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Development of Semantic Web-based Knowledge Management for Nuclear Reactor (KMNuR) Portal

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ABSTRACT

A web portal for nuclear reactor domain has been developed and is christened as Knowledge Management for Nuclear Reactor (KMNuR). This article reports about the development of the portal for fast breeder test reactor (FBTR). The methodology adopted for the development of the portal is described. Formats like RDF (Resource Description Framework), OWL (Web Ontology Language), Graphs, UML (Unified Modeling Language) were used to represent nuclear reactor knowledge. The ontology for the portal is created using Protégé. Central data processing system of the FBTR is taken as an example for giving the details of the functionality of KMNuR portal and its knowledge representation.

Keywords: Ontology, RDF, OWL, UML, OWLGrEd, semantic web, knowledge management portal

1. INTRODUCTION

The semantic web enables intelligent search by offering greater functionality and interoperability for automatic knowledge extraction by machines[1]. Ontology is used to define a set of assertions and relations among the objects for specifying the concepts involved[2]. A survey is carried out to study the state-of-the-art of development of ontology in various domains and is based on the available research papers in refereed journals, reports in the respective domains, scholarly articles, etc. The tools required for the development, ontology language used for representation, programming language, database, reasoner, etc., employed in the various domains were surveyed[3]. The survey revealed that in domains like power plants and atomic energy, the ontology development is rather limited, which leds to taking up the development of the ontology for nuclear reactor domain. As part of the programme of development of semantic web-based knowledge management, portal in the nuclear reactor domain is being pursued for enabling the scientists and engineers effectively create, share and reuse ontology. The requisite ontology for the Fast Breeder Test Reactor (FBTR) at Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, is being developed by collecting the knowledge from the nuclear domain experts.

Systematic preservation of knowledge plays key role to improve the productivity and performance of any organisation. One of the prime objectives of any knowledge management portal is to capture the knowledge existing in a particular domain and preserve it for the future. It involves the creation of knowledge-base by collecting all the requisite knowledge available in a given domain. To achieve this, efforts are required to employ a suitable mechanism for obtaining and integrating the collective knowledge in the domain. In a domain like operation of a power plant, the knowledge is obtained from diverse areas like design, operational, maintenance, safety, quality assurance, etc. Preserving the same would result in saving time and effort in troubleshooting the problems and carry out apt maintenance of the plant. The content of the portal needs to be organised, in such a way that the adopted ontology would be known to the users to make an effective usage of the same. A semantic web-based knowledge representation is designed to capture the knowledge existing in nuclear reactor domain and preserve it for the future. As with the passage of time, the people involved in the design and commissioning of nuclear systems would be replaced by new manpower. The other focus for the development of the portal is to make the skill/expertise available to the new workforce.

Considering the life cycle of any nuclear plant, the knowledge-base creation not only helps to sustain the existing nuclear reactors but also in the design, construction, commissioning and operation of the reactors likely to be built in the future. A knowledge management portal has been developed for FBTR and christened as KMNuR (Knowledge Management for Nuclear Reactor) portal. Creating KMNuR portal

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would cater to making the accumulated knowledge available as reference to operational personal and also to the new work force.

The portal has been developed using Java and the MySQL database at the backend and employs tools like Protégé IDE (Integrated Development Environment) for ontology development[4] and OWLGrEd (Ontology Editor for Compact UML-style OWL Graphic Notation) for UML generation. The objective of the portal is to develop an ontology that would enable effective usage of the contents being made available by the user community. The obtained knowledge about the nuclear reactor is stored in formats like RDF (Resource Description Framework), OWL (Web Ontology Language), graphs, UML (Unified Modeling Language). RDF structure represents standard syntax for describing the meaning of data and OWL represents the standard to describe the relationship between the data[5].

2. KNOWLEDGE MANAGEMENT PORTALS IN NUCLEAR RELATED DOMAIN

International Atomic Energy Agency (IAEA) provides guidelines and framework[6-7] for designing the portal for knowledge management systems, which cover plant policies, its strategy, operation, safety, management and performance information, etc. IAEA aims to identify knowledge domains like major nuclear reactors, radiation effects, waste and transport safety and then to capture and share the critical knowledge in each domain. This would lead to preserving the institutional memory and stimulate new knowledge for current as well as future generation of scientists, engineers and technicians. Emergency response, country specific information, nuclear installation, thematic knowledge, etc., are also covered[8]. IAEA also conducts various technical meetings and conferences to collect knowledge from various nuclear power plants.

