Operator Support System Design for the Operation of RSG-GAS Research Reactor

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Abstract. The components of RSG-GAS main control room are facing the problem of material ageing and technology obsolescence as well, and therefore the need for modernization and refurbishment are essential. The modernization in control room can be applied on the operator support system which bears the function in providing information for assisting the operator in conducting diagnosis and actions. The research purpose is to design an operator support system for RSG-GAS control room. The design was developed based on the operator requirement in conducting task operation scenarios and the reactor operation characteristics. These scenarios include power operation, low power operation and shutdown/scram reactor. The operator support system design is presented in a single computer display which contains structure and support system elements e.g. operation procedure, status of safety related components and operational requirements, operation limit condition of parameters, alarm information, and prognosis function. The prototype was developed using LabView software and consisted of components structure and features of the operator support system. Information of each component in the operator support system need to be completed before it can be applied and integrated in the RSG-GAS main control room.

Keywords: operator support system, RSG-GAS, control room

1. Introduction
RSG-GAS reactor has been operating for about 30 years, so it is certain that many components will experience the problem of ageing or obsolescence technology. To anticipate these problems, the program for refurbishment or modernization was established. According to this program and challenge, an integrated computer-based operator support system (OSS) in the control room is developed. The operator support system is aimed at improving operator effectiveness and performance by providing information for diagnosis of system condition, detection system, operation procedure, and component information presented at control room. Refurbishment of the main control room requires good planning and comprehensive consideration on operation characteristics and design features. Moreover, the design process must follow the requirements and principles of human factor engineering in order to obtain a safe, efficient and reliable control room [1-3].

The control program of RSG-GAS is distinguished as control of reactor operation safety and target irradiation control [4]. Most of the drive system is regulated and controlled from RKU and a small portion through local panels. Reactor control is performed by the reactor operator at the reactor control desk in the main control room. There are two modes in the reactor control performing which are...
manual mode and automatic mode. The status of the control rods used as a main device in power generation settings is shown by an indicator located on the reactor control desk [4,5].

In advanced reactors, auxiliary systems are designed by applying the modern technology in instrumentation, information and computation [1,5,6]. Additional function applied on the operator support system includes a high-level information display that allows the operator to know the condition of the reactor quickly, early fault detection system, and computer-based procedures [5-7]. Those functions are expected to reduce the operation failure due to human error (operator error). In addition to technological approaches, consideration of human aspect in the design of modern support system is also implemented, such as consideration on cognitive activities of the operator [5,8-10]. To achieve a suitable operator support system, the design of support system and its features should be tested and evaluated using modeling and simulators before being applied to the real control room [3,11-14].

The objective of this research is to obtain a model/prototype of computer based operator support system design that can be further implemented in RSG-GAS control room. The design adopts the progress of technology especially for information processing and visualization. The model obtained in this study can then be further developed by adding operational scenarios as well as other relevant information. The research methodology includes the study of operation scenario of RSG GAS, identification of component at control room based on design document and observation, and discussion with reactor personnel. Based on the information obtained in above stage, structure and components of the operator support system prototype was designed.

2. Theory

2.1. Components of RSG-GAS control room

The design of main control room as the center of interaction and control should be continuously improved to be more suitable with operator needs and task functions [1,2]. The Main Control Room of RSG GAS consists of information related with the main functions, auxiliary systems and supporting installations, managing the basic requirements for the operation of the reactor and other important systems. Figure 1 shows the components and layout of the main control room of RSG GAS. The reactor protection panel is installed in the RKU and is a part of the reactor protection system. In the reactor protection system (RPS), testing instruments and switches for conducting signal testing including the signal characteristics of engineered safety features is installed.

The reactor power regulation system is carried out by maneuvering the control rod (8 pieces, JDA01 to JDA08) inside the core. This reactor operation can be done manually or automatically. Reactor power regulation and controls are performed from the CWA01 reactor control desk, control rod status information which consists of control rod group (7 bank control rod) and a regulatory control rod (1 piece) are provided in control desk. Control line from the operator will be stopped if the reactor protection system generates a scram signal and control rod will be rapidly dropped and cause the reactor to shut-down. Indicators shown for the operation of each control rod show the position/status of the control rods, that are: up position, down position, 100% absorber down position, armature drop position, armature coupled position and overload insert position. The control rod position setting is done via a push button located on the control desk CWA01, that also displays the control rod position indicator. The signal from the control desk is connected to the electronic cabinet in the Marshalling box before it is connected to the drive system in the reactor [4].

