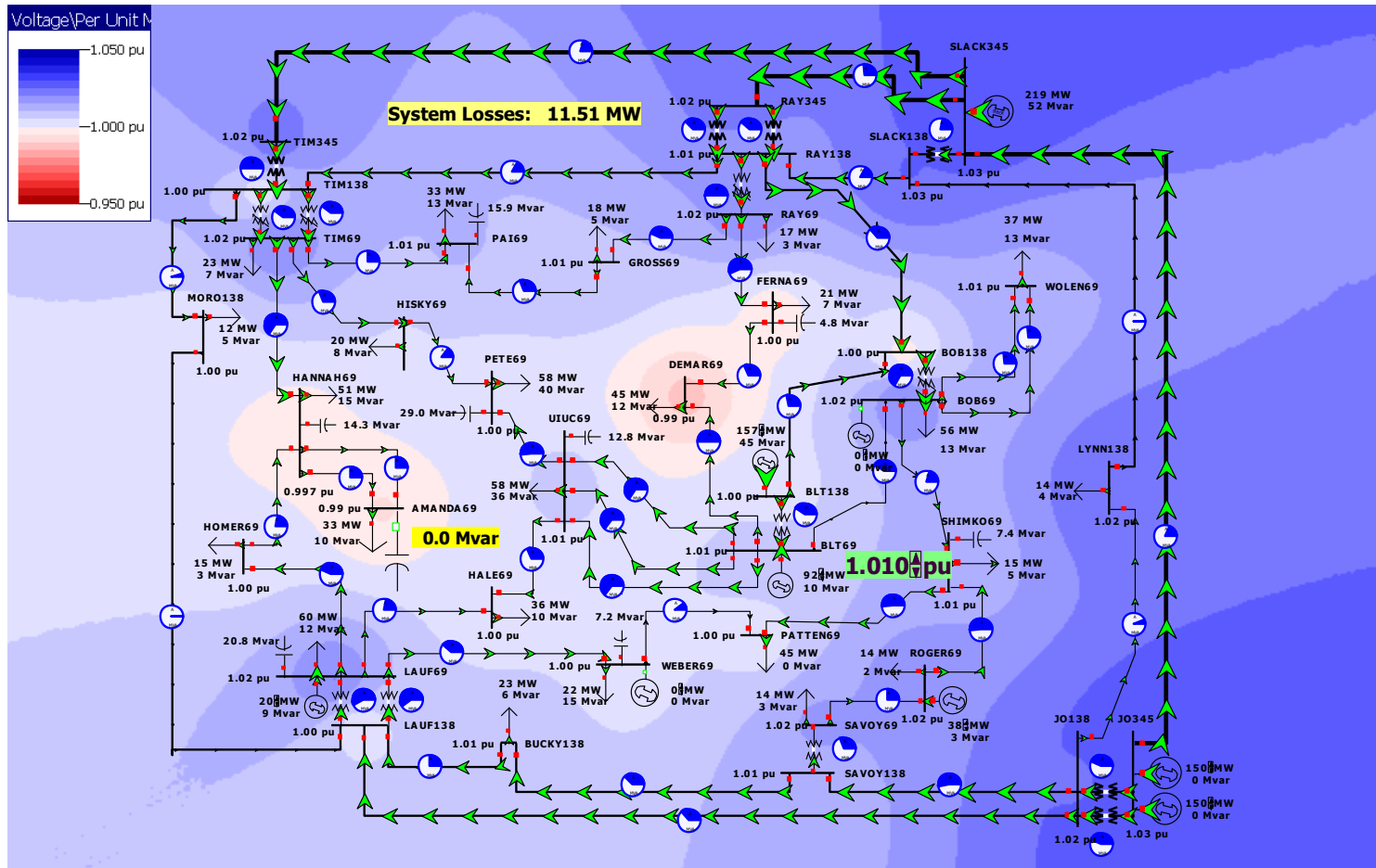


Lecture 4

Voltage Regulation Example: 37 Buses

Automatic voltage regulation system controls voltages.



Display shows voltage contour of the power system

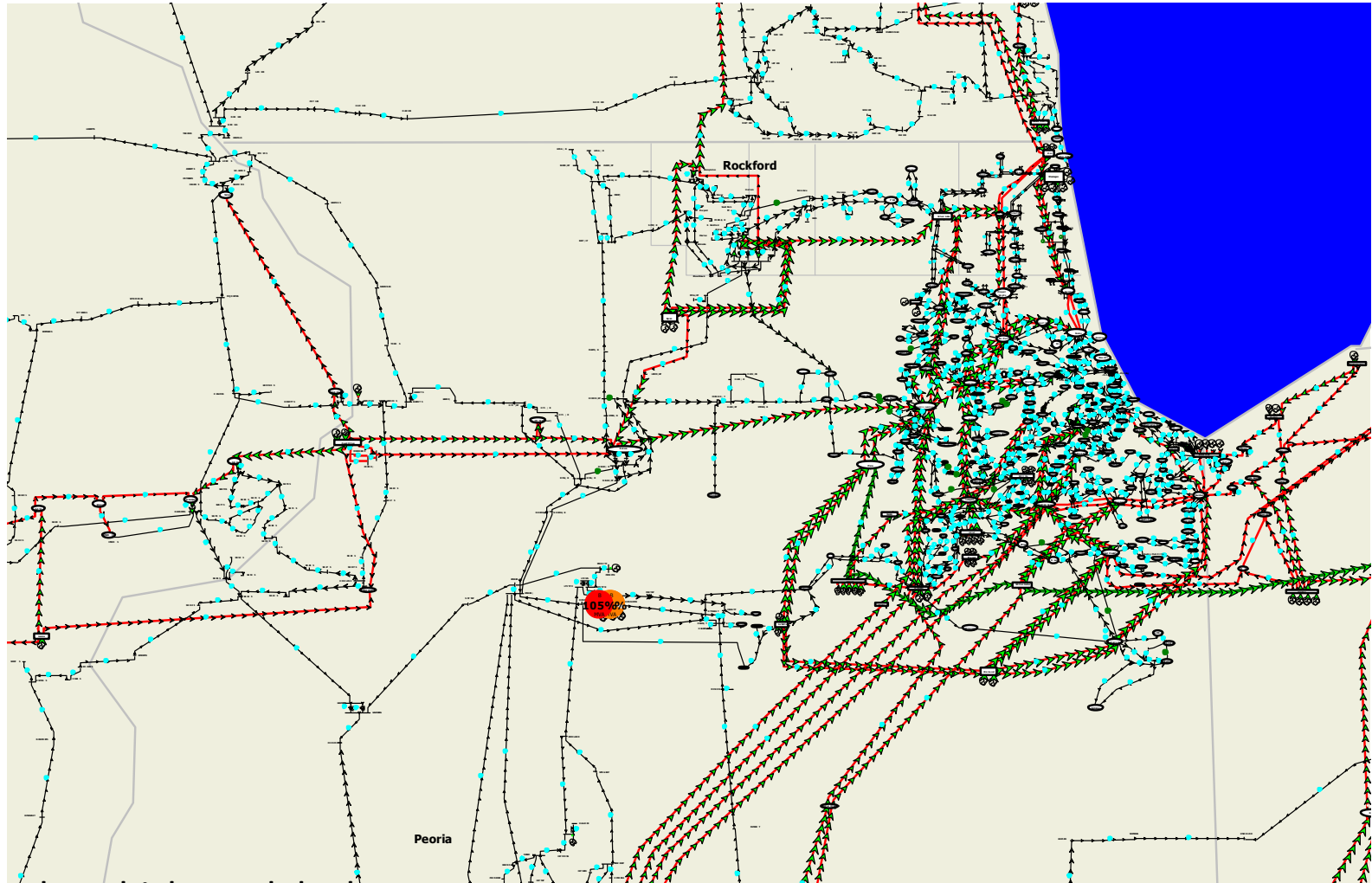
Real-sized Power Flow Cases

- Real power flow studies are usually done with cases with many thousands of buses
 - Outside of ERCOT, buses are usually grouped into various balancing authority areas, with each area doing its own interchange control.
- Cases also model a variety of different automatic control devices, such as generator reactive power limits, load tap changing transformers, phase shifting transformers, switched capacitors, HVDC transmission lines, and (potentially) FACTS devices.

Sparse Matrices and Large Systems

- Since for realistic power systems the model sizes are quite large, this means the Y_{bus} and Jacobian matrices are also large.
- However, most elements in these matrices are zero, therefore special techniques, sparse matrix/vector methods, are used to store the values and solve the power flow:
 - Without these techniques large systems would be essentially unsolvable.

Eastern Interconnect Example



Example, which models the Eastern Interconnect contains about 43,000 buses.

Solution Log for 1200 MW Outage

```
Message Log
Transformer 38422 TO 38880 CKT 1 tap ratio moved from 1.03272 to 1.02613
Transformer 38424 TO 39270 CKT 1 tap ratio moved from 1.02500 to 1.01875
Transformer 38430 TO 39177 CKT 1 tap ratio moved from 1.01875 to 1.01250
Transformer 38431 TO 39283 CKT 1 tap ratio moved from 1.00634 to 0.99975
Transformer 38432 TO 38887 CKT 1 tap ratio moved from 1.03272 to 1.02613
Transformer 38446 TO 39305 CKT 1 tap ratio moved from 1.02600 to 1.01925
Transformer 38506 TO 39475 CKT 1 tap ratio moved from 1.06250 to 1.05625
Transformer 38512 TO 39479 CKT 1 tap ratio moved from 1.05000 to 1.04375
Transformer 38512 TO 39479 CKT 2 tap ratio moved from 1.05000 to 1.04375
Transformer 38519 TO 38518 CKT 1 tap ratio moved from 1.02500 to 1.01875
Transformer 38529 TO 38879 CKT 1 tap ratio moved from 1.01188 to 1.00494
Transformer 38530 TO 39489 CKT 1 tap ratio moved from 1.09630 to 1.08979
Transformer 38710 TO 39580 CKT 1 tap ratio moved from 1.06875 to 1.04375
Transformer 38874 TO 39529 CKT 1 tap ratio moved from 1.07111 to 1.06491
Transformer 39802 TO 39801 CKT 1 tap ratio moved from 1.06875 to 1.04375
Transformer 39802 TO 39801 CKT 2 tap ratio moved from 1.06875 to 1.04375
Transformer 36759 TO 36757 CKT 1 phase moved from -0.4 to 0.0
  Changing impedance for transformer F PAR; R (36759) TO F PAR;05 (36757) CKT 1 due to impedance correction table
  From 0.00051+j 0.01733 to 0.00050+j 0.01708
Transformer 36822 TO 36820 CKT 1 phase moved from -1.1 to -0.8
  Changing impedance for transformer HARBO; B (36822) TO HARBO;85 (36820) CKT 1 due to impedance correction table
  From 0.00052+j 0.01672 to 0.00052+j 0.01654
Transformer 37074 TO 37072 CKT 1 phase moved from -13.4 to -14.4
  Changing impedance for transformer NORTH; B (37074) TO NORTH;35 (37072) CKT 1 due to impedance correction table
  From 0.00064+j 0.02308 to 0.00066+j 0.02349
Transformer 37075 TO 37073 CKT 1 phase moved from -13.3 to -14.5
  Changing impedance for transformer NORTH; R (37075) TO NORTH;85 (37073) CKT 1 due to impedance correction table
  From 0.00098+j 0.02698 to 0.00102+j 0.02812
Transformer 37160 TO 37158 CKT 1 phase moved from 4.5 to 5.2
  Changing impedance for transformer RIDGE; B (37160) TO RIDGE;B5 (37158) CKT 1 due to impedance correction table
  From 0.00073+j 0.02093 to 0.00079+j 0.02246
Transformer 37262 TO 37260 CKT 1 phase moved from 0.6 to 0.9
  Changing impedance for transformer SLINE; B (37262) TO SLINE;25 (37260) CKT 1 due to impedance correction table
  From 0.00073+j 0.01630 to 0.00075+j 0.01664
Transformer 37263 TO 37261 CKT 1 phase moved from 1.9 to 2.1
  Changing impedance for transformer SLINE; R (37263) TO SLINE;55 (37261) CKT 1 due to impedance correction table
  From 0.00080+j 0.01790 to 0.00082+j 0.01822
Taps at 29 transformers adjusted
Finished voltage control loop iteration: 1
Number: 0 Max P: 76.500 at bus 37074 Max Q: 35.235 at bus 39802
Number: 1 Max P: 0.041 at bus 37072 Max Q: 0.752 at bus 37158
Number: 2 Max P: 0.001 at bus 66779 Max Q: 0.003 at bus 66779
Calculating Transformer Tap Sensitivities for 1 Transformers
Transformer 36758 TO 36756 CKT 1 phase moved from 2.3 to 2.8
  Changing impedance for transformer F PAR; B (36758) TO F PAR;55 (36756) CKT 1 due to impedance correction table
  From 0.00058+j 0.01729 to 0.00060+j 0.01773
Taps at 1 transformers adjusted
Finished voltage control loop iteration: 2
Number: 0 Max P: 46.296 at bus 36758 Max Q: 3.004 at bus 36756
Number: 1 Max P: 0.015 at bus 36756 Max Q: 0.177 at bus 36756
Number: 2 Max P: 0.000 at bus 32274 Max Q: 0.000 at bus 36314
Finished voltage control loop iteration: 3
AGC in area ALTE changed gen 1 at bus 39152 by -1.00 MW to 521.0
AGC in area ALTE changed gen 2 at bus 39153 by -1.00 MW to 527.9
AGC in area ALTE changed gen 4 at bus 39207 by -0.63 MW to 328.5
```

In this example the loss of a 1200 MW generator in Northern Illinois was simulated. This caused a generation imbalance in the associated balancing authority area, which was corrected by a redispatch of local generation.