NERS 551	**Winter 2022**

Homework III Submission

February 21, 2022 — Zhuo Chen (chzhuo)

1 Formulate the prompt jump approximation in words.

The PJA is the method for an approximate treatment of the prompt jump-type flux adjustment during a gradual reactivity insertion. It consist of approximating the rapid prompt jump response of the neutron flux to changes in reactivity or independent source by an instantaneous response.

2 Derive the PJA equatinon with one group of delayed neutrons

Set Λ to zero in the six-group point-kinetic equation,

$$0 = [\rho(t) - \beta(t)]p(t) + \frac{F_0}{F(t)}\sum_k \lambda_k \zeta_k(t) \tag{1}$$

and

$$\dot{\zeta_k(t)} = -\lambda_k \zeta_k(t) + \frac{F(t)}{F_0}\beta_k(t)p(t) \tag{2}$$

Similarly, the one group kinetic equations corresponding to the prompt jump in the point reactor model are given by

$$0 = [\rho(t) - \beta(t)]p(t) + \lambda\zeta(t) \tag{3}$$

and

$$\dot{\zeta(t)} = -\lambda\zeta(t) + \beta p(t) \tag{4}$$

By eliminating $\zeta(t)$, the kinetic equation in the PJA for one delayed neutron group is obtained in the form

$$\dot{p(t)} = \frac{\lambda\rho + \dot{(\rho)}}{\beta - \rho}p(t) \tag{5}$$

3 Question 3

Explain for which type of transients PJA with one group delayed neutrons will be a good and a poor approximation compared to point kinetics with 6 delayed groups (use a sketch). PJA is more effective in short-term transient but less effective for long term transients. The power in PWR under two circuimstance are showin in Fig.1.

In a PWR, the control rod ejection is a quick transient, we would expect to see the reactor power arise in the start and then gradually die down. The second case, the stream lien breakdown,

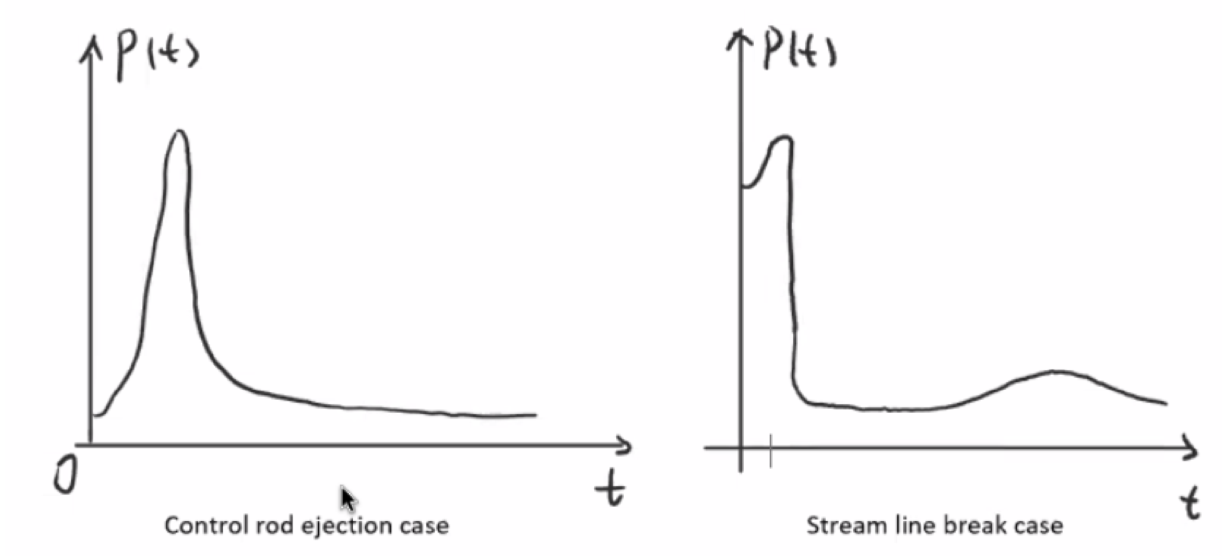

Figure 1: The p(t) for control rod ejection and stream line break in a PWR.

is a slow transient. The power rise a little, then greatly suppressed by the feedback mechanisms, therefore, it dies down relatively fast.

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0.945β must be used since in Fig.(10.2) in the textbook, this results to a relatively flat top in the curve.

From Eq.(10.49)

$$\frac{\gamma}{\beta} = -\frac{\bar{\lambda}}{p^{00}} \tag{6}$$

we have

$$p^{00} == -\frac{\bar{\lambda}\beta}{\gamma} \tag{7}$$

in this question, since $\gamma = -0.8\$/fp \cdot s$, $\bar{\lambda} = 0.4392$ and $\beta = 0.0067$, we have

$$P^{00} = -0.0036783\$$$

5 Linear Feedback

Calculate the burst width in a superprompt-critical transient with the linear energy feedback model from the formula derived in the text. For the prompt jump, $\rho_{\rho_1} = \rho_1 - \beta = 0.1\$$ and

$$p^0 = -\frac{\rho_1}{\rho_1 - \beta} p_0 = 11 p_0 \tag{8}$$

at time t_m, p^0 reaches the maximum power, and

$$t_M = \frac{\Lambda}{\rho_b} ln(\frac{\rho_b + \rho_{\rho_1}}{\rho_b - \rho_{\rho_1}}) \tag{9}$$

where,

$$\rho_b = \sqrt{\rho_{\rho_1} - 2\Lambda p^0} = 0.00137 \tag{10}$$

therefore,

$$t_M = \frac{10^{-5}}{0.00137} ln(\frac{0.00137 + 0.1 \times 0.0075}{0.00137 - 0.1 \times 0.0075}) = 0.008944s \tag{11}$$

and the maximum power is

$$P_M = p^0 - \frac{\rho^2_{rho_1}}{2\Lambda\gamma} = 11p_0 + \frac{(0.1 * 0.0075)^2}{2 \times 10^{-5} \times 0.8 \times 0.0075} p_0 = 15.6875p_0 \tag{12}$$

After the prompt jump,

$$p(t) = \frac{P_M}{cosh[\frac{\rho_b}{2\Lambda}(t - t_M)]}^2 \tag{13}$$

with approximation neglecting heat release and p_0 under the integral, we have

$$Q(t_2) = \int_0^{t_2} p(t)dt = \int_0^{2t_m} [\frac{P_M}{cosh[\frac{\rho_b}{2\Lambda}(t - t_M)]^2}]dt = 0.25p_0 \cdot s \tag{14}$$

5.1 The neglect of the heat release

For an oxide fuel rod with 0.6cm diameter,

$$\lambda_H = 0.5s^{-1}$$

then the energy deposit after the prompt jump becomes

$$Q(t_2) = \int_0^{t_2} p(t)dt = \int_0^{2t_m} [\frac{P_M e^{-\lambda_H(2t_M - t)}}{cosh[\frac{\rho_b}{2\Lambda}(t - t_M)]^2}]dt = 0.2489p_0 \cdot s \tag{15}$$

5.2 Neglect of P_0 under the feedback integral

Considering the p_0 in the integral, the energy deposit after the prompt jump becomes,

$$Q(t_2) = \int_0^{t_2} p(t)dt = \int_0^{2t_m} [\frac{P_M}{cosh[\frac{\rho_b}{2\Lambda}(t - t_M)]^2} - p_0]dt = 0.2321p_0 \cdot s \tag{16}$$