Solution 1

4.8 Using the turbine/governor model of (4.100) and (4.116), with

$T_{SV} = 0.2$ sec $\quad P_C = 0.7$ pu $\quad R_D = 0.05$ pu
$T_{CH} = 0.4$ sec $\quad \omega_s = 2\pi\, 60$ r/s

(a) Find the steady-state values of P_{SV} and T_M if $\omega = 376.9$ r/s.
(b) Find the dynamic response of P_{SV} and T_M if ω changes at time zero to be 376.8 r/s.

Eqn 4.100;

$$T_{CH} \cdot \frac{dT_M}{dt} = -T_M + P_{SV}$$

Eqn 4.116;

$$T_{SV} \cdot \frac{dP_{SV}}{dt} = -P_{SV} + P_C - \frac{1}{R_D}\left(\frac{\omega}{\omega_s} - 1\right)$$

(a) in steady state;

$$0 = -T_M + P_{SV} \longrightarrow P_{SV} = T_M$$

$$0 = -P_{SV} + P_C - \frac{1}{R_D}\left(\frac{\omega}{\omega_s} - 1\right)$$

$$P_{SV} = P_C - \frac{1}{R_D}\left(\frac{\omega}{\omega_s} - 1\right)$$

$$= 0.7 - \frac{1}{0.05}\left(\frac{376.9}{2\pi \cdot 60} - 1\right)$$

$$\boxed{\begin{aligned} P_{SV} &= 0.7048\,\text{pu} \\ \therefore T_M &= 0.7048\,\text{pu} \end{aligned}}$$

(b) Plugging in all known values, the differential equations become;

$$0.4 \cdot \frac{dT_M}{dt} = -T_M + P_{SV} \quad \text{— } 1$$

$$0.2\,\frac{dP_{SV}}{dt} = -P_{SV} + 0.7 - \frac{1}{0.05}\left(\frac{376.8}{2\pi \cdot 60} - 1\right)$$

$$0.2\,\frac{dP_{SV}}{dt} = -P_{SV} + 0.7101 \quad \text{— } 2$$

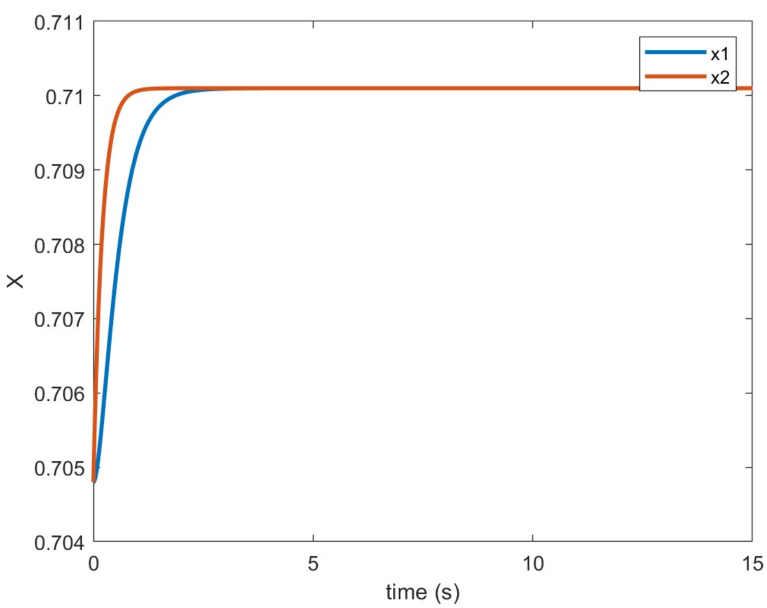
$T_M = x$, $P_{SV} = y$

$$\dot{x} = \frac{1}{0.4}(-x + y)$$

$$\dot{y} = \frac{1}{0.2}(-y + 0.7101)$$

initial values:
$x(0) = 0.7048$
$y(0) = 0.7048$

You can use any method to solve the above differential equations.
I used RK2 code from previous assignment (HW1)



$x1 = T_M$
$x2 = P_{SV}$

Solution 2

Open PowerWorld

Go to case summary (under Case Information)

MW Generation = 1449.4 MW

MVar Generation = 406.1 MVar

Total Generation MVA = 1505.22 MVA

Generator at bus 3 = 254.01 MVA ($\therefore$ 250 MW, 45 MVar)

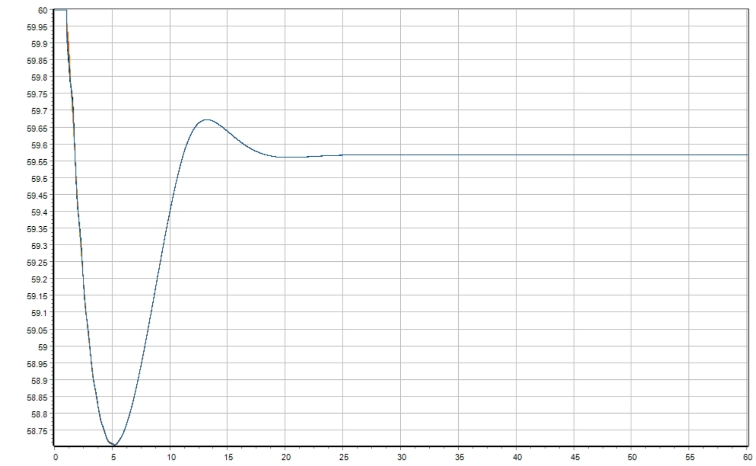
$$\Delta f = \frac{-R \times \Delta P_{gen,MW}}{\sum_{\text{online Gens}} S_{i,MVA}}$$

$$= \frac{-0.05 \times 250}{1850} = -0.00676 \text{ pu}$$

$$\approx -0.405 \text{ Hz}$$

Final frequency = 60 − 0.405 Hz

= 59.59 Hz



FROM POWERWORLD.