The Gesellschaftfür Anlagenund Reaktorsicherheit (GRS), Germany, carries out research in the areas of reactor safety, radioactive waste management, radiation and environmental protection. An intranet portal has been set up by GRS to prevent the knowledge loss and the ontoprise semantic tool was used for the ontology representation[9]. The portal developed by GRS[10] is embedded with, document management, yellow pages, announcements, data collections, support information, suggestion box, new sticker for work scope news, message boards for department and knowledge representations of skill areas, etc.

The Krško Nuclear Power Plant (Krško NPP) is a pressurised light water reactor power system of Slovenia. The intranet portal (named IntraNEK) at Krško NPP, allows the user to access various plant applications and links. In this portal, equipment details, structures, documents, human, regulatory requirements and commitments, non-conformances, failure analysis, domestic and industry operating experience and corrective actions are covered. It envisaged establishing guidance on the effective and efficient use of operating experience information to improve plant/personnel safety, plant reliability and commercial performance[11].

Kazakhstan Atomic Energy Committee has developed a portal to serve their day-to-day activities and to support working processes and to manage the documentation[12]. It also facilitates to create knowledge-base thereby providing an archive for nuclear knowledge.

NuArch project, developed at Italy Trieste School of Nuclear Knowledge Management, uses a web crawler that will identify and harvest the nuclear information resources from the internet[13]. The harvested information is automatically indexed and stored in a high-volume archive with version control and makes them accessible to the user.

KOZLODUY NPP, Bulgaria portal is developed based on FrameWork1.1 and DotNet Nuke. Plant operation, safety, system data, training and human resources, etc., are covered in the portal. In addition, online technical parameters of the nuclear power plant units are also highlighted (as referred from the IAEA technical report)[6].

National Nuclear Energy Commission (CNEN), Brazil developed a nuclear knowledge portal for licensing and controlling the nuclear activities[14]. This portal defines the knowledge tree about licensing, control, legislation, regulation, training and documentation as main classes. Fuel cycle installation, radioactive installation, nuclear waste management, administrative rules and resolutions are defined as subclasses of the knowledge tree. It also provides an opportunity to share information and knowledge in real time among the collaborators.

ANENT (Asian Network for Education in Nuclear Technology) web portal has been developed by Korean Atomic Energy Research Institute, Nuclear Training Centre, Korea. This portal is being used to share information about nuclear education and training information materials with the members of its institutions[15-16].

Japan Atomic Energy Research Institute (JAERI) constructed a knowledge management framework for nuclear energy policy. This framework covers up-to-date important intellectual assets of JAERI[17].

The knowledge management portals are developed for their respective institutes by employing semantic web. As most of these web portals are intranet-based, not many details are available in the published literature. Neither the data structure information about the portals nor the methodology adopted to implement the development of portal could be obtained.

In this work, the development of the KMNuR portal is described. KMNuR comprised of knowledge represented in different semantic formats like RDF, OWL and UML so as to enable the web crawler to share and reuse nuclear knowledge.

3. SYSTEM ARCHITECTURE OF KMNuR WEB PORTAL

The system architecture of KMNuR is represented in Fig. 1. Protégé tool is used for developing the ontology. The KMNuR web portal is a client/server architecture having user interface in the frontend and database at the backend. The frontend of the user interface developed using Java web application allows the user to get the requisite knowledge about the FBTR from MySQL database at the backend. Net Bean IDE is used for developing the Java web-based application, and Glass Fish server for publishing the web application. The knowledge pertaining to FBTR system is obtained from the data sources like journals, books, internal reports, existing data at IAEA, open archives and from nuclear experts. The data is stored in the MySQL database in formats like RDF, OWL, UML, and graph. Users can select the particular format to retrieve the knowledge about the nuclear system of their choice.

