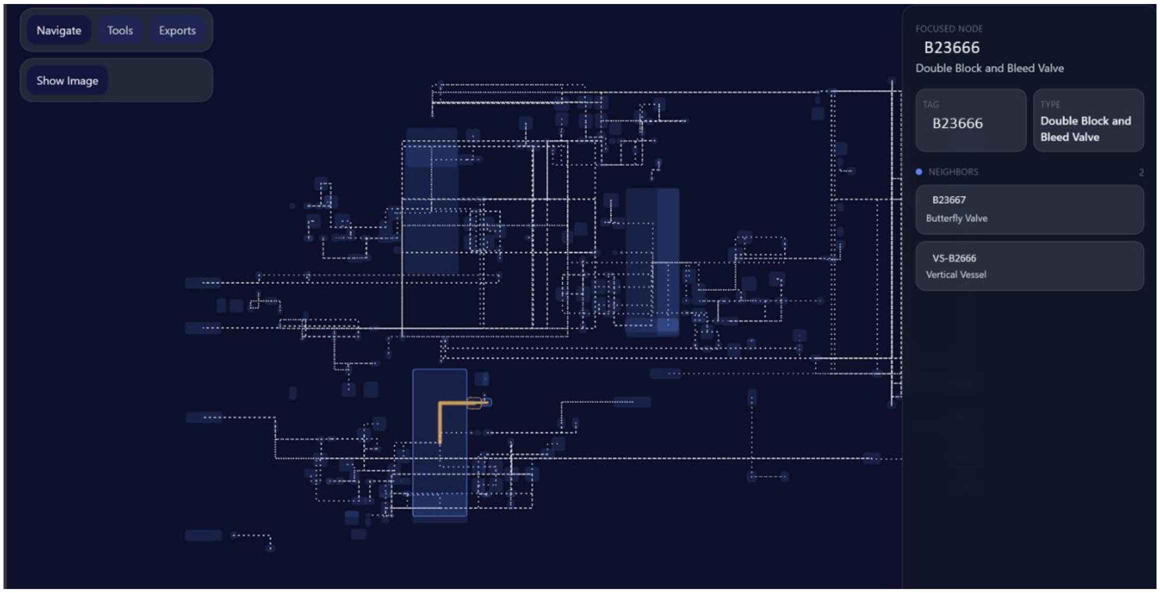
Figure 1: DeepIQ Architecture

We now illustrate how this process can be executed in DeepIQ in a few simple steps.

Step 1: Extracting P&ID Network Topology

The DeepIQ P&ID Extraction Workflow processes engineering drawings to extract:

- Equipment and instrument symbols (nodes),
- Connectivity paths (edges), and
- Relationship semantics (process flow, signal, or mechanical links).



FOCUSED NODE
B23666
Double Block and Bleed Valve

TAG
B23666

TYPE
Double Block and Bleed Valve

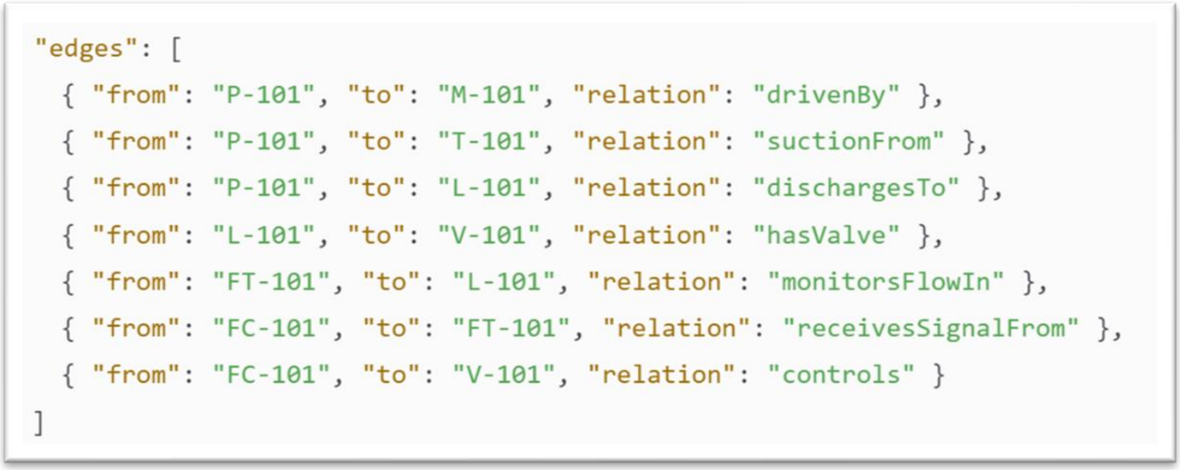
NEIGHBORS 2

B23667
Butterfly Valve

VS-B2666
Vertical Vessel

Figure 2: A Sample Digitized P&ID generated by DeepIQ’s Gen AI engine

A sample (simplified) view of the extracted network topology is shown in Figure 3



```
"edges": [
  { "from": "P-101", "to": "M-101", "relation": "drivenBy" },
  { "from": "P-101", "to": "T-101", "relation": "suctionFrom" },
  { "from": "P-101", "to": "L-101", "relation": "dischargesTo" },
  { "from": "L-101", "to": "V-101", "relation": "hasValve" },
  { "from": "FT-101", "to": "L-101", "relation": "monitorsFlowIn" },
  { "from": "FC-101", "to": "FT-101", "relation": "receivesSignalFrom" },
  { "from": "FC-101", "to": "V-101", "relation": "controls" }
]
```

