Module T1
Transmission

Power Point Slide Set b

Power Flow Limitations

- Overload:
  - line
  - transformer
- Voltage:
  - out of limits
  - voltage instability
- Transient
  - early-swing tripping
  - oscillation undamping

Overload (for lines)

- I-squared R losses cause heat, expansion, sag
- Line sag into tree can cause short and outage
- Get's worse with increased I
- So we limit I
- But other factors also have influence
  - wind speed
  - ambient temperature
  - sun
  - duration of particular loading level (continuous, 30 min?)

How to Determine Current Limit ?

- Conductor cannot sag more than x feet.
- For given wind speed, ambient temperature, solar level, duration, we can calculate current limit.
- What levels of these factors to choose?
  - Wind speed=2.2 ft/sec (1.5 mph)
  - Temp=40 degrees C (104 degrees F)
  - Bright sun
  - time=continuous
- Handle uncertainty with “worst-case” analysis

What would continuous rating be for other conditions?

Case	Wind Speed (mph)	Air Temp (C)	Solar Condition	Rating (amps)
Base	1.5	40	Sun	730
1	0.0	40	Sun	480
2	3.0	40	Sun	877
3	1.5	20	Sun	954
4	1.5	0	Sun	1130
5	1.5	40	No Sun	835

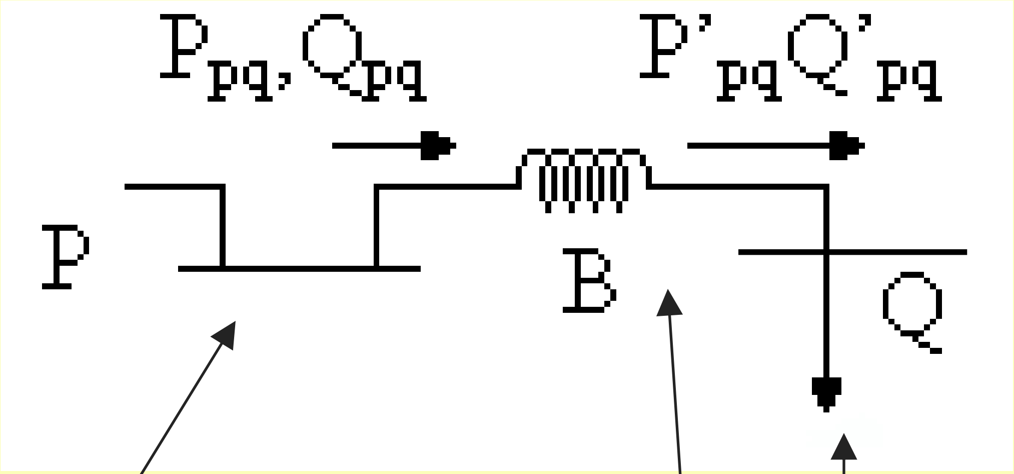
A better way to identify ratings is do assess influencing factors statistically,

e.g.,

what is probability of sag exceeding X feet if current is 900 amperes for 30 minutes?

Voltage Instability

- Caused by reactive power deficiency in network
  - decreased reactive supply (loss of generation)
  - increase reactive demand (increased load or loss of line)
- Results in uncontrollable voltage decline
- Worst case is major blackout.
- Low voltage magnitudes typically indicate voltage instability may be “close,” but high voltage magnitudes do not indicate voltage instability is “far.”



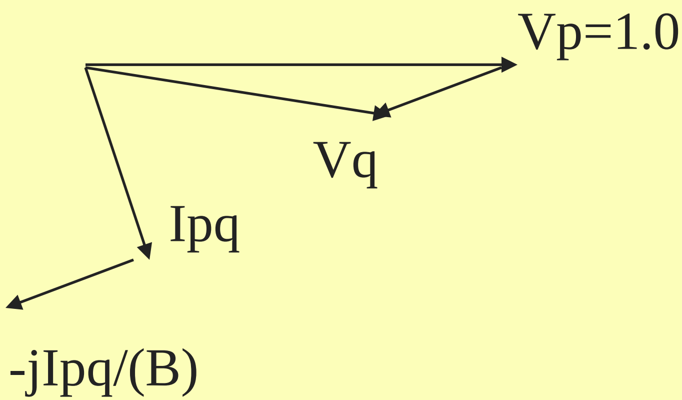
1.0 pu voltage

As P'pq+jQ'pq load increases, current magnitude increases.