The methodology for developing components of the portal for the FBTR domain involves the following steps:

(a) Ontology is created by defining the classes, subclasses, object properties, data properties for each system by receiving the expert knowledge

(b) The created ontology is verified and validated by checking the inferred knowledge to remove any logical inconsistency. The verification is carried out by starting any one of the reasoners like Fact++, Hermit, and Pellet

(c) RDF/XML and OWL/XML rendering file options available in the Protégé tool, are utilised to generate the RDF, OWL files for the given ontology. These data are captured and stored in the database, which would aid the machine processing by allowing the crawler to crawl the web to extract the knowledge embedded in the system

(d) The graphical representation of the knowledge is created using Onto_graph and the image is saved in jpeg or gif file format. This is an add_on tool available in the Protégé

(e) OWLGrEd is another program which when executed simultaneously with Protégé tool, would enable the user to export the ontology to construct a UML diagram

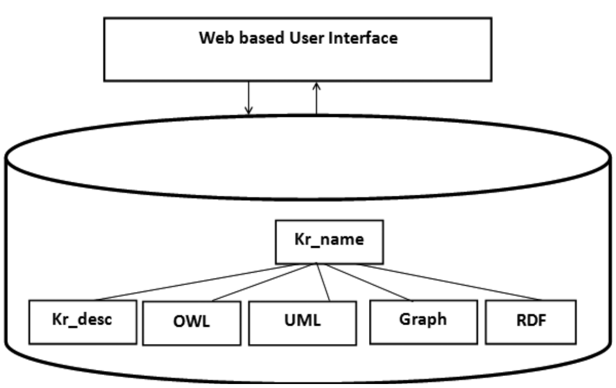

Figure 1. System architecture of knowledge management portal for nuclear reactor.

The collected knowledge and information of each system are stored in the database, for the user and agent programme to, retrieve, process and display the knowledge.

A screen shot of KMNuR portal main page is shown in Fig. 2 and is expanded and shown in Fig. 3 and Fig. 4. The left side frame of the web portal, lists out the names of the systems related to the nuclear reactor domain such as: reactor core, control rod drive mechanism, primary sodium system and the parameters such as neutron flux, gamma ray source, reactor steady state, etc. Systems and parameters of the nuclear reactor, whose knowledge is represented in the KMNuR portal, are listed out in Table 1. When the user selects a particular system it will provide information about the same on the right side frame. RDF or UML diagram or OWL buttons are made available in the portal, enabling the user to view the acquired knowledge. Since the UML images are complex in nature, zoom facility is offered to get an enlarged view.

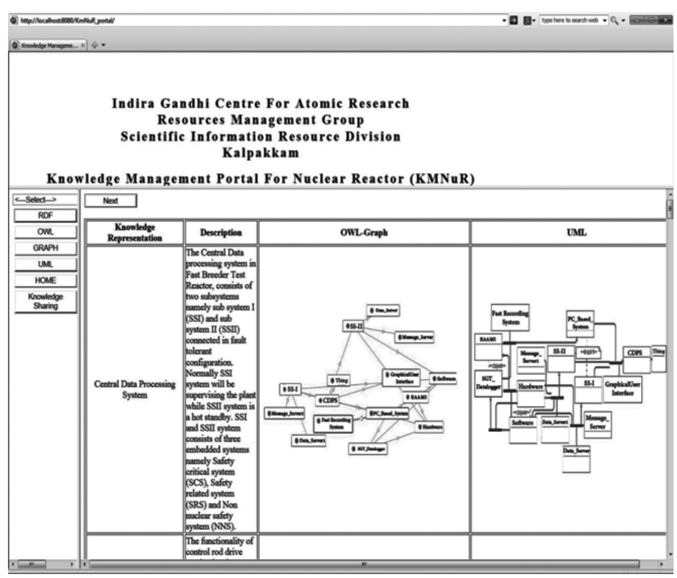

Figure 2. Knowledge management portal for nuclear reactor showing the knowledge representation of each system, its description, OWL_Graph and UML_diagram.