Figure 3: Example JSON Output of P&ID Network Topology Extraction

This creates a semantic network model describing how assets interact rather than just what they are.

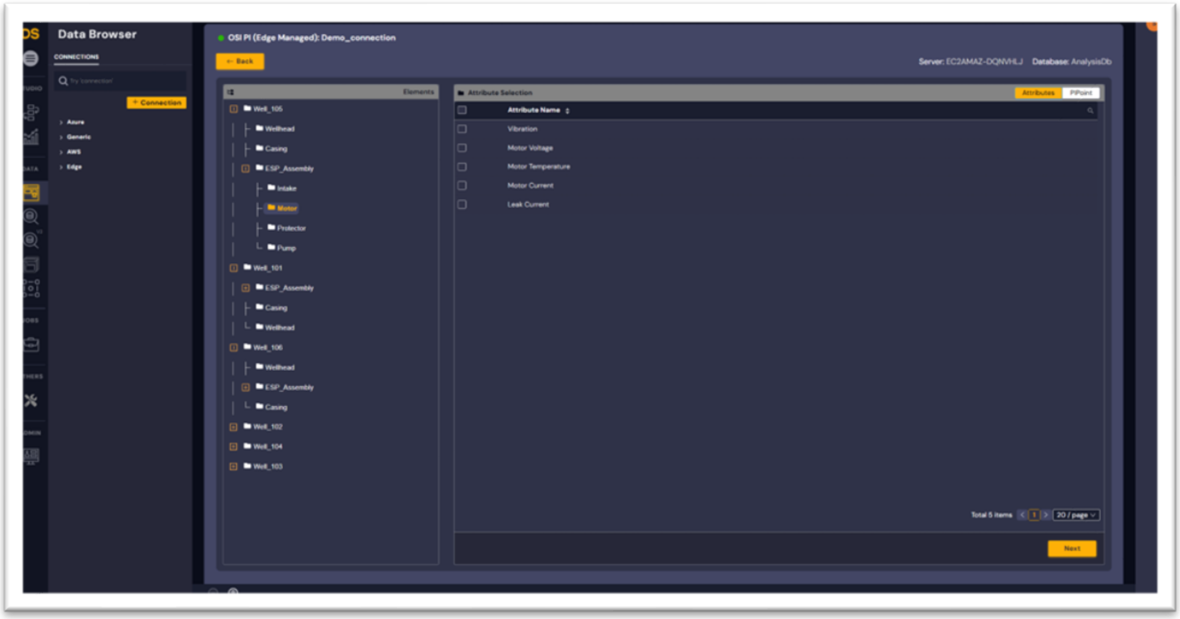
Step 2: Extracting the PI AF Hierarchy

The DeepIQ PI Ingestion Workflow connects to the OSIsoft PI AF server and extracts:

- The asset hierarchy (e.g., motors, pumps, tanks, valves, controllers, transmitters),
- The element templates and attribute definitions, and
- The associated PI tag mappings for each property.

DeepIQ Data Integrator provides a unified and secure interface for accessing operational data sources within air-gapped environments. To comply with industrial network security constraints, Data Integrator does not require any inbound connectivity into protected OT zones. Instead, it leverages a connector agent deployed inside the secured network, which initiates outbound, firewall-approved requests to local data sources.

The AF hierarchy is monitored for changes and ingested as a structured JSON as shown below.



□	Attribute Name
□	Vibration
□	Motor Voltage
□	Motor Temperature
□	Motor Current
□	Leak Current

