Introduction

The term “Digital Twin” has tended (of late) to refer mostly to the end-use application of algorithms or models - simulation, analytics, optimization - of physical assets in the digital domain.

Digital twins consist of three components: a data model, a set of analytics or algorithms, and knowledge. The *Knowledge* part can be captured into a special form of the *Data Model* part, namely: A Semantic Model of assets.

A semantic model has a special ability to contextualize very complex, engineering-oriented data to guide Big Data/Data Science as well. An example: a semantic model could give an industry-specific context on top of data in a Data Lake and could “pre-cluster” information for the (non-process expert) data scientist to begin his or her work.

The model gives a common frame of reference and a means to communicate between the process expert and the data scientist. We’ll use examples of **thermal power generation plants** and **their assets**, but those examples should extend to the other process industries as well.

Semantic Modeling

A semantic model is a type of data and information model, that can organize and store information about the asset, *and* the asset’s relationships to surrounding components, other assets, systems, and fleet of plants. We’ll use the Graph Database construct for this modeling.

Graph databases support a very flexible and fine-grained data model that allows you to model and manage rich domains in an easy and intuitive way. You keep the data as it is in the real world: small, normalized, yet richly connected entities. This allows you to query and view your data from any imaginable point of interest. If you’re experienced in modeling with relational databases, think of the ease and beauty of a well-done, normalized entity-relationship diagram: a simple, easy to understand model you can quickly whiteboard with your colleagues and domain experts. A graph is exactly that: a clear model of the domain, focused on the use cases you want to efficiently support.

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PI&D files can be exported as CSV files containing the flow and Instrumentation information which are used to model the basic Digital Twin graph. This graph can now further evolve by adding more information from the documentation available like manuals, vendor data sheets, handbooks etc.

