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Study on an ISO 15926 based data modeling methodology for nuclear power industry

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1. Introduction

ISO15926 "Integration of life-cycle data for process plants including oil and gas production facilities" is an international standard for the representation of process plant life-cycle information. The scope is therefore data integration and data to support the whole life of a plant. This representation is specified by a generic, conceptual Data Model (DM) that is independent of any particular application, but that is able to record data from the applications used in plant design, fabrication and operation. The data model is designed to be used in conjunction with Reference Data (RD): standard instances of the DM that represent information common to a number of users, plants, or both.

This paper introduces a high level description of the structure of ISO 15926 and how this can be adapted to the nuclear power plant industry in particular.

2. ISO 15926 and Reference Data Library

2.1 General introduction of ISO 15926

ISO 15926 based integration of plant lifecycle information implies the capability to hold data used by any application, therefore the generic model which is independent of use of the data, and the life-cycle aspect implies independence of phase. Another use of ISO 15926 is to use its generic Reference Data to add precision to exchange of data between existing systems. Importing data to an ISO 15926 data store can be seen as a specialized case of such data exchange, and is also the case that forms the basis for the data exchange specification. A product catalogue based on ISO 15926 also needs to define a standardized export format that can be read by other applications. Common to the two use-cases, exchange and integration, is to define standard "formats" for import/export of ISO 15926 data, and exchange of data to support this. These "formats" are known as "Templates", and a brief description of this concept will be defined. As data integration is one of the possible uses of the templates, all templates will be designed so that they meet this objective.

2.2 Reference data library of ISO 15926

The purpose of the Reference Data Library (RDL) is to provide precise meaning to project data. Project data can be data related to individual objects in a plant, or the types of Commercially Off The Shelf (COTS) standard types of equipment that is used to construct the plant. The so called Nuclear Power Plant (NPP) RDL would cover both.

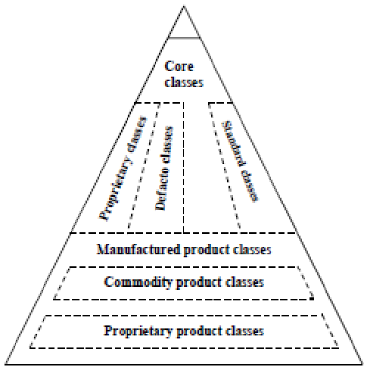

Fig. 1. Structure of the RDL[1]

Core class is a commonly used subdivision corresponding to terms used in common language. The conditions for membership are often not formally defined. (e.g. Pipe, floor, pump, and light bulb are all core classes)

Standard class is a class whose specification for membership is owned or controlled by standardization body and is publicly available. Standard classes result from the work of national, international, or industry standardization bodies and cover sizes, shapes, materials, performance, and manufacturing processes of equipment and materials. The rules for exclusion and inclusion (or conformance) are agreed by an open, consensus process and are made publicly available. A standard class may only constrain one particular aspect and often be insufficient to determine usage or full manufacturing specifications. (e.g. The ASME B16.9 standard constrains the dimensions and shapes of steel butt-welding pipe fittings)

Commodity product class is a manufactured product class whose members conform to open agreed standards. Commodity product classes have sufficient characterization to indicate suitability of use. They are specializations of one or more de facto classes, standard classes, or both. The resulting specification is nonproprietary as no one organization controls it. (e.g. The type of light bulb known as 60 W 230 V E27 is a commodity product class)

Manufactured product class is a class whose members are individuals produced by a manufacturing process. The members of a manufactured product class may be discrete or may be batches or continuous flows, such as process fluids. (e.g. “Phillips lightbulbs 60 W 230 V E27 is an example of a manufactured product class whose members are discrete. Subclass of commodity product classes light bulb 60 W 230 V E27)

The below are class examples of ISO 15926 RDL.

The ‘standard classes’ are specializations of ‘core classes’, e.g. the ‘standard class’ T5 APPARATUS IEC 60079-0 (http://data.posccaesar.org/rdl/RDS1084094) is a subclass of the ‘core class’ SURFACE TEMPER - ATURE RATED APPARATUS (http://data.posccaesar.org/rdl/RDS1090889).