Figure 4: Sample Edge Hierarchy as shown in DeepIQ's Data Integrator

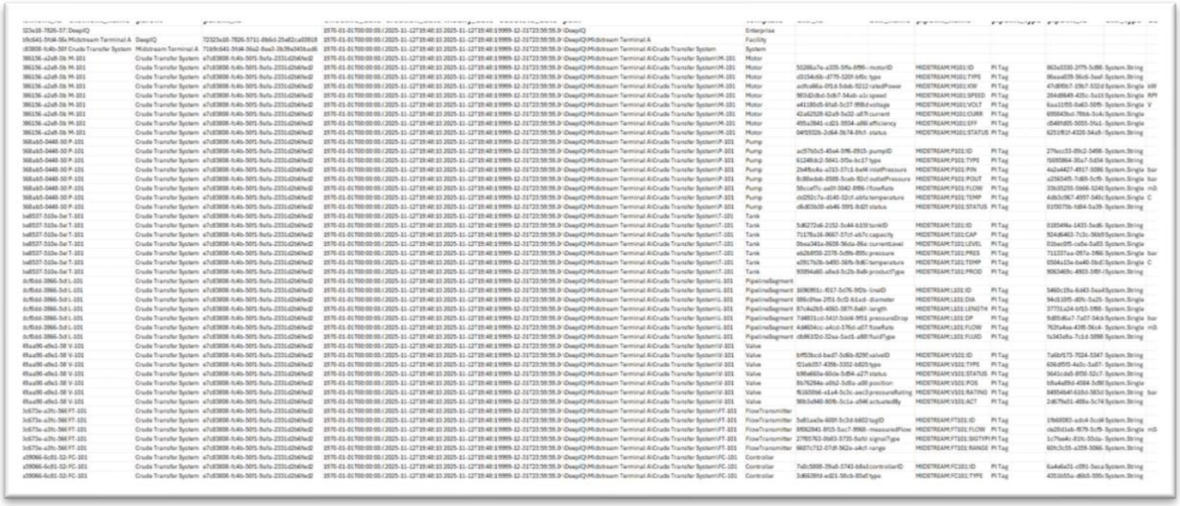
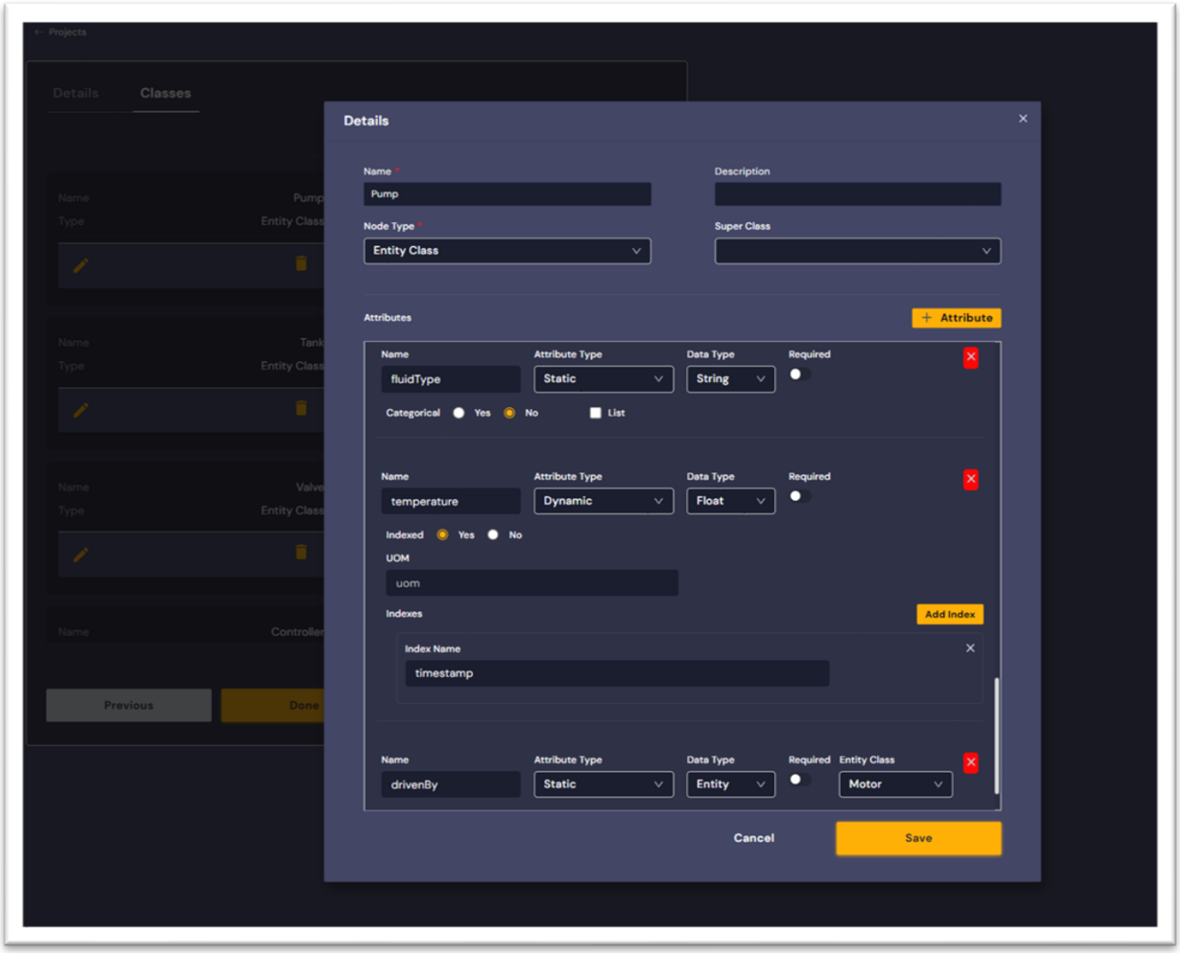


Figure 5: Sample CSV Snapshot of PI AF Hierarchy Ingested by DeepIQ

Step 3: Defining the Knowledge Graph Schema

DeepIQ’s knowledge graph schema acts as the unifying model connecting PI, P&ID, and business data.



