Development of a new control Algorithm for Power Controller Simulation for 1MWatt Research Reactor

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DATE : TUESDAY, 8TH OCTOBER 2013
SESSION : 11.25 – 11.50 A.M.
VENUE : BILIK SEMINAR, BLOK 11, AGENSI NUKLEAR MALAYSIA

CONTENTS

ABSTRACT

The Reactor TRIGA PUSPATI (RTP) was installed in the year 1982. The control rod mechanism is very important in reactor operation meaning to control reactivity or neutron production in the reactor. It has 4 control rods. The current control rods movements are by sequential means 1 control rod is move at one time. A new control algorithm for Power Controller Simulation has been developing to control the movement of the control rods with uniformly and orderly.

By using the Gradient Method which is mathematical expression for the coupling between neutronics & thermal-hydraulics that is considered as the structure of a RTP model of the system. Purpose of the modeling is to reproduce the dynamic behavior of the reactor on the entire operating power range (1MWatt). A zero dimensional approach is accounted for & the coupling between neutronics & thermal-hydraulics in natural circulation is considered. The model has been validated through comparison with experimental data, concerning different power transients. For neutronics, point reactor kinetics model with multiple energy group & 6 delayed neutron precursors group has been adopted. The system reactivity can be modified moving the control rods, which allows the reactor to operate at different power levels. As far as thermal-hydraulics is concerned, 2 regions have been defined, i.e. the fuel & the coolant. Heat exchange (convective & conductive) has been modeled by proper adoption of a global heat transfer coefficient. This has been considered as a function of coolant mass flow rate through the core to introduce the effects of force natural cooling (using pump during operation), neutronics & thermal-hydraulics are coupled together by means of fuel & moderator temperature feedback coefficients. The large thermal inertia due to the mass of water in the tank containing the reactor core causes temperature variation during transient to be very small. Therefore, moderator temperature feedback coefficient strongly influences the dynamic behavior of the system & has been estimated making a best-fit between the model response & the experimental data regarding positive reactivity insertion in the system at difference power levels.

The results obtained show the reactor powers, reactivity, period, control rods positions, fuel & coolant temperature. The nonlinear system of 11 coupled ODE has been solved by means of Simulink (The MathWorks, Inc. R2010a), which represented a reliable tool for dynamic & control analysis. The model reproduces the real behavior of the system in a very satisfying way.

INTRODUCTION

Project development contribution and history development of power controller simulation

- Upgrading the Reactor Control Console to Digital Systems (P30009000370001), RMK10, ReDICS Project (Ir Dr Mohamad Puad Hj Abu, BTR) (2010 - 2014)
- Science Fund Project (03-03-01-SF0159), Development of Automated Controller System for Controlling Reactivity by Using FPGA (Izhar Abu Hussin, BTR) (2012 - 2014)
- PQRD Project (EDG-12-8), The Development of Reactor Console Simulator (Mohd Idris Taib, BKS) (2012 - 2013)

BACKGROUND

- Reactor TRIGA PUSPATI was installed in the year 1982
- Reactor Staff to monitor reactor variables and to control the core flux through the control rods and Nucleonic channels.
- The method to control the reactivity in the reactor?
  - neutron absorbing material (Boron Carbide) or control rods are required to control the number of neutrons that are directly proportional to reactivity.
- Control rod drive mechanism is very important to control reactivity in the reactor. There are 4 control rods ; 1 air follower control by pneumatic drive and 3 fuel follower control by electromagnetic drive mechanism.
- Current algorithm control rods movement are sequential means one control rod is move one at a time. Only one control rod is used for power regulation.
- Safety function in I&C system: control reactivity and power level
- Function I&C :
  - for **monitoring** and display reactor parameters.
  - means of **protecting** the reactor from abnormal circumstances that could result accidents.
  - means of **controlling** the reactor power by withdrawal and positioning the control rods, maintaining and regulating the reactor power 'set ' value.

Problem Statements

- ReDICS project just for operation and control of RTP only.
- There are no simulator system in ReDICS project as well as in Malaysia
- No structure of a RTP model coupling between neutronics and thermal-hydraulics by simulation.
- Current controller used for control is not so precious and optimum because tuning the control parameters is only by manual.
- In PQRD project the simulation is for the current I&C system for RTP and simulation model is static behavior.
- No human capital and expert for this field.
- Expensive cost to develop reactor simulator (estimated ~ USD 30 millions)

Objectives

- To develop a new control (computer based technology) Algorithm for Power Controller Simulation for 1MWatt Research Reactor model by using Matlab / Simulink in high safety nuclear operation.
- Purpose is to produce the dynamic behavior of the reactor TRIGA PUSPATI model simulation.
- The development of this project research including design, software development, testing and validation & verification for new control computer algorithm for power controller simulation and produce precise control parameters.
- Development of local expert in reactor control system and development of local technology and industry in Nuclear I&C.

