REACTOR INSTRUMENTATION AND CONTROL

1. 370/CSMP Dynamics Simulation of PWR Power Plant, *H. Austregésilo Filho, R. Y. Hukai, V. R. Schad (IEA-Brazil)*

A mathematical model for the dynamics simulation of a PWR power plant was formulated to study response functions and control parameters of the plant under large load variations. In this simulation, models of the components of primary and secondary circuits were programmed using the Continuous System Modeling Program[1] (CSMP) language in an IBM 370/155 computer. It was shown that modeling in CSMP language can provide a simple digital computer simulation in agreement with predicted PWR power plant transients. Figure 1 is a schematic diagram of the overall control system.

For the reactor core simulation, point kinetics with 6 delayed-neutron precursors was used. The input for the kinetics equations are the reactivity due to control rod movements and feedback from fuel and coolant temperature and pressure coefficients. Temperature distribution in the fuel element and coolant was obtained using n (usually 12) heat transfer axial mesh points.

A simplified model was developed to simulate the once-through countercurrent steam generator. Six mesh points were shown to be adequate to simulate the analyzed transients. The simulated pressurizer controller was programmed to give an adequate insurge and outsurge in accordance with the thermodynamic conditions in the primary circuit. In the calculations, the primary pressure is determined by mass, volume, and energy balance and is controlled by immersion heaters and spray valves. All primary piping sections were simulated to account for the time delays.

In the secondary-circuit steam line, turbogenerator and feedwater line were simulated. The enthalpy of the steam line was considered to be constant but account was taken of the steam compressibility and momentum, and the propagation of pressure transients (40-psi peak pressure limit for steady-state operation). The turbogenerator was simulated by a single pressure stage unit; steam quality and flow change instantaneously with the electric power. The feedwater line was considered run by a constant speed pump and controlled by a flux variable feedwater valve.

The following control systems were simulated: (a) reactor control system composed of a temperature mismatch system that constantly monitors the average temperature of the coolant and compares this to a reference temperature which is a function of the electrical load demand; power mismatch system that constantly compares the thermal and electric power. This control system regulates the control rods; (b) pressurizer pressure control system that commands the heater and spray system to compensate pressure variations; (c) steam dump control system which allows large and sudden (up to 85%) load decrease through four bypass valves to the condenser. To simulate the Angra I Plant, four levels of temperature error signals corresponding to the actual four power levels were taken; (d) a simplified model was used to simulate the control system of the steam admission valve to the turbine and the feedwater control valve.

Various transients were examined including large step load rejections of 85 and 50% of full load, ±10% step load change, and 5% min ramp load increases and decreases. Satisfactory results of the plant performance and its control system were verified by comparing these results