Details

Name * : Pump
Description :
Node Type * : Entity Class
Super Class :

Attributes

Name: fluidType | Attribute Type: Static | Data Type: String | Required: ○
Categorical ○ Yes ● No □ List

Name: temperature | Attribute Type: Dynamic | Data Type: Float | Required: ○
Indexed ● Yes ○ No
UOM: uom
Indexes
Index Name: timestamp

Name: drivenBy | Attribute Type: Static | Data Type: Entity | Required: ○ | Entity Class: Motor

Figure 6: Defining the Knowledge Graph Schema in DeepIQ

While the above UI shows a manual way of creating the knowledge graph schema, DeepIQ provides extensive support for generating these schemas automatically using existing data sources such as OPC UA hierarchies, AF template classes or external OWL ontologies.

In our simple example, we create definition of classes, attributes, and relationships, as shown in Table 1.

Table 1: Core Equipment Classes, Properties, and Relationships in the DeepIQ Knowledge Graph Schema

Class	Example Properties	Example Relationships
Pump	flowRate, inletPressure, outletPressure	drivenBy(Motor), suctionFrom(Tank)
Motor	speed, voltage, current	drives(Pump)
Tank	level, pressure	feeds(Pump)
Valve	position, type	controlledBy(Controller)

Controller	setPoint, outputSignal	controls(Valve)
FlowTransmitter	measuredFlow	monitorsFlowIn(Pipeline)

Step 4: Creating Knowledge Relationships and Instances

Now, that the schema is available, we move the next step of populating the instances and relationships in the schema.

The DeepIQ AF Transformation Workflow converts the extracted AF JSON into actual entity instances in the knowledge graph.

In our simple example in Table 2, the following instances are created.

Table 2: Sample Asset Instances and Equipment Types Created in the DeepIQ Knowledge Graph

Tag	Description
M-101	Motor
P-101	Pump
T-101	Tank
L-101	PipelineSegment
V-101	Valve
FT-101	FlowTransmitter
FC-101	Controller

Each instance inherits its attributes from the AF data (e.g., ratedPower, inletPressure, flowRate) and is automatically mapped to its PI tag references.

