Feedback Power Control for TRIGA-II Research Reactor

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1. Introduction

Experimental result on power control for a research reactor is presented. Considering various design features for reactor safety, we developed a simple and easy-to-implement controller with a limiting function of power-change-rate as well as fine tracking performance. The proposed controller has been designed, simulated, and applied to TRIGA-II type research reactor successfully.

2. Design, Simulation and Experiment

2.1 Control System Design

The reactor model in the simulation describes behaviors of the neutron and precursors, iodine and xenon, decay heat by fission products, and fuel, coolant, and reflector temperatures by means of the well-known point kinetics and dynamics model [4], which is omitted in this paper. Fig. 1 describes the designed control system (DACS, Data Acquisition and Control System) for reactor power control. DACS receives field signals including neutron detector signals and generates control command for rotating step motor connected to control rod.

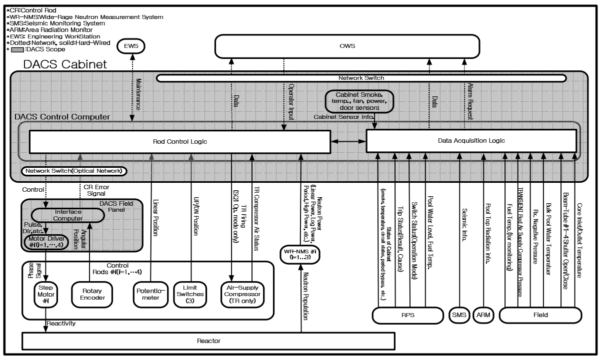

Fig. 1. MATLAB/SIMULINK Simulation Structure

2.2 Simulation and Power Controller Design

The reactor power control logic is demonstrated in Fig.2. The simulation program used to implement the control system is *SIMULINK* that is an *MATLAB* -based GUI environment for multi-domain simulation and model-based design for dynamics. The controller has been tested and proven in the simulation, which is omitted in this paper.

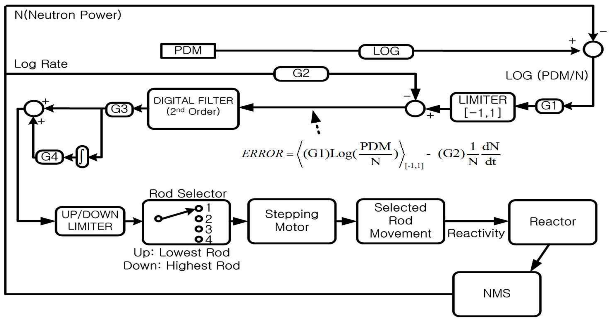

Fig. 2. Proposed Power Control Algorithm.

The control action is defined as the movement of the CAR (Control Absorber Rod) that result in reactivity insertion or removal to/from the reactor. If the control action (controller output) is positive, then the CAR is pulled up and the reactivity is inserted, and vice versa.

The main idea of power control algorithm is to track the power demand, as long as limiting the change rate of power to a pre-defined value. The control logic operates as follows.

The logarithm of the ratio of the demand power to the current power should be equal to zero at a steady state and, therefore, this value is used as an error signal for controller. The maximum reactivity change per unit time should be limited and, for this purpose, the controller is designed in such a way that the log-rate signal ($(1/N)(dN/dt)$) will not exceed 5% PP (Present Power) rate of change for the whole control process. To implement this function, we define the error signal for P-control as

$$ERROR = [(G1)Log(\frac{PDM}{N})]|_{+/-1} - (G2)\frac{1}{N}\frac{dN}{dt}.$$

Then, when the reactor output N is small, the term ERROR grows up and the P-control generates relatively big control action and $(1/N)(dN/dt)$ also grows big. Since The first term $(G1)Log(PDM/N)$ is limited in the rage [-1,1], control action grows up before $(G2/N)(dN/dt)$ becomes 1. Since we want the log-rate to be maintained below the 5%PP bound, we set as $G2$ =0.2. Then, the control action stops growing up when log-rate becomes 5%PP.
The integral control action was also adopted to reduce steady-state error. The up/down limiter finally limits the CAR speed to the permitted range.