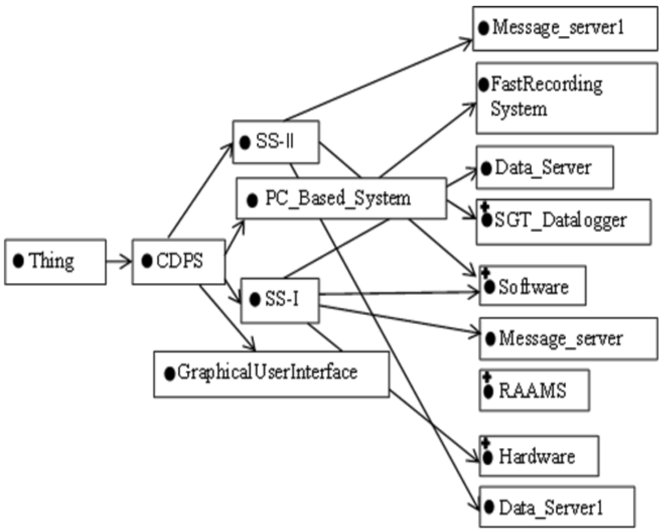

Figure 3. OWL-GRAPH enlarged image of Fig. 2 for CDPS consisting of SS-1, SS-2, message server, dataserver, fastrecording system, steamgeneratorsystem, graphical user interface, hardware, software, pc_based_system and their relationships.

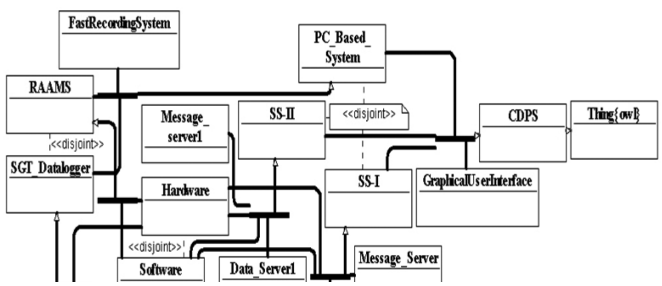

Figure 4. UML diagram enlarged image of Fig. 2 for CDPS system.

The overall aim of the KMNuR portal is to integrate and infer the semantic knowledge needed by the users in performing the nuclear reactor domain tasks. As an example, Central Data Processing System (CDPS) is taken for the analysis to discuss the representation of the KMNuR portal. CDPS in FBTR consists of two subsystems namely Sub System I (SSI) and Sub System II (SSII), and connected in fault tolerant configuration. SSI and SSII systems consist of three embedded systems, namely, safety critical system (SCS), safety related system (SRS), and non-nuclear safety system (NNS). It also consists of radiation and air monitoring system (RAAMS) for the processing of data related to radiation, data server for acquiring nuclear data from the embedded system, message server system for retrieving fault messages from embedded system, fast recording system for recording analysis of safety parameters, etc. Figure 3 depicts the enlarged image of the CDPS in OWL sgraph format. The enlarged image of the CDPS in UML diagram format is shown in Fig. 4. For further enunciating the details, UML diagram for neutron energy is shown in Fig. 5. It can be seen that

Table 1. Systems and parameters of nuclear reactor represented in the KMNuR portal

S. No.	Name of the system
1.	Central Data Processing System
2.	Control Rod Drive Mechanism
3.	Electrical System
4.	Emergency Core Cooling
5.	FBTR Offsite Power Supply
6.	Flux
7.	Fuel Fabrication Oxide to Carbide
8.	Fuel Fabrication Oxide to Metal
9.	Gamma Interaction with Materials
10.	Gamma Ray Source
11.	LOR Parameter
12.	Metal Fuel Fabrication
13.	Mettalic Fuel
14.	Neutronic_Channels
15.	Ne_Interaction with Materials
16.	Net Reactivity
17.	Neutron Energy
18.	Neutron Fission
19.	Neutronic Instrumentation
20.	Nuclear_Reaction
21.	Nuclear Data
22.	Nuclear Design
23.	Nuclear Design Test
24.	Nuclear Power Plant
25.	Nuclear Reactor FBTR
26.	Permissive circuits
27.	Primary Sodium Circuit
28.	Radiation
29.	Reactivity Feedback
30.	Reactor Accident
31.	Reactor Accidental Condition
32.	Reactor Assembly
33.	Reactor Core
34.	Reactor Dynamics
35.	Reactor FueL Handling
36.	Reactor Shielding
37.	Reactor Shutdown Mechanism
38.	Reactor Start Up Condition
39.	Reactor State
40.	Reactor Steady State
41.	Reactor Transients state
42.	Safety Analysis
43.	Scram Parameter
44.	Secondary Sodium System
45.	Shielding Materials

46.	Shield within Reactor
47.	Special_Transport_Equation
48.	Spent_Fuel
49.	Steam Generator
50.	Steam Water
51.	Transport Equation

the details like, the class, subclass, the relationship between them and their instances, are given.

