Realizing a Flexible Grid Infrastructure

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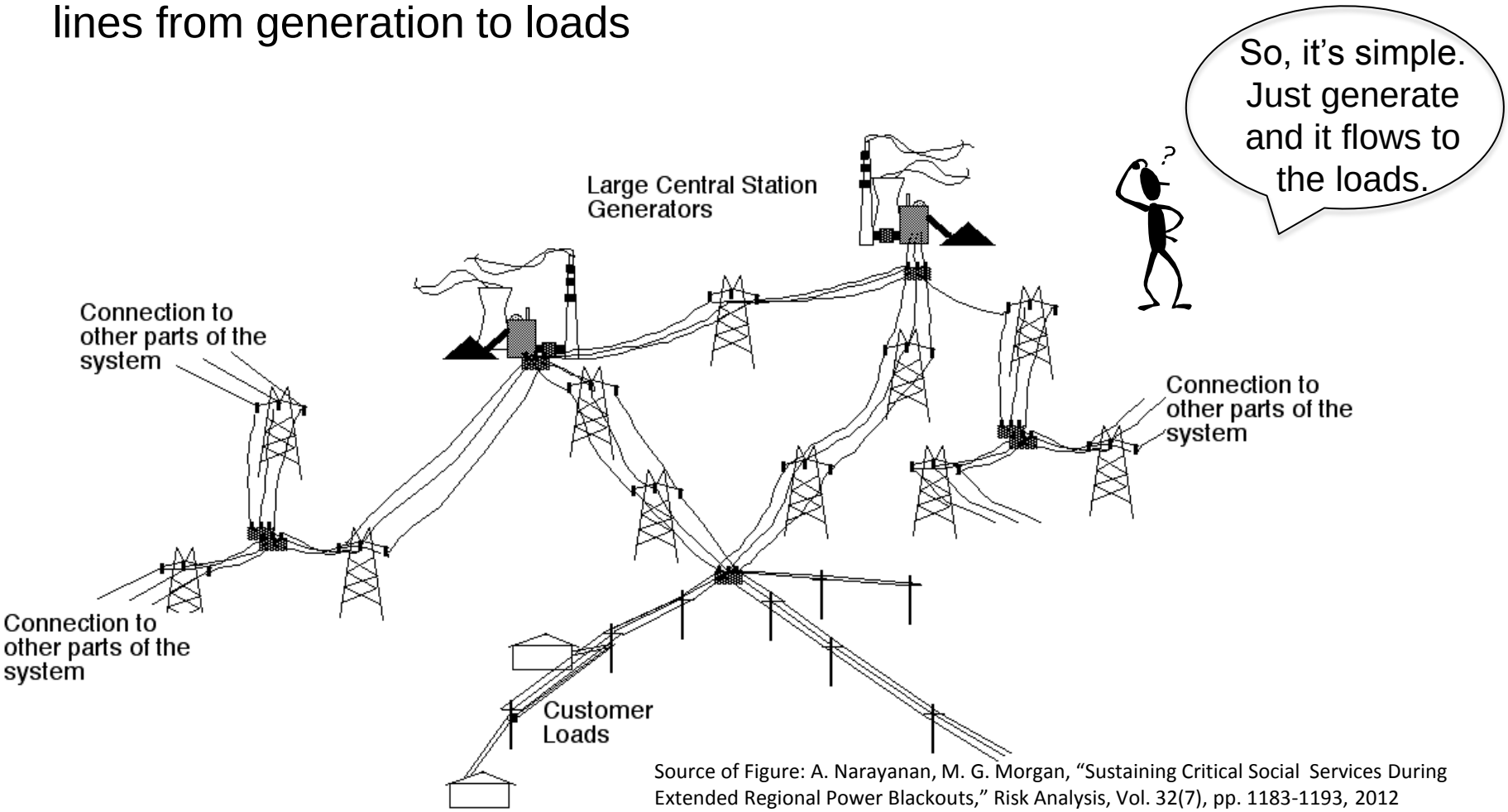
Introduction