For reactor operation, the display provided at the RKU includes the status of the primary cooling system, secondary cooling, auxiliary system, ventilation system, and control rod position. Furthermore, display for safety-related system variables are installed on control equipment and RKU control desk. The information is grouped into three groups: controlled component state information from the Engineered Safety Feature System (ESFS), Status information on the reactor protection panel and other variables groups. The MCR safety panel also displays the status of reactor protection system and the amount of the output signal, as well as information from the system variables that are
important for safety. Moreover the reactor protection panel is also provided with the buttons/switch used to monitor the output signal and test back from ESFS. Hence, general condition of Reactor Instrumentation and Control System (SIK), Reactor Protection System (SPR), and mechanical facilities connected to SPR can be monitored through the Reactor Protection Panel. The reactor protection panel consists of 15 columns and several rows that are grouped into three groups, namely group A for alarms, group B includes the information of the neutron flux density, unbalanced load, gamma dose rate, while group C consists the test button, the triggering criterion of the scram signal and instrument for testing information [4,14].

![Figure 1. Components and layout of RSG GAS Main Control Room [4]](image)

2.2. RSG-GAS operation

Operation of RSG-GAS is categorized into four types: start-up, low power reactor operation, high power operation, power change/maneuvering, shutdown and reactor scram. The requirements and characteristics of the operation as well as the indicators to be considered for each mode of operation may vary. One of them is the use of indicators JKT 01 to JKT 04, each have functions in different ranges. In addition to the information content, communication in the control room is required to convey the conditions and requirements of operating parameters, information on limit conditions (scram reactor period, reactivity, etc.) and to determine actions in operation. Operating characteristics that need to be considered include the reactor start-up operation to the high power during the decreasing of Xenon. The parameters that should be noticed by operator in conducting the settings/operations include reactor periods and reactivity. The terms and limitations of reactivity and power settings are taken into account to avoid reactor scram [4,15].

To maintain the operator performance in conducting the task, the shift work system is applied on RSG-GAS operation. In one day operation is divided into 3 shifts, each shift for 8 hours. One shift operation consists of at least one supervisor, two operators, one radiation protection officer and one maintenance/maintenance worker. To support the reactor operation there are 11 supervisors, 21 operators, 20 person for maintenance technicians, and 9 person for maintenance supervisors. Qualifications and training for personnel working in the reactor facility is established and stated in BAPETEN Chairman Regulation No.6 of 2013 [16].

3. Methodology
The main objective of this study is to develop a prototype design for the operator support system based on the reactor operation characteristics and system features. The research methodology included the study of the RSG GAS operating system based on documents/procedures, control room observations, and conducting discussions with reactor personnel. Identification is focused on the availability of data and information systems on the existing control room, operator needs and requirements, input-output components, operational scenario, and operator tasks in some operational scenarios. The following step is determining the features and structure of the operator support system based on the data collected data. The features and structures obtained are subsequently used in the design of support system prototype/model using LabView software.

4. Result and discussion

4.1. Reactor operation scenario applied in the OSS design

Most of the reactor operation action at RSG-GAS is performed by the operator from the control desk in control room in manual or automatic mode. Prior to reactor operation all required conditions and limits for operation must be satisfied, i.e., all safety-related systems must be able to operate or perform their function. The design of the support system should contain information for the preparation of the operation. In the event of deviation during operation, the reactor is allowed to continue operating until the end of the cycle if the limits and operating requirements are not exceeded. The simulated operating scenario of the reactor is divided into three categories: Power operation (Mode 1) that is start-up operation up to power operation > 3% full power; Low power operation (Mode 2) which is distinguished into low power operation with natural convection cooling and Low power operation with forced convection cooling; and Reactor shutdown (Mode 3) as shown in Table 1.

