The Data-Centric MSO Fire Analysis and Data Visualization Based on the Cable Management System in Nuclear Power Plants

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1. Introduction

In nuclear power plants (NPPs), the cables are very important fire hazards and are core elements for power and signal transmission. The layout, installation conditions, environmental factors, etc. of cables determine the fire propagation path and damage range. Based on these results, it is crucial to determine whether safety-related equipment can operate normally in NPPs. Therefore, this paper aims to develop a system that can utilize KEPCO E&C Cable Management System (KCMS) as a basis for applying the integrated fire hazard analysis system (KFAS+, KEPCO E&C Fire Analysis System Plus) in the construction and operating NPPs. This system focuses on the real-time cable data for fire hazard analysis (FHA), safety shutdown analysis (SSA), multiple spurious operations (MSO) Analysis, and other comprehensive fire analyses, providing methods and data visualization techniques.

2. Cable management system as data infrastructure for fire analysis

The cable management system can provide the necessary information for fire hazard analysis in real-time. It includes the safety-related equipment and its alternative equipment information related to cables, making cable routing path a critical piece of information in fire analysis. Therefore, using a single cable management system for fire hazard analysis in NPPs can offer the significant synergistic effects. Fig.1 shows you the system configuration of the new fire hazard analysis system (KFAS+).

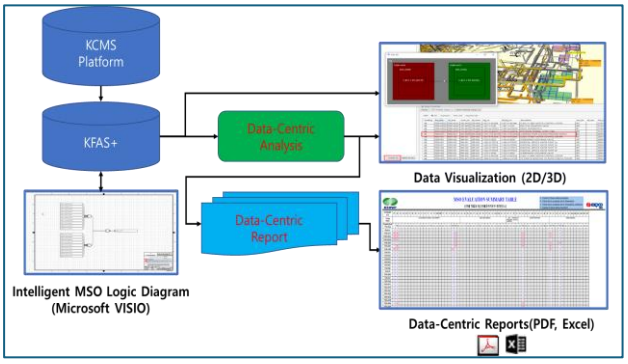

Fig. 1. System configuration of the new fire hazard analysis system(KFAS+) based on cable management system(KCMS)

The real-time cable information provision, real-time data changes of cables, and continuous real-time fire hazard assessment in NPPs significantly improve the efficiency and reliability of the analysis processes and results.

3. Fire analysis with data visualization techniques

3.1. Intelligent MSO logic diagrams

Through various data visualization methods, the analysis results are presented in a way that allows users to intuitively understand the results. Especially, intelligent MSO logic (system, equipment, and cable logics) diagrams are generated automatically from the logic statements to understand the complicated logic statements. Conversely, the complicated logic statements can be extracted automatically from the intelligent logic diagrams with smart symbols to make the MSO logic maintenance easier.

In summary, the intelligent logic diagrams provide easy understanding of the complicated logics through the visual representation, enhancing the effectiveness of MSO analysis logic maintenance. Fig.2 shows you the automatic generation of system logic statements and success paths of scenario-20 from the intelligent logic diagram using the smart logic symbols.

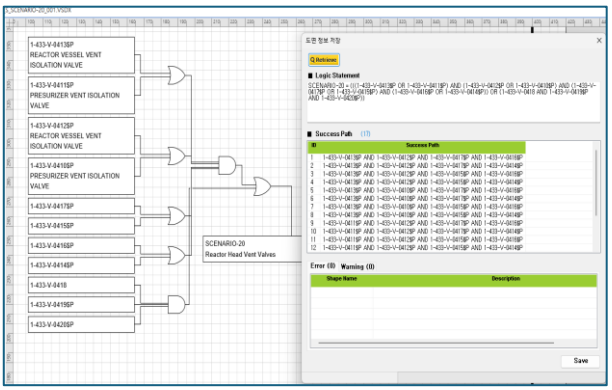

Fig. 2. Intelligent MSO logic diagram for easy understanding and maintenance of the logics by 2D visualization

3.2. Data-centric fire hazard analysis

KFAS+ is the new fire hazard analysis system which is composed of FHA, SSA, and MSO analysis in NPPs. It contains the analysis results which can be retrieved freely by using the structed query language (SQL) to validate

the analysis results. Fig.3 shows you the codes of the analysis result and their status icons in KFAS+. In Fig.4, the analysts can retrieve the results easily by using the simple SQL and understand the results intuitively.

