16:332:599:02 – Smart Grid
Project Report

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May 9th, 2018

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1 Case Study/Problem Formulation

For the single-line diagram in Figure 4 convert all positive-sequence impedance, load, and voltage data to per unit using the given system base quantities. Run the power flow program and obtain the bus, line, and transformer input/output voltages

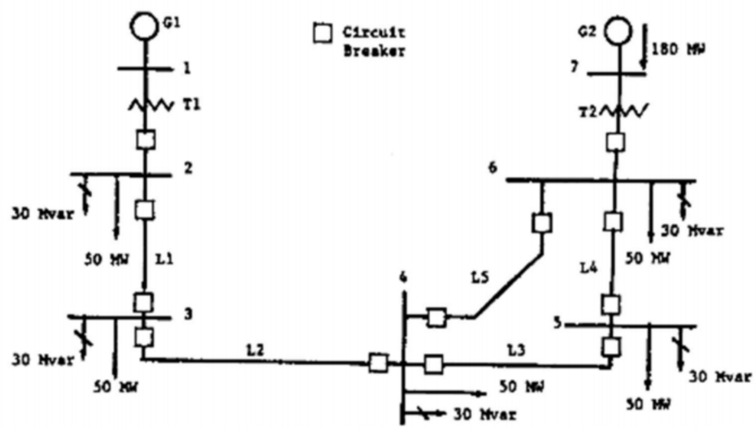

Figure 1: Original Circuit

Generator Ratings	
G1	$100MVA$, $13.8kV$, $x'' = 0.12$
G2	$200MVA$, $15.0kV$, $x'' = 0.12$
The generator neutrals are solidly grounded	

Transformer Ratings	
T1	$100MVA$, $13.8kV\Delta/230kVY$, $x = 0.1$ per unit
T2	$200MVA$, $15kV\Delta/230kVY$, $x = 0.1$ per unit
The transformer neutrals are solidly grounded	

Transmission Line Ratings	
All Lines	$230kV$, $z_1 = 0.08 + j0.5\Omega/km$, $y_1 = j3.3E-6S/km$, $Max\ MVA = 400$
Line Lengths	$L_1 = 15km$, $L_2 = 20km$, $L_3 = 40km$, $L_4 = 15km$, $L_5 = 50km$

Power Flow Data	
Bus 1	Swing bus $V_1 = 13.8kV$, $\partial_1 = 0°$
Bus 2, 3, 4, 5, 6	Load buses
Bus 7	Constant voltage magnitude bus, $V_7 = 15kV$, $P_{G7} = 180MW$, $-87MVAr < Q_{G7} < +87MVAr$

System Base Quantities
$S_{base} = 100MVA$ (three-phase)
$V_{base} = 13.8kV$ (line-to-line) in the zone of G_1

