

ECEN 667 Fall 2023 Homework 6

Due on Tuesday Nov 21, 2023

1. In the Lecture 18 single cage induction motor example (introduced on slide 16) determine the operating slip if R_r is changed to 0.04 and X_r is changed to 0.05 with the load still consuming 100 MW of real power.

This problem can be solved in multiple ways. It can be solved analytically by hand, by using Powerworld, or by coding in MATLAB.

In this solution, it is solved by code.

```
Rs=0.01;
Xs=0.06;
Xm=4.0;
ws = 2*pi*60;
Pe = 0.8;

Rr=0.04;
Xr=0.05;

Xp = Xs+(Xr*Xm)/(Xr+Xm);
X = Xs+Xm;
Top = (Xr+Xm)/(ws*Rr);

VD=0.995;
VQ=0;

syms s ID IQ EDP EQP;

func = [EDP + Rs*ID - Xp*IQ - VD;
EQP + Rs*IQ + Xp*ID - VQ;
ws*s*EQP - (1)*(EDP + (X-Xp)*IQ)/Top;
-1*ws*s*EDP - (1)*(EQP - (X-Xp)*ID)/Top;
Pe - VD*ID - VQ*IQ];

j = jacobian([func(1),func(2),func(3),func(4),func(5)],[s ID IQ EDP EQP]);
x = [0.01; 1; 1; 1; 1];

for i=1:5
    J = subs(j,[s ID IQ EDP EQP], transpose(x));
    J = double(J);
    J = inv(J);

    temp = subs(func,[s ID IQ EDP EQP], transpose(x));
    temp = double(temp);
    x = x - (J*temp);
end

display(x);
```

```
x =
    0.0338
    0.8040
   -0.3146
    0.9525
   -0.0848
```

2. Using the case **B2_IndMotor_DoubleCage** use PowerWorld to plot the torque-speed curve. Then vary the induction motor parameters to determine their impact on the torque-speed curve. Which parameters are most important in increasing the starting torque?

The induction motor in the PW case has multiple parameters that can be changed. The impact of Ra, Xa, R1, X1, R2 and X2 is shown in the table below:

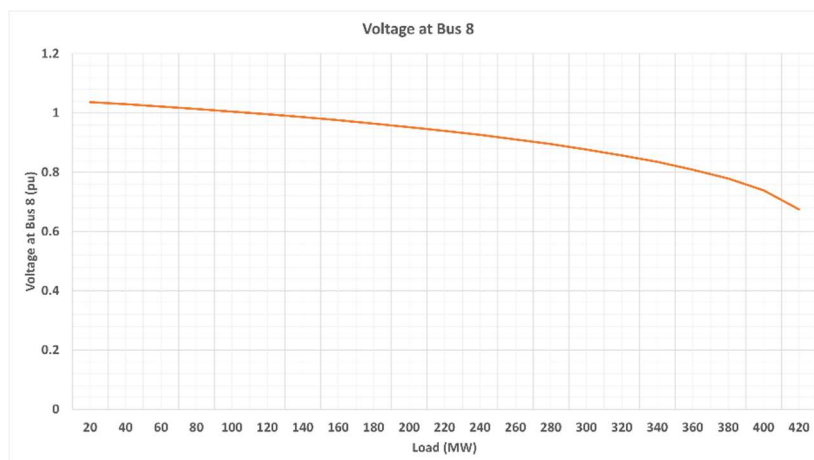
Case	1	2	3	4	5	6	7	8
Ra	0	0.05						
		starting torque reduced						
Xa	0.1	0.06	0.3					
		starting torque reduced						
Xm	4	4	4	20				
				no effect				
R1	0	0.03	0.03	0.03	0.15			
					starting torque increased			
X1	0	0.04	0.04	0.04	0.04	0.2		
					reduced starting torque			
R2	0	0.01	0.01	0.01	0.01	0.01	0.05	
							starting torque increased	
X2	0.1	0.08	0.08	0.08	0.08	0.08	0.08	0.4
								starting torque increased

Case	9	10	11	12	13	14	15
Ra	0	0.0001					
		starting torque slightly increased					
Xa	0.1		0.04				
		starting torque increased significantly					
Xm	4	4	4	1			
				dec. slight			
R1	0	0.03	0.03	0.03	0.01		
					starting torque halved		
X1	0	0.04	0.04	0.04	0.04	0.01	
					starting torque increased significantly		
R2	0	0.01	0.01	0.01	0.01	0.01	0.001
						graph shape changed	
X2	0.1	0.08	0.08	0.08	0.08	0.08	0.08
							starting torque decreased

Above 12 cases are simulated by changing one parameter at a time. For the first 6 cases the values are increased and their effect on Torque-Speed Graph is observed. For the last 6 cases the values are decreased and their effect on Torque-Speed Graph is observed. The parameters that significantly decrease or increase the starting torque are Ra, Xa, X1, R2, X2.