3.1 Database Structure of KMNuR

Database structure of KMNuR (Table 2) consists of fields like: Unique identification number (Id_no), name of the systems (Kr_name), its description (Kr_desc), OWL-Graph, Rdf_desc, Owl_desc and UML diagram. The details of main and auxiliary systems of the FBTR are inputted and loaded in to the database.

3.2 Representing RDF in KMNuR Portal

RDF is a metadata, defined in the W3C (world wide web consortium) family and is used for illustrating the relationships between the various object resources[18]. It is a URI (Uniform Resource Identifier) based syntax data representation which allows a secure and reliable mechanism for metadata exchange between the web applications[19]. RDF files for each of the system are generated using Protégé and stored in the database. When a particular system in the nuclear domain is selected from the list, the corresponding matching RDF information is displayed in the main window. For example, when CDPS is selected in RDF format, it lists out the classes and their relationship.

Table 2. Structure of KMNuR table in MySQL database to store the system information, image of OWL graph, imageof UML, its description, RDF and OWL description

Field	Type	Key
Id_no	integer(10)	Primary Key
Kr_name	varchar(30)	-
Owl_graph	Longblob	-
Uml	longblob	-
Kr_desc	varchar(1000)	-
Rdf_desc	varchar(2000)	-
Owl_desc	varchar(2000)	-

3.3 Representing OWL in KMNuR

The web ontology language (OWL) is an extension of RDF and RDF Schema (RDF-S). It facilitates greater machine interpretability of the web content than that supported by XML, RDF and RDF-S, by providing additional vocabulary along with formal semantics. It describes properties like: disjointedness, cardinality, equality, symmetry, transitivity, functional, inverse and enumerated relations between the classes. Using the