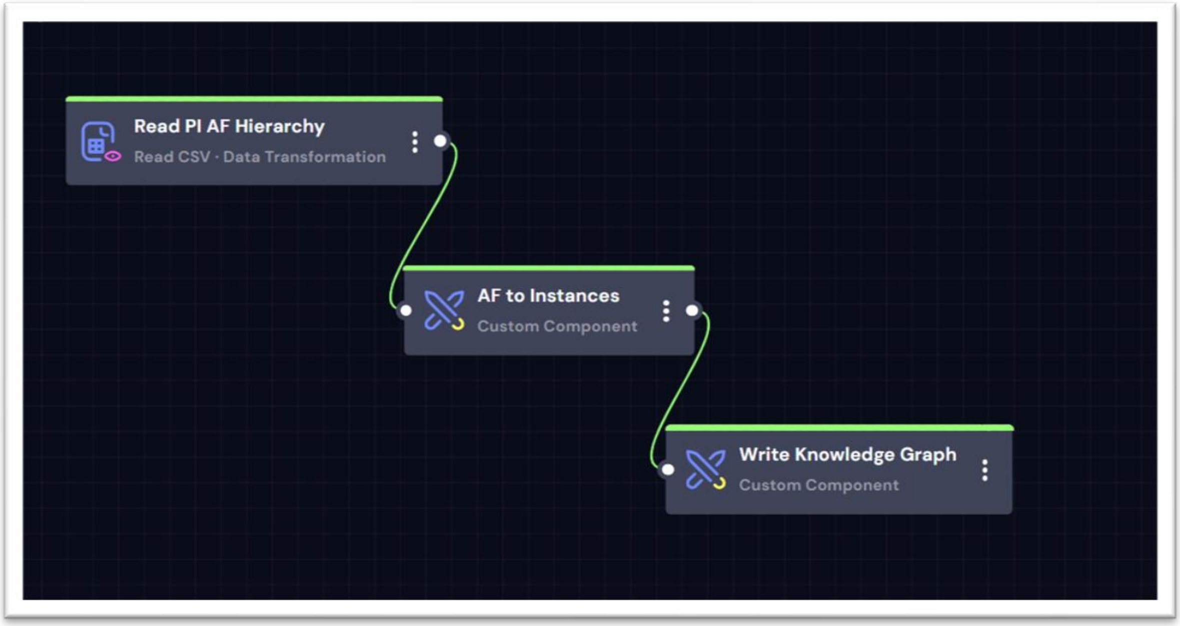
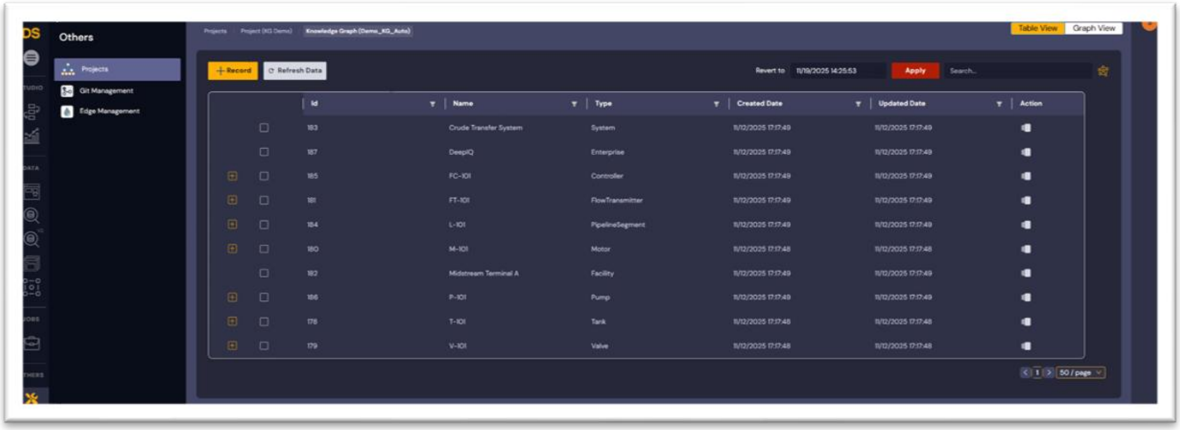


Figure 7: Workflow for Transforming PI AF Hierarchy into Knowledge Graph Instances



		Id	Name	Type	Created Date	Updated Date	Action
	□	183	Crude Transfer System	System	11/12/2025 17:17:49	11/12/2025 17:17:49	
	□	187	DeepIQ	Enterprise	11/12/2025 17:17:49	11/12/2025 17:17:49	
⊞	□	185	FC-101	Controller	11/12/2025 17:17:49	11/12/2025 17:17:49	
⊞	□	181	FT-101	FlowTransmitter	11/12/2025 17:17:49	11/12/2025 17:17:49	
⊞	□	184	L-101	PipelineSegment	11/12/2025 17:17:49	11/12/2025 17:17:49	
⊞	□	180	M-101	Motor	11/12/2025 17:17:48	11/12/2025 17:17:48	
	□	182	Midstream Terminal A	Facility	11/12/2025 17:17:49	11/12/2025 17:17:49	
⊞	□	186	P-101	Pump	11/12/2025 17:17:49	11/12/2025 17:17:49	
⊞	□	178	T-101	Tank	11/12/2025 17:17:48	11/12/2025 17:17:48	
⊞	□	179	V-101	Valve	11/12/2025 17:17:48	11/12/2025 17:17:48	

Figure 8: Knowledge Graph User Experience: Tabular View of Asset Properties and Relationships

The DeepIQ P&ID Transformation Workflow establishes relationships between instances based on the extracted connectivity model as shown in Table 3:

Table 3: Asset Relationships and Their Operational Meanings in the DeepIQ Knowledge Graph

Relationship	Meaning
Pump P-101: drivenBy→ Motor M-101	Mechanical link
Pump P-101: suctionFrom→ Tank T-101	Fluid source
Pump P-101: dischargesTo→ PipelineSegment L-101	Fluid discharge

L-101: hasValve→ Valve V-101	Flow control
FlowTransmitter FT-101: monitorsFlowIn→ L-101	Measurement
Controller FC-101: receivesSignalFrom→ FT-101	Signal input
Controller FC-101: controls→ V-101	Control output

This step links the static equipment structure from AF with functional logic from P&ID.