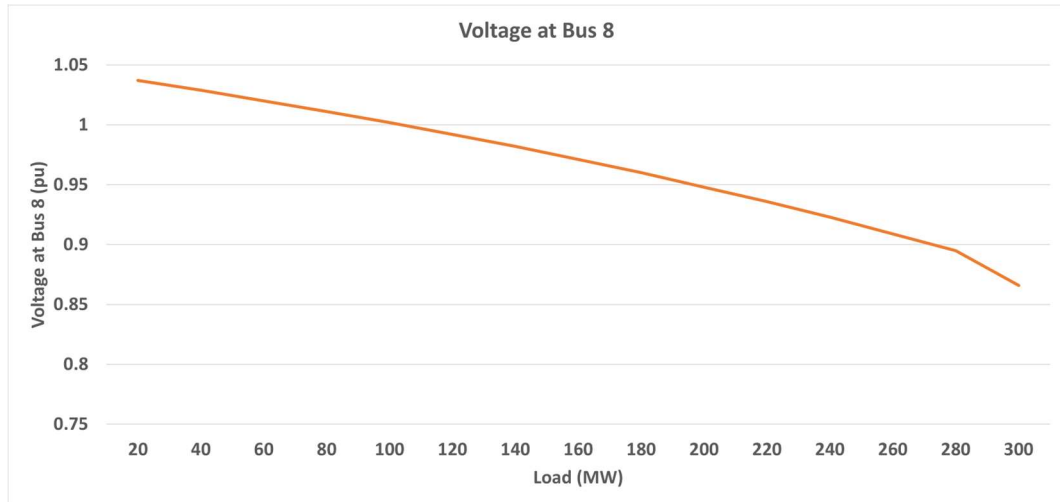
3. Book Problem 7.1 using PowerWorld with the case **HW6_Prob_3a** except varying the real and reactive power load at bus 8 in 20 MW increments (with the Mvar scaled as well keeping the initial 2 P/Q ratio) starting at 20 MW until you reach maximum loadability. Plot the voltage at bus 8.

Load at bus 8 is increased from 20MW to 420MW in the steps of 20MW. Below graph is obtained:



- Repeat Problem 3, except using the case **HW6_Prob_3b case**, which is similar to the book Problem 7.2 using participation factor AGC control and modeling reasonable reactive power limits.

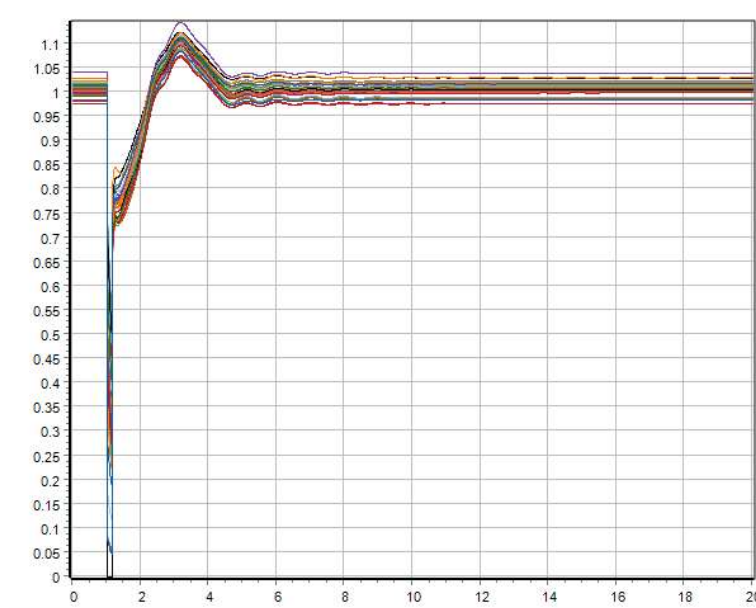
The increase in load in the previous problem is made up mostly by the slack bus. The participation factor of slack bus generator is decreased while it is increased for the other two generators. The following PV curve is obtained:



As observed the nose point is reached earlier. This case now has realistic reactive power limits instead of really large values used in the previous problem.

