Voltage Stability & Reactive Power Control

Objective #11

Important Topic in Power Systems

- Students should relate to importance of Voltage Regulation
  - Brown Outs
  - Increased Loading in current environment
  - It’s a real world problem
  - Need for load shedding as required
  - Important subject to Power Utility industry

Steady State Stability Control

- Steady-state limit – loss of synchronism
- Power output will decline for torque angles greater than 90 deg
- This is the limit of power than can be supplied by the synchronous generator
- In actual systems, torque angle limits are approx 45 deg

Steady State Stability Limit

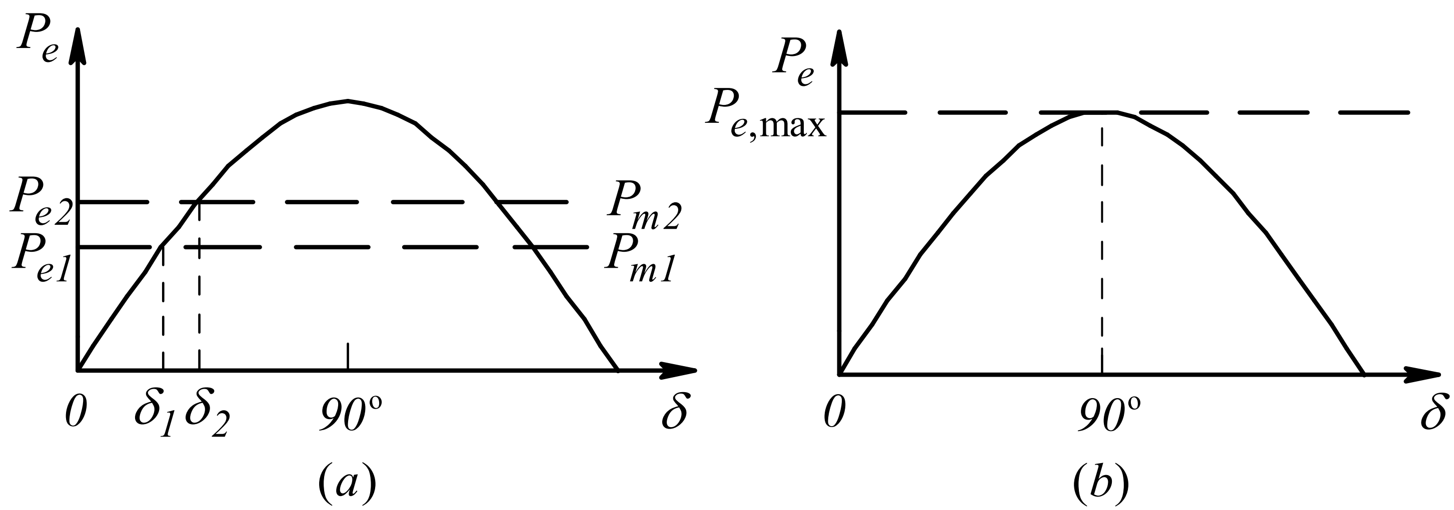


Fig. 9-12 Steady state stability limit.

Field Excitation to Adjust Reactive Power

- In Over-Excited mode: supplies reactive power – like a capacitor
- In Under-Excited mode: absorbs reactive power – like an inductor
- Therefore control of the excitation voltage to the synchronous generator can be used to control reactive power & voltage control
- Automatic Voltage Control (AVR)

Automatic Voltage Regulation (AVR)

