The Study of Main Component of the High Temperature Gas-cooled Reactor Balance of Plant using Local Component

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Abstract. National Nuclear Energy Agency (BATAN) as a research and development institution related to nuclear energy has designing Nuclear Power Plant (NPP) as one of the solutions to meet energy needs in Indonesia. This alternative electric power plant can be used as back up of fossil base power plant and maintaining the basic load of electric consumption. This research purpose is to simulate the balance of plant of the designed NPP and comparing the main component need to be produce by local industry. The simulation was created using Chemcad software to describe the process and component analysis of the NPP. The simulations done also can increase the economic efficiency. Simulation results show the component data which can be used as a reference for the selection of the main components and pipes would be used in the construction of the reactor. The simulation results data of this simulation also can be uses to decide the local component that can apply in future NPP.

1. Introduction
Most energy in Indonesia is currently filled with utilizing fossil fuel. Energy needs in Indonesia continue to increase annually, to solve this problem there must be considering using several new and renewable energy sources. One of best candidate energy source is Nuclear energy. In a Global scale of Indonesia for 2040 Special Volume reviews predicted increase to almost 50 x 10¹⁸ J needed for Nuclear energy [1]. The construction of NPP in Indonesia has been planned for a long time by BATAN. The Reactor should be one of the best solutions because the other energy source such as the chemical and liquid fuel production quite complex considering the supply chain [2]. The reactor design carried out by BATAN is currently a fourth generations reactor which is a HTGR. This type of reactor was chosen because of the high safety factor. The reactor designed by BATAN is an Industrial and Steam Power Plant (PeLUIIt), this reactor is designed with a power of 150 MW. This reactor was designed to generate electricity and steam to be used for industrial purposes. HTGR research progress in global was started by German many decades ago and recently the research lead by China.

HTGR design as commercial NPP generally choose because of its safety factor. The PeLUIIt design offer many utilities when it operates. Before the construction, the design should be validated and verification that the safety standard has been completed. This research would be basic for understanding the process of BATAN design on nuclear reactor. The simulation result also can be used to other simulations in a different arrangement of the design. The model- based simulation generally decided by the accuracy of model represent the real condition in a same tame using simple approaches [3]. The simulation also can be used to enhance the skill of designer to know the error and provide information
to the operator in control room after NPP constructs [4]. This research is important because the results of the simulations carried out serve as a reference for the availability of viewing components from current local industry conditions. In the preliminary assumptions, the design would need specific component that must be fabricated because it is not the general market consumption. In further scope the simulation has advantage because it can be more economical efficient than creating real experiment set to know the phenomenon.

The research performing a process simulation that occurred in a steady state. The simulation results are used as data to determine the needs of the components and pipes to be used. The selection of components out based on the calculation of ideal conditions in the circumstances of the operation. For the development simulation can be enhance using web-bases simulation. This kind of simulation has a good point in control from the distance. The simulation can be access and be modify by research team member [5]. Simulator of NPP can be classified to several kind. There is offline and online simulator. Type of simulators and their purpose can be divided to simulator games, Desk-top simulators and control room simulators [6]. There are at least three stages use of simulator studies: (1) systematic studies of natural condition and its complexity (2) full scale simulation which can be adjust by the operator base on condition change (3) the flexibility and low cost to test alternative design [7]. Calculations made are taken into consideration in selecting the component specifications to be used. Equilibrium conditions in the designed reactor system are calculated using the help of Chemcad software. Chemcad is software commonly used in determining the calculation of system equilibrium in equilibrium. In the future most of process design and simulation will be using software that integrated together to solve global optimization problems [8].

2. Methods
The PeLUIt NPP design basically was the modification of the Experimental Power Reactor which is a Non-Commercial Power Reactor (RDE RDNK) that BATAN is working on inspired by HTR10 and HTR PM models. The most obvious PeLUIt design difference is the amount of output power of 10 MW and 150 MW. Unlike the water-cooling type reactor, the High Temperature Reactor (HTR) model has more complex flow and heat transfer with higher turbulence levels. This has led to the need to also calculate the thermohydraulic parts as a consideration [9]. The limits values operation and safety were shown in Table 1.

