Decomposed Functional Behavior of Helium Purification Support System for Experimental Power Reactor (RDE) Type Using Sequence Diagram

Kussigit Santosa, Restu Maerani, Sudarno
Centre for Nuclear Reactor Technology and Safety, National Nuclear Energy Agency of Indonesia (BATAN), Kawasan Puspiptek Serpong Gd. 80 Tangerang Selatan 15310, Indonesia

Email: kussigit@batan.go.id

Abstract. Instrumentation and Control (I&C) system in Nuclear Power Plant (NPP) has a key role to maintaining the safety and control the integrated system to operate the NPP. The aim of helium purification instrumentation system in High Temperature Gas-cooled Reactor-test Module (HTR-10) reactor is to reduce chemical impurity levels in the primary helium cooling system and to eliminate the fission products of radionuclide gas. Indonesia conduct a research about Experimental Power Reactor (RDE) with HTR-10 type of reactor, then the helium purification system has an important role since this reactor will use helium in the primary cooling system. Since this HTR-10 type of reactor is had been develop by Tsinghua University in China since 1995, then for development of RDE in Indonesia should refer to the initial design of HTR-10 from China, and continuing to improve the design by decomposed the system function so that RDE design will more safety and reliable. After decomposed the new system of helium purification, the sequence diagram of helium purification will developed to review the new system function of helium purification instrumentation. Sequence diagram is system engineering methodology which can help the design engineer or system engineer to understand the system behavior by mention in to important requirement of the system. By this sequence diagram, it hope that the design engineer will clearly understand the functions and translate in to design synthesis and architectural design in the next step of development phase of helium purification I&C system.

Keywords: Helium Purification, HTR-10, Sequence Diagram, RDE

1. Introduction
In developing of experimental power reactor (RDE) in Indonesia, the National Nuclear Energy Agency of Indonesia (BATAN) should determine the standards and design criteria for the structure, system and components for the type of reactor that selected to be build and developed in Indonesia. Since Indonesia was chose to develop High Temperature Gas-cooled Reactor-test Module (HTR-10) technology, then the system engineer and design engineer who develop should refer to the design specification and design requirements for the HTR-10 type of reactor. This activities are included in the reverse engineering process, which is to understand how the initial design of HTR-10 is developed.

Initially HTR-10 is developed by Tsinghua University from 1995 and reach the first critically in 2000 [1]. The reason why BATAN choose RDE is designed by referring HTR-10 technology, is by
analyzed the cost effectiveness, reduce complexity of the Instrumentation and Control (I&C) system, more reliable system and for the safety aspects. In China, one of their reason to choose HTGRs reactor because the economics reason that it can reduce the investment for a single module of about 110 million USD [2]. But the reasons is not only concern to reduce cost, it also proven that HTR-10 is the only of pebble-bed HTGR test reactor in the world which had ability to give benefits to the environment to test and produce fuels and to conduct gas turbine systems test in an integrated systems[2].

Commonly I&C system is developed by complex system to control the many functions of the components and systems to keep the plant in normal operation and safe condition. By this reasons, RDE should developed by improving the previous technology of the HTR-10 from the Tsinghua University design. The design engineer should collaborated with the system engineer how to minimized the complex system by develop reverse engineering program, modified the decomposition of the system functions before develop the architectural design. Therefore for development of Helium Purification System (HPS) as the one of the I&C system which have function to keep the purity of helium, sequence diagram is develop to simulated the modified integrated system function in HPS.

The purpose of develop sequence diagram will help the system engineer to explain the behavior of the system function, and it will help the design engineer to interpret the system in to the design synthesis and design architecture to be implemented.

2. Sequence diagram method

2.1 Sequence diagram

The sequence diagram is used primarily to show the interactions between objects in the sequential order that those interactions occur. Much like the class diagram, developers typically think sequence diagrams were meant exclusively for them. However, an organization's business staff can find sequence diagrams useful to communicate how the business currently works by showing how various business objects interact. Besides documenting an organization's current affairs, a business-level sequence diagram can be used as a requirements document to communicate requirements for a future system implementation. During the requirements phase of a project, analysts can take use cases to the next level by providing a more formal level of refinement. When that occurs, use cases are often refined into one or more sequence diagrams.

An organization's technical staff can find sequence diagrams useful in documenting how a future system should behave. During the design phase, architects and developers can use the diagram to force out the system's object interactions, thus fleshing out overall system design.

One of the primary uses of sequence diagrams is in the transition from requirements expressed as use cases to the next and more formal level of refinement. Use cases are often refined into one or more sequence diagrams. In addition to their use in designing new systems, sequence diagrams can be used to document how objects in an existing system currently interact. This documentation is very useful when transitioning a system to another person or organization.

2.2 Helium Purification Instrumentation System

As the one of function from I&C system, HPS (Helium Purification System) has a role to removal of chemical and particulate contaminants from the primary coolant to maintain specified values, supplying purified helium to the systems and filled with helium, removal of helium from the primary system and the helium filled supporting systems and storage in the purified gas store, relieving pressure and dumping helium from helium filled auxiliary and supporting systems and, possibly storing of radioactively contaminated helium, evacuation of primary systems and helium supporting systems. HPS consists of several component for filtering the helium from chemical and radioactive impurities, heat exchange component, pipelines, valves, instrumentation sensors, and regeneration system[5]. HPS are included in the safety class 4 from the regeneration systems and auxiliary system[6].
3. Development Helium Purification System

Development of sequence diagrams intended for the design implementation of RDE by refer to the HTR-10 type, which is system engineer will be able to review the function of each component in the system helium purification from the previous design. Whether this system will continue to use the same function functionality, or will be modified for system optimization.

