Submodular Optimization for Voltage Control in Power Systems

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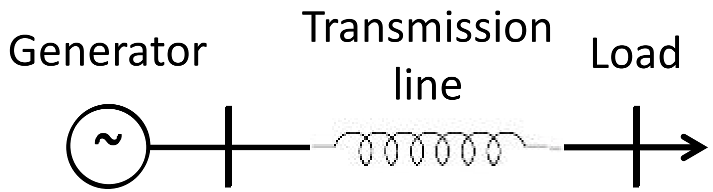
Power System Stability

Power systems are large-scale interconnected networked systems



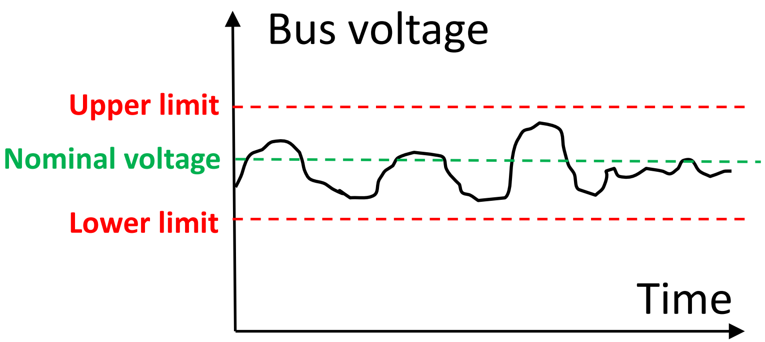
Power system stability: the ability to regain a state of operating equilibrium following a disturbance