Table 1: Circuit Values

2 Detailed Solution

2.1 Calculating Per Unit Values

$$per\ unit\ (pu)\ value = \frac{Actual\ value}{Base\ value}$$

In zone $G1$, base values are,

$$S_{base} = 100MVA$$

$$V_{base_{L-L}} = 13.8kV$$

@ $G1$

$$S_{G1_{(pu)}} = \frac{100MVA}{100MVA} = \boxed{1pu}$$

$$V_{G1_{(pu)}} = \frac{13.8kV}{13.8kV} = \boxed{1pu}$$

$$x''_{(new)} = \boxed{0.12pu}$$

@ $T1$

$$S_{T1_{(pu)}} = \frac{100MVA}{100MVA} = \boxed{1pu}$$

$$V_{T1_{(pu)}} = \frac{13.8kV}{13.8kV} = \boxed{1pu}$$

$$x_{(pu)} = \boxed{0.1pu}$$

@ Bus 2

$$Q_{Load} = 30MVAr$$

$$Q_{Load_{(pu)}} = \frac{30MVAr}{100MVA} = \boxed{0.3pu}$$

$$P_{Load} = 50MW$$

$$P_{Load_{(pu)}} = \frac{50MW}{100MVA} = \boxed{0.5pu}$$

@ L_1

$$L_1 = 15km$$

$$z = 0.08 + j0.5\Omega/km$$

$$Z_{total} = (15km)(0.08 + j0.5\Omega/km) = \boxed{1.2 + j7.5\Omega}$$

$$\theta = tan^{-1}\left(\frac{7.5}{1.2}\right) = \boxed{80.91°}$$

$$|Z_{total}| = \sqrt{(1.2)^2 + (7.5)^2} = \boxed{7.59539\Omega}$$

$$Z_{total} = \boxed{7.59539\angle 80.91°\Omega}$$

$$Z_{total_{(pu)}} = 7.595 \cdot \left(\frac{100MVA}{(230kV)^2}\right) = \boxed{0.014358pu}$$

@ Bus 3

$$Q_{Load} = 30MVAr$$

$$Q_{Load_{(pu)}} = \frac{30MVAr}{100MVA} = \boxed{0.3pu}$$

$$P_{Load} = 50MW$$

$$P_{Load_{(pu)}} = \frac{50MW}{100MVA} = \boxed{0.5pu}$$

@ Bus 4

$$Q_{Load} = 30MVAr$$

$$Q_{Load_{(pu)}} = \frac{30MVAr}{100MVA} = \boxed{0.3pu}$$

$$P_{Load} = 50MW$$

$$P_{Load_{(pu)}} = \frac{50MW}{100MVA} = \boxed{0.5pu}$$

@ Bus 5

$$Q_{Load} = 30MVAr$$

$$Q_{Load_{(pu)}} = \frac{30MVAr}{100MVA} = \boxed{0.3pu}$$

$$P_{Load} = 50MW$$

$$P_{Load_{(pu)}} = \frac{50MW}{100MVA} = \boxed{0.5pu}$$

@ Bus 6

$$Q_{Load} = 30MVAr$$

$$Q_{Load_{(pu)}} = \frac{30MVAr}{100MVA} = \boxed{0.3pu}$$

$$P_{Load} = 50MW$$

$$P_{Load_{(pu)}} = \frac{50MW}{100MVA} = \boxed{0.5pu}$$

@ L_2

$$L_2 = 20km$$

$$z = 0.08 + j0.5\Omega/km$$

$$Z_{total} = (20km)(0.08 + j0.5\Omega/km) = \boxed{1.6 + j10\Omega}$$

$$\theta = tan^{-1}\left(\frac{10}{1.6}\right) = \boxed{80.91°}$$

$$|Z_{total}| = \sqrt{(1.6)^2 + (10)^2} = \boxed{10.127191\Omega}$$

$$Z_{total} = \boxed{10.127191\angle 80.91°\Omega}$$

$$Z_{total_{(pu)}} = 10.127191 \cdot \left(\frac{100MVA}{(230kV)^2}\right) = \boxed{0.019144pu}$$

@ L_3

$$L_3 = 40km$$

$$z = 0.08 + j0.5\Omega/km$$

$$Z_{total} = (40km)(0.08 + j0.5\Omega/km) = \boxed{3.2 + j20\Omega}$$

$$\theta = tan^{-1}\left(\frac{20}{3.2}\right) = \boxed{80.91°}$$

$$|Z_{total}| = \sqrt{(3.2)^2 + (20)^2} = \boxed{20.254382\Omega}$$

$$Z_{total} = \boxed{20.254382\angle 80.91°\Omega}$$

$$Z_{total_{(pu)}} = 20.254382 \cdot \left(\frac{100MVA}{(230kV)^2}\right) = \boxed{0.038288pu}$$

@ L_4

$$L_4 = 15km$$

$$z = 0.08 + j0.5\Omega/km$$

$$Z_{total} = (15km)(0.08 + j0.5\Omega/km) = \boxed{1.2 + j7.5\Omega}$$

$$\theta = tan^{-1}\left(\frac{7.5}{1.2}\right) = \boxed{80.91°}$$

$$|Z_{total}| = \sqrt{(1.2)^2 + (7.5)^2} = \boxed{7.59539\Omega}$$

$$Z_{total} = \boxed{7.59539\angle 80.91°\Omega}$$

$$Z_{total_{(pu)}} = 7.595 \cdot \left(\frac{100MVA}{(230kV)^2}\right) = \boxed{0.014358pu}$$