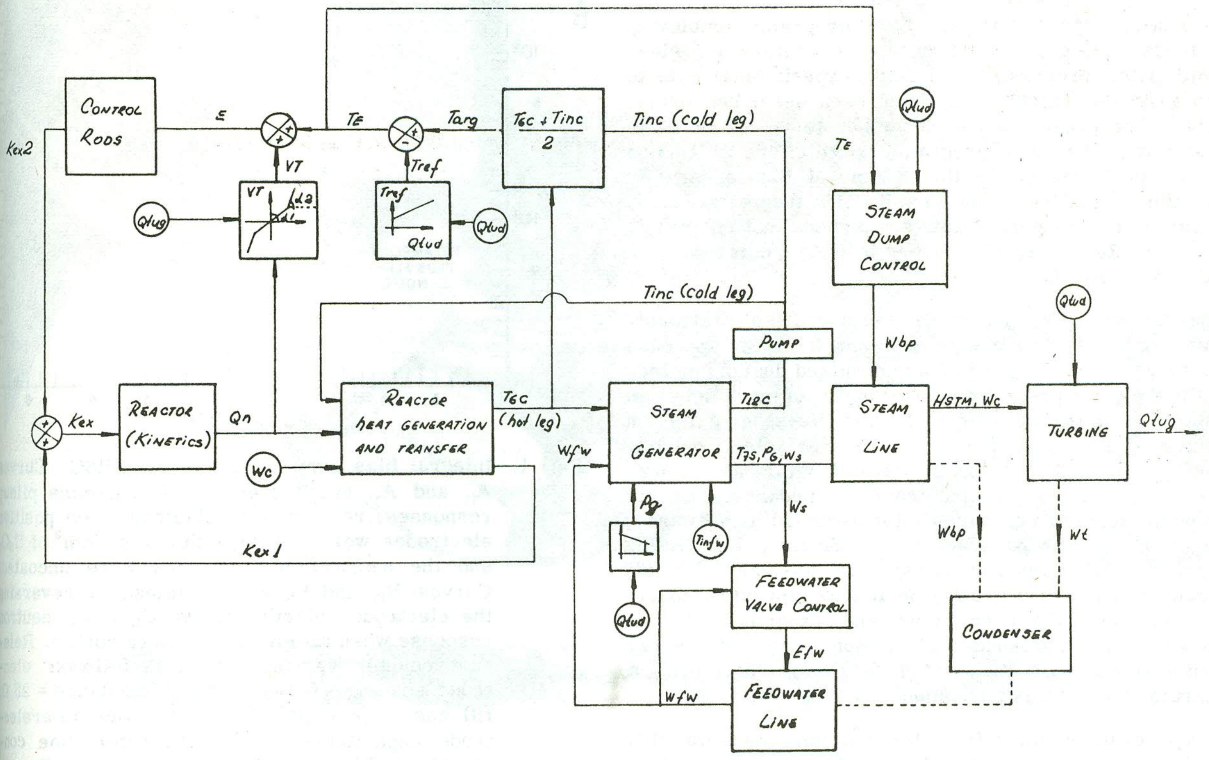

Fig. 1. Block diagram of the control system for a PWR plant.

with data available in the Angra dos Reis I PSAR[2] and open literature.[3,4]

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1. *System 370/Continuous System Modeling Program User's Manual*, IBM Application Program.

2. "Preliminary Facility Description and Safety Analysis Report," Usina Nuclear de Angra dos Reis, Unidade no. 1, Furnas Centrais Elétricas S/A., 1, *2* (1972).

3. P. T. CHRISTY and V. J. GALAN, "Power Train: General Hybrid Simulation for Reactor Coolant and Secondary System Transient Response," BAW-10070, B&W Power Generation Group, Nucl. Power Generation Topical Report (July 1973).

4. T. W. KERLIN et al., "Theoretical and Experimental Dynamic Analysis of the H. B. Robinson Nuclear Plant," *Nucl. Technol.*, 30 (Sep. 1976).

2. Analysis of a High-Sensitivity Fission Counter for Operation in High Gamma Fields, *K. H. Valentine, R. S. Burns, J. T. De Lorenzo, W. T. Clay (ORNL)*

A potential application for a high sensitivity fission counter (HSC) that can operate in high gamma fields is an ex-vessel, low-level flux monitor for an LMFBR. In this case, the anticipated design environment includes a gamma flux of 10^4 to 10^5 R/h and a maximum operating temperature of 300°F. The ex-vessel placement of the counter requires a neutron counting sensitivity of ~ 10 counts s^{-1} $[(nv)_{th}]^{-1}$. To achieve this sensitivity from a single counter, the electrode area and fissile inventory must necessarily be large ($\sim 10{,}000$ cm^2 and 20 g ^{235}U, respectively). Consequently, problems associated with interelectrode capacitance and ^{234}U alpha background are more severe than those normally encountered in fission counter design. Optimization of design variables is therefore essential to the design of a practicable HSC.

Counting channel analysis (CCA) programs, employing the fundamentals of fission counter operation and electronic pulse processing and using experimental data to normalize the calculations, have been described previously.[1] The present paper describes tests conducted to substantiate the CCA programs' predictions of fission counter performance in the regime of high sensitivity operation. In addition, the results of a theoretical study of heavy-ion transport in solids and gases (not rigorously treated in Ref. 1) which are pertinent to the design of an HSC are presented.