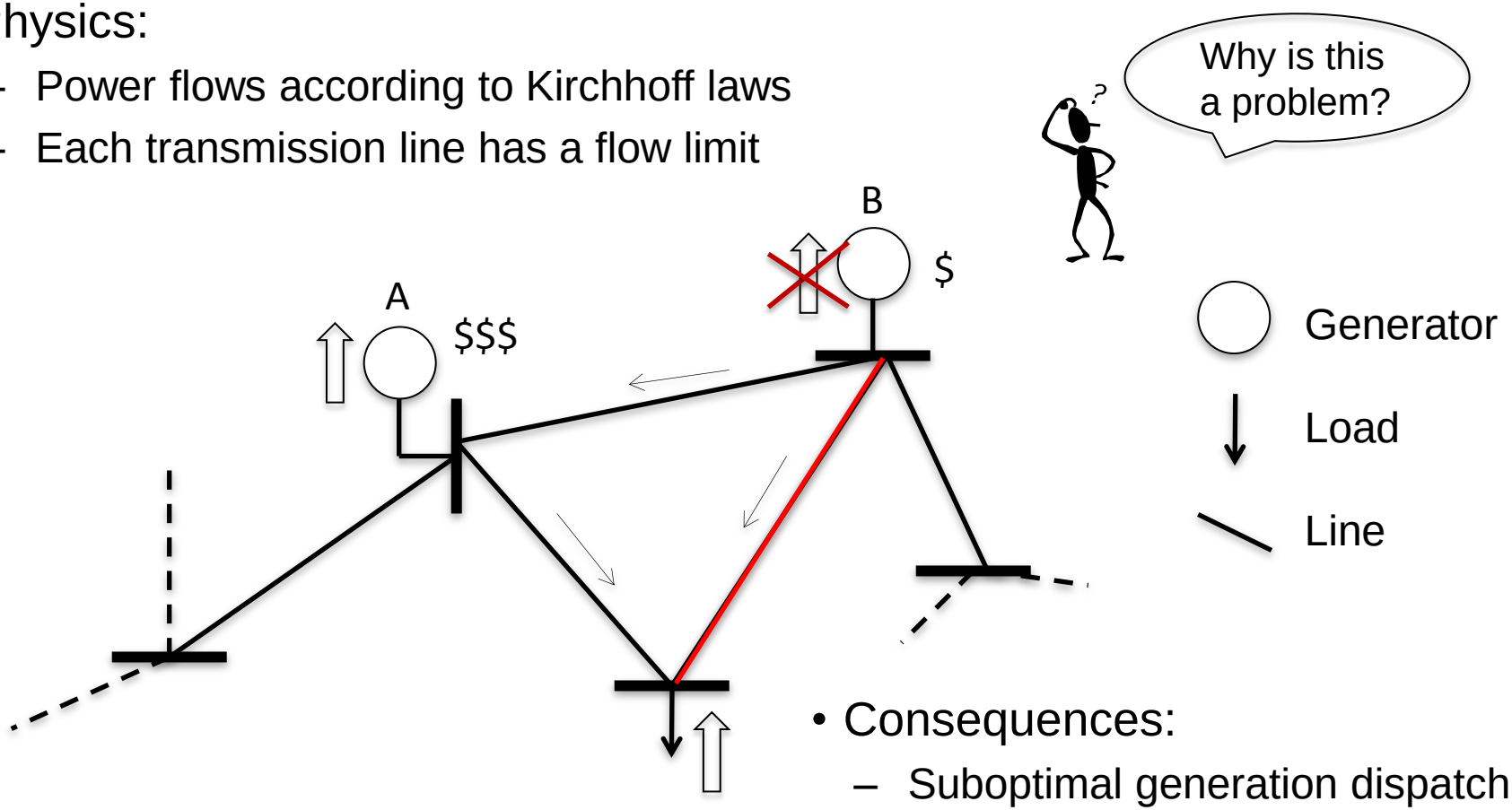
- Electric power is transmitted over a meshed network of transmission lines from generation to loads



Source of Figure: A. Narayanan, M. G. Morgan, "Sustaining Critical Social Services During Extended Regional Power Blackouts," Risk Analysis, Vol. 32(7), pp. 1183-1193, 2012

If only there weren't the laws of physics …

- Physics:
  - Power flows according to Kirchhoff laws
  - Each transmission line has a flow limit



- Consequences:
  - Suboptimal generation dispatch
  - Curtailment of available renewable generation

