Short Circuit Analysis on HPS Electrical System

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Abstract. An electrical short circuit analysis on Helium Purification System (HPS) - Reaktor Daya Experimental has been conducted. Short circuit fault is a frequent disruption of the electrical power system. Short circuit failure can cause the flow of the current to be large, the amount of electric current that flows can damage electrical equipment. The electric power system is important auxiliary system arranged for the RDE component test loop to each its safety and operation objective. In this paper consists of the electrical short circuit analysis using ETAP on HPS electrical power supply and RPS of RDE. This research may be more complex from a computational point of view, in particular when the network has remarkable dimensions or when meshed networks and asymmetric faults are dealt with.

Keywords: short circuit analysis, HPS, RDE, and ETAP.

1. Introduction

The construction of the RDE will enable Indonesia to gain the experience and capability to build and operate a non-commercial power plant that can generate electricity. The proposed RDE is a high temperature gas-cooled reactor (HTGR), capable of generating electricity and can meet other applications (cogeneration), such as coal liquefaction and gasification, oil pickup enhanced oil recovery, and seawater desalination, as well as hydrogen production [1].

Currently BATAN has planned to build an experimental reactor (RDE) of type Pebble Bed Reactor (PBR) with low power to master this technology. The plan has so far been embodied in the preparation of the conceptual design by 2015, the drafting of the basic design in 2017 and the preparation of detailed early-stage designs planned for 2018. High-temperature, high-temperature gas nuclear reactors, particularly the pebble bed reactor type (PBR) is one of the designs of advanced generation reactors that are very interesting. This reactor design offers excellent safety features as well as potential cogeneration applications. For Indonesia, PBR becomes one of the interesting candidates that can provide solutions for national energy needs in the form of electricity and heat for industrial development need. The study of PBR design and its application in Indonesia including software development for PBR design has been done since the 1990s. Since the last two years, BATAN has taken the initiative to conduct a PBR design study by designing 10 MW RDE.[2,3,4].
To support the RDE program, several test facilities will be built including Helium Purification system (HPS). The power supply system on the HPS should have a reliable electrical system, since it is closely related to the Reactor Protection System (RPS) in the RDE.[5,6,7]

The reliability of the power supply system on the HPS is very important to maintain the supply of electrical energy at this test facility, so that the short circuit analysis on the RDE electrical system becomes short circuit interference which is a frequent disruption of the electrical power system. Short circuit failure can cause the flow of the current to be large, the amount of electric current that flows can damage electrical equipment in the circuit.

The magnitude of the flow of short-circuit current is influenced by the location of the disturbance. if the disturbance gets closer to the source, the noise current will be even greater. How to overcome short circuit, need to be done short circuit analysis to know how big the short circuit current will happen. So that the right protection system on the power system can be determined. The analysis of short-circuit interfaces is an analysis that studies the contribution of short-circuit current flows that may flow on every branch within the system during short circuit breakdowns that may occur within the electrical system. The analysis of short-circuit interference is important for determining the short circuit rating, in order to protect the device and the equipment distribution system from the effects of the load.

2. System Description of HPS

The design of Helium Purification System (HPS) as shown in Figure 1.

![Figure 1. Helium Purification System of RDE](image)

The HPS test facilities must have sufficient supply of electrical energy and a reliable protection system, either in the load flow, the grounding system related to the protection of direct or indirect lightning strikes, so short circuit analysis and setting CB or electrical component protection is very important. The test facility shall be equipped with a neutral ground earthing system, since neutral ground earthing systems will affect the measurement results in the instrumentation system, control and data acquisition. The electrical single line diagram of HPS as shown in Figure 2.
Figure 2 shows that the main TR-1 transformer supplying the test facility is designed to be sufficient for the electrical energy requirements of the test facility. In addition, the protection system equipment must function properly in the sense that the protection system must have good coordination, which means that if the Circuit Breaker on HPS trip then the only option is CB in QMF-8 instead of CB in PC 1. The rating and the settings of CB and Fuse protection equipment are important.[8]. The electrical short circuit analysis using ETAP is important for determining the flow of load and the setting of safety component protection on RDE electrical supply of HPS.

2.1. Short Circuit Analysis using ETAP

The modeling of the electric bus system on HPS is shown in Figure 3. [9].