Since the CCA programs had not been previously applied to a practical design problem, the basic approach was to use them to predict an optimized design and then to simulate the predicted optimum, in as much detail as possible, with an experimental, variable-spacing fission counter (VSC). In addition to its variable electrode spacing, the VSC also has the capability for easy alteration of preamplifier input cable impedance, fill-gas composition and pressure, interelectrode capacitance, and pulse processing electronics. Single-pole, CR-RC filtering[2] (high pass-low pass) was assumed for all calculations and used in all experiments. Initial comparisons between CCA predictions and experimental data indicated that the model of fission fragment energy deposition was not sufficiently detailed. Therefore, a separate study of this phenomenon was necessary.

One result obtained from the transport study was that the yields of fission fragments resulting in useful pulses from positive and negative electrodes are not equal, especially when the counter is designed for high gamma fields. The differential yield increases with increasing interelectrode capacitance and increasing fill-gas pressure. This result has been verified experimentally, as demonstrated in Fig. 1, which shows integral bias curves separately for each electrode polarity (curves A_n and B_n). The discriminator setting required to reduce the count rate from a 10^5 R/h gamma dose rate to 1 count/s (estimated from the measured response at a dose rate of 2.5×10^5 R/h) (Ref. 3) is about 16 pulse-height units. At this setting, the negative electrodes (curve B_n) are about 50% more efficient in yielding useful fission pulses. Thus, adjustment of the fissile coating thickness on the positive and negative electrodes provides the designer an additional optimization variable, which apparently has no significant effect on the gamma pileup response (curves A_γ and B_γ). Pushing this example to its limit, i.e., coating only negative electrodes, could result in a counter having an equivalent neutron sensitivity (compared to

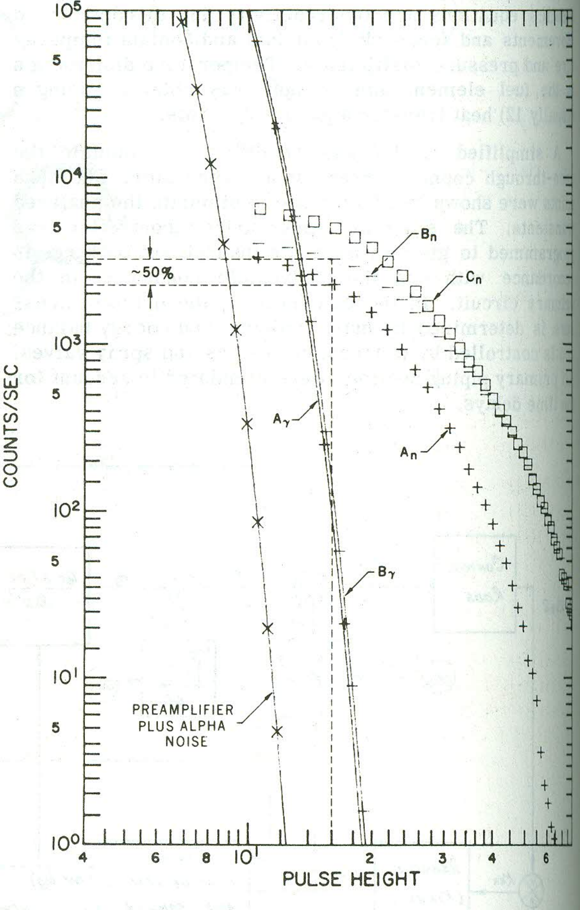

Fig. 1. Integral bias curves for a mockup HSC. Curves A_n and A_γ are the neutron and gamma pileup responses, respectively, obtained when positive electrodes were coated with 2.0 mg/cm^2 of U_3O_8 and the negative electrodes were uncoated. Curves B_n and B_γ were obtained by reversing the electrode polarity. Curve C_n is the neutron response when all electrodes were coated. Relevant counter variables were as follows: electrode spacing = 0.4 cm, cable impedance = 25 Ω, fill gas = Ar + 10% CO_2 at 724 Torr, interelectrode capacitance = 1100 pF, filter time constants = 50 ns, and interelectrode voltage = 400 V dc.