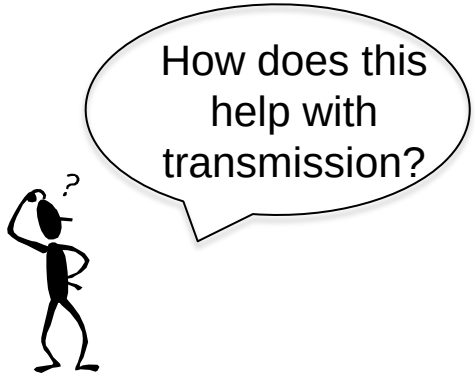
Possible Solutions

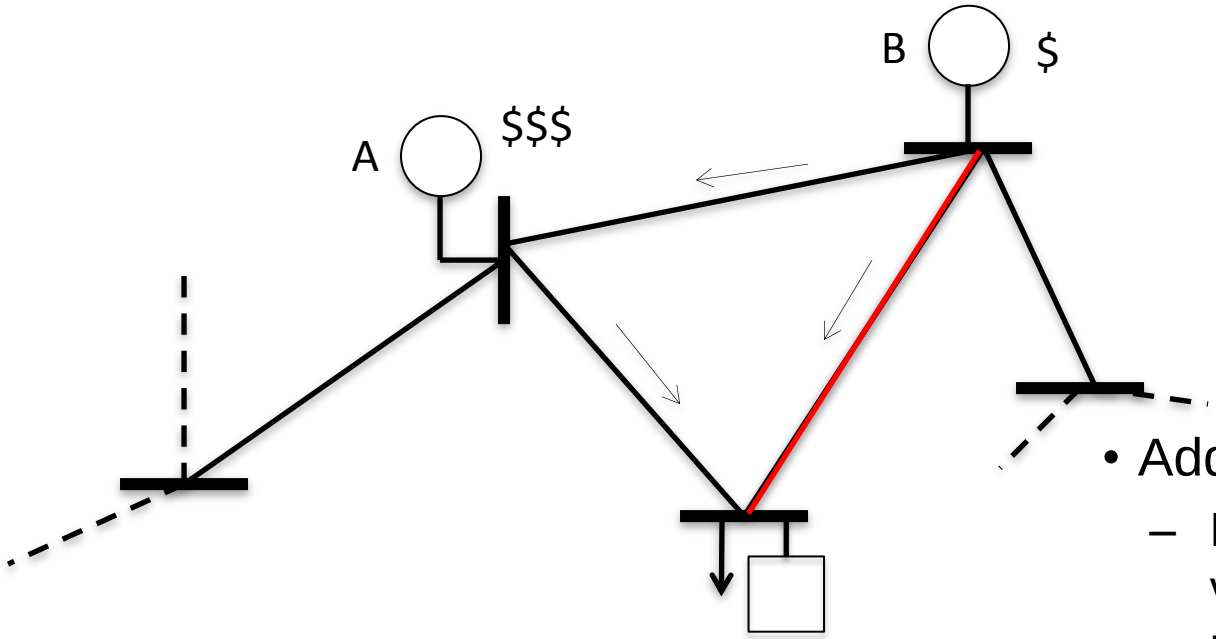
- Generation
  - Operation at suboptimal generation dispatch
  - Generation closer to loads
- Transmission
  - Additional transmission lines
  - Advanced material conductors
  - Dynamic line ratings
  - Topology switching
- Grid Technologies
  - Storage devices
  - Flexible AC Transmission Systems (FACTS)
  - High Voltage DC lines

⇨ *Power grid becomes flexible which meets the needs of an electric power system with significant amounts of variable renewable generation*

Storage Devices

- Concept:
  - Store energy now and use it later
- Solution Approach:
  - Transmit power and store when line is underused
  - Supply load from storage when line is at limit



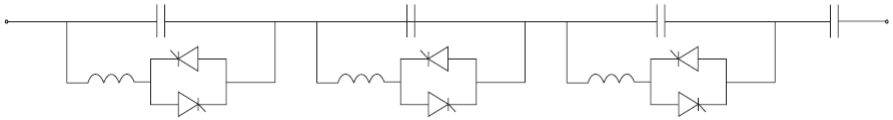