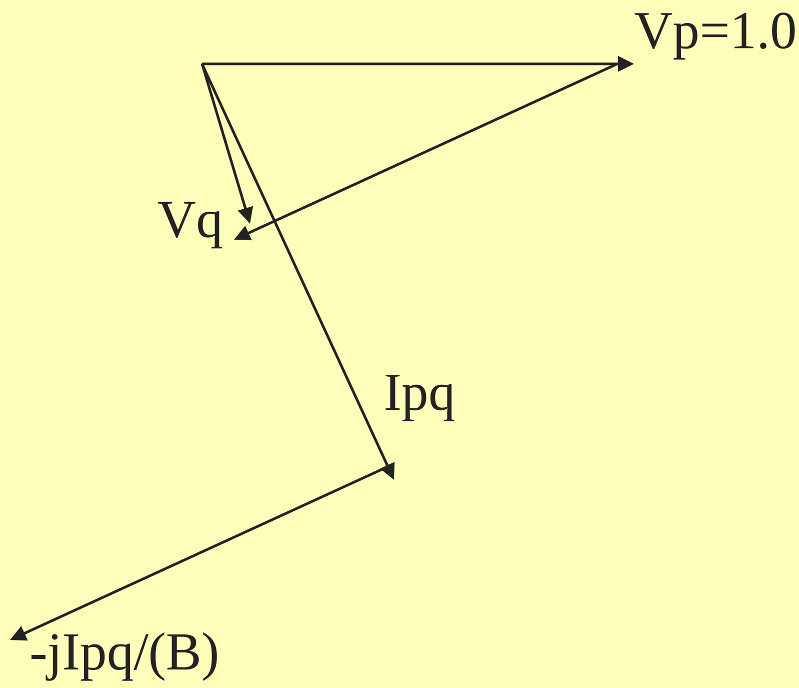
$$V_q = 1.0 - I_{pq}/(-jB)$$
$$= 1.0 - jI_{pq}/B$$