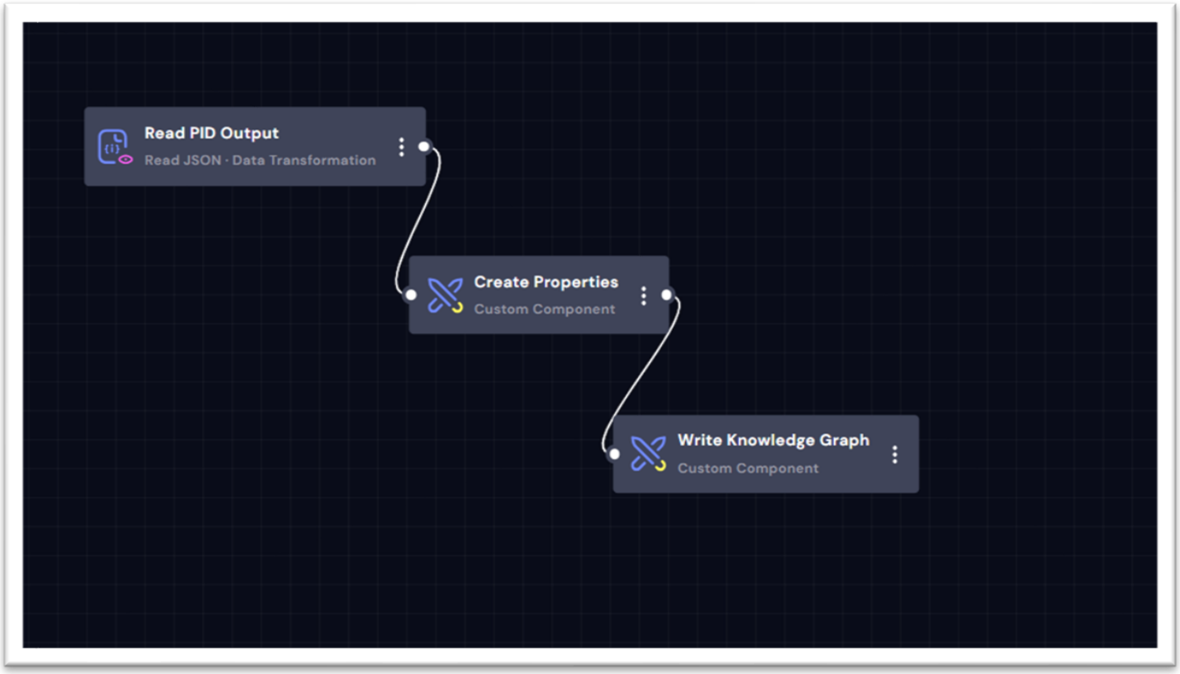


Figure 9: Workflow for Transforming P&ID Digitization into Knowledge Graph Relationships

Step 6: Ingesting and Linking PI Time Series Data

The DeepIQ PI Time Series Ingestion Workflow continuously ingests live and historical process data from PI Data Archive and associates it with the relevant entity properties in the graph.

The data enrichment work also enriches timeseries data using advanced statistical algorithms including interpolation, imputation and noise removal.