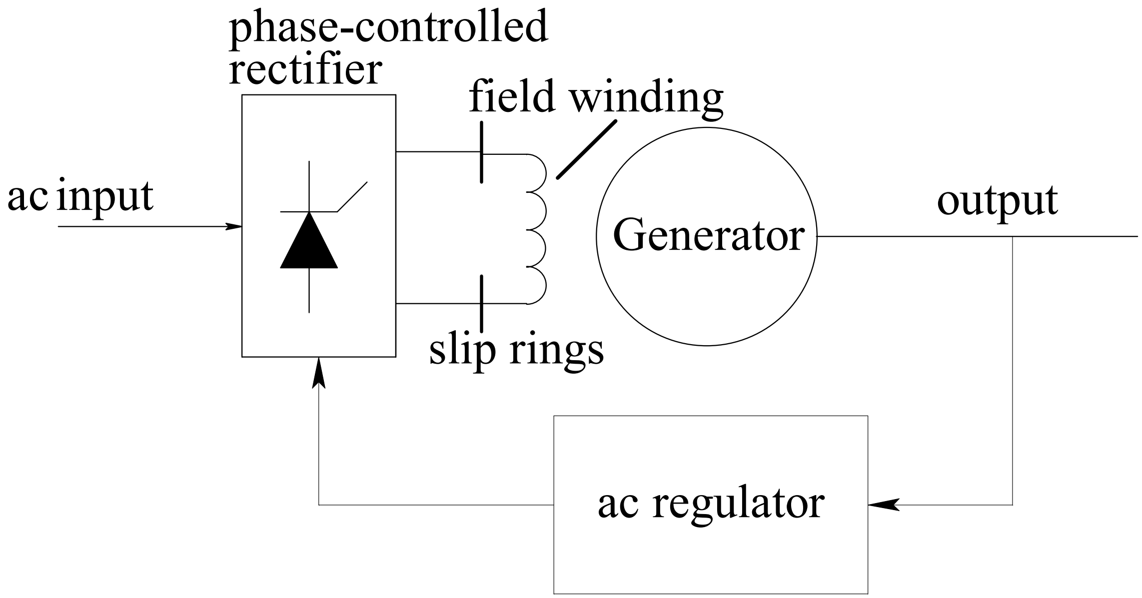


Fig. 9-15 Field exciter for automatic voltage regulation (AVR).

Synchronous Condensers

- Synchronous motor, connected to grid, to supply reactive power
- Control is done through field excitation control – as in synchronous generators
- There is no turbine, since small amount of power is supplied by the grid

A Radial System

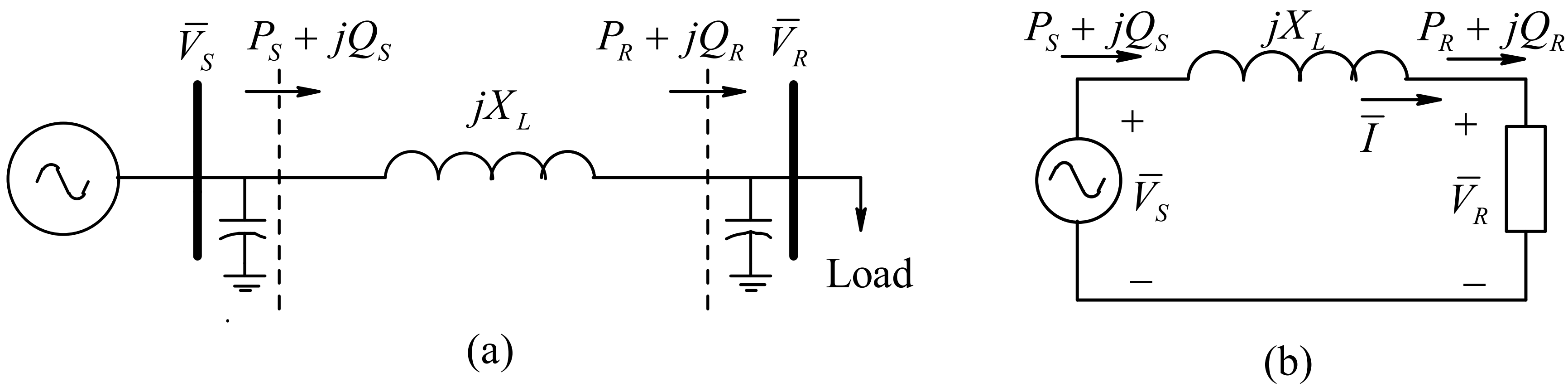


Fig. 10-1 A radial system.