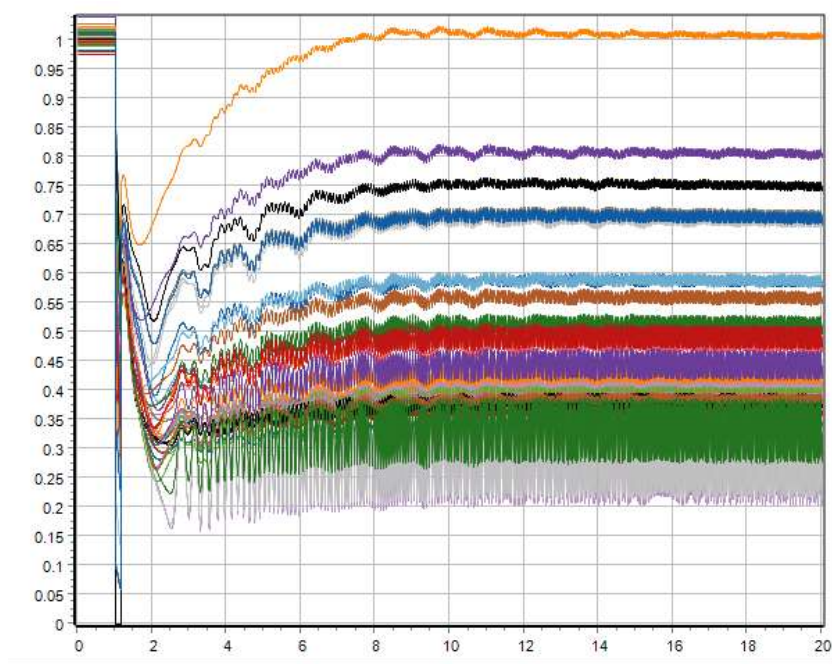
- In PowerWorld open the **HW6_Prob5_37BusCLOD case**, which represents the loads at all the buses using the CLOD model discussed in class. The contingency is a nine cycle fault on the line between buses 28 and 31, cleared by opening the line. In the Model Explorer select **Transient Stability, and Load Characteristics** to view and change the CLOD model parameters. Comment on the impact of varying the percentage of large motors, small motors, discharge lighting and constant power load.

Running transient stability without any change gives the following result. The system settles to an equilibrium after an initial overshoot.

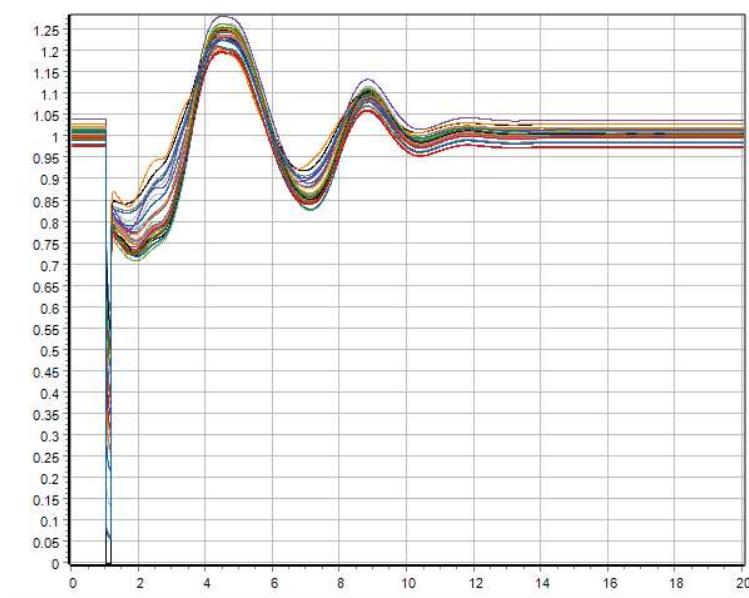


To truly understand the impact of each component, each one is changed to a maximum (i.e. 100%)

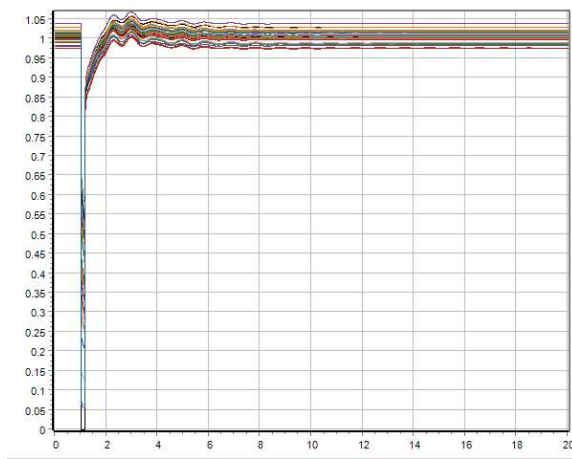
With Large motors at 100% (rest at 0), the following plot is obtained. The system does not seem to settle to a stable equilibrium.