From Figure 3, for electric power systems with n-bus quantities, the node current equations can be written:

$$ I_{bus} = Y_{bus} \ V_{bus} \quad [1] $$

With $I_{bus}$ is the vector of the injected bus current. The flow is positive if heading for the bus and negative if leaving the bus. $V_{bus}$ is a bus voltage vector measured from the reference node. $Y_{bus}$ is the bus admittance matrix. This matrix is in the shape of the diagonal elements of each node and the diagonal between the vertices. If the bus current is known, equation [1] can be solved for the n-bus voltage, ie:

$$ V_{bus} = Y_{bus}^{-1} \ I_{bus} \quad [2] $$
\( Y_{bus}^{-1} \) is the inverse of bus admittance matrix or impedance matrix bus \((Z_{bus})\).

The power system network as shown in Figure 4 of the line can be converted to perunit admittances on the basis of MVA. The use of Kirchoff Current Law on this bus is given in the equation:[10].

\[
I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \quad j \neq i
\]

active power \( P \) and reactive power \( Q \) on bus-\( i \) are :

\[
P_i + jQ_i = V_i I_i^* 
\]

or

\[
I_i = \frac{P_i - jQ_i}{V_i^*}
\]

Substitution  eq [5] to eq [3], will be:

\[
\frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \quad j \neq i
\]

A short-circuit is an accidental or intentional low resistance or impedance connection established between two points in an electric circuit that bypasses part of the circuit. The location of short circuit is HPS- bus.

3. Methodology
The step of short circuit analysis electrical power supply of HPS-RDE component test loop is based on the load flow of calculation. Flow chart of short circuit analysis is shown Figure 4.

![Figure 4. Flow Chart Short Circuit Analysis](image-url)
4. Results And Discussion

System design consists of the design of electrical power systems design. The main design principles are defined to meet the project objective, including technical feasibility, safety and reliability, flexibility, and later-upgrade sustainability. The single line diagram of HPS electrical system supply HPS of RDE test loop facility is shown in Figure 5.

![Figure 5. Single Line diagram of HPS power supply](image-url)
Figure 5 shows a single line diagram with field data input on PC1 panel and PLN transformer, also data obtained from the load design for load requirements of the HPS test facilities to be installed. After the load flows on all buses are no problem, then the simulation of the short circuit analysis is run. If there is a problem in one of its buses, i.e.: there is a red bus indicated at panel bus, check the error of parameter data input. The short circuit analysis of HPS electrical system using ETAP is shown in Figure 6.

From figure 6 shows that the voltage drop at HPS-Panel 0.236 kV or 23.6 Volt and the short circuit current is 14.5 kA. From control room panel the voltage is 23.6 Volt, and there is no current flow from its bus, because the location of short circuit at HPS-bus panel. The setting of CB is 14.5 k
Ampere. The current flow at PLN line is 13.66 kA (setting CB of TR-1). The current flow at Generator is 0.801 kA. The short circuit report from ETAP as shown at Table 1.

### Table 1. Short Circuit Analysis using ETAP

| Contribution | 1/2 Cycle |
|--------------|-----------|
|              | % V From Bus | kA Real | kA Imaginary | Imp. | kA Symm. | Magnitude |
| From Bus ID  | To Bus ID    |         |              |      |          |           |
| HPS-PANEL    | Total        | 0.00    | -10.126      | 1.0  | 14.520   |
| QFM-71       | HPS-PANEL    | 62.23   | 10.406       | -10.126 | 1.0 | 14.520   |
| * PANEL-PC-1 | QFM-6        | 62.23   | 0.000        | 0.000 | 9999.0 | 0.000     |
| * Bus 1      | PANEL-PC-1   | 62.23   | 0.544        | -0.677 | 1.2  | 0.861     |
| * PANEL-PC-1 | QFM-71       | 62.23   | 10.406       | -10.126 | 1.0 | 14.520   |
| * PANEL-PC-1 | QFM-812      | 62.23   | 0.000        | 0.000 | 9999.0 | 0.000     |

The table 1 shows the short circuit analysis of the HPS facilities. It shows both the current flows and the voltage drop on the load component. The real current component is 10.406 kA and the reactive current is -10.126 kA so the total current magnitude of HPS panel is 14.52 kA, the panel bus of PC 1 is 14.52 kA.

### 5. Conclusion
Electrical short circuit analysis on HPS electrical system has been conducted using ETAP software. The designed of short circuit analysis is simulated by ETAP. After 3 phase short circuit at HPS Bus, the voltage decrease from 380 Volt to be 23.6 Volt. The current of short circuit is 14.52 kA, and it will be used as the setting electrical component protection such as Circuit Breaker (CB).

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