Voltages and Current Phasors with Both-Side Voltages at 1 PU

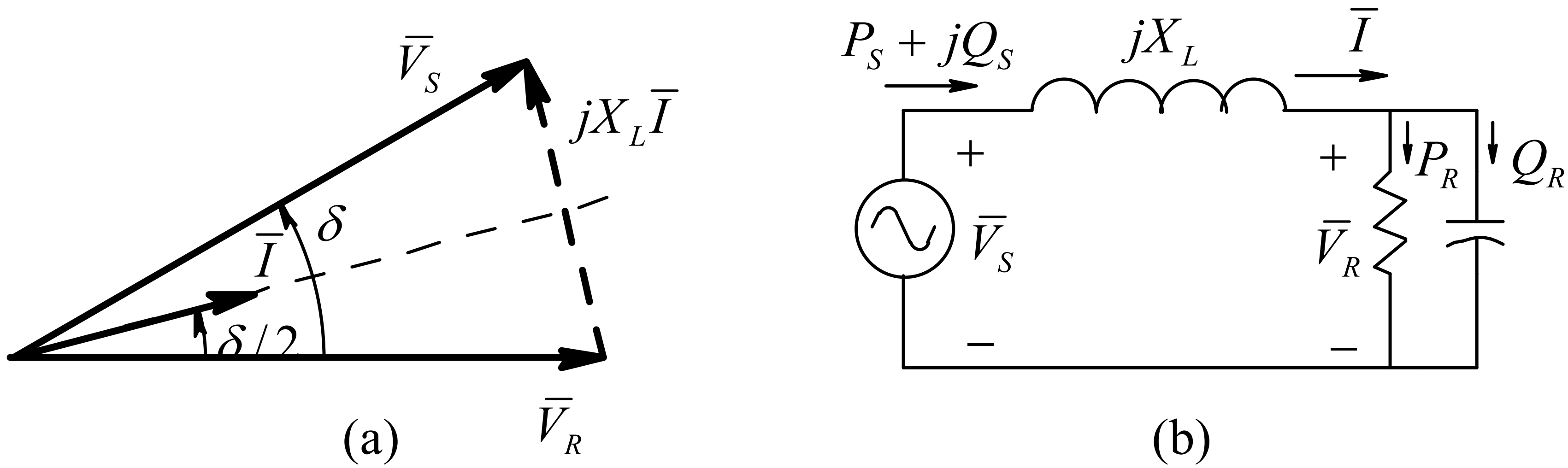


Fig. 10-2 Phasor diagram and the equivalent circuit with $V_S = V_R = 1\text{pu}$.

Voltage Regulation

- For Vs to equal Vr, the receiving end of a transmission line must provide Reactive Power (Qr)
- Higher load at the receiving end requires more reactive power to prop up the voltage
- The sending-end must provide an equivalent amount of Reactive Power – since the total amount of Reactive Power must be constant

Voltage Regulation (cont)

- Since the transmission line has distributed parameters (series inductance and parallel capacitance), then the voltage profile along the line can change with loading
- If the load equals the surge impendance, then the voltage is constant along the line
- If loading is greater than SIL, then the voltage will sag along the line.
- If loading is less than SIL, then voltage will be higher along the line

Voltage Profile for Three Values of SIL

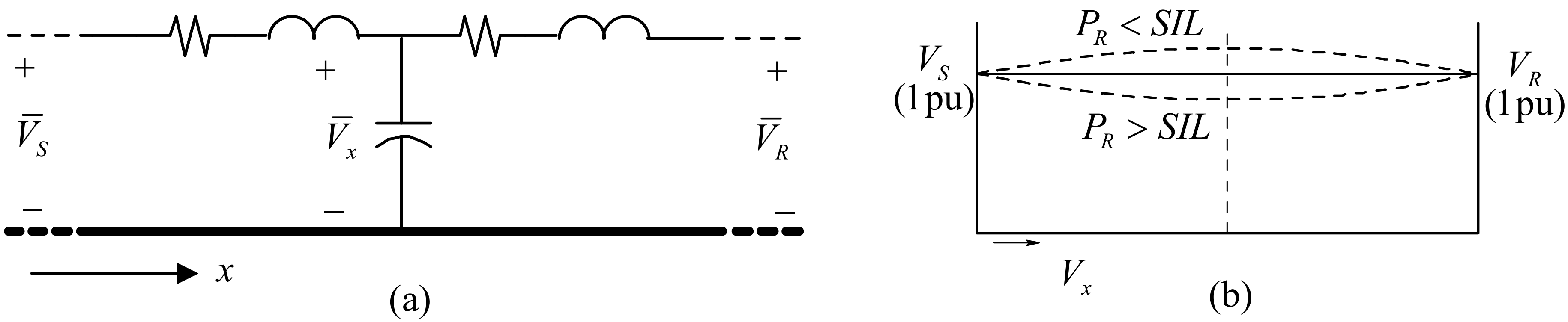
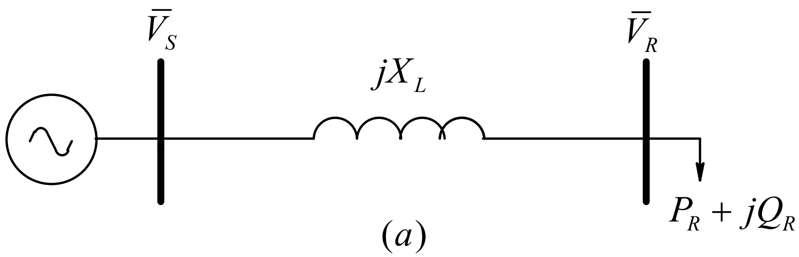