METHODOLOGY

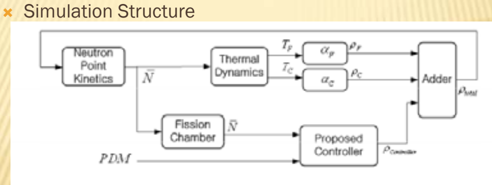
- Literature review, collection of technical specification equipments & software, scientific papers and history parameters data in the reactor operation(baseline data)
- Design the new algorithm for controlling reactivity and power.
- Software development by using Matlab / Simulink
- Dynamic behaviour
  - Neutronics – point kinetics model with one energy group and six delayed neutron precursors group
  - Thermal-hydraulics – fuel and coolant
  - Force natural cooling
- The nonlinear system of 11 coupled ODE has been solved by means of Simulink (MathWorks, Inc R2010a) – represented a reliable tool for dynamic and control analysis.
- Model has been validated through comparison with experimental data (concerning different power transient and control rod calibration)
- Performance test at RTP reactor (Malaysia) of covering fail-safe, reliable, fast acting and accuracy.
- Validation and verification to evaluate the prototype from regulatory body and establish nuclear application institute.
- Establishment the manual of the prototype and final report

RESULTS

- New method and technique using new design algorithm for power simulation
- New process by improving the accuracy of new absorber control movement and reactivity
- Design algorithm based on new drive mechanisms capability 0.02mm resolution
- Response algorithm to be more faster (real time).
- Demonstrator / prototype of new Control Computer Algorithm for Power Simulation for 1MW Research Reactor.

POWER CONTROLLER SIMULATION

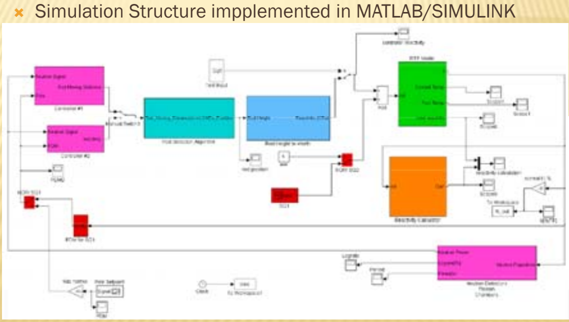
- Simulation Structure



*point kinetics and thermal dynamics were used for reactor model
*modeling parameters were obtained from literature and information from RTP
*power controller was developed by Sabri

