KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

ELECTRICAL ENGINEERING DEPARTMENT

EE 520 – Term 131

HW # 4: Stability Studies

From Text: 11.5; 11.7; 11.14 (using MATLAB)

Key Solutions

11.5. Two synchronous generators represented by a constant voltage behind transient reactance are connected by a pure reactance $X = 0.3$ per unit, as shown in Figure 91. The generator inertia constants are $H_1 = 4.0$ MJ/MVA and $H_2 = 6$ MJ/MVA, and the transient reactances are $X_1' = 0.16$ and $X_2' = 0.20$ per unit. The system is operating in the steady state with $E_1' = 1.2$, $P_{m1} = 1.5$ and $E_2' = 1.1$, $P_{m2} = 1.0$ per unit. Denote the relative power angle between the two machines by $\delta = \delta_1 - \delta_2$. Referring to Problem 11.4, reduce the two-machine system to an equivalent one-machine against an infinite bus. Find the inertia constant of the equivalent machine, the mechanical input power, and the amplitude of its power angle curve, and obtain the equivalent swing equation in terms of δ.

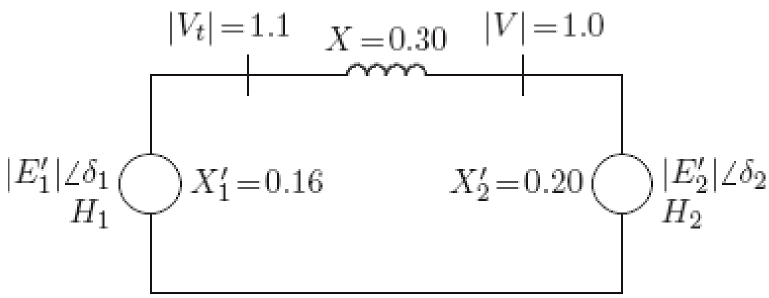

FIGURE 91
System of Problem 11.5.

Referring to Problem 11.4, the equivalent parameters are

$$H = \frac{(4)(6)}{4+6} = 2.4 \ \text{ MJ/MVA}$$

$$P_m = \frac{(6)(1.50) - (4)(1)}{4+6} = 0.5 \ \text{ pu}$$

$$P_{e1} = \frac{|E_1||E_2|}{X} \sin(\delta_1 - \delta_2) = \frac{(1.2)(1.1)}{0.66} \sin\delta = 2\sin\delta$$

Since $P_{e2} = -P_{e1}$, we have

$$P_e = \frac{(6)(2\sin\delta) + (4)(2\sin\delta)}{4+6} = 2\sin\delta$$

Therefore, the equivalent swing equation is

$$\frac{2.4}{(180)(60)} \frac{d^2\delta}{dt^2} = 0.5 - 2\sin\delta$$

or

$$\frac{d^2\delta}{dt^2} = 4500(0.5 - 2\sin\delta) \quad \text{where } \delta \text{ is in degrees}$$

11.7. A three-phase fault occurs on the system of Problem 11.6 at the sending end of the transmission lines. The fault occurs through an impedance of 0.082 per unit. Assume the generator excitation voltage remains constant at $E' = 1.25$ per unit. Obtain the swing equation during the fault.

The impedance network with fault at bus 1, and with with $Z_f = j0.082$ is shown in Figure 93.

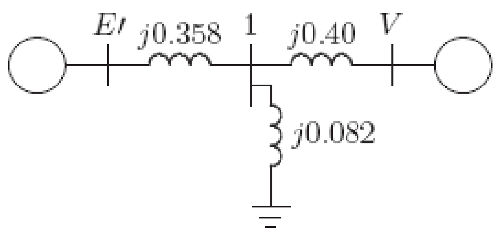

FIGURE 93
Impedance network with fault at bus 1.

Transforming the Y-connected circuit in Figure 93 into an equivalent Δ, the transfer reactance between E' and V is

$$X = \frac{(0.358)(0.082) + (0.358)(0.4) + (0.4)(0.082)}{0.082} = 2.5 \text{ pu}$$

$$P_{2\,max} = \frac{(1.25)(1)}{2.5} = 0.5$$

Therefore, the swing equation during fault with δ in radians is

$$0.03\frac{d^2\delta}{dt^2} = 0.77 - 0.5\sin\delta$$

11.14. The machine of Problem 11.6 is delivering a real power input of 0.77 per unit to the infinite bus at a voltage of 1.0 per unit. The generator excitation voltage is $E' = 1.25$ per unit. Use **eacpower(P_m, E, V, X)** to find
(a) The maximum power input that can be added without loss of synchronism.
(b) Repeat (a) with zero initial power input. Assume the generator internal voltage remains constant at the value computed in (a).

In Problem 11.6, the transfer reactance and the generator internal voltage were found to be $X = 0.758$ pu, and $E' = 1.25$ pu.

We use the following commands

```
disp('(a) Initial real power P0 = 0.77')
P0 = 0.77; E = 1.25; V = 1.0; X = 0.758;
h=figure;
eacpower(P0, E, V, X)
h=figure;
disp('(b) Zero initial power ')
P0 = 0;
eacpower(P0, E, V, X)
```

which result in

```
(a) Initial real power P0 = 0.77
Initial power                     =  0.770 p.u.
Initial power angle               = 27.835 degrees
Sudden additional power           =  0.649 p.u.
Total power for critical stability =  1.419 p.u.
Maximum angle swing               =120.617 degrees
New operating angle               = 59.383 degrees
Current plot held
(b) Zero initial power
Initial power                     =  0.000 p.u.
Initial power angle               =  0.000 degrees
Sudden additional power           =  1.195 p.u.
Total power for critical stability =  1.195 p.u.
Maximum angle swing               =133.563 degrees
New operating angle               = 46.437 degrees
```