Research and Development of BIM Operation and Maintenance System in Nuclear Power Plant

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Abstract. The BIM (Building Information Modeling) operation and maintenance management system of the nuclear power plant has been developed to cope with the security risks in the operation and maintenance process of nuclear power plant, the difficulty in querying the operation and maintenance status, the low work efficiency and the difficulty in statistical analysis of various large-scale operation and maintenance data. Practice has shown that the BIM operation and maintenance management system enhances the safety of the plant; on the other hand, the convenience of the results information query improves the professionalization, refinement and systematization of the nuclear power plant safety and operation management; in that way, the safety management efficiency of nuclear power plants will be comprehensively improved.

1. Introduction
The nuclear power plant which belongs to China Guangdong Nuclear Power Group Co., Ltd. still uses the traditional pattern in the operation and maintenance mode, which has many drawbacks and hidden dangers in the operation and maintenance process. Research and practice indicate that using BIM technology to establish a refined model of the main structural components of nuclear power plants and their ancillary facilities, platform development is based on BIM technology, combined with the characteristics of safe operation and maintenance management of nuclear power plants to finish the development of nuclear power plants based on BIM technology Dimension management platform can solve the above problems. The visualization, integration and refined management of the main structural components of the nuclear power plant and its ancillary facilities are displayed in the platform to realize the intelligent operation and maintenance of the nuclear power plant.

2. Demand analysis
The purpose of developing BIM operation and maintenance management system of nuclear power plant is to improve information transmission efficiency and safety factor and to solve large-scale operation and maintenance data analysis, which provides data support for safe operation and maintenance decision-making.

The main requirements of the BIM-based nuclear power plant operation and maintenance management platform development system are as follows:
Facing multiple roles. The platform users include system administrators, inspection personnel, technicians, and civil engineers of power plant. The corresponding permissions should be set according to the responsibilities of different roles.

Displaying informationized related functions of plant operation and maintenance safety assessment. Safety assessment work including the evaluation process, structure query and other works can be finished in system. On the other hand, Optimizing the original workflow and improve work efficiency.

Displaying the information of Nuclear power plant area. Statistical analysis and centralized display of the data generated by the operation and maintenance of the plant area.

Mobile inspection.

3. System design
After comprehensive analysis of the demand report, programmers designed a BIM operation and maintenance management system for the nuclear power plant. The management information system is composed of a system server, a web page and a mobile end. The nuclear power plant BIM operation and maintenance management system is in B/S mode, with object-oriented and .net server page (lightweight page processing) technology, based on 3DGIS+BIM platform for application function development, which users (including system administrators, inspection personnel, technicians, civil engineer of power plant etc.) log in through the browser. The background system includes application IIS 6.0 and Server 2008 R2 database. A firewall is set in the background system to ensure the stability and security of the operation of the BIM operation and maintenance management system of the nuclear power plant.

4. Business Process

4.1. Security assessment process
Establishing a complete assessment method by entering safety data for evaluation and verifying data completeness, then giving an evaluation report.

![Safety assessment flow chart](image)

Figure 1. Safety assessment flow chart.

4.2. Factory inspection process
The civil engineer of the power plant sets the standard checklist content and generates the inspection process. The inspection personnel initiates the inspection on the web page and completes the inspection on the mobile end. The technician receives the completed inspection work order for technical review, they have right to return the work order or pass it. When it passes, civil engineer the power of plant civil
engineer makes the final step confirmation. The process is finished when confirmation is passed, otherwise it will be returned and refilled.

![Inspection flow chart](image)

Figure 2. Inspection flow chart.

5. **Security evaluation core algorithm**

5.1. **Verification of fire resistance limit of fire protection zone of nuclear power plant**

Assuming that all combustibles in the fire zone are burned out, the steps to verify the fire resistance of the fire zone are shown in Figure 3 [1-2].

![Fire load calculation flow chart](image)

Figure 3. Basic steps for fire endurance verification of fire zones.

5.2. **Calculation of fire load and fire load density**

Total fire load in a fire zone is [1]:

$$CC = \sum_{i=1}^{N} M_i C_i$$

(1)

$CC$ is the total load of fire (MJ); $M_i$ is the quality (kg) of the first combustible in the fire zone. $C_i$ is the corresponding combustion heat value.
According to the formula, the fire load density in the fire zone can be calculated as[1]:

$$DCC = \frac{CC}{A} = \frac{\sum_{i=1}^{N} M_i c_i}{A}$$  \hspace{1cm} (2)

$DCC$ is the fire load density $(MJ/m^2)$; $A$ is the floor area within the fire zone; $(m^2)$; It should be noted that when the fire compartment consists of multiple compartments, $A$ is the sum of the floor areas of the respective compartments, that is $A = \sum_{k=1}^{K} A_k$, the fire load density calculated in the formula (2) is actually the average fire load density. According to this, by calculating the fire load density of each compartment, the fire load density distribution in the fire compartment can be further obtained.