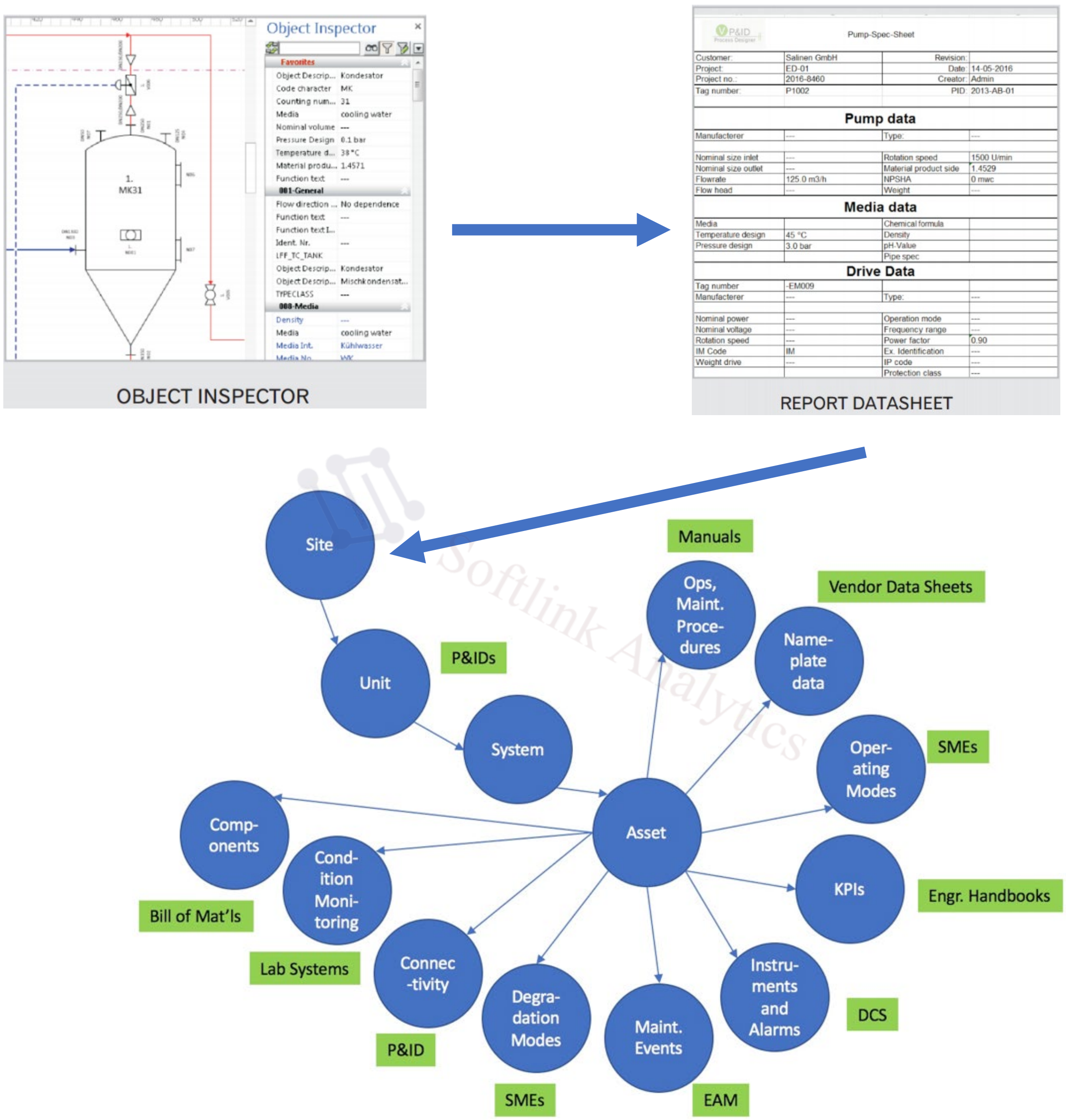


Figure 1. General Semantic Model (and supporting System of Record in green) for a Thermal Generation Power Plant

Taxonomy for Digital Twin Creation

Moving from the general model to a specific semantic model will require the following to be represented:

1. Asset Hierarchy
2. Asset Componentry
3. Asset Instrumentation
4. Asset Management Problem and Failure Codes
5. Plant and Asset Operational Modes and Malfunctions

Asset Hierarchy

The asset hierarchy is used to model the entire fleet of power plants within the generation company. The general Taxonomy for graph modeling is as follows:

Starting with physical location (site), it moves to Unit number (usually generation sites will have more than one unit on location), and then the various systems within that unit. The Unit/System breakdown usually follows the structure as organized in and indicated by the plant's Piping and Instrumentation Diagrams (P&IDs).

Having a semantic model structure for plant breakdowns is the first way to look at each plant member within the fleet on an "apples-to-apples" basis. For example, an M&D engineer could query for instrumentation or asset management data from "all plants that have turbine-driven boiler feed pumps;" a tree structure or graph query allows intuitive access to the data.

Following from this breakdown, the subsystems, and individual assets on for each system/P&ID sheet are modeled; for this and the subsequent sections discussed below, the Asset will be the "center of the universe" in terms of interest and usefulness for Operations, Maintenance, and M&D. Figure 2 shows an example Asset Hierarchy (in Mind Map format):