The parameters regarding operating requirements and safety constraints are shown in the information display of support system, such as in forced convection is covering the maximum power parameters of the reactor, maximum power factor of inlet pool temperature, reactor water level, and minimum flow rate. While in natural convection parameters that are considered include the thermal power of the reactor, the minimum period of reactor and the height of the pool water. In addition, the requirements for activating the reactor protection system to be fulfilled prior to the operation are also presented, e.g. for the operation mode 2 reactor shall not be turned on if non-functioning channel exist.

In principle, the information system in the support system contains all parameters related to the safety system that must be met as a condition for operation. In addition, the support system also displays deviations occur during operation, and information according to the limitations/operating requirements that should not be exceeded.

The operating characteristics and parameters shown in the information system design and procedures in the simulation/model of operator support systems are:

- Characteristics of core loading and burning fractions: the cycle in using of fork absorber or operation time (MWD), fluens boundary, maximum drop test of control rods, burning fraction for spent fuels.
- Shutdown reactivity and control rod configuration: shutdown reactivity margin, control rod reactivity, maximum deviation of bank control rod position, control rod position indicator status, maximum drop time for 80% drop and average time drop of all absorber (Mode 1 and Mode 2).
- Reactor cooling parameters: minimum primary system flow rate, total mass flow rate to cool irradiated insertion at core and reflector, grid position, nuclear heat channel factor for each configuration of steady-state core and specific core (axial maximum 1.6 and radial max 2.6).
Table 1. Reactor operation scenarios applied in the OSS prototype/model

| Reactor operation mode | Mode 1 (power operation) | Mode 2 (low power operation) | Mode 3 (shutdown reactor) |
|------------------------|--------------------------|-------------------------------|---------------------------|
| Operation characteristics | Reactor power > 3% of full power | Mode 2a: -primary cooling stopped -Reactor power < 1% of full power | Control rod position at the lowest level |
|                         |                          | Mode 2b : -Primary cooling operated -Reactor power < 3% of full power | Meter indicator : zero |
|                         |                          |                               | Position of 6 contact system switch : open |
|                         |                          |                               | Start-up key position : off |

4.2. Structure and features of the OSS prototype
The prototype of the operator support system contains three main information groups, namely the preparation of operations, the implementation/execution of the operation and the database system procedure. Operating sequences in support system designs/model are based on RSG-GAS operation scenarios. The OSS design would be useful in performing appropriate actions. For example in power operation (Mode 1) and low power operation (Mode 2), if required condition is not yet fulfilled, the OSS will displayed the task/action that should be performed by operator such as related to core cooling, eg: keep reactor remain in shut down condition, control flap position of the inlet isolation valve at heat exchanger in the primary system done flap position positioning from valve Inlet of heat transfer isolation of the primary system, or check another factor initiated the flow increase /decrease. Furthermore, reduction of irradiated target number or increase of hydraulic resistance, and changing of core configuration are carried out. The structure and sample picture of the designed operator support system prototype/model is presented in figure 2.

Other features embeded in the prototype were designed to assist the operator in conducting diagnosis of operation condition, such as in a scram condition. Reactor scram mode is generally performed automatically by the reactor protection system. Therefore the information due to parameter that triggers the occurrence of reactor shutdown/scram is displayed in the designed operator support system prototype prototype. The scram parameters shown in the display includes start-up flux > 105, start-up reactivity accident (periods of interim flux <5 second), reactivity accident at power range, beam tube flooding, cooling channel closed, and primary pump fails.

Figure 2. Component structure and sample mimic of the OSS prototype
5. Conclusion
Refurbishment and modernization of RSG GAS control room has been planned and partly implemented. The approach for modernization was conducted in this study through the provision of operator support system at main control room. The prototype of operator support system in this study was developed based on reactor operation scenario, system features, and operator needs. Operation scenarios applied in the OSS prototype are low power operating scenario, power operation and reactor scram. The designed OSS consist of main components which related to the operation preparation, operation execution, and operation procedure. The prototype design provides essential information that would be useful for operator in performing appropriate actions and in conducting diagnosis especially during abnormal conditions. Information of each component in the operator support system structure should be completed before it can be applied and integrated in the RSG-GAS main control room.

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