1 (d)

2 (a)

3 (c)

4 (c)

5 (c), (d)

6 (a)

7 (a), (b)

8 (a)

9 i - (B), ii - (C), iii - (D), iv - (E), v - (A)

## 10 After separation in area -1:

(1) For generation-load balance in area -1, we have,

$$3.0 \times (1 + 1.5\frac{\Delta f}{f_o}) = 2.0 \times (1 - 10\frac{\Delta f}{f_o})$$

Solving for $\Delta f$ we get,

$\Delta f$ = -2.04 Hz

Therefore, the steady state frequency in area- 1 is **47.96** Hz.

(2) To determine the variation of centre of frequency $\Delta f(t)$, the swing equation is written in the COI frame as follows:

$$\sum M_i \frac{d\omega_i}{dt} = \sum Pmi - \sum Pei \quad (1)$$

$$M_T \frac{d\omega_{COI}}{dt} = \sum Pmi - \sum Pei \quad (2)$$

Therefore,

$$M_T \frac{d\omega_{COI} - \omega_B}{dt} = M_T \frac{d\Delta\omega_{COI}}{dt} = \sum Pmi - \sum Pei \quad (3)$$

where, $M_i = \frac{2H_i}{\omega_B}$, $\sum M_i\omega_i = M_T\omega_{COI}$ and $M_T = \sum M_i$

Using the given values of $H_i$, $M_T$ = 0.0573 (MJ/MVA)/rad s$^{-1}$

We can reconize that

$$\sum Pmi - \sum Pei = 2.0 \times (1 - 10\frac{\Delta f}{f_o}) - 3.0 \times (1 + 1.5\frac{\Delta f}{f_o})$$

Taking $\Delta f = \frac{\omega_{COI} - \omega_B}{2 * \pi} = \frac{\Delta\omega_{COI}}{2 * \pi}$, we have

$$\sum Pmi - \sum Pei = -0.078\Delta\omega_{COI} - 1 \tag{4}$$

Using (4) in (2) we get,

$$0.0573\frac{d\Delta\omega_{COI}}{dt} = -0.078\Delta\omega_{COI} - 1$$

or

$$0.7345\frac{d\Delta\omega_{COI}}{dt} = -\Delta\omega_{COI} - 12.8205 \tag{5}$$

Now, taking Laplace transform on both sides and rearranging the terms we get,

$$\Delta\omega_{COI}(s) = \frac{-12.8205}{s(1+s0.7345)}$$

The time domain response is given as follows:

$$\omega_{COI}(t) = -12.8205(1-e^{\frac{-t}{0.7345}}) \ \ \texttt{rad/s}$$

The settling time constant is **0.7345 s.** The settling time is nearly 4 to 5 times this value.

(3) For a steady state frequency dip of 49.5 - 50 = -0.5 Hz ($\Delta f$), the new generation is

$$2.0 \times (1 - 10\frac{\Delta f}{f_o}) = 2.2 \ \ \texttt{p.u.}$$

and the load on the system is:

$$3.0 \times (1 + 1.5\frac{\Delta f}{f_o}) = 2.955 \ \ \texttt{p.u.}$$

For generation-load balance the amount of load to be shed is (2.955 -2.2)= **0.755** p.u.