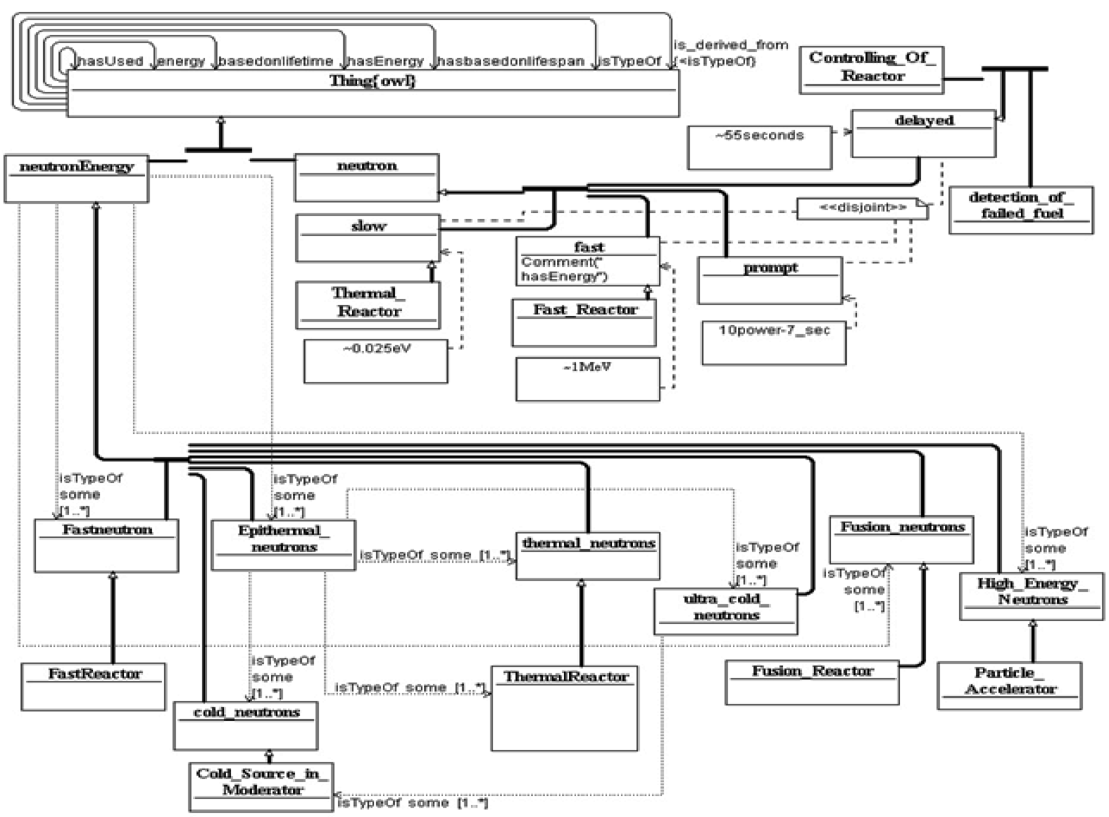

Figure 5. UML diagram of neutron energy.

OWL language, all the components like concepts, instances, properties (or relations) and axioms of ontology are created[20]. OWL Lite, OWL DL (Description Language) and OWL Full, are the three different versions of the OWL sub languages[21] and aims to bring the reasoning power of description logic to the semantic web. For the CDPS system, by clicking the OWL button in the KMNuR portal, the corresponding OWL file for the CDPS system is listed out.

3.4 Representing OWL-GRAPH in KMNuR

Properties and relationships of the nuclear knowledge are viewed in graphical representation by using the Onto_graph plug-in available in Protégé. The same can be stored in the graphical formats like jpeg, gif, emf, bmp, etc. In the case KMNuR database OWL_GRAPH in jpg file formatis stored.

3.5 Representing OWL_UML in KMNuR

UML is a general-purpose modelling language used to capture the information about different views of systems, like static structure and dynamic behaviour. UML and OWL have identical characteristics for defining classes, associations, properties, packages, types, generalisation and instances, etc[22]. OWLGrEd is UML style-based graphical notation editor for OWL. Each individual tool of OWLGrEd is created through a specially designed tool, Transformation Driven Architecture (TDA), for storing the information like types, styles, constraints and relationships among the elements[23]. Both the Protégé and TDA tools need to be executed in parallel, to convert the OWL to UML. In the Protégé tool, 'EXPORT to TDA' menu option is available to convert OWL to UML. When the option is used, the OWL file is opened in TDA program automatically. Similarly, to export the ontology from OWLGrEd to Protégé, user has to right-click on the UML diagram and select 'Export to Protégé' option. In the KMNuR portal, rollover to zoom_in facility is also available to view the enlarged size of the UML image for a particular system.

4. KNOWLEDGE SHARING IN KMNuR

In the KMNuR web portal, pressing the 'Knowledge Sharing' icon allows the users to submit the new knowledge to the system. Several aspects of knowledge available in the FBTR system are collected by interviewing the domain experts. The accumulated information is compiled and converted to RDF, OWL formats. When the information about the knowledge created is available in the machine readable format, details like: name of the submitting knowledge, contributing authors are filled in. Once the relevant data is entered, it is submitted to the database for approval by pressing the 'Submit the Knowledge' button. The data is stored in the database and needs approval of the administrator for getting added to the web portal. The knowledge database is shown in the Table 3. By pressing the 'view pending knowledge-base', the pending knowledge can be viewed.

Table 3. Database structure of knowledge-base in MySQL database

Field	Type
Km_name	varchar(30)
Km_authors	varchar(100)
Km_desc	varchar(2000)
Km_RDF	varchar(2000)
Km_OWL	varchar(2000)
Km_UML	varchar(2000)
Approval_Status	char

At the development stage the authors are playing a dual role of accumulating related information from the nuclear reactor domain experts and converting them and storing them in formats like RDF, OWL, Graphs and UML. Once the portal is deployed in public domain, initially it is being planned on the intranet of the organisation, it is envisaged that the domain experts provide the information relating to the nuclear reactor and an administrator would facilitate making it available in the machine readable format and uploading in to the portal. As part of further development, efforts would be put in for developing appropriate tools for automating the process of converting accumulated knowledge from the domain experts into machine readable format.