2.2 Application to TRIGA-II Reactor

The designed controller has been simulated (omitted in this paper), and applied to an actual research reactor (TRIGA-II reactor). The RPT (Reactor Performance Test), one of the commissioning tests, shows that the proposed scheme tracks various PDMs from 0.1%FP (full power) to 100%FP properly(Fig. 3) even though there is relatively large measurement noise in neutron detectors(Fig. 4). The performance at low and very low power levels (Fig.5 and Fig.6) shows large overshoot due to the measurement noise, but this is acceptable since reactor protection system does not shutdown the reactor at low power level. Thus, overall, it is concluded that the control performance of the proposed scheme shows fine performance for research reactor power control.

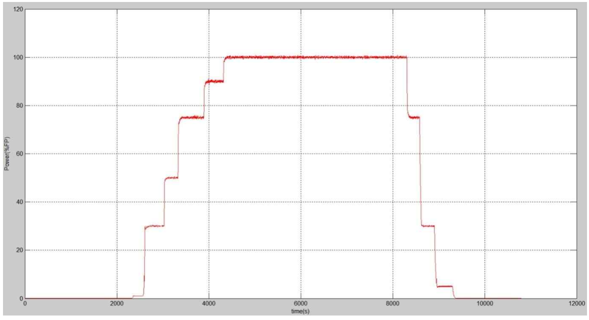

Fig. 3. Power control performance in commissioning test(during 12,000s) with the PDM changes in sequence: 0.1%, 1%, 30%, 50%, 75%, 90%, 100%, 75%, 30%, 5%, and 0.1%.

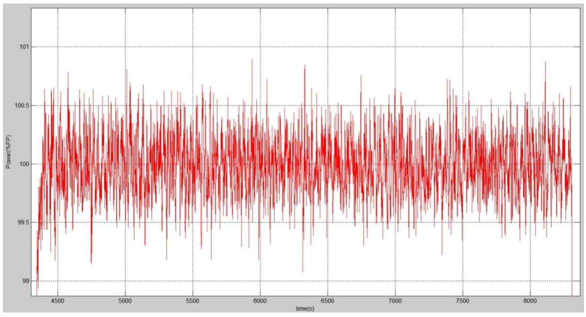

Fig. 4. Power oscillation (measurement noise) around 100%FP

In the square wave mode, which is unique to TRIGA type reactor, Fig.7 shows that the overshoot at the moment of transient rod firing (shooting up one rod to insert large reactivity, for experimental purpose) exists, but the power is soon regulated showing stable control performance.

3. Conclusion

A power control method for a TRIGA-II type research reactor has been designed, simulated, and applied to actual reactor. The control performance during commissioning test shows that the proposed controller provides fine control performance for various changes in reference values (PDM). Further research may include model-based approach with proper robustness to disturbances.

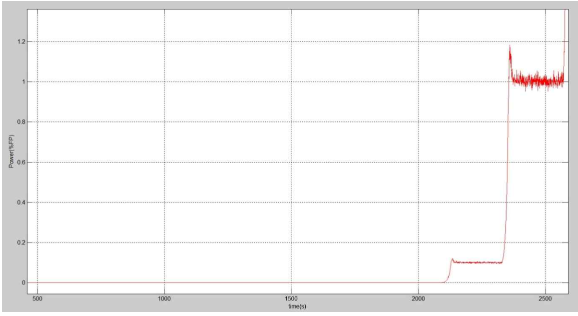

Fig. 5. Power control performance around 0.1% and 1% of power

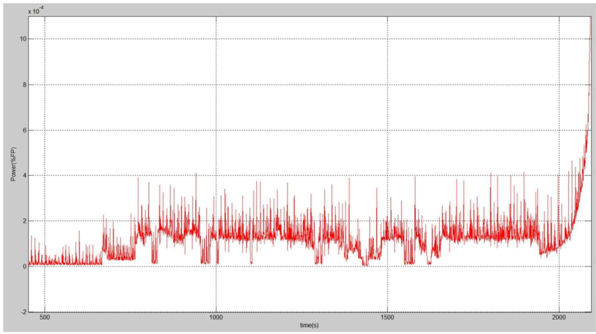

Fig. 6. Power control performance at very low power

Fig. 7. Square-Wave operation mode

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