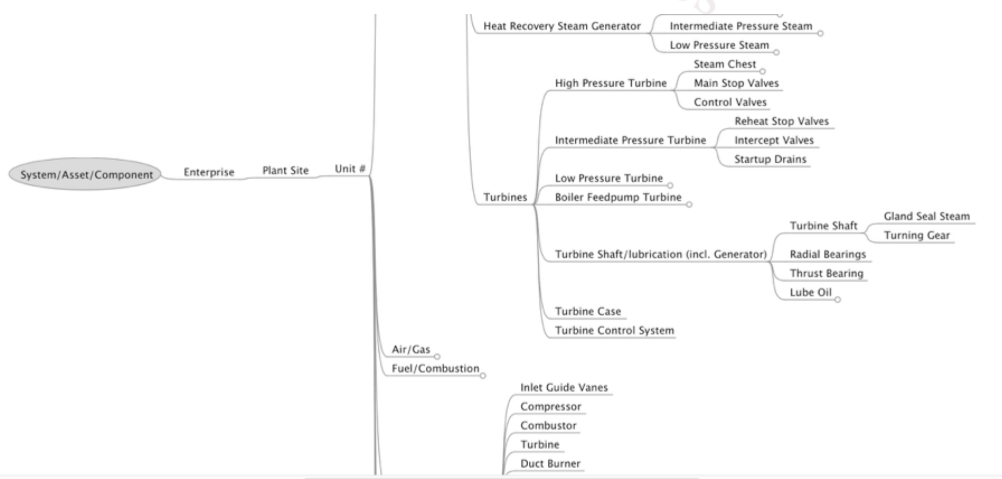


Figure 2. Asset Hierarchy Semantic Model Example

Asset Componentry

Once it is possible to navigate from Site/Unit/System/Subsystem/Asset, now we may wish to be able to break the understanding of the asset down in a couple of ways. First, certain complex "assets" are actually almost systems unto themselves. An example is a main steam turbine, which has a complex set structure ("high, medium, and low-pressure sections"), as well as supporting equipment ("lube oil skid, seal steam system") which need to be modeled. Secondly, each asset can be further broken down by components, and parts. For example, a boiler feedpump has a case, rotor, pump stage, pedestal, driveshaft, balance system, etc. (Figure 3). **Asset componentry would be on the level as might be described by the asset's vendor data sheet, or cross-sectional diagram (Figure 4).**