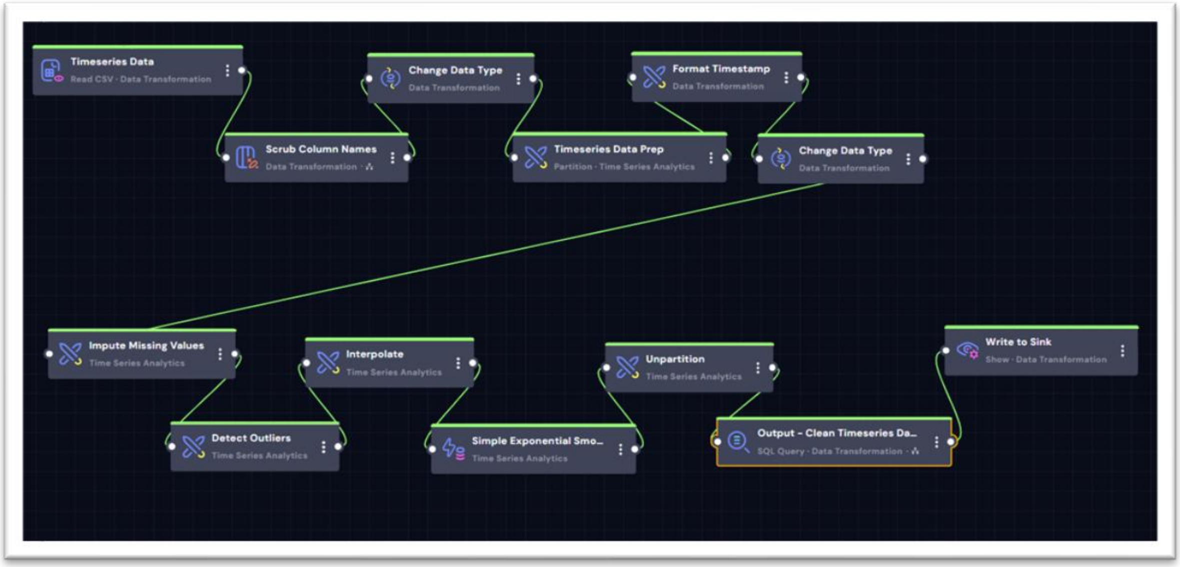


Figure 10: Workflow for Cleaning and Transforming PI Time Series Data in DeepIQ

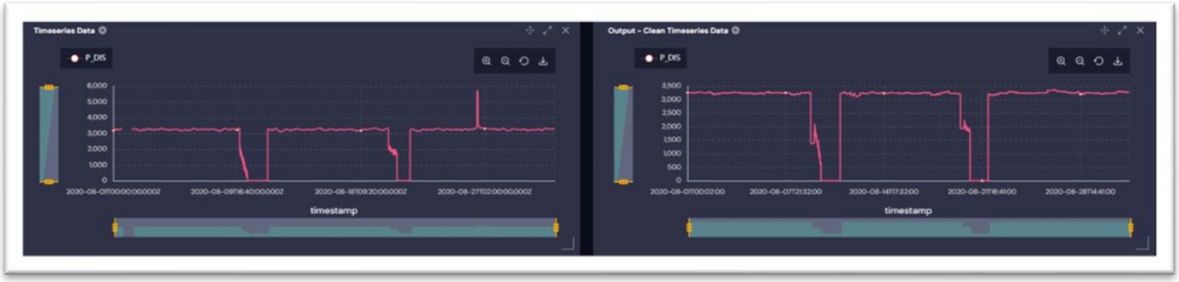


Figure 11: Comparison of PI Time Series Data Before and After Cleaning

This makes time series trends directly available within the knowledge graph context, enabling queries like:

> *“Show flow rate vs motor current for Pump P-101 during the last 24 hours.”*

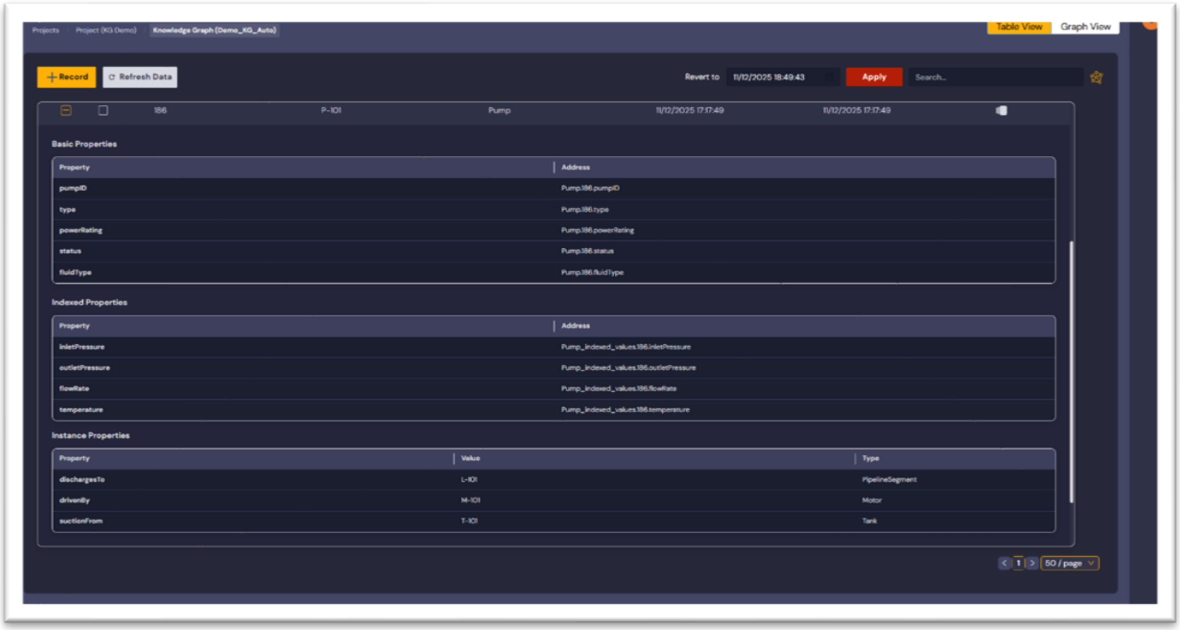
Step 7: Unified View in the Knowledge Graph

Once both AF and P&ID transformations are complete, we have implemented a connected knowledge graph where:

- Equipment, instruments, and pipelines are nodes,
- P&ID relationships are edges, and
- PI attributes and time series are attached as properties.

This provides a single queryable layer that combines:

- Operational context (from PI),
- Physical connectivity (from P&ID),
- And optional business metadata (from ERP, CMMS, or inventory systems).