5.3. Fire duration and maximum fire temperature calculation

Assuming that a fire occurs in a fire zone, all combustible materials are burned out, and that there is no active and passive fire-fighting intervention in this process, in this way, according to the fire load density curve[3], the duration of the assumed fire can first be calculated and according to the standard heating curve[3] (shown in Figure 5), the maximum ambient temperature in the fire zone during the duration of the fire is calculated.

According to the fire load density curve[1] in Figure 4, the assumed fire duration can be calculated as:

$$t = \begin{cases} 0.0481 \times DCC, & DCC \leq 1060 \\ 0.0908 \times DCC \times 45.22, & 1060 < DCC \leq 2550 \end{cases}$$  \hspace{1cm} (3)

$t$ is assumed to be the duration of the fire (min); $DCC$ is the fire load density calculated in equation (2). It should be pointed out that: ① Because the literature[1-3] does not give a specific calculation formula for the fire load density curve, the fire load density curve given in equation (3) (as shown in Figure 4) is fitted from the data given in the report[1]; ② The fire load density curve in[3] can only consider the limited fire load density value, therefore, for the fire load density value which is over the range of values shown in equation (3), this calculation method will not be considered for the time being.

According to the standard heating curve in Figure 5, the maximum ambient temperature in the fire zone can be calculated as:

$$T = 345 \times \log(8t + 1) + T_0$$  \hspace{1cm} (4)

$T$ is the highest temperature in the fire zone. $T_0$ is the initial temperature, $t$ is the fire duration calculated in the formula (3).

Based on the above calculation results, it can be seen that the actual fire duration of the entire fire zone (or the time when the fire in the fire zone breaks through the fire barrier) is:
\[ t_1 = \max[t, t_0] \] 

\( t_0 \) is the design fire endurance of the fire compartment. The fire endurance of the fire zone is considered to be satisfactory when it is assumed that the duration of the fire is less than the design fire endurance.

6. System implementation

The BIM operation and maintenance management system of the nuclear power plant includes 5 main modules and 24 sub-modules. The user logs in to the operation and maintenance management system to manage the operation and maintenance of the nuclear power plant, so that the work efficiency is greatly improved.

The statistical analysis of the massive data generated during the operation and maintenance process is also completed by the operation and maintenance management system. Users can call the statistical analysis results at any time to make a fully control about the operation and maintenance status of the plant and provide data basis for the operation and maintenance planning of the next stage.

1. Preventive management
   1. Start the inspection. 2. Inspection results review. 3. Standard checklist management. 4. Check data analysis. 5. Defect type management.
2. Safety management
   1. Material storage management. 2. Control area radiation field management. 3. Underground pipeline. 4. Personnel positioning. 5. Fire barrier management. 6. Safety work training.
3. Security assessment
   1. Settlement assessment. 2. Fire safety. 3. Anti-Typhoon defense station.
4. Data management
   1. Basic data management. 2. Build parameter configuration. 3. Model update. 4. Build a classification. 5. Fire safety configuration. 6. File management.
5. System management
   1. User management. 2. Department management. 3. Role management. 4. Log management.

7. Conclusion

1. Programmers develop a BIM operation and maintenance management system for nuclear power plant based on browser/server structure. (2) Users can log in to the BIM operation and maintenance management system of the nuclear power plant and call the information generated during the operation and maintenance process. The system accelerates the information transmission between each functional departments in order to realize the information sharing. (3) Users can log in to the BIM operation and maintenance management system of the nuclear power plant, manage the operation and maintenance inspection efficiently, and create a closed loop of inspection work in order to improve work efficiency. (4) Statistical analysis of large amounts of data generated during operation and maintenance is performed in the function management system of the operation and maintenance platform to facilitate users to query statistical analysis results and provide data support for operation and maintenance decisions. (5) Through the operation test of Daya Bay Nuclear Power Station, the operation and maintenance system effectively improved the professional, refined and systematic level of nuclear power plant safety and operation management, and comprehensively improved the safety management efficiency of nuclear power plant.

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