

Lecture 5

Interconnected Operation

- Power systems are interconnected across large distances.
- For example most of North America east of the Rockies is one system, most of North America west of the Rockies is another.
- Most of Texas and Quebec are each interconnected systems.

Balancing Authority Areas

- A “balancing authority area” (previously called a “control area”) has traditionally represented the portion of the interconnected electric grid operated by a single utility or transmission entity.
- Transmission lines that join two areas are known as tie-lines.
- The net power out of an area is the sum of the flow on its tie-lines.
- The flow out of an area is equal to
total gen - total load - total losses = tie-line flow

Area Control Error (ACE)

- The area control error is a combination of:
 - the deviation of frequency from nominal, and
 - the difference between the actual flow out of an area and the scheduled (agreed) flow.
- That is, the area control error (ACE) is the difference between the actual flow out of an area minus the scheduled flow, plus a frequency deviation component:
- ACE provides a measure of whether an area is producing more or less than it should to satisfy schedules and to contribute to controlling frequency.

$$ACE = P_{\text{actual tie-line flow}} - P_{\text{sched}} + 10\beta\Delta f$$

Area Control Error (ACE)

- The ideal is for ACE to be zero.
- Because the load is constantly changing, each area must constantly change its generation to drive the ACE towards zero.
- For ERCOT, the historical ten control areas were amalgamated into one in 2001, so the actual and scheduled interchange are essentially the same (both small compared to total demand in ERCOT).
- In ERCOT, ACE is predominantly due to frequency deviations from nominal since there is very little scheduled flow to or from other areas.

Automatic Generation Control

- Most systems use automatic generation control (AGC) to automatically change generation to keep their ACE close to zero.
- Usually the control center (either ISO or utility) calculates ACE based upon tie-line flows and frequency; then the AGC module sends control signals out to the generators every four seconds or so.