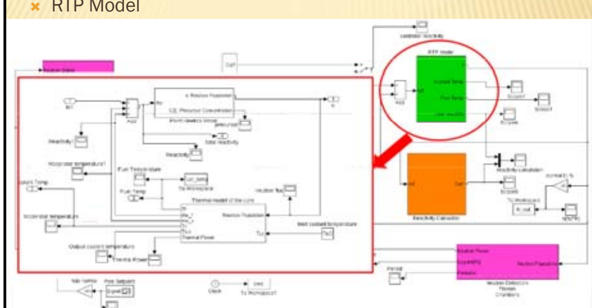
POWER CONTROLLER SIMULATION

- Simulation Structure impplemented in MATLAB/SIMULINK



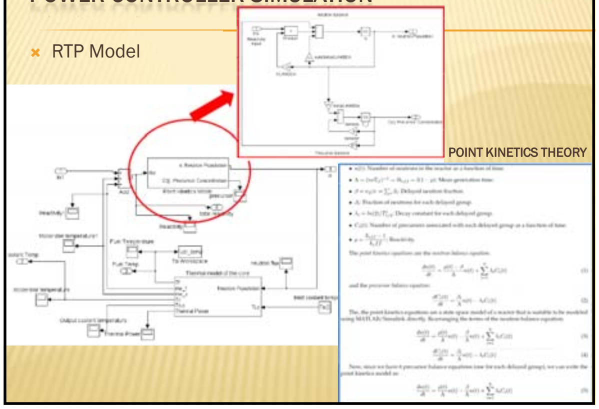
POWER CONTROLLER SIMULATION

- RTP Model

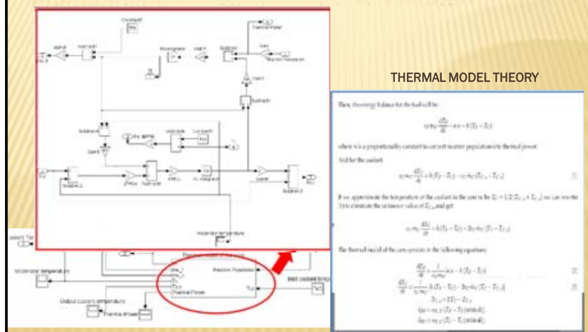


POWER CONTROLLER SIMULATION

- RTP Model

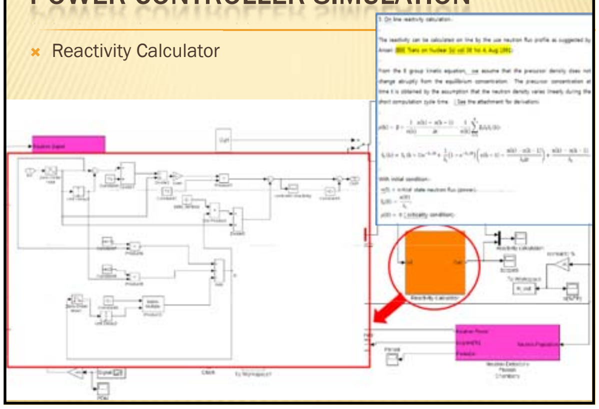


POWER CONTROLLER SIMULATION



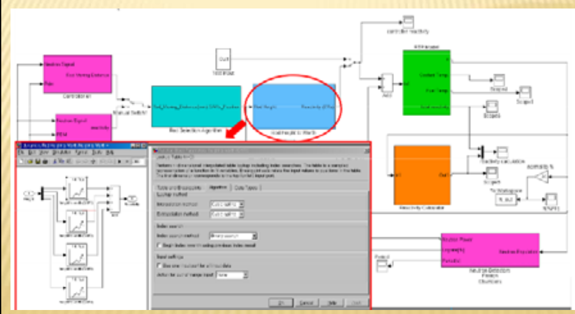
POWER CONTROLLER SIMULATION

- Reactivity Calculator



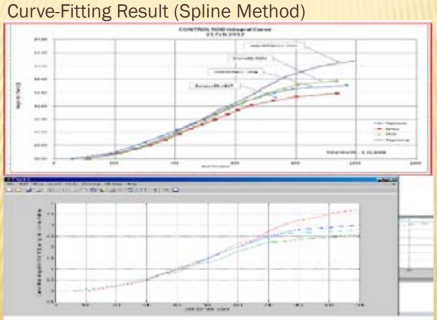
POWER CONTROLLER SIMULATION

- Curve-Fitting from CR position to reactivity



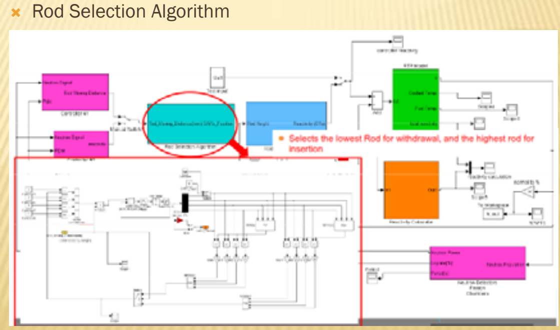
POWER CONTROLLER SIMULATION

- Curve-Fitting Result (Spline Method)



