Topics for Today:

- Announcements
  - Software: online students - apply for ATP/ATPDraw license, verify licensing when you receive it by e-mail, and we will mail you the install CD.
  - Office: EERC 614. Phone: 906.487.2857
  - Recommended problems & all solutions: 13 solns now posted.
  - Homework Syst Op - due this Friday. Online students need more time?

Ongoing topics...

Chapter 16 - Stability

- Dr. Mork’s lecture notes “System Stability” – See Week 13.
- Basic overview. Lead-in to EE6210 (Kundur’s taxonomy).
  - Angle stability vs. voltage stability
  - Small disturbance vs. Transient stability
  - H: Stored energy per MW, J: rotational moment of inertia
  - Coherency
  - Swing Equation
  - Equal area review
  - Reclosing strategies
Power System Stability
- Ability to remain in operating equilibrium
- Equilibrium between opposing forces

Angle Stability
- Ability to maintain synchronism
- Torque balance of synchronous machines

Voltage Stability
- Ability to maintain steady acceptable voltage
- Reactive power balance

Transient Stability
- Large disturbance
- First-swing aperiodic drift
- Study period up to 10 s

Mid-term Stability
- Severe upsets; large voltage and frequency excursions
- Fast and slow dynamics
- Study period to several min.

Long-term Stability
- Uniform system frequency
- Slow dynamics
- Study period to tens of min.

Small-Signal Stability

Non-oscillatory Instability
- Insufficient synchronizing torque

Oscillatory Instability
- Insufficient damping torque
- Unstable control action

Large-Disturbance Voltage Stability
- Large disturbance
- Switching events
- Dynamics of ULTC, loads
- Coordination of protections and controls

Small-Disturbance Voltage Stability
- Steady-state P/Q - V relations
- Stability margins, Q reserve

Local Plant Modes
Interarea Modes
Control Modes
Torsional Modes

* With availability of improved analytical techniques providing unified approach for analysis of fast and slow dynamics, distinction between mid-term and long-term stability has become less significant.

Figure 2.9 Classification of power system stability
\[ P_{1 \rightarrow 2} = \frac{V_1 V_2}{X} \sin (\delta_1 - \delta_2) \]

\[ Q_{1 \rightarrow 2} = \frac{\sqrt{3} V_2}{X} \cos (\delta_1 - \delta_2) - \frac{\sqrt{3} V_1}{X} \]

- **P**: most sensitive to \( V \).
- **Q**: most sensitive to \( V \).

Stability Swing: typically 1-2 Hz.

**Diagram:**

1. \( P \rightarrow jX \rightarrow Q \)
2. \( \text{Cap bank or SVC} \)

\( V_1, \delta_1 \)

\( V_2, \delta_2 \)
- Lossless: $R_a = 0$
- Balanced 3Φ operation
- Balanced loads
- 3Φ faults, 3Φ trips/recloses.
$T_\alpha = J\alpha = J \frac{d\alpha}{dt}$

$F = Ma$

Small $H$

Large $H$

$25^\circ$