The ‘manufactured product class’ ROSEMOUNT 3051CG5A22A1KB4I1L4M6Q4 (http://data.posccaesar.org/rdl/RDS38822373265) is a subclass of ROSEMOUNT 3051CG (http://data.posccaesar.org/rdl/RDS571392990) which is a higher level ‘manufactured product class’ and a subclass of the ‘standard class’ T5 APPARATUS IEC 60079-0 (http://data.posccaesar.org/rdl/RDS1084094) indicating its surface temperature protection level. ROSEMOUNT 3051CG is again a subclass of the ‘core class’ GAUGE PRESSURE TRANSMITTER (http://data.posccaesar.org/rdl/RDS818999).

3. RDL extension for NPP industry

3.1 Extension method

NPP RDL can be fully integrated with the existing RDL developed for process plants and Oil & Gas production facilities. The only extension that is required for the ‘core class’ level is to add classes representing equipment types and systems not used in the process plants and Oil & Gas industry. For the ‘standard class’ level will similarly have to add classes representing classes from standards not used in the process plants and Oil & Gas industry. The same also applies for the ‘Manufactured Item Classes’ level where one will similarly have to add classes representing COTS-equipment not used in the process plants and Oil & Gas industry.

In the following author has used Reactor Coolant Pump (RCP) as an example. The term Reactor Coolant Pump (RCP) can mean two things(Fig. 2).

Definition 1: A ‘functional location’ on a Process Flow Diagram (PFD) or on a Piping and Instrumentation Diagram (P&ID). This is indicating a position in a system where one wants to pump the coolant. I.e. “what”, not “how”. The classes “COOLANT PUMP” http://posccaesar.org/rdl/RDS16768899 and “MAIN COOLANT PUMP” http://posccaesar.org/rdl/RDS409519851 are intended for this purpose.

Definition 2: A “purpose built” pump to do just this, i.e. pump the coolant. This is “how” the pumping is to be achieved. The RCP’s in a NPP RDL will belong here.

For a diagram of how this is intended(Fig. 2). The dotted vertical line indicates that there are multiple classes in between.

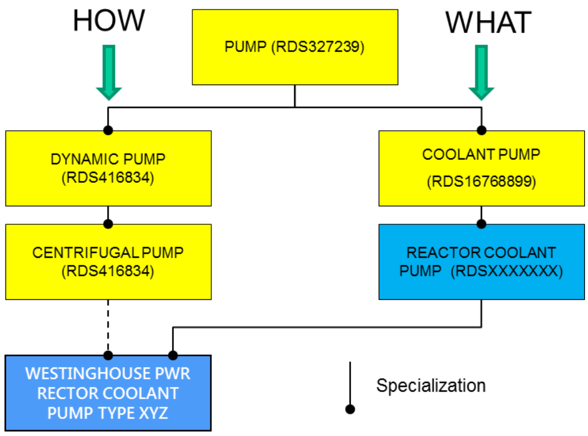

Fig. 2. Class hierarchy example

3.2RDL class extension example

From Figure 3 we can see that the pump has an impeller and a vertical shaft, so it appears that this is as a minimum a subclass of “VERTICAL SUSPENDED CENTRIFUGAL PUMP” (http://data.posccaesar.org/rdl/RDS866114), possibly a LINE SHAFT CENTRIFUGAL PUMP (http://data.posccaesar.org/rdl/RDS1128509). A more precise specialization will have to be done by a pump expert. These classes are ‘core classes’, but further inspection might lead to the discovery that this Westinghouse pump type (class) is a subclass of one of the more specialized classes, which will also have some of the API 610 standard pump configurations as subclasses. From browsing the internet it appears to be many slightly different configurations, which will have to be classes in their own rights.