Before develop sequence diagram, by information from Figure 1, we can describe which component that had a function to be keep or modified. Figure 2 was represent the functional decomposition from helium purification from HTR-10.

**Figure 1.** Schematic Helium Purification of HTR-10 [7]

**Figure 2.** Functional Decomposition of Helium Purification System

After decompose the functional system, the design engineer can develop the design synthesis and translate it in to design architecture to complete the helium purification system design. To state which function that must be develop in to design architecture, the design engineer should understand the
system function and each component. Sequence diagram is one of the system engineering approach which help the engineer to describe the behavior of the system and components [8]. M. Hasan 2017 [8], had been state that before develop sequence diagram, the activity which is in Figure 3 below should be follow:

![Sequence Diagram Generation](image)

**Figure 3. Sequence Diagram Generation[8]**

The first step is to define the block and its function, after the block is specified, the next step is to determine the input and output of each block as well as the next step is to define the operational scenario, determine the sequence logic and the flow of information. After all the steps are completed just create a sequence diagram.

4. Results and Discussion

HPS is additional function from I&C system for RDE. Helium gas was an inert gas which has ability as material in cooling system for HTGR reactor type. Relatively, helium was very stabil in high temperature. Currently, BATAN had a plan to develop this type of reactor. For the research and development for the cooling system from reactor vessel still need to be continued with more deeply. The studies which need to be implement was to understand the function of HPS by reviewing the system function of HPS using sequence diagram which represent in Figure 4.

![Sequence Diagram for HPS](image)

**Figure 4. Sequence Diagram for HPS**

HPS have entity with concerning in one object. Each entity has their specific function. In this research HPS is divided as six entity which has function in helium purification system. Whether each entity will have future study in the future development, or will be kept or modified is depend on the
review after this study. In this HPS, the entity is consist of filter class which this filter has a function become dust removal, cooper oxide Bed, water separator, molecular sieve and carbon active absorber. Another entity has a regeneration system which had heater and helium gas flow rate.

Particulate impurities are carbon dust which may be mixed with fission products, while the gaseous impurities are \( \text{O}_2, \text{N}_2, \text{H}_2\text{O}, \text{CH}_4, \text{CO}, \text{CO}_2, \text{and H}_2 \). Dust removal is the object of the filter class, the function of this object is to filter the impurities in the form of dust. To know whether the function of this entity is still within tolerable limits can be analyzed and observed the difference of incoming and outgoing pressure.

For sequence diagrams, this entity will send messages about pressure and flow rate and impurity. If pressure and flow rate are in accordance with the provisions (30 bar and 10.5 Kg / h) then helium gas may be further filtered Filter. The next is entity cooper oxide bed, this entity is assisted by the entity heater to obtain optimum temperature conditions (250°C) and convert \( \text{H}_2 \) to \( \text{H}_2\text{O} \) and \( \text{CO} \) to \( \text{CO}_2 \) and check whether \( \text{H}_2 \) and \( \text{CO} \) compounds are still widely present at this stage. The next step is the task of entity cooler and separator, this entity is emphasized to separate the result from previous entity that is \( \text{H}_2\text{O} \) and \( \text{CO}_2 \). To be able to separate \( \text{H}_2\text{O} \) and \( \text{CO}_2 \) flow conditions are conditioned at 40°C. In addition, the entity molecular sieve also helps to separate \( \text{H}_2\text{O} \), \( \text{CO}_2 \) and also \( \text{CH}_4 \). The final step is to separate the fission product compounds such as Krypton, Cesium from Helium gas. For that Entity must set the operating temperature conditions -160 °C. From the all entity is analyzed one by one either in software or hardware that each each entity needs to be developed, maintained or even eliminated.

5. Conclusion

Sequence diagram are created because they are a means to represent system behavior and interactions between components. Benefits developing sequence diagram is to help reverse-engineering processes and re-engineering processes for RDE as this can help system engineers and design engineers to review detailed system function and implementation later on new RDE designs that will be created in Indonesia related to instrumentation and control design of HPS.

Acknowledgments

Author wishing to thanks to Center for Nuclear Reactor Technology and Safety – BATAN, and Indonesian Ministry of Research, Technology and High Education (Kemenristekdikti) FY 2018 for financial support through the research.

References

[1] Chen F, Dong Y and Zhang Z 2016 Post-test Simulation of the HTR-10 Reactivity Insertion Without Scram Ann. Nucl. Energy 92 36–45
[2] Zhang Z and Yu S 2002 Future HTGR developments in China after the criticality of the HTR-10 Nucl. Eng. Des. 218 249–57
[3] Wu Z, Lin D and Zhong D 2002 The Design Features of the HTR-10 Nucl. Eng. Des. 218 25–32
[4] Brinkmann G and Will M 1990 Concept Licensing Procedure for an HTR-Module Nuclear Power Plant Nucl. Eng. Des. 121 293–8
[5] Natesan K, Purohit A and Tam S W 2003 Materials Behavior in HTGR Environments
[6] Wu Z and Xi S 2002 Safety Functions and Component Classification for the HTR-10 Nucl. Eng. Des. 218 103–10
[7] Yao M S, Wang R P, Liu Z Y, He X D and Li J 2002 The helium purification system of the HTR-10 Nucl. Eng. Des. 218 163–7
[8] Hasan M M, Elakrat M, Mayaka J and Jung J C 2017 Application of Sequence Diagram to The Reverse Engineering Process of The ESF-CCS Model Based System Engineering - Korea System Engineering Society Spring Conference 2017