When user inputs knowledge, one of the issues to be addressed is the need for checking for similarity with the existing knowledge. The ontology loaded by the user is to be compared with existing collection of knowledge to avoid duplicate entry in to the portal. After initially calculating the matching the approval_status field in the knowledge database is updated. To aid the process of checking, a Quick Mapping Evaluator (QME) program was developed for ontology mapping[24]. QME allows the user to select the required ontology alignment algorithm for extracting the shared knowledge. An ontology matching algorithm[25], that aids the agent program to filter and collect the knowledge for the search, reuse, share thereby giving relevant answers to the user query has been used in the development of the portal. The application of the ontology matching algorithm is demonstrated by taking two examples and details are briefly described below. The matrix rank-based algorithm will optimise the search time and retrieve the relevant knowledge and aid in avoiding addition of duplicate, redundant knowledge and same knowledge from different sources.

Case 1: Ontologies developed for (i) steam generator detectors and (ii) steam generator protection systems, are shown in Fig. 6 and Fig. 7 respectively. Using matching algorithm, these inputs were processed

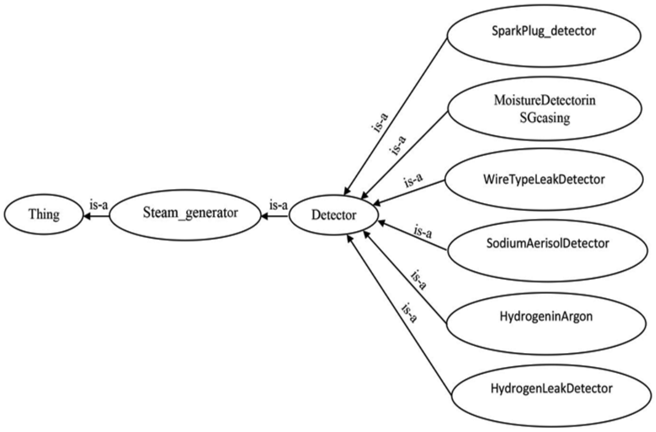

Figure 6. Ontology of steam generator (SG) detector systems.

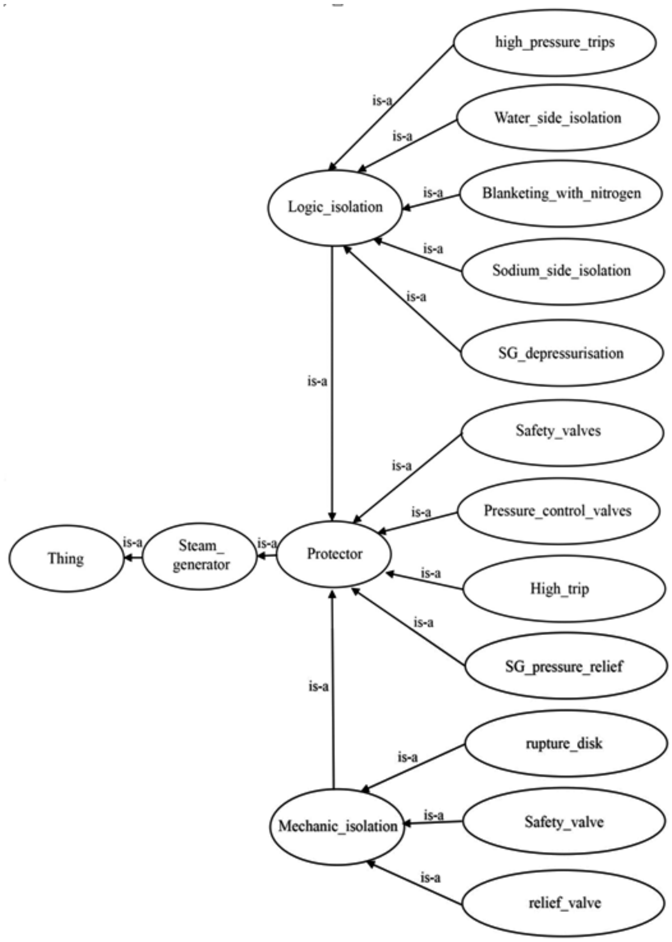

Figure 7. Ontology of steam generator protection systems.