$$Vq = 1.0 - Ipq/(-jB)$$
$$= 1.0 + (-jIpq/B)$$

Lagging case, light loading



Lagging case, heavy loading

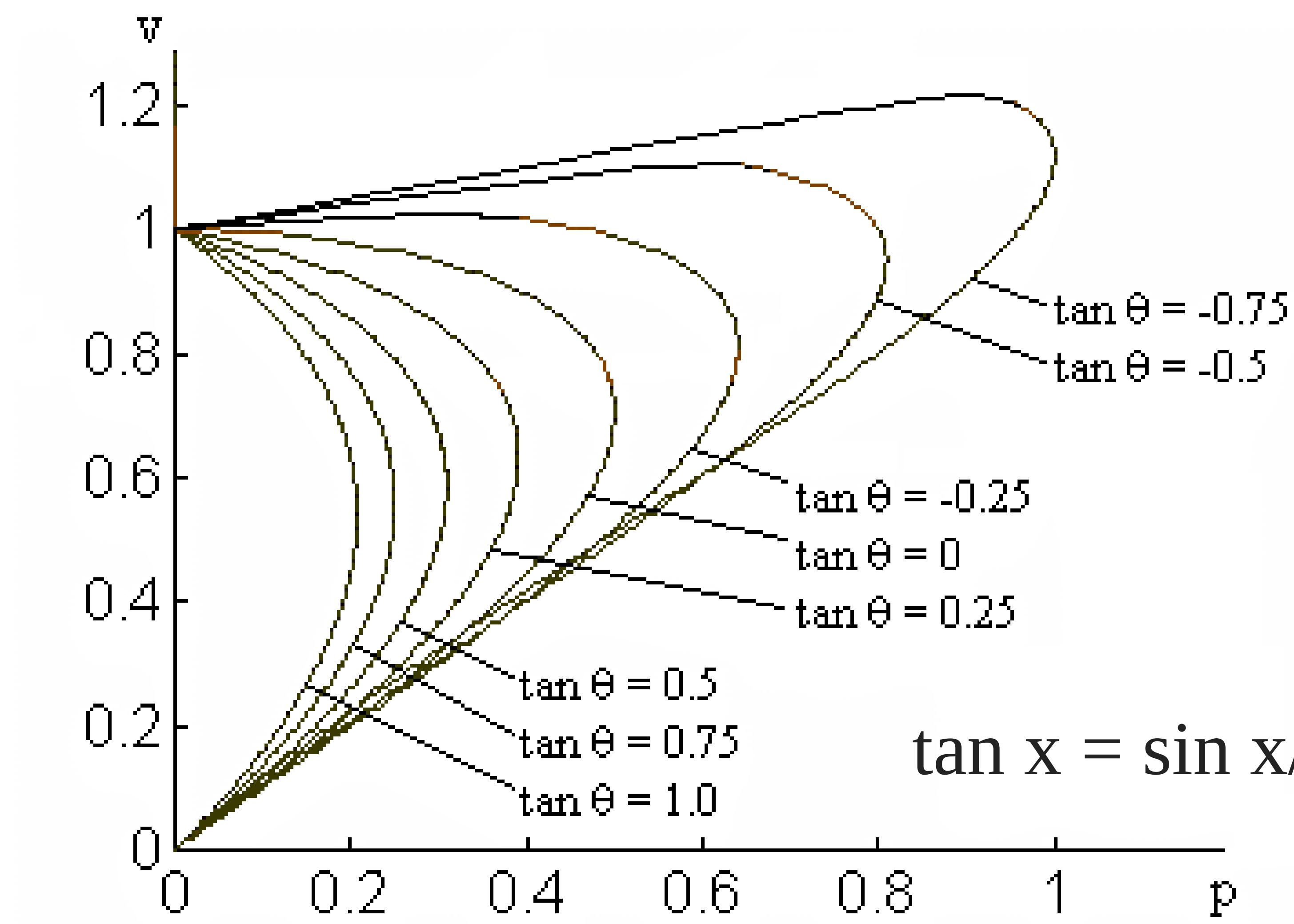


Compare the lengths of Vq

There exists a loading level beyond which it is not possible to sustain the voltage at the q-bus. This is the limit associated with voltage instability.

This is illustrated on the following page for various values of power factor.

Note that for leading power factor, the instability point (power transfer limit) is at a high voltage. See if if you can use phasor diagrams to verify this.



tan x = sin x/cos x

Transient Instability

- Caused by a fault.
- Very short time period (fault lasts for a 4-12 cycles, gen trips in < 3 seconds)
- During fault, electrical power goes to 0.
- Mechanical power stays constant.
- Generator accelerates.
- Can trip on overspeed if fault-on acceleration is too great.
- Must limit generation to avoid this problem.