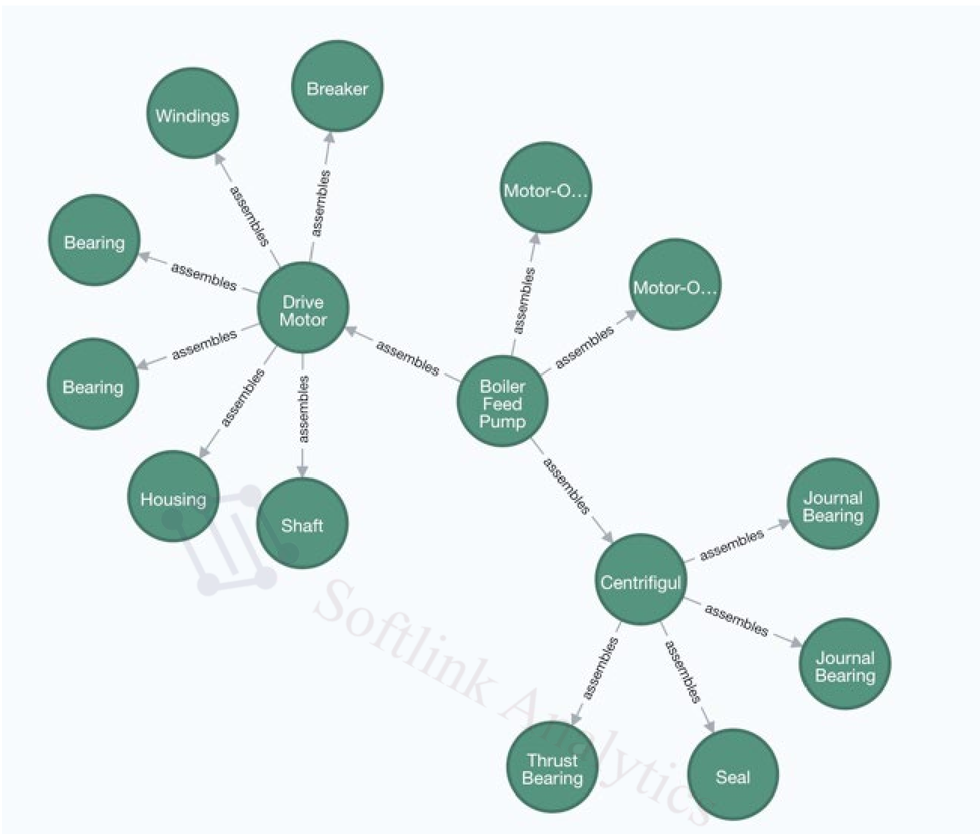


Figure 3. Asset Componentry Model for a Motor-Driven Pump

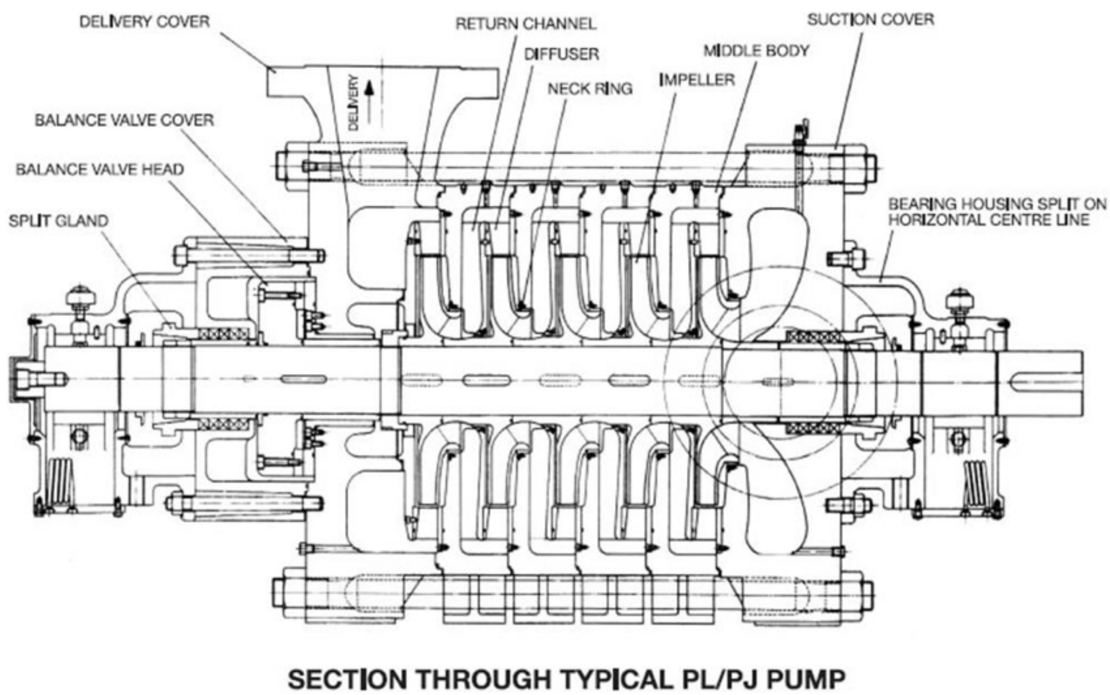


Figure 4. Pump Cross-Section Diagram, showing Components

Asset Instrumentation

Mapping Asset Instrumentation within the semantic model gives the distinct advantage of being able to navigate instruments via the asset hierarchy, rather than from the (sometimes cryptic) instrument tag list. Example (fictitious): “Site Harris, Unit 1, Boiler Feedpump 1A, Discharge Pressure,” as opposed to “1A1PT101.”

The common asset hierarchy gives the ability to navigate from a common-sense understanding, rather than requiring a mental concept of interpreting “regular expressions” within the tag name coding structure. This is especially important when the fleet of plants contain units of different types, heritages, or legacies (such as in a plant acquisition, where the previous owner may have employed some different standard in tag naming conventions, or even some different data historian vendor). **This is the first example of the ability noted earlier for a semantic model to cut across and unify different “namespaces” within a system-of-record. Figure 5 shows a simple instrumentation semantic model segment.**