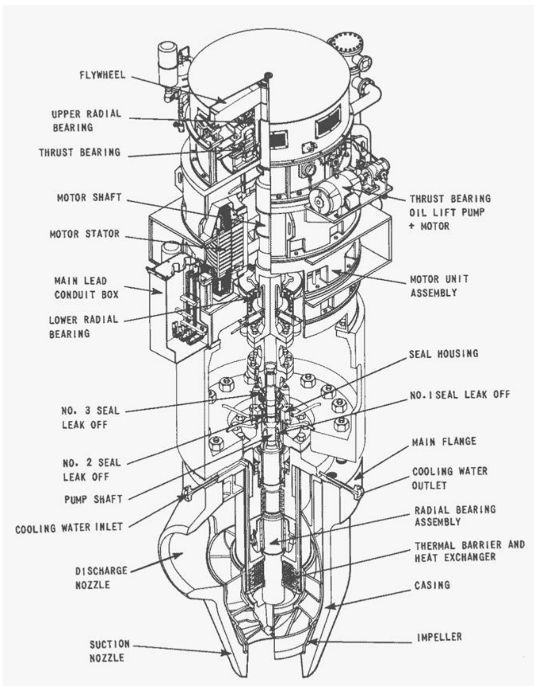

Fig. 3. Westinghouse reactor coolant pump

The main parts/features of the pump type (class) in Figure 3 are listed in the Table 1, also indicating if the class/property exists in the RDL.

Table I: Classes that will represent some main parts of a reactor coolant pump

Description	Class	URI
Impeller	PUMP IMPELLER	http://data.posccaesar.org/rdl/RDS816299
Suction nozzle	INLET NOZZLE	http://data.posccaesar.org/rdl/RDS43167562153
Discharge nozzle	DISCHARGE NOZZLE	http://data.posccaesar.org/rdl/RDS402642231
Casing	SINGLE TYPE CASING	http://data.posccaesar.org/rdl/RDS881459
Thermal barrier	No	
Heat exchanger	HEAT EXCHANGER	http://data.posccaesar.org/rdl/RDS304199
Radial bearing assembly	RADIAL BEARING BEARING ASSEMBLY	http://data.posccaesar.org/rdl/RDS6810280 http://data.posccaesar.org/rdl/RDS12956450
Cooling water inlet	No	
Cooling water outlet	No	
Pump shaft	PUMP SHAFT	http://data.posccaesar.org/rdl/RDS869714
Main flange	No	
No. 1 seal leak off	No	
No. 2 seal leak off	No	
No. 3 seal leak off	No	
Seal housing	No	
Lower radial bearing	No	
Main lead conduit box	No	
Motor unit assembly	No	
Motor stator	ELECTRICAL STATOR	http://data.posccaesar.org/rdl/RDS891449
Motor shaft		
Thrust bearing	THRUST BEARING	http://data.posccaesar.org/rdl/RDS6810235
Thrust bearing oil lift pump and motor	No	
Upper radial bearing	No	
Flywheel	FLYWHEEL	http://data.posccaesar.org/rdl/RDS13662164

All of the instances in the table above will be modelled as parts of a REACTOR COOLANT PUMP, mandatory or optional, based on the particular subclass. These are all 'core classes' and when "related in the appropriate way" becomes a product model for a particular class of products. For the WESTINGHOUSE PWR RECTOR COOLANT PUMP TYPE XYZ user will just have to add Westinghouse classes corresponding to the entries in the table, e.g. which type of SINGLE TYPE CASING is used for a particular model/variant.

3.3ISO 15926 modelling of property

The term "property" is used with many meanings in the industry, and is often also known as "characteristics" or "attributes". ISO 80000-01[2] defines the following categories of "quantities", "units" and "properties":

- International System of Quantities (ISQ)
- International System of Units (SI)
- Ordinal quantity
- Nominal property

These are dealt with by separate model entities, except for references that will have to be handled separately. One of the design criteria for ISO 15926 is that "properties/attributes/characteristics become relationships". A relationship needs to have domain and range defined. The question then becomes "which properties/attributes/characteristics becomes which type of relationship", and "what is the domain and range". This can normally be determined from the "values" of the properties in the source documentation.

