Abstract

The PUSPATI TRIGA Reactor (RTP) undergoes 30 years safe operation. Currently, the existing power control system does not satisfied. Therefore, a new controller were proposed to overcome the performance of RTP. Nuclear reactor are nonlinear system, and the power keep increasing continuously with time. Thus the controller re important to ensure the stability of the system. The RTP power were regulated by moving the control rods. There are Shim, Regulating, Safety and Transient with different enrichment of Uranium Zirconium Hydride thus provide different power
level. The modelling of RTP were determine using black box theory accomplished by MATLAB System Identification. The Proportional-Integral-Derivative (PID) controller was designed to control the power performance after determine the appropriate model of RTP. The PID value were tuned until the satisfied obtained. The power control steady state error less than 1%, with minimum settling time and rise time. The simulation result of PID validate with RTP real data to analyses the performance of proposed controller.

**Key Words:** PUSPATI TRIGA Reactor (RTP); Power Control System; Proportional-Integral-Derivative (PID); Black Box

# 1 Introduction

PUSPATI TRIGA Reactor (RTP) was successful installed and reach its critical state on 1982. RTP TRIGA Mark II reactor are Small Modular Reactor (SMR), pool type and time varying plant. This nuclear research reactor capable to operate until 1MW thermal power. The main purpose of RTP are for education and training. Besides that, RTP also offers facilities for research and development in various scientific field related to nuclear. The RTP power control system just upgraded from analog system to automated power control system. This system was introduced by Korea Atomic Energy Research Institute (KAERI). Power control system are very important in nuclear reactor to avoid any abnormality and accident during operation. Therefore, appropriate controller that ensure the safety are necessary to design. This paper proposed Proportional Integral (PID) controller for RTP power control system.

## 2.0 Literature Review

### 2.1 Modelling

The modelling of nuclear research reactor consist of six delayed neutron groups, temperature feedback of coolant and fuel, and effect of Xenon concentration (1). Antonio Cammi (2013) proposed zero dimensional approach to reproduce the dynamic behavior of TRIGA Mark II reactor. The model has been validated with real data to verify the goodness of the model (2). However due to limitation of parameter data in RTP, the system identification using black box theory were applied to describe the dynamic behavior of RTP. Black box determine the transfer function by matching the test data. Therefore, the black...
box does not need any physical reference from the plant (3). The advantage of black box theory is the system can be modeled without any inner structure information (4). Besides that, black box are suitable for system-level simulation and good for stability analysis. Furthermore, the compute model also capable to estimate and generate the transient response and steady state for efficiency of the system. Furthermore, black box also ensure accuracy, effectiveness and ability to reproduce a new models of nonlinear system (5).

2.2 PID controller

Currently, the reactor power tracking is not satisfied and need some modification. The RTP power control performance has longer settling time and rise time when reach the desired level. The main function of controller to receive signals from transmitter and compare with the reference value. Based on the error obtained, the actuator received the control signal from the controller to converge the error equal to zero. The proportional gain produced overshoot and steady state error are still present. The combination of smaller proportional gain and integral gain eliminate the overshoot and steady state error. PID controller are widely applied in world control industry due to its simplicity in tuning and implementation (6). Furthermore, PID controller guarantee good performance in the present of disturbance that affect the efficiency of system dynamic. Shreyas, (2016) proposed multiscale PID control for temperature control system. Based on the result, multiscale PID gives satisfied performance in term of tracking the set point and disturbance rejection compared to conventional PID (7).

3.0 Methodology/Materials

3.1 RTP Modelling

The development of power control system was designed as in Figure 1. The modelling of RTP was carried out to determine the dynamic behavior of RTP. MATLAB System Identification is employed to determine the dynamic behavior of RTP. Figure 2 illustrate the power control system of RTP. The design of RTP has been estimated making a best fit to RTP performance on the entire operating power range which consiste of controller, rod selection, height to worth, coupling of neutronic and thermalhydraulic. The fission chamber acts as neutron detector and convert the signal from RTP model to actual power.
Power Demand (PDM) as input generate the movement of control rod to control the reactivity in the reactor core. The conversion between fission process to thermal power occur produce the final reactor power as the output signal for system identification. Obtained data is computed in MATLAB to generate the mathematical transfer function of RTP dynamic behavior. Two identical loop ascension power experiment using regulating rod was carried out. The regulating rod were chose due to its high sensitivity and accuracy. The first loop was selected for estimation while the second loop for the validation.
Figure 3: Input and Output Signal for System Identification

An approximated linear process model fitted 94

\[ \frac{4.734s + 1.008}{842.5s^2 + 58.06s + 1} \]  

(1)

3.2 PID controller Design

The proposed algorithm is PID controller in which the proportional gain, integral gain and derivative are set at certain value. The PID mathematical equation express as follow:

\[ G_c(s) = K_p + \frac{K_i}{s} + K_ds \]  

(2)

From the auto tuning using MATLAB/Simulink, the obtained value of \( K_p = 0.85, K_i = 0.00017 \) and \( K_d = 1.246 \). Figure 3 shows the PID controller design for RTP power control system.

Figure 3: Simulink Model for RTP Power Control System

4 Results and Findings

The result of PID controller shown in Figure 4. From the graph below, it can be observed the improvement of RTP power control performance using PID controller. The rise time and settling are shorter with PID compared to real data. Besides that, the RTP performance also still under trip limitation consideration which is less than 10% overshoot and short period.
Figure 5 below illustrate the performance of PID controller for daily operation 10%-75% and maximum operation 10% to 100%. From the result, the PID controller able to improve the performance of current controller.

The summary performance of PID controller shown in Table 1 quantitatively. Based on Table 1 clearly describe the behavior of PID controller that provide a good result in term of rise time and settling time.

<table>
<thead>
<tr>
<th>Property</th>
<th>Current Controller</th>
<th>PID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time</td>
<td>122 sec</td>
<td>130 sec</td>
</tr>
<tr>
<td>Setting Time</td>
<td>160 sec</td>
<td>184 sec</td>
</tr>
<tr>
<td>Percent OverShoot</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Steady state error</td>
<td>0.8%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>
2 Conclusion

A dynamic model of the RTP was developed using system identification in order to design RTP controller. Simulation result of PID controller were compared with real data showing the improvement performance using this model. From the result shows that PID controller offers better result which reduce settling time and rise time. However, further investigation and experimental activities are necessary in order to find the best controller for RTP.

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References