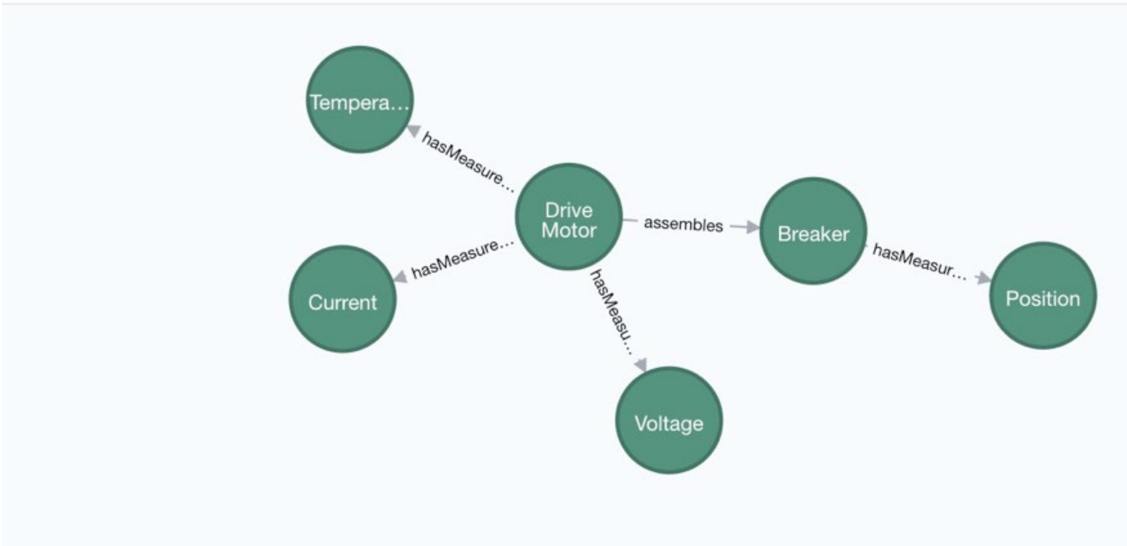


Figure 5. Semantic Model Portion for Drive Motor Instrumentation

Asset Management Problem and Failure Codes

For a given asset class (e.g. Pump), **it is useful to know the most common problem and failure types and being able to correlate problem and failure events with time series (e.g. data historian) and other data sources**.

It is typical for failure event data to be recorded via unstructured text; to be able to perform robust reliability analyses, **the events must be classified according to Problem Code, and Failure Code.** Unstructured technical maintenance data, such as technician comments recorded in the "description" field of an asset management work order, can be converted into structured data.

The semantic model can be used to maintain a taxonomy of problem and failure codes, and the codes can use an "inheritance" feature of the model to incorporate the base asset's (i.e. process pump is base asset to condensate pump) Problem and Failure Codes in addition to its own specific codes.