Oscillatory Instability

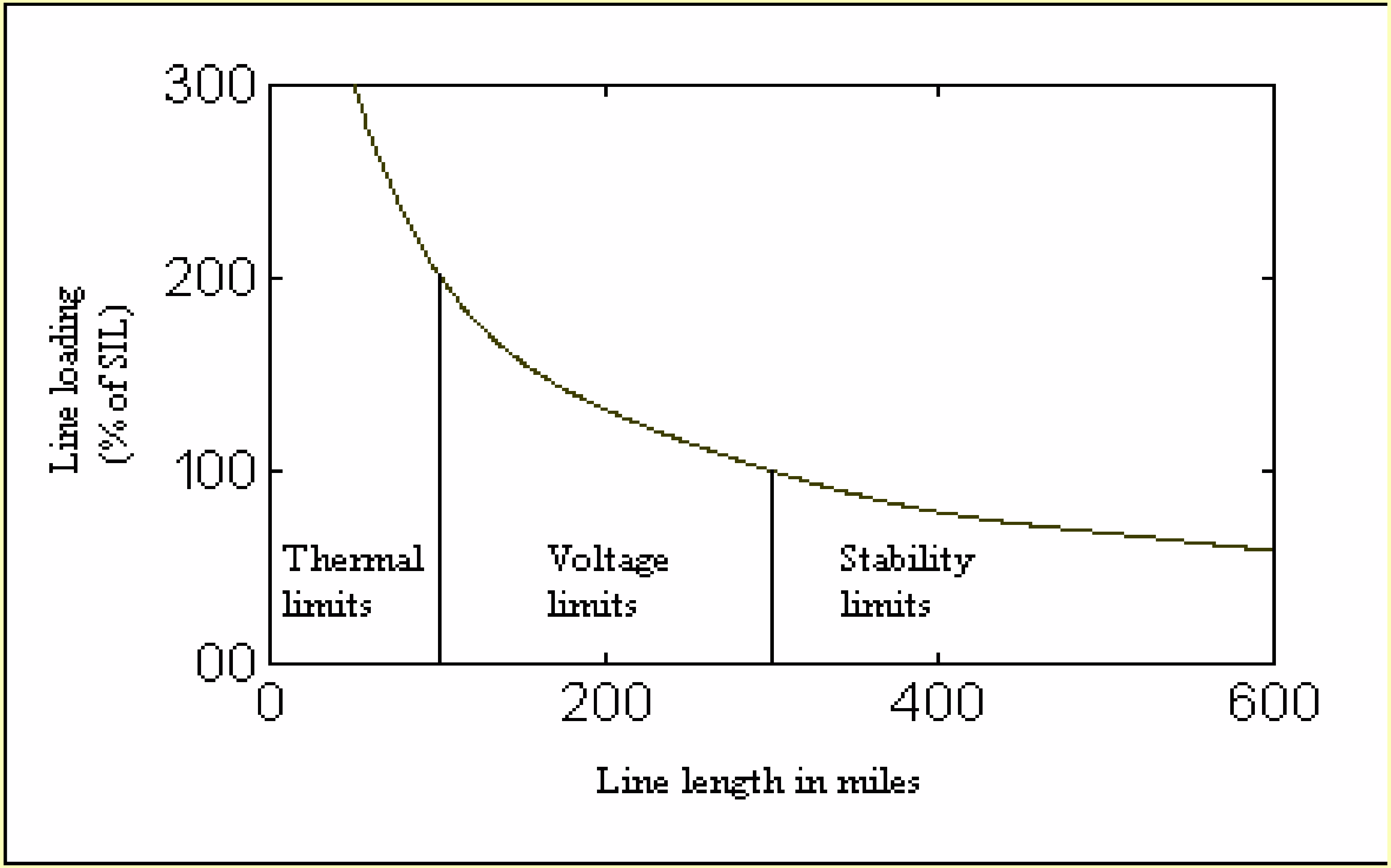
- Caused by perturbation in system
- System oscillate following perturbation
- If unstable, oscillations grow in magnitude
- Ultimately, generators will trip.
- Worst-case consequence is blackout.
- Must limit long distance transmission levels to avoid this problem.

Surge Impedance Loading

- Characteristic (surge) impedance: Zc=sqrt(L/C)
- Units of Zc are ohms: a pure resistance!
- Surge impedance loading:

$$SIL = \frac{|V_{rated}|^2}{Z_C}$$

- When line is supplying SIL, $Q_{caps} = Q_{loss}$
- So line neither supplies or absorbs reactive power to or from the network.
- It is a figure of merit for classifying limitations and their causes.



300
200
100
00
0
200
400
600
Line loading
(% of SIL)
Line length in miles
Thermal
limits
Voltage
limits
Stability
limits

FACTS devices:

- Flexible AC Transmission Systems
- Thyristor is used for FAST control for alleviating transient problems.
- But they are also useful for controlling overload and voltage instability.

TCSR, TCSC, TCPAR, UPFC