	B1	B2	....	B16
A1	1	0	....	0
A2	0	0	....	0
A8	0	0	....	0

Figure 8. Resultant matrix for steam generator for a case given in Fig. 6 and Fig. 7.

and an 8x16 matrix was constructed (Fig. 8). It was found that the common matching entity is the ‘steam generator’ and a value of ‘1’ is set in the matrix. In the matrix, all values are ‘0’ except in the first row and first column. When the rank of the matrix is calculated, it will yield the value of the rank to be ‘1’, indicating that there is a partial overlap existing between these two ontologies.

Case 2: The ontology developed for control rod drive mechanism is shown in Fig. 9. The ontologies for steam generator detector system (Fig. 6) and control rod drive mechanism are compared. An 8x18 matrix was constructed and all the rows and columns were found to be ‘0’ resulting in the rank of the matrix being ‘0’ (Fig. 10). This is due to the fact that the ontology of the control rod related information and steam generator system are not directly connected. Hence, it is concluded that these two ontologies are unique dealing with distinct information.

The KMNuR is deployed presently in the intranet to address issues related to nuclear KM of FBTR. The initiative to develop the portal is an attempt to integrate the existing information bases about FBTR in an easily accessible form. Feedback and inputs from the domain experts will further enhance and enrich the available knowledge of KMNuR to maintain the required quality. Finally the portal would be deployed across the www to share the knowledge relating to fast breeder reactors, enabling thereuse, share and process the nuclear knowledge.

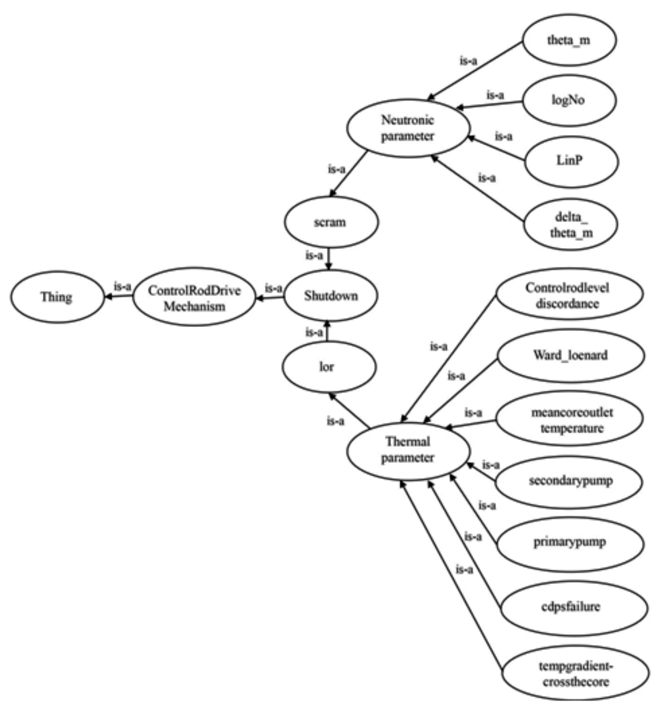

Figure 9. Ontology of control rod drive mechanism (lor – lowering of control rod, scram – safety control rod activation mechanism).

	B_1	B_2	……….	B_{18}
A_1	0	0	…………	0
A_2	0	0	…………	0
A_8	0	0	…………	0

Figure 10. Resultant matrix for control rod drive mechanism for a case given in Fig. 6 and Fig. 8.

5. SUMMARY

The need for knowledge management portals and portals developed by other countries in respect of nuclear power plants were discussed. Details of the development of a semantic web portal for nuclear reactor domain, christened as KMNuR, were described. The system architecture of the developed portal has been described. A client/serverarchitecturehas been adopted for the development of the web portal. The features of the portal embedded with various format like RDF, OWL_Graph and the structure of database employed for storing the knowledge of FBTR are described.

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