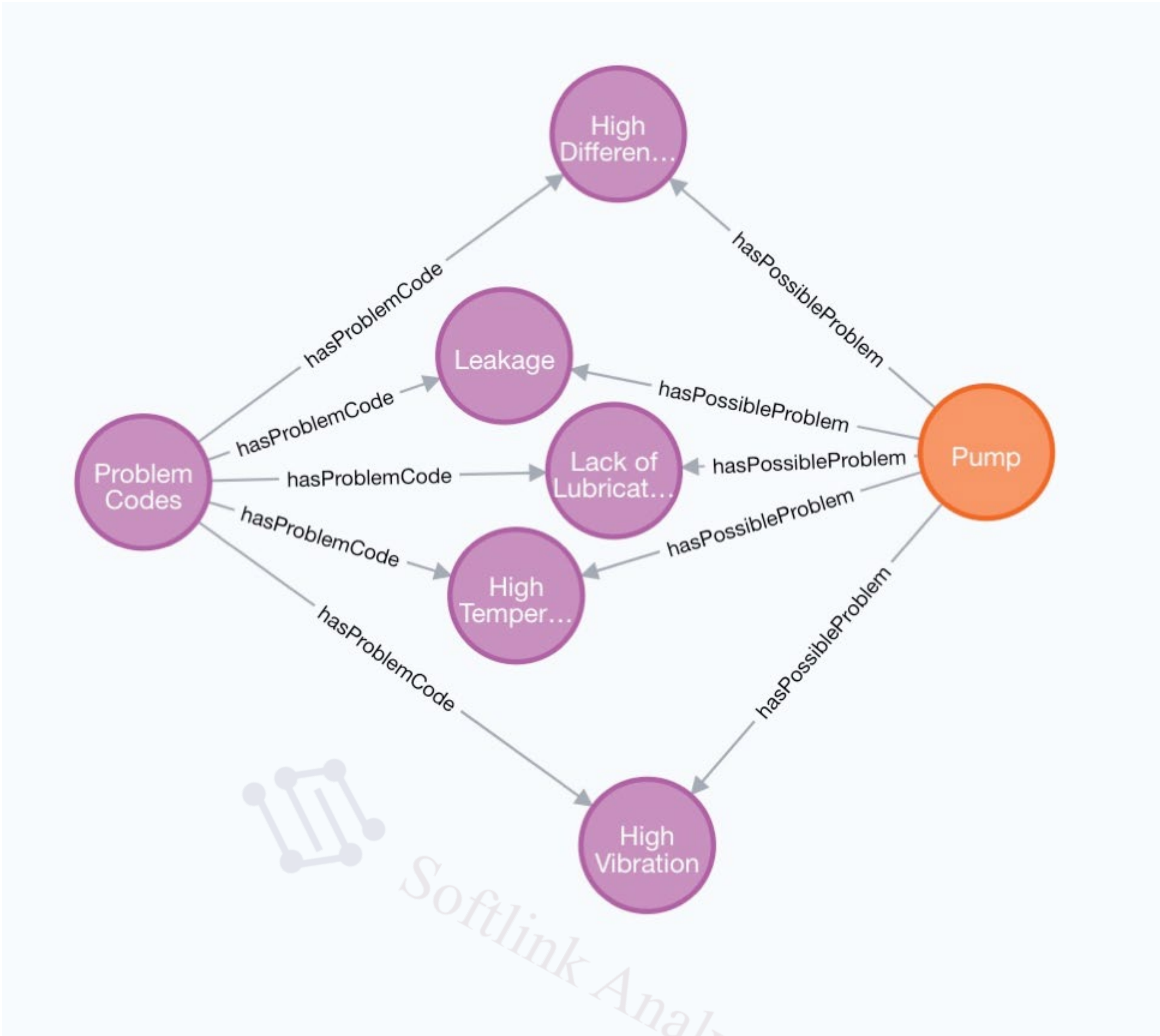


Figure 6. Sample Problem Codes for a General-Purpose Pump Asset

Plant and Asset Operational Modes and Malfunctions

Finally, the semantic model contains knowledge of Plant and Asset operating modes. These serve as the target classification labels for an advanced Digital Twin application: a Plant and Asset "Behavior Catalog." AI and ML techniques can be used to parse through historical data, trained to spot normal and abnormal operating modes; This event data can be used to identify precursors to failure, or to correlate asset reliability to operating mode history.