" Quantities" defined in ISO 80000 are represented as instances of 'single_property_dimension' as shown in Figure 3, and with the Units of Measure as instances of 'scale'. The same applies to "quantities" defined by other standardization bodies e.g. Energistics. Ordinal quantities are dealt with in a similar way, while nominal properties covers many sub-categories that are dealt with by a pattern for each category. This is required to take advantage of the "inheritance" that is offered by the ISO 15926 way of representing information.

" Properties" that are "qualifications" of a quantity, e.g. OPERERATING WEIGHT (http://posccaesar.org/rdl/RDS1661800301) where "operating" represents the "qualification" are all modelled as instances of 'class_of_indirect_property'. In the example we have domain ARTEFACT (http://posccaesar.org/rdl/RDS422594) and range WEIGHT RANGE (http://posccaesar.org/rdl/RDS1468222121) according to Figure 4.

The 963 instances of 'class_of_indirect_property' in the properties spreadsheet of ISO/TS 15926-4 (see http://standards.iso.org/iso/15926/-4) does not have domain and range specified, and are as such not valid instances of ISO 15926-2. The majority of the properties that should have been represented as 'class_of_indirect_property' in the RDL have been represented as 'single_property_dimension' due to lack of domain and range data from the source data.

It follows from the diagram that the domain and range taxonomies have to be put in place as part of this update in order to have a proper "inheritance" of properties. For OPERERATING WEIGHT as modelled above it follows that we have seen this as only being relevant for ARTEFACT and its subclasses, and that the range is WEIGHT RANGE as this is often stated with a tolerance. It can also be seen that there are a set of more specialized subclasses of OPERERATING WEIGHT based on how it is determined, adding precision to user's data.

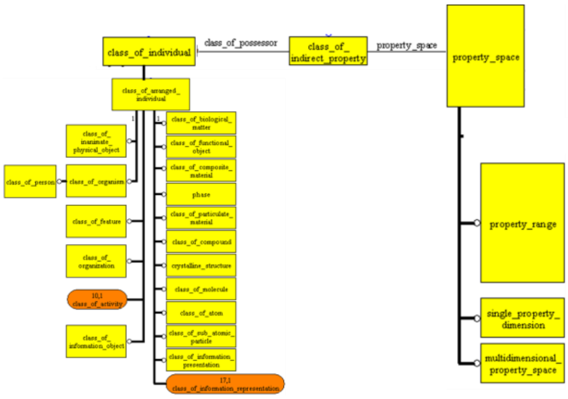

Fig. 4. Express-G diagram of ISO 15926 data model for class of property

HEAT EXCHANGER (http://data.posccaesar.org/rdl/RDS304199) is an example of where we have started to add properties to their appropriate product class, but it is obvious from the list of properties that this will have to be updated as EARTHQUAKE LOAD belongs much higher in the taxonomy.

FLUID CONTAINER (http://data.posccaesar.org/rdl/RDS898290191) is an example of a high level class that is starting to have a decent set of properties assigned (even if some will have to be updated). These properties will then be inherited down to SINGLE TYPE CASING (http://data.posccaesar.org/rdl/RDS881459) which is relevant in the actual case.

When the ontology all properties, both those that are directly related to the domain class in focus, and those that are inherited from its superclasses will appear in the section for "indirect properties". It will also be visible if the property is optional and/or mandatory. This can then be displayed in a tabular form so that the appropriate properties can be flagged as relevant or not in the actual case.

3. Conclusions

This paper introduces ISO 15926 methodology and how to extend the existing RDL for nuclear power industry. As the ISO 15926 representation is independent of applications, interfaces to existing or future applications have to be developed. Such interfaces are provided by Templates that takes input from external sources and "lifts" it into an ISO 15926 repository, and/or "lowers" the data into other applications. This is a similar process to the process defined by W3C. Data exchange can be done using e.g. XML messages, but the modelling is independent of technology used for the exchange. ISO 15926 based RDL is useful for NPP class standardization and lifecycle data integration.

Acknowledgement

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