f = 59.55 Hz (approx.)

Solution 3

In steady state, the block diagram will reduce to;

$P_{ref} = R_{perm} \times P_{mech} + \Delta\omega$ (in steady state, $\Delta\omega = 0$)

$\therefore P_{ref} = 0.05 \times 1$

$= 0.05$ pu.

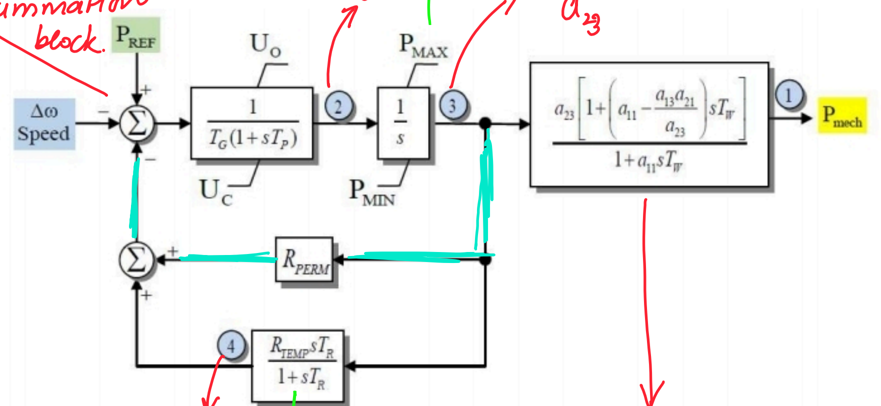
at this summation block.

integrator block

P_{mech}

a_{23}

0



0

derivative block

can be broken into 2 blocks.

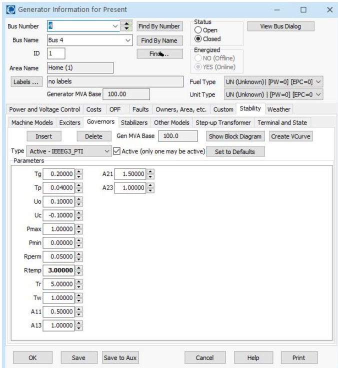
$$\boxed{\frac{a_{23}}{1+a_{11}sT_w}} + \boxed{\frac{(a_{23}a_{11} - a_{13}a_{21})sT_w}{1+a_{11}sT_w}}$$

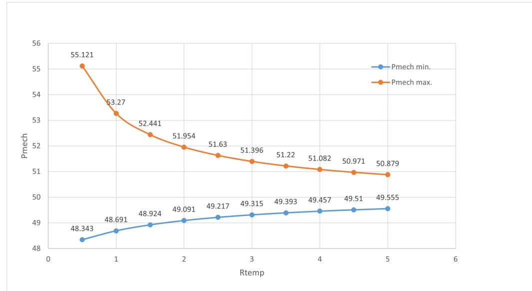
first order lag block

derivative block.

Solution 4

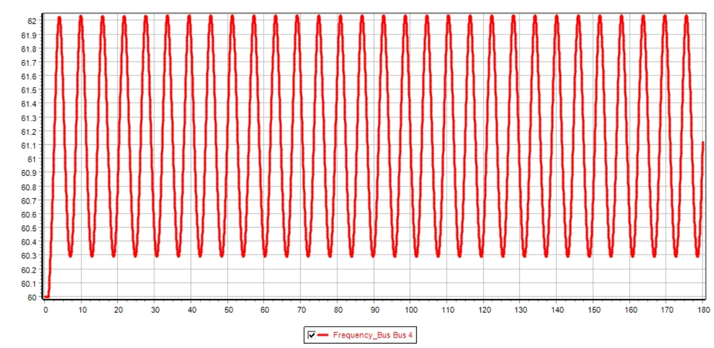
Rtemp can be changed in the generator dialog box.





Solution 5

Keeping K_i and K_d as zero, the value of K_p is varied to obtain marginally stable bus frequency. The below marginally stable bus frequency is obtained at $K_p = 10.9$



Thus $K_u = 10.9$ and $T_u = 6.0$

For PID tuning;

$K_p = 0.6\, K_u = 6.54$

$K_i = 2 \times \frac{K_p}{T_u} = 2.18$

$K_d = \frac{K_p * T_u}{8} = 4.905$

Using these tuning parameters, the bus frequency behaves as below: The freq settles at 60.428 Hz.