186	P-101	Pump	11/12/2025 17:17:49	11/12/2025 17:17:49

Basic Properties

Property	Address
pumpID	Pump.186.pumpID
type	Pump.186.type
powerRating	Pump.186.powerRating
status	Pump.186.status
fluidType	Pump.186.fluidType

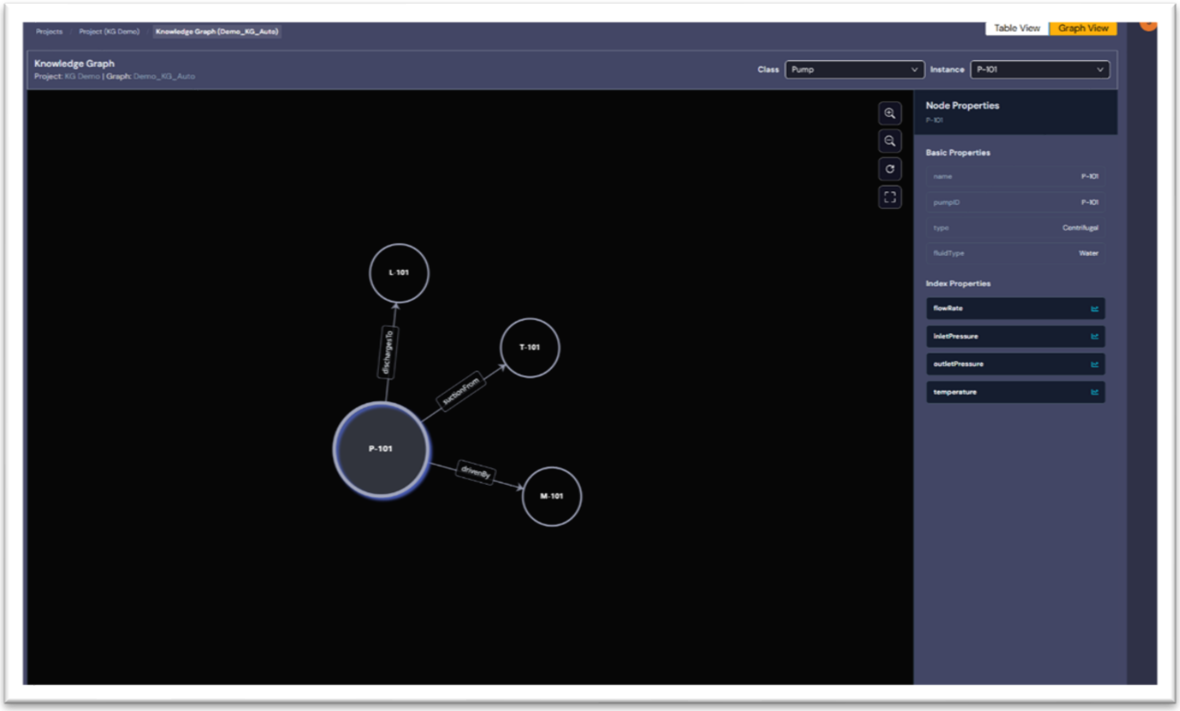
Indexed Properties

Property	Address
inletPressure	Pump_indexed_values.186.inletPressure
outletPressure	Pump_indexed_values.186.outletPressure
flowRate	Pump_indexed_values.186.flowRate
temperature	Pump_indexed_values.186.temperature

Instance Properties

Property	Value	Type
dischargesTo	L-101	PipelineSegment
drivenBy	M-101	Motor
suctionFrom	T-101	Tank

Figure 12: View of Knowledge Graph Instances, Relationships and their Properties in DeepIQ



Knowledge Graph
Project: KG Demo | Graph: Demo_KG_Auto

Class: Pump
Instance: P-101

Node Properties
P-101

Basic Properties

name	P-101
pumpID	P-101
type	Centrifugal
fluidType	Water

Index Properties

- flowRate
- inletPressure
- outletPressure
- temperature

Figure 13: Knowledge Graph Visualization showing Pump Instance (P-101)

Benefits of This Integrated Approach

The integration of PI, P&ID, and business system data using DeepIQ's knowledge graph platform delivers a range of significant benefits for industrial operations. By unifying engineering, operational, and business information into a single, connected model, organizations can unlock new capabilities in analytics, streamline data access, and scale insights across assets and facilities.

Table 4 summarizes the key capabilities enabled by this approach and the value they provide.

Table 4: Key Capabilities and Value Enabled by DeepIQ's Integrated Knowledge Graph Approach

Capability	Enabled By	Value
Unified digital twin	DeepIQ Knowledge Graph	Combines engineering, operational, and business data
Contextual analytics	PI + P&ID integration	Enables root-cause and performance correlation
Simplified data access	DeepIQ transformations	Single semantic layer for analytics tools

Scalability	DeepIQ orchestration	Works across assets, units, or entire facilities

Conclusion

This example illustrates how DeepIQ simplifies the creation of an industrial knowledge graph that integrates engineering, operational, and business data sources.
By combining PI AF hierarchies, P&ID topologies, and time series data, DeepIQ enables:

- Holistic visibility into process behavior,
- Contextualized analytics and machine learning, and
- A foundation for autonomous optimization and predictive maintenance.