@ L_5

$$L_5 = 50km$$

$$z = 0.08 + j0.5\Omega/km$$

$$Z_{total} = (50km)(0.08 + j0.5\Omega/km) = \boxed{4 + j25\Omega}$$

$$\theta = tan^{-1}\left(\frac{25}{4}\right) = \boxed{80.91°}$$

$$|Z_{total}| = \sqrt{(4)^2 + (25)^2} = \boxed{25.317978\Omega}$$

$$Z_{total} = \boxed{25.317978\angle 80.91°\Omega}$$

$$Z_{total_{(pu)}} = 25.317978 \cdot \left(\frac{100MVA}{(230kV)^2}\right) = \boxed{0.04786pu}$$

@ Bus 7

$$P_{G7_{(pu)}} = \frac{180MW}{100MVA} = \boxed{1.8pu}$$

$$\frac{-87MVAr}{100} < Q_{G7_{(pu)}} < \frac{87MVAr}{100}$$

$$-0.87pu < Q_{G7_{(pu)}} < 0.87pu$$

$$V_{T2_{(pu)}} = \frac{15kV}{13.8kV} = \boxed{1.086956pu}$$

2.1.1 Per-Unit One-Line Model

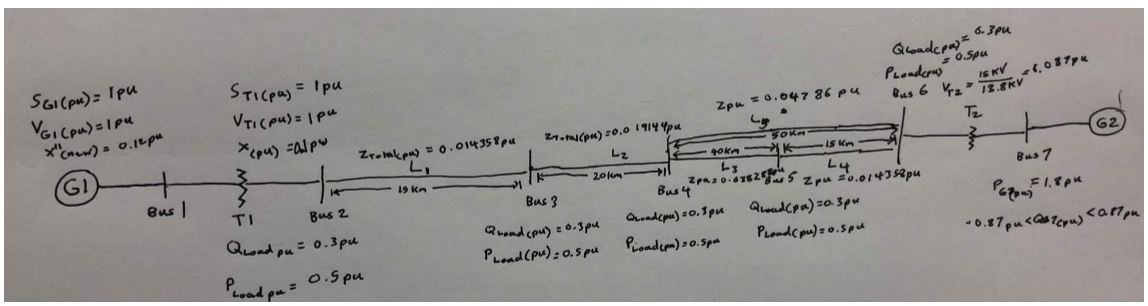

Figure 2: Per-Unit One-line Diagram

2.2 Compute All Bus Voltages

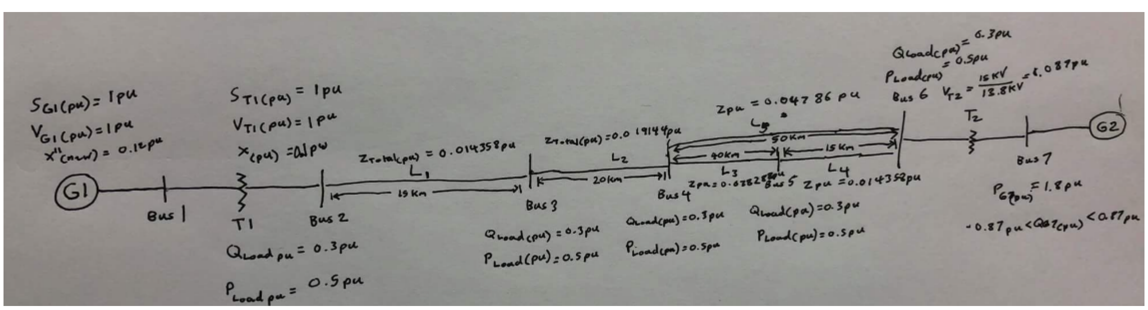

Figure 3: PowerWorld Diagram

2.2.1 Newton-Raphson Method

2.3 Compute All Power Values

2.3.1 Compute Power Flow on Each Line (In/Out)

2.3.2 Compute Line Losses

2.3.3 Compute Generated Power

3 Conclusions

References

Appendices

A Code