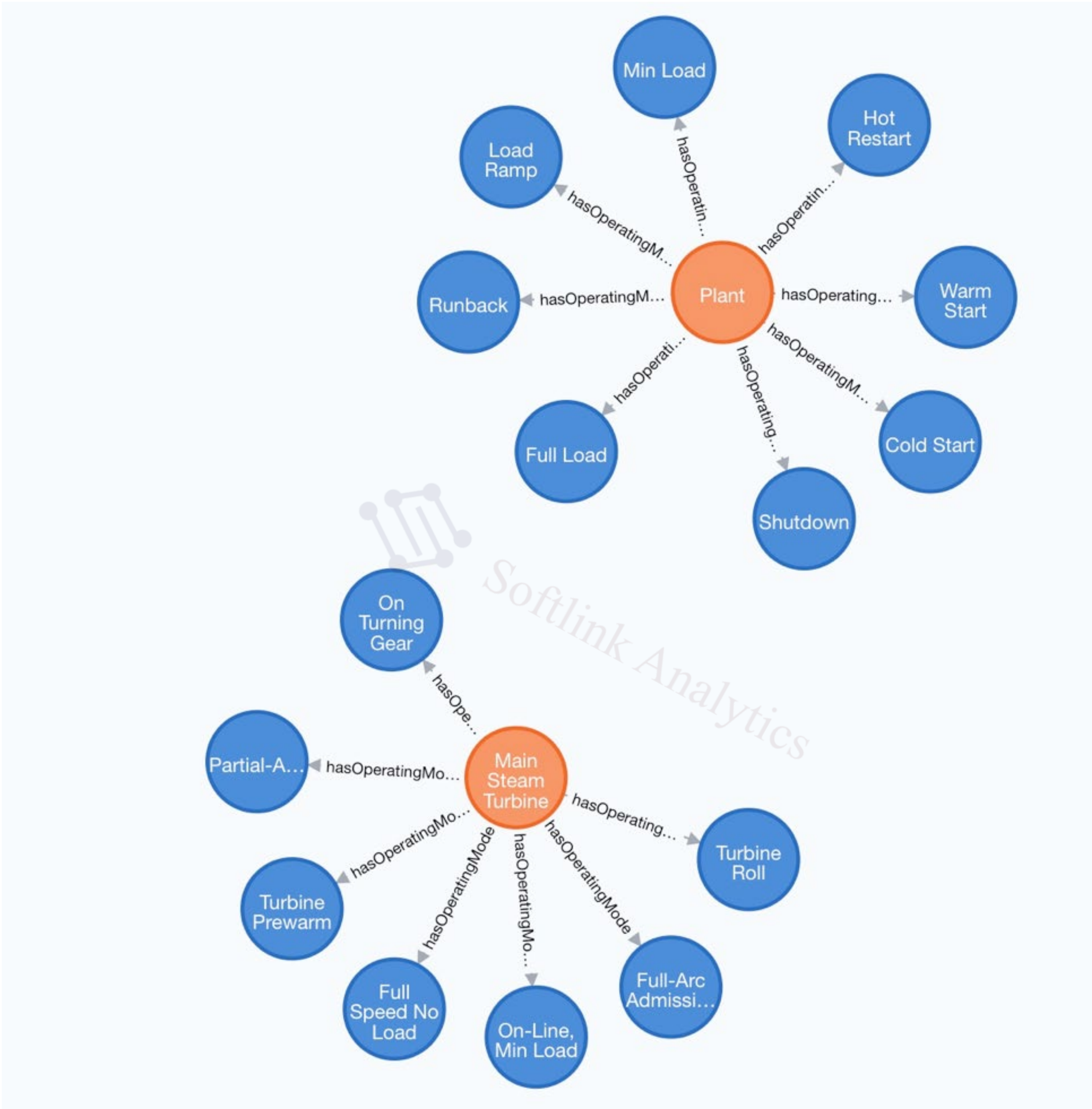
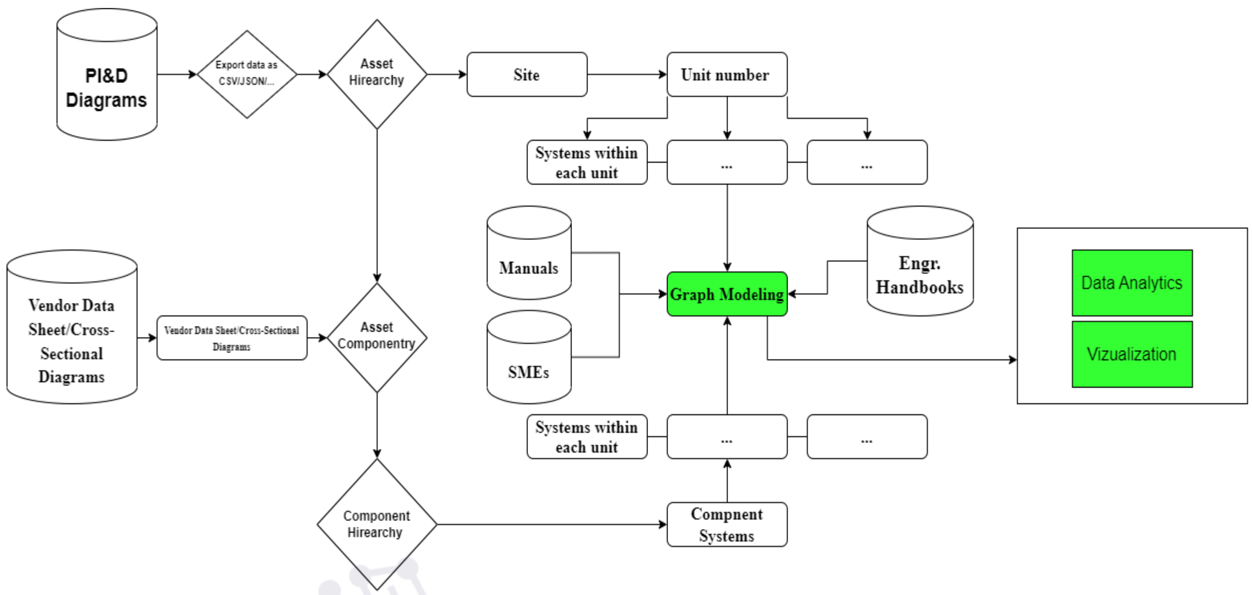


Figure 7. Representative Plant and Steam Turbine Operating Modes

Digital Twin Creation Schematic Flowchart:



This process adopted by **Softlink Analytics** caters to the following list of usecases for the manufacturing sector:

- Failure Isolations in complex process networks
- Pattern Identification and assimilation in real time at scale.
- Process Optimization using Graph Clustering algorithms
- All Stakeholders of Manufacturing can acquire knowledge seamlessly, reducing overheads and knowledge transfer time significantly.
- Nth Degree impact analysis through graph traversal in real time.
- Componentry instrumentation and Process standardization can be achieved effectively.

References

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