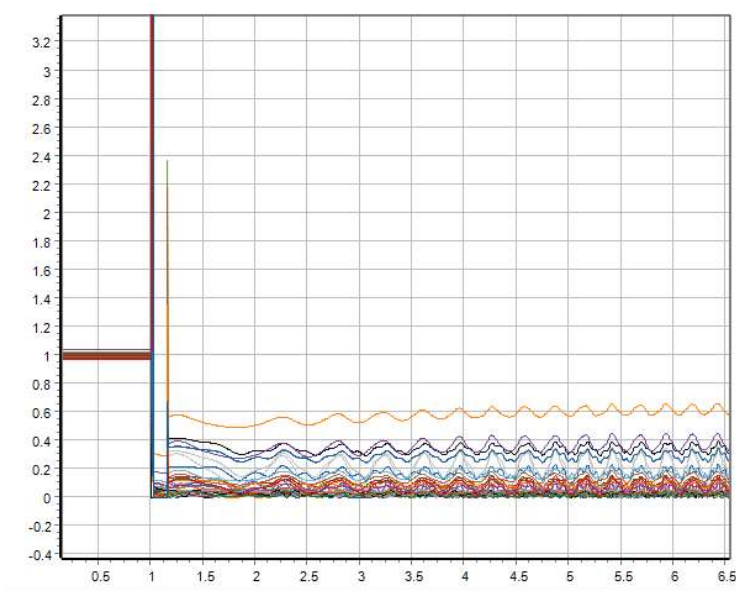
With Small motors at 100% (rest at 0), the following plot is obtained. The system settles to a stable equilibrium after a few oscillation cycles.



Now, with discharge lighting at 100% (rest at 0), the following plot is obtained. The system settles to a stable equilibrium and does not experience as many oscillations.



Finally, with constant power load at 100% (rest at 0), the voltages spike and collapses. This can be attributed to the lack of reactive power flow in the system.

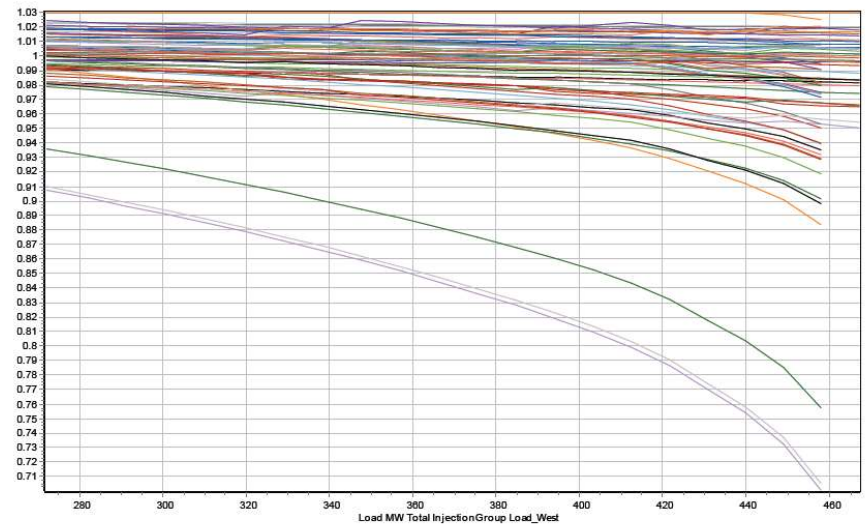


6. In PowerWorld using the case **HW6_Bus37_PV** do PV curve analysis except rather than using the base case, do it what you think is the worst single line contingency (from a PV perspective). Use the case load increment value of 10 MW. You can ignore transmission and transformer flow limits, and bus voltage magnitude limits. Turn in your results.

There are multiple ways to define worst case contingency. When the line between bus Oak69 and Walnut69 as a contingency, the surrounding lines get overloaded and Powerworld indicates it as critical.

Contingency Scenario	Crit ▼	Plot?
L_000012OAK69-000018WALNUT69C1	YES	<input checked="" type="checkbox"/>

The change in bus voltages is as below. There is not much variation in the PV curve.



While looking at the plot by itself it doesn't look like a worst-case contingency, but this plot can be compared with another randomly selected contingency: Opening the line between Redbus69 and Peach69. The knee-point or nose point is obtained at a much higher loading!

