EN-634 NUCLEAR REACTOR THERMAL-HYDRAULICS
Assignment-6

1. Design a 3000 MW(th) bare cylindrical PWR, whose height to diameter ratio is 1. The fuel to coolant volume ratio is to be maintained equal to 1 in a square lattice. The system pressure and core inlet temperature shall be 175 bars and 285^o C respectively. If the reactor has to work under the following three thermal constraints,

(i) maximum power density = 250 W/cc,
(ii) Maximum clad surface heat flux = 125 W/cm^2 and,
(iii) Maximum core outlet temperature = 325^o C,

Compute,

(a) Reactor dimensions and volume,
(b) fuel element diameter and lattice pitch,
(c) number of fuel elements,
(d) mass flow rate and average coolant velocity.

You may assume: c_p of coolant = 6 kJ/kg-K, Overall peaking factor = 3.64

Note: All the rods when properly arranged forms the circle of radius R. Thus the total are of the unit cells is equal to the circle area.

2. A PWR of cylindrical shape has a thermal power of 1893 MW, radius = 1.5 m and height = 3.3 m. The extrapolated radius and height may be assumed as 1.67 m and 3.6 m respectively. The reactor is cooled by 40.8 X 10^6 kg/hour of water entering at 285^o C.

Determine,

(a) P_r , P_z and $P_{overall}$,
(b) the pressure of the system, if the exit conditions at the hot channel should be saturated liquid. Note that $h_{liquid}(T,p) = u_f(T) + pv_f(T)$. Therefore, one can take p to be approximately 150 bar and get your result using steam tables and linear interpolation.

3. It may be assumed that the power distribution in the hot channel of a BWR may be given as

$$q(z) = q_{max} e^{\frac{-\alpha z}{L}} \sin(\pi z / L)$$

where z=0, corresponds to the bottom of the channel, L is the length of the core and α is a system parameter Derive the expression for P_z.

4 Read the Section on decay heat power level in your text book (Kazimi and Todreas) in addition to your notes. Consider an Indian PHWR operating at 800 MW(th) of fission power. Calculate the value of the normalised decay heat power (P/P_o) at 1minute, 1 hour, 1 day and 1 month after shut down, if the reactor had operated for 1 day, 1 month and 1 year at full power level before being shut down. Use Way and Wigner formulation, fit for ANS-71 curve given in the class and Eq. (3.71) of your text

5.(a) Show that if the heat generation can be approximated as

$q''' = A \; I_0(\kappa r)$, where, $\kappa = \dfrac{1}{L_f}$, where L_f is the diffusion length in the fuel material, then the same can be expressed as

$$q''' = \overline{q'''}\left(\frac{\kappa r}{2}\right)\frac{I_0(\kappa r)}{I_1(\kappa R)},$$

(b) Having expressed f(α) as $\left(\dfrac{\beta}{2}\right)\dfrac{I_0(\beta\alpha)}{I_1(\beta)}$, where $\beta = \kappa R$, and $\alpha = \dfrac{r}{R}$, proceed to show that

$$M_1 = \frac{I_0(\beta) - I_0(\beta\alpha)}{2\beta I_1(\beta)},$$

6. Consider a BWR fuel pellet 12.4 mm OD, gas gap of 0.2 mm and clad thickness of 1 mm. Assuming K_{clad} = 14 W/m-K, the value of $\int kdT$ for fuel as given in Eq. 8.16 (c) in Kazimi and Todreas and clad surface maintained at 275^{o} C, compute the fuel centre line temperature for q''= 1 MW/m^2 for the cases, (a) uniform heat generation and (b) diffusion approximation with κ = 0.24 cm. You may choose to use 5500 W/m^2-K for the value of gap conductance.