| Parameter                                      | Operation | Safety |
|-----------------------------------------------|-----------|--------|
| Max neutron flux at low power (>15 MWt)       | 150%      | 15 MW  |
| Max neutron flux at middle power (15-75 MWt)  | 110%      | 120%   |
| Minimum reactor period                        | 45 s      | 20 s   |
| Max. He outlet temperature                    | 780°C     | 790°C  |
| Max He inlet temperature                      | 270°C     | 290°C  |
| Max He flowrate                               | 110%      | 120%   |
| Max. thermal power increase                   | 2.3%/min  | 3.5%/min|
| Max. primary pressure increase                | 0.01 MPa/min | 0.03 MPa/min |
| Max. primary pressure decrease                | 0.01 MPa/min | 0.03 MPa/min |
| Max. ratio of He and steam flowrate           | 1.20      | 1.30   |
| Max. ratio of steam and He flowrate           | 1.17      | 1.33   |
| Max He humidity                               | 50 ppmv   | 800 ppmv|
| Max. steam pressure decrease                  | 0.6 MPa/min | 1.0 MPa/min |
| Max. deviation for He flowrate                | 20%       | 20%    |

Simulation has two types, steady and dynamic. The simulation in this study is basically a simulation at a steady state [11]. Simulator design can basically be used for transient conditions and analysis of emergency conditions, verification of design changes, power tests produced, and verification of system design and integration [12]. Mass balance and energy produced can also be calculated. The main purpose in making simulations for the design that is being done is to guarantee in terms of safety. To fulfill this
requirement, it is necessary to do a lot of verification and validation of the design that is done. Granting licenses to continue to improve safety and reduce risk in accordance with the new technology used by [13]. The simulation in this research split into two steps, the primary and the secondary system, and how to connect this system. In primary loop, cooling system using gas as coolant and not mix with the water from the secondary loop [14]. Continuous improvement needs to be done with regard to all circumstances so that it can provide an overview of the most effective reactor design in energy and mass balance. In the cooling system section, further research is also needed because the amount of power produced by the power plant is strongly influenced by the success in the cooling process [15]. Combining both primary and secondary loop to create full simulation of the NPP design would describe the process of the balance of plant. The simulation result can be used to decide which component already exist as local component. The flow of the research simulation can be describe as shown in Figure 1.

![Flowchart of the Research](image_url)

**Figure 1.** Flowchart of the Research

3. Results and Discussion
Simulation result of the PeLUIt 150 MW after combining the primary and secondary system shown in Figure 2. The simulation describes the process between two loops of fluid inside the cooling system and how the heat generation each loop. There are three main variables for each main component:
temperature, pressure, and flow rate of the coolant. The other variable is not shown Chemcad but recorded by simulation result data sheet.

![Figure 2. Simulation Results of PeLUIt 150 MW](image)

The simulation adds some virtual component to make a simple running because some limitation of the available component in Chemcad. This system can represent the general design for the 150 MW PeLUIt which consists of a helium gas primary cooling system reactor and a cooling system that uses water. In accordance with the hypothesis in the previous simulation, the simulation results which are a combination of the two previous simulations have finally changed the previous conditions. Some of these changes occur in the magnitude of the magnitudes and constants associated with the amount of energy generated. In the first simulation the heat absorbed amounted to 150.3549 MJ / h finally changed to 150.3427 MJ / h. Meanwhile some thermohydraulic parameters are maintained as values in the previous simulation.

The stream properties possessed by this combined simulation show that changes in several degrees of celsius, but there are some parts that do not experience changes in temperature. The phenomenon where enthalpy values change almost in all parts which are components of the system cycle with water flow is interesting. This changing enthalpy value is more or less caused by mixing the flow that occurs in the steam generator with helium flow. It is supported that the molar flow value does not change significantly. The stream properties of PeLUIt 150 MW for each component detailed in Table 2.
4. Conclusion
Simulations for the 150 MW reactor model are made by combining two different fluid streams. Physical phenomena that occur affect the thermohydraulic value in the reactor system. Variations in making simulation schemes are interesting because optimization for the system is the best. Addition of components to the simulation design can affect the balance of plant and mass-energy balance. Simulation that has been done can be used as a reference as the selection of reference components that can be used when the reactor will be built. Simulation results cannot yet be ascertained for determining the availability of components that have been produced locally in Indonesia. The same is true for the selection of pipes to be used. The determination of pipe size can be done directly from the simulation results. Further research is needed regarding the selection of components available in Indonesia whether these components can be used for the purposes of nuclear power plants.

Simulation base on Chemcad for the steady state condition of PeLUIt model process can be use in describe the balance of plant the NPP model which is the scale-up of the RDE-RDNK design by BATAN. However, limitation on the simple simulation model there are some variable not calculated. The manufacture of the component also become other case to solve. Some calculated component doesn’t produce for general industrial usage. There are two options to solve this problem, using the new manufacture product or using the existing component but re-arrange the simulation. The better option was created the new simulation that suit to the local industry component that produce in Indonesia. From this simulation, the research show there would be need another study and continuous comparation about the capability of the local industry to support the nuclear plant construction.

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