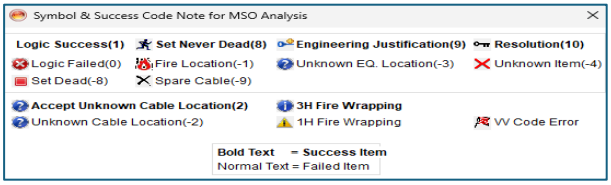

Fig. 3. The code values and icons of MSO analysis result

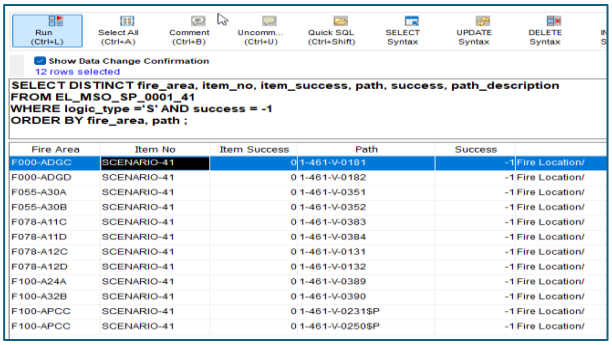

Fig. 4. The data retrieval using SQL and the codes in KFAS+

In Fig.5, the result of scenario-41 in the hierarchical data structure view makes the analysts understand the easier than normal data structure view.

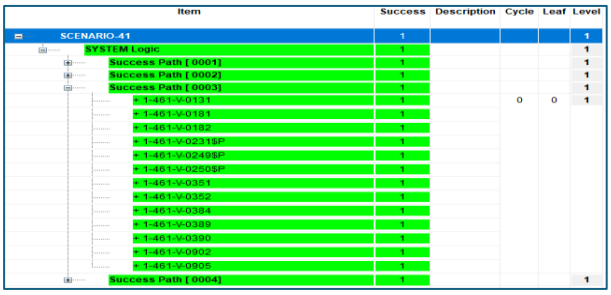

Fig. 5. The example of the analysis results of scenario-41 represented in hierarchical data structure view in KFAS+

In Fig.6, the tree view with multi-levels of MSO scenario-41 makes the analysts understand the results intuitively.

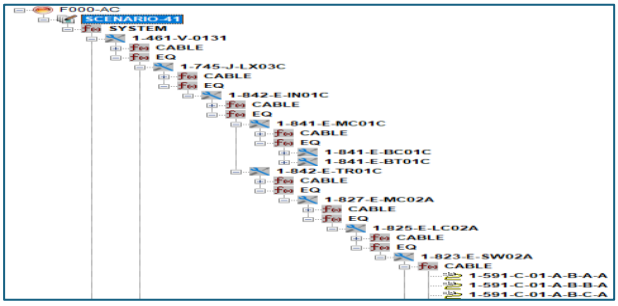

Fig. 6. MSO scenario-41 in fire area F000-AC represented in tree view with multi-levels

3.3. 3D visualization

The fire areas, fire zones, rooms in NPPs are the essential spatial information required for the fire analysis, along with cable routes and equipment location information. The 3D model of NPPs visually presents the spatial information, cable routes, equipment location along with the analysis results, offering intuitive insights and problem-solving approaches to analysts. Fig.7 shows the 3D model in which contains the safety-related equipment (in pink room) and its alternative equipment (in blue room).

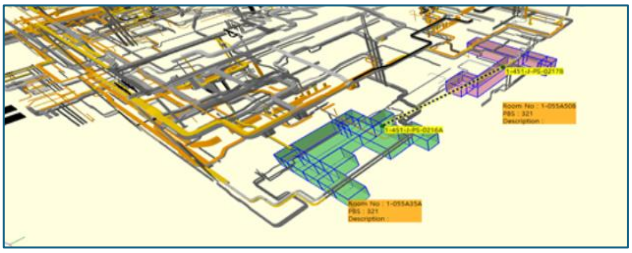

Fig. 7. The identification of the location of safety-related equipment and its alternative equipment in 3D model

3.4. Data-centric reports

The data-centric reports are generated automatically in various-formatted tables to improve productivity and intuitive understanding of the analysis results. Fig.8 shows the MSO evaluation summary table which contains all the MSO scenario results for each fire area.

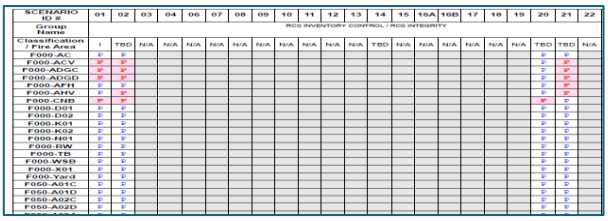

Fig. 8. The example of auto-generative MSO evaluation table

4. Conclusion

This paper presents a data-centric fire hazard analysis method based on the cable management system and the various data visualization approaches including the 3D model. By utilizing the real-time cable information from the cable management system and data visualization, it improves the reliability of analysis data, supports the intuitive analysis results interpretation, and aids decision-making. The goal of this research is to supply the core data for fire hazard analysis from the cable management system and to facilitate its application in the construction and operation NPP businesses. To implement this approach in NPPs projects, we will customize the software for the specific projects and incorporate nuclear quality assurance (NQA) measures. In addition, we have the plan to integrate 'KFAS+' with 'SAREX' (Safety Analysis and Risk Evaluation eXpert) for the probabilistic safety assessments (PSA) that employs fault tree analysis (FTA) methodology in NPPs.

REFERENCES

[1] GUIDEANCE FOR POST FIRE SAFE SHUTDOWN CIRCUIT ANALYSIS, NEI (Nuclear Energy Institute), Rev.3, pp.83-99, 2011