Fig. 10-3 Voltage profile along the transmission line.

Voltage Collapse

- As line loading increases, the receiving end voltage drops
- Continued loading reaches a "critical" point – beyond which the receiving end voltage collapses
- Lagging power factor loading is worse in terms of voltage stability compared to unity power factor
- Even leading power factor loads can cause voltage collapse and high load values

"Nose" Curves at Three Power Factors as a function of Loading



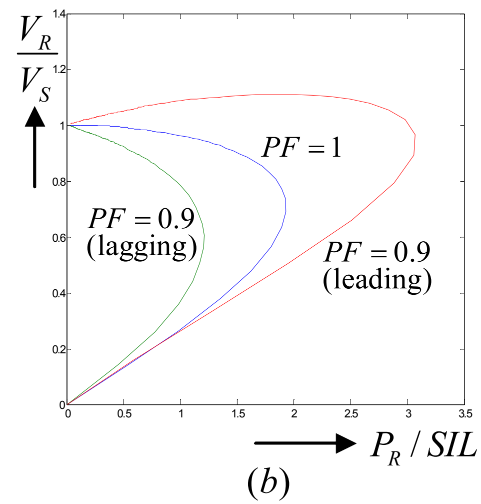


Fig. 10-4 Voltage collapse in a radial system (example of 345-kV line, 200 km long).

Prevention of Voltage Instability

- Voltage instability is the result of highly loaded systems
- Voltage instability is associated with the lack of reactive power
- Therefore it is necessary to have a reserve of reactive power
- i.e. systems are more stable at leading power factors

Synchronous Generator Reactive Power Supply Capability

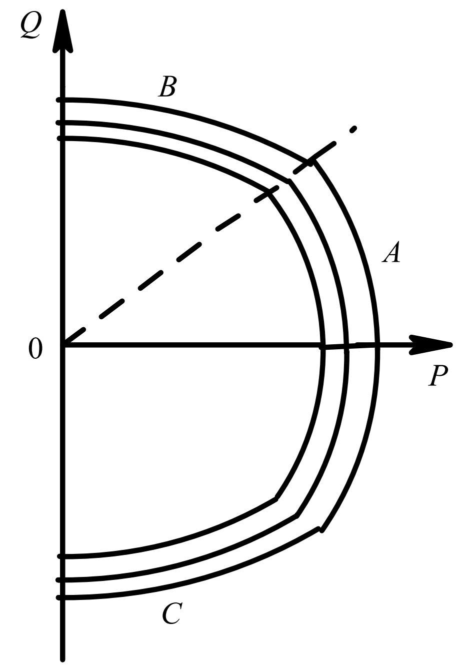


Fig. 10-5 Reactive power supply capability of synchronous generators.

Methods to supply Reactive Power

- Synchronous generators – discussed earlier
- Static VAR Compensators (SVC) – Capacitor banks switched in
- Thyristor Controlled Reactor – variable control
- Parallel combination of SVC & TCR
- STATCOM – like a controllable reactive current source on the bus – for HVDC lines, converters can supply or absorb reactive power
- Thyristor-Controlled Series Capacitor (TCSC) – series cap reduces the effect of the line inductance and can be adjusted to appear either more inductive or more capacitive.

Open Discussion

- Feedback?
- Other key concepts?
- Review commercially available equipment?
- Discuss which systems the local utility uses for voltage control
- Students look at economics of different approaches?