- Voltage stability
- Generator rotor angle stability

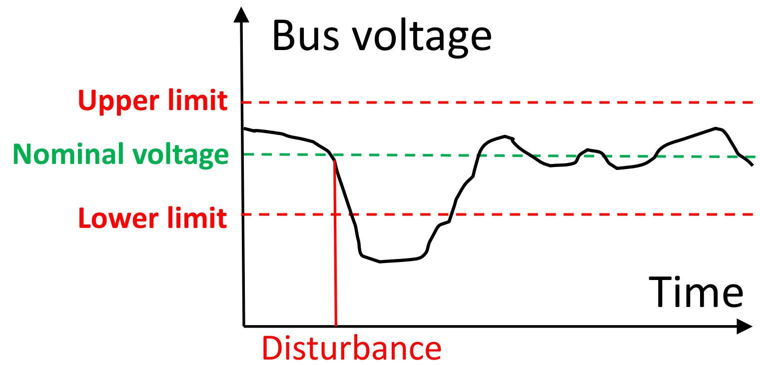
Voltage Stability in Power Systems

Ability to maintain voltages of every bus within desired limits

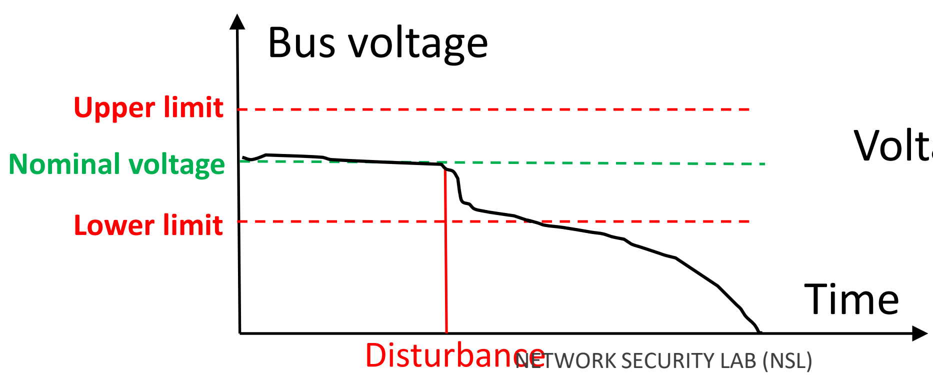
1) Under normal condition



2) After disturbances



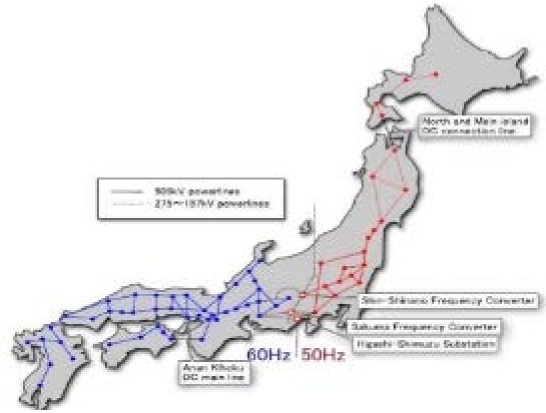
Instability may cause voltage collapse



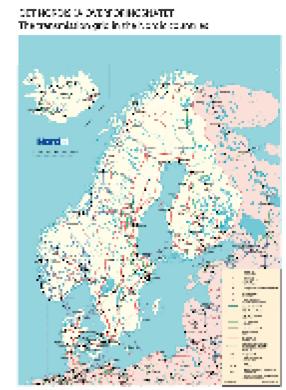
Voltage drops uncontrollably

Voltage Instability and Blackouts

U.S. and Canada, 2003



Tokyo, Japan, 1987



Sweden, 1983

Voltage instability a key factor in originating the 2003 blackout

Tokyo blackout in 1987 caused by voltage instability

Sweden experienced voltage instability following disturbance in 1983

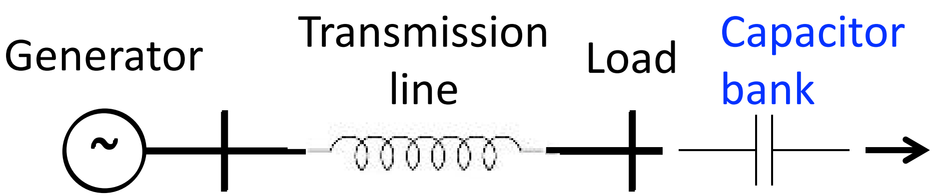
Loss of power to 2.8 million households for 3 hours

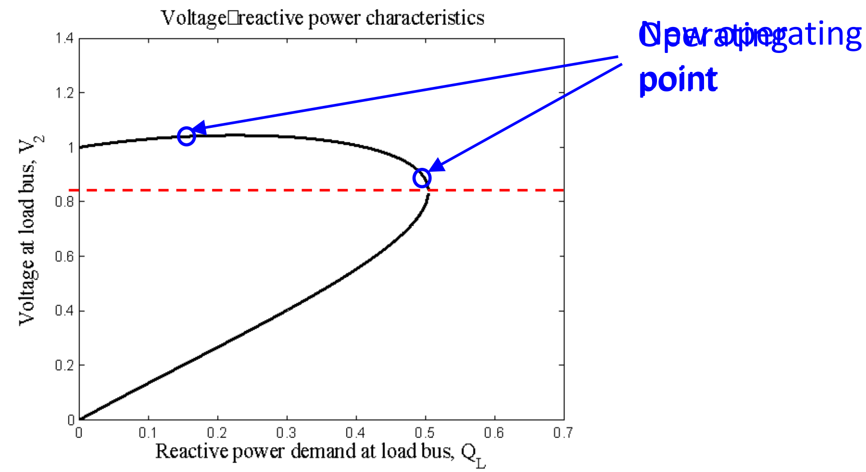
55 million people lost power for up to three days, with an economic cost of $5-10B

Swedish blackout affecting 4.5 million people (southern half of country) for 5 hours

How does the power system control voltage?

Voltage Control



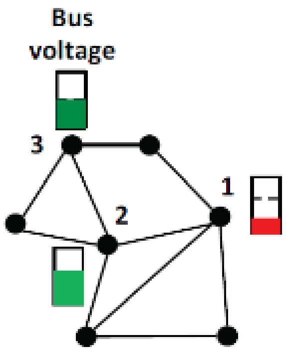


Power demanded by load: Power = P + jQ

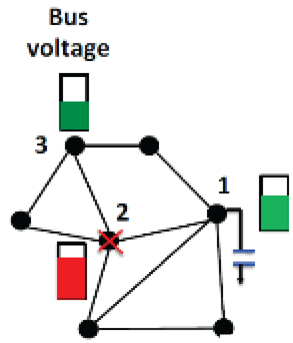
Real power Reactive power

- Voltage deviates from desired value when reactive power supplied by generator cannot meet demand at load
- Reactive power can be injected at a bus by switching on capacitor banks at load buses (incurs switching cost)

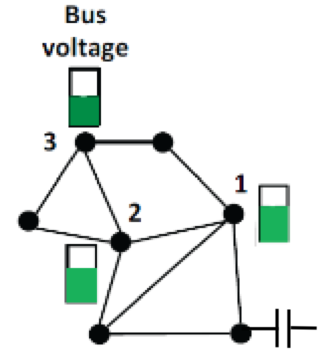
Voltage Control Challenges



Problem:
Voltage collapse imminent at bus 1



Solution 1:
Voltage at bus 2 exceeds desired level



Solution 2:
Voltage stability restored

- Reactive power injections at one bus may impact voltages at multiple neighboring buses

- **Key question:** Where to inject reactive power to reach desired voltage?