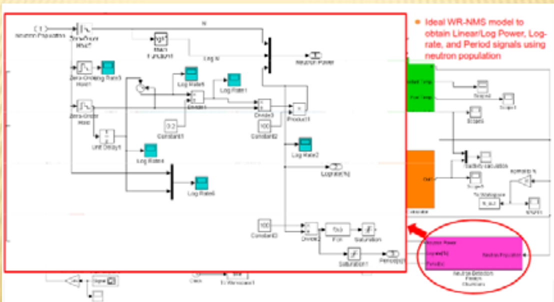
POWER CONTROLLER SIMULATION

- Rod Selection Algorithm



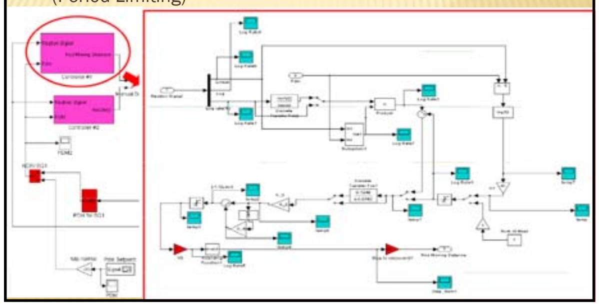
POWER CONTROLLER SIMULATION

- WR-NMS



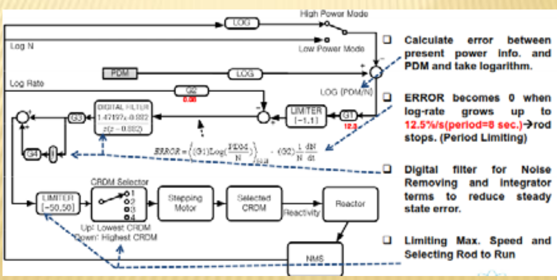
POWER CONTROLLER SIMULATION

- Power Controller
- Control Logic for PDM tracking and Log-rate Limiting (Period Limiting)

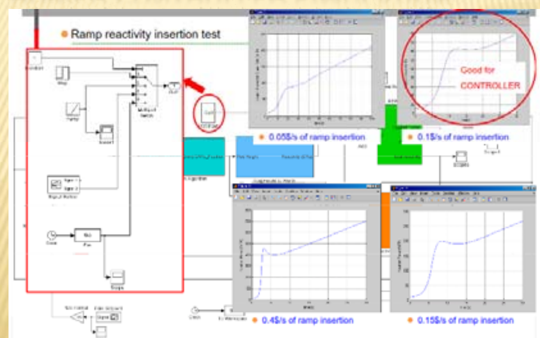


POWER CONTROLLER SIMULATION

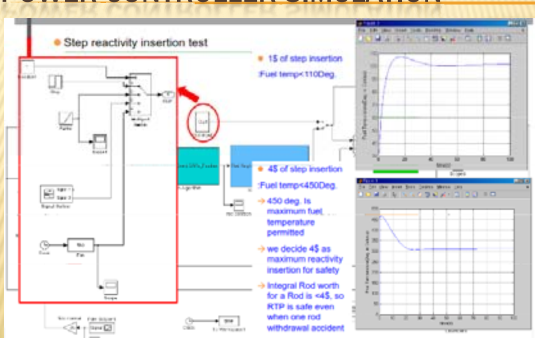
- Power Controller for PDM tracking and Period/Max. speed Limiting



POWER CONTROLLER SIMULATION

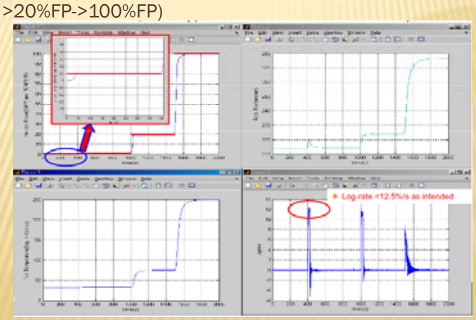


POWER CONTROLLER SIMULATION



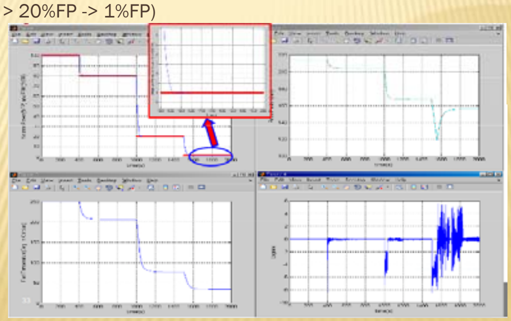
POWER CONTROLLER SIMULATION

- Case 1: NOR mode, Power-Up (PDM 0.1%FP->1%FP->20%FP->100%FP)



POWER CONTROLLER SIMULATION

- Case 2: NOR mode, Power-Down (PDM 100%FP -> 80%FP -> 20%FP -> 1%FP)



FUTURE WORKS

- Continues Development of Power Controller Simulation
- Optimization of controller parameters
- Simulation improvement
- Publishing paper

PROSPECT

- Establish new control Algorithm for Power Controller Simulation for 1MW Research Reactor for Reactor Operator Training.
- Increase the scope research for Small Medium Reactor (SMR).
- Develop Nuclear Reactor Simulator / Laboratory at Nuclear Malaysia

- QUESTION AND ANSWER SESSION

- THANK YOU FOR YOUR ATTENTIONS