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A Study On Chemistry Knowledgebase For Failure Diagnosis In Nuclear Power Plants

Yuchun Li[1], Jun Tian[2], Di Wu[3], Feng Zhong[1], Hongying Zhou[2], Zhaojin Xu[1], Fan Yang[1], Haiqiang Lu[3]

[1]School of Chemistry &Biological Engineering,
Changsha University of Science & Technology,
Changsha 410114, China; [2] Research Institute of Nuclear Power Operation,
Wuhan 430223, China;
[3]Daya Bay Nuclear Power Operation and Management Co.Ltd.,
Shenzhen 518124, China

Abstract

A knowledgebase which aided failure diagnosis in nuclear power plants was studied in this paper. Expression methods were studied for chemistry indicator knowledge through knowledge structure analysis. Three kinds of knowledgebase were explored and analyzed. Through discussion and evaluation of diagnosis process, the knowledgebase proved to be effective for diagnosis work of failure analysis in unclear power plants.

Keywords: Chemistry indicator; Knowledge expression; Knowledgebase pattern

1. Introduction

With development of monitoring and supervision level in nuclear power plants, it is necessary to explore intelligent system such as diagnosis, analysis of chemistry indicator. Chemistry indicator knowledgebase cannot only provide useful diagnosis

[1] *Yuchun Li, (1972-), male, PhD, Professor, Email: iamlyc@263.net,*
Mobile: +86-15386400818, Fax: +86-731-85258733

information, but also present a platform for case set, major key set and judgment set etc.

Knowledgebase is a set of knowledge and consists of concepts, facts and rules [1]. The former two items can be related with elements in relation database. It is also called ‘data of knowledgebase’; the latter can be classified as deductive rule for logical derivation and complete restraint rule for certifying of the facts [2,3].

Knowledgebase was originated from a database system. Database system was used for dealing with ‘real’ data. When the database was developed to the deductive database, especially database based on logic, knowledgebase was formed for storing and managing knowledge [4].

2. Chemistry indicators

Chemistry indicators explored in this study were mainly from blowdown system of steam generator (SG) in nuclear power plants. Such system can be indicated as ‘APG’ system in plants. There are three functions for APG system: extracting blowdown water from SG , monitoring chemistry indicator of blowdown water and purification for blowdown water for recovery. Table 1 shows the control standard for chemistry indicator of the APG system in nuclear power plants.

For example, APG-λ^+ indicated cation conductivity of APG blowdown water, which can show the quantity of conductive species. In chemistry indicator knowledge [5], some major information can be resolved as followed:

Concepts: APG-λ^+ -- indication of quantity of conductive species

Facts: APG-λ^+ can be determined by conductivity analyzer after through ion exchange resin of the water sample.

Table 1 Chemistry indicator in APG system

Indicator	Unit	Limit	Monitor frequency
λ^+ (25℃)	μS/cm	< 1.5	continuous
Na^+	μg/kg	< 3	continuous
pH (25℃)		9.4~9.7	continuous
Ammonia	mg/kg	determined by pH	1/week
Cl^-	μg/kg	< 2	1/week
SO_4^{2-}	μg/kg	< 2	1/week

Rules: If APG-λ^+ is larger than 1.5μS/cm, then SG water may be contaminated. Because change of APG-λ^+ value indicates obvious dissolved electrolyte in solution, i.e., SG water, contamination happened in this condition.

If above information were expressed in 'knowledgebase language', then knowledge of APG-λ^+ can be listed as followed:

$C_{APG\text{-}\lambda+}$ = [quantity, conductive, species] = [c_1, c_2, c_3]

$F_{APG\text{-}\lambda+}$ = [determination, analyzer, after, ion exchange, resin, water sample] =[f_1, f_2, f_3,f_4, f_5, f_6]

$R_{APG\text{-}\lambda+}$ = [larger than, 1.5, μS/cm, species, SG,contaminate] = [r_1, r_2, r_3, r_4, r_5]

3. Three methods for chemistry indicator expression

3.1 Knowledge points

There were three kinds of knowledge types, which included knowledge point, knowledge piece and knowledge case. Knowledge point meant statement expression; if K1 was referred to knowledge point, its mathematical expression can be listed as followed:

$$K1 = \{s_0,s_1,s_2,s_3,...,s_n\} \tag{1}$$

For example, APG - Na can indicate free hydroxide and contamination of blowdown water in SG; APG - Na was generally controlled under 10μg/kg, which can decrease the possibility of caustic stress corrosion of transfer tube of SG as reasonable as possible. In the above statement, s_0 can indicate 'APG - Na',s_1 can indicate 'free hydroxide and contamination', s_2 'blowdown water', s_3 'SG', etc.. The knowledge 'K1' of APG - Na can be transformed to {s0,s1,s2,s3,..., sn}, and such knowledge must be identified and recognized by computer as programmed.

3.2 Knowledge pieces

Knowledge piece indicated knowledge set based on horizontal and vertical direction; if K2 was referred to knowledge piece, its mathematical expression can be shown in Fig.1(a).

$$K2 = \begin{pmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ & \cdots & & \\ s_{m1} & s_{m2} & \cdots & s_{mn} \end{pmatrix}$$

(a)

$$K2_{APG\text{-}Na} = \begin{pmatrix} \text{Reason1} & \text{Damage1} & \text{Action1} \\ \text{Reason2} & \text{Damage2} & \text{Action2} \\ \text{Reason3} & \text{Damage3} & \text{Action3} \\ \cdots & \cdots & \cdots \\ \text{Reason}_j & \text{Damage}_j & \text{Action}_j \end{pmatrix}$$

(b)

Fig.1 Schematic model of knowledge piece

For example, as for APG - Na, if APG - Na was out of control limit, there would be warning in computer monitoring system. Diagnosis would be initiated immediately and concrete reason would be diagnosed. K2 was a knowledge set of all reason, damage, and action item. However, K2 can only provide possible reasons, and not concrete reason; and the true answer must exist in some place in K2 set. In combination with diagnosis, concrete reason can be finally found in $K2_{APG\text{-}Na}$ matrix, such as the region marked with the red line in Fig.1(b).

3.3 Knowledge cases

Knowledge case meant the case process and its all related knowledge; if K3 was referred to knowledge case, its mathematical expression can be shown in Fig.2. It can be seen that concrete reason, damage and action knowledge of case must exist in matrix 'K3-A', and case process must exist in matrix 'K3-B'. So, K3 can be expressed as knowledge for the case of field in nuclear power plants. In Fig.2, the case related to APG - Na was obviously a complex matrix with dimension of j×i.

$$K3_{APG\text{-}Na} = \text{K3-A} \cdot \text{K3-B} = \begin{pmatrix} \text{Reason1} & \text{Damage1} & \text{Action1} \\ \text{Reason2} & \text{Damage2} & \text{Action2} \\ \text{Reason3} & \text{Damage3} & \text{Action3} \\ \cdots & \cdots & \cdots \\ \text{Reason}_j & \text{Damage}_j & \text{Action}_j \end{pmatrix} \begin{pmatrix} s_{11} & s_{12} & \cdots & s_{1i} \\ s_{21} & s_{22} & \cdots & s_{2i} \\ & \cdots & & \\ s_{31} & s_{32} & \cdots & s_{3i} \end{pmatrix}$$

Fig.2 Schematic graph of knowledge case

4. 'Field - code' pattern of chemistry knowledgebase

Field - code' can be suitable for large-scale knowledgebase and expert system. In this pattern, all useful knowledge may first be stored in a relation database with only link by special code. The 'code' was only connection between program and knowledgebase; at the same time, program, such as expert diagnosis or knowledge retrieval, must call the handle of ‘code’ and provide the corresponding function.

Table 2 showed the relation between code and chemistry indicator in APG. Here the first four numbers were symbol for chemistry indicator in the whole eight-number-code. ‘0002’ indicated ‘APG - Na’. Table 3 showed the code rule for main item knowledge in chemistry indicator knowledgebase. ‘01’~ ‘09’ were employed for different meaning from ‘Control limit’ to ‘Case’.

Table 2 Code for APG chemistry indicator

No.	Chemistry indicator	Code
1	APG-λ+	0001××××
2	APG-pH	0002××××
3	APG-Na	0003××××

Table 3 Code for main item knowledge of APG chemistry indicator

No.	Code	Indication
1	××××01××	Control limit
2	××××02××	Definition & characteristic
3	××××03××	Factors
4	××××04××	Mechanism
5	××××05××	Cause
6	××××06××	Damage
7	××××07××	Action
8	××××08××	Execution level
9	××××09××	Case

Table 4 Code and implication for APG – Na

No.	Code	Implication
1	00030100	Control limit of APG - Na
2	00030110	P≤25%Pn RP mode (Power operation mode of reactor)
3	00030111	Expectation value λ^{+}（25℃）< 1.0 μS/cm
4	00030112	Expectation value Na < 20 μg/kg
5	00030113	Level 2 of λ^{+}（25℃）Limit
6	00030114	Level 2 of Na Limit
...	...	...

Table 4 showed the detailed item knowledge in chemistry indicator (APG - Na) knowledgebase, and the last two numbers can mark meaning of each detailed item. When detailed item should be called by diagnosis program, eight-number-code would be used in programming without caring about concrete knowledge information.

Besides, if there is revision or adjustment of knowledge information, database must be opened and edited through database tools. In principle, it is impossible to revise the database directly for programming; so authorization must be granted before knowledge revision. However, it is allowed for the user to edit '××××09××' (i.e. 'case' field) information.

5. Conclusions

Three kinds of knowledgebase of chemistry indicator can store all kinds of empirical and hierarchical information for analyzing chemistry state of SG blowdown water. Knowledge point, knowledge piece and knowledge case proved to be feasible in knowledgebase construction. The proposed knowledgebase can effectively realize diagnosis work and discover fault timely when it was used in failure analysis of SG water chemistry.

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