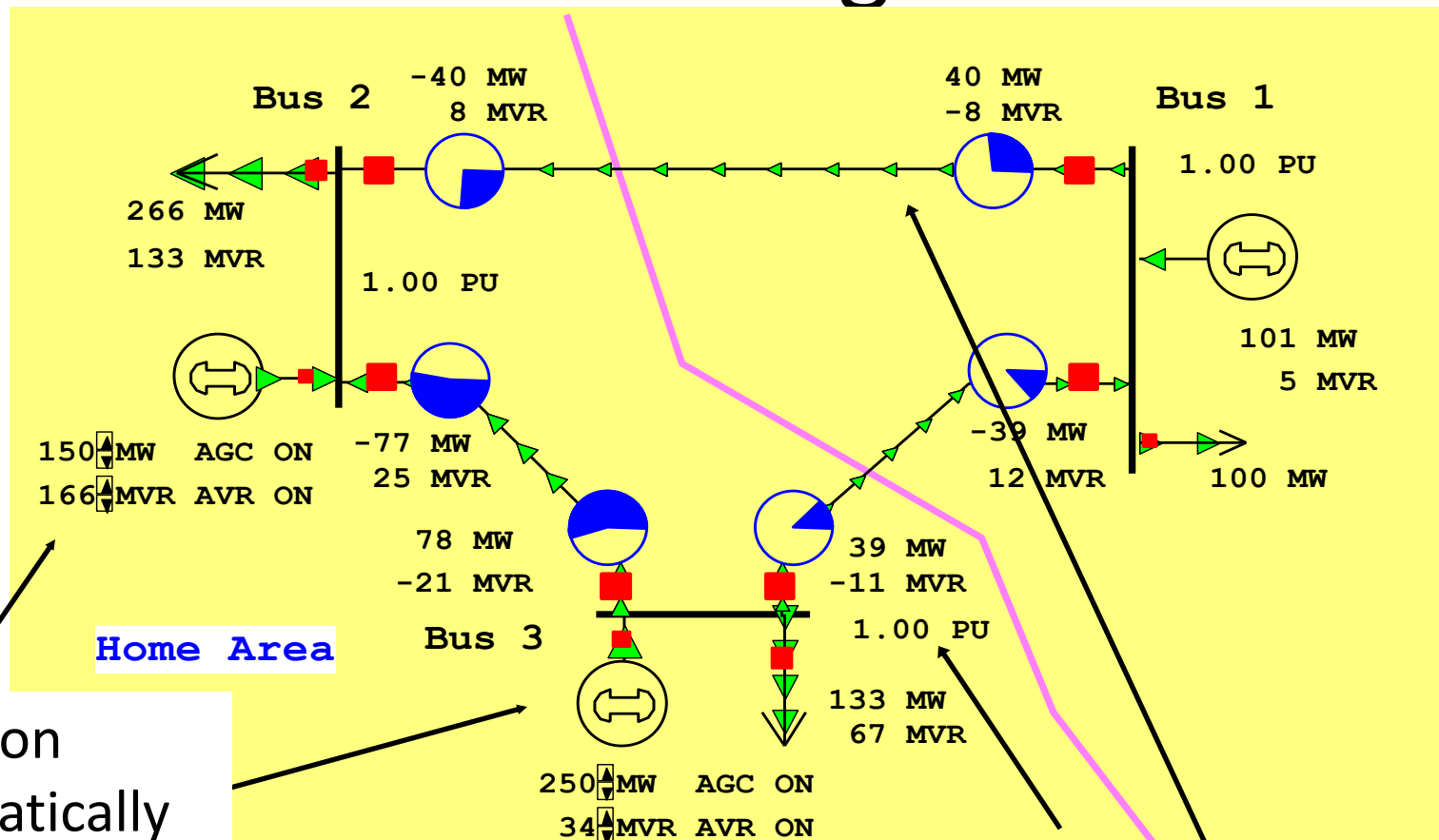
Power Transactions

- Power transactions are contracts between generators and (representatives of) loads.
- Contracts can be for any amount of time at any price for any amount of power.
- Scheduled power transactions *between* balancing areas are called “interchange” and implemented by setting the value of P_{sched} used in the ACE calculation:
 - $ACE = P_{\text{actual tie-line flow}} - P_{\text{sched}} + 10\beta \Delta f$
 - ...and then controlling the generation to bring ACE towards zero.

“Physical” power Transactions

- For ERCOT, interchange is only relevant over asynchronous connections between ERCOT and Eastern Interconnection or Mexico.
- In Eastern and Western Interconnection, interchange occurs between areas connected by AC lines.

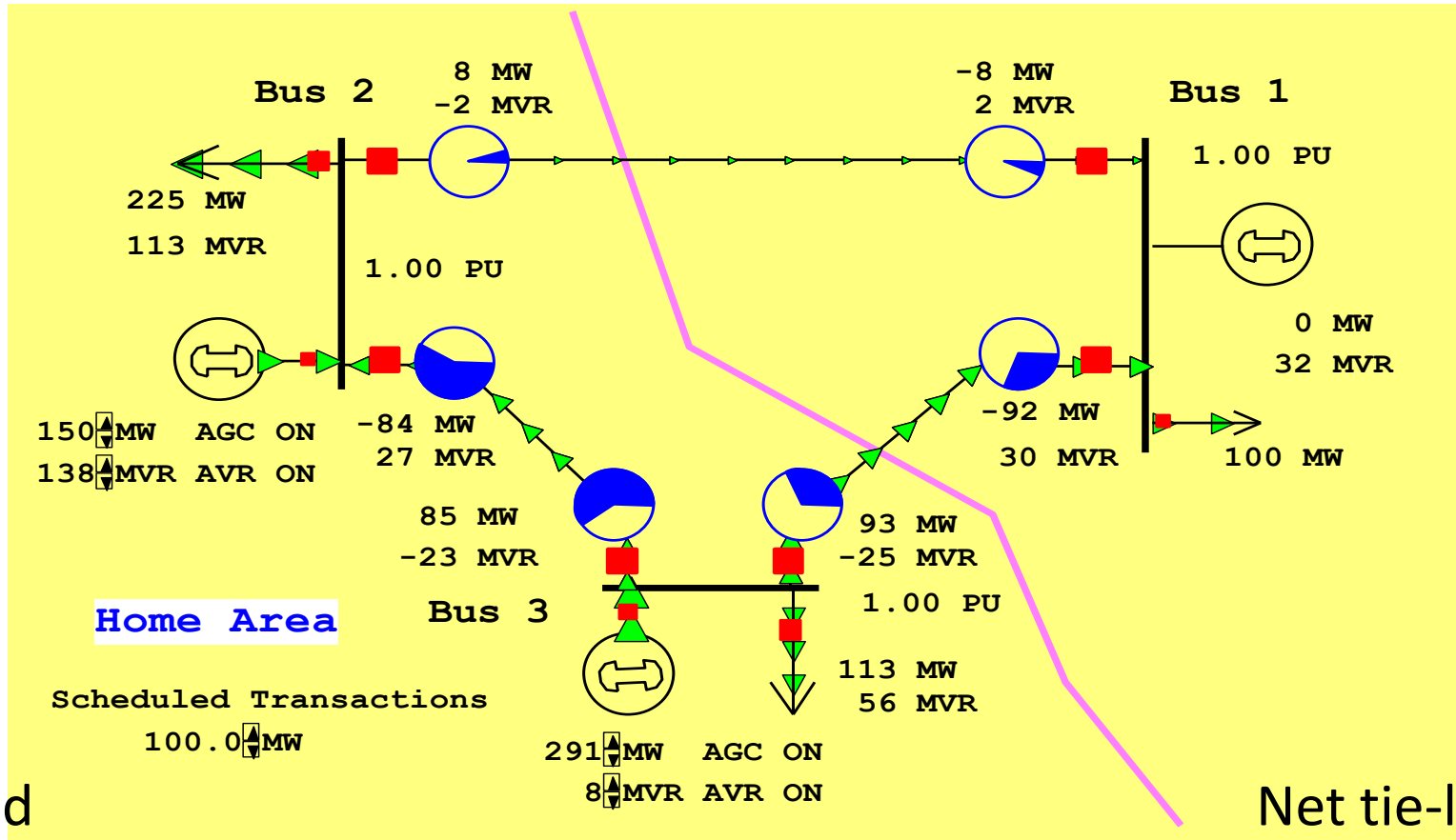
Three Bus Case on AGC: no interchange.



Generation is automatically changed to match change in load

Net tie-line flow is close to zero

100 MW Transaction between areas in Eastern or Western



Scheduled
100 MW
Transaction from Left to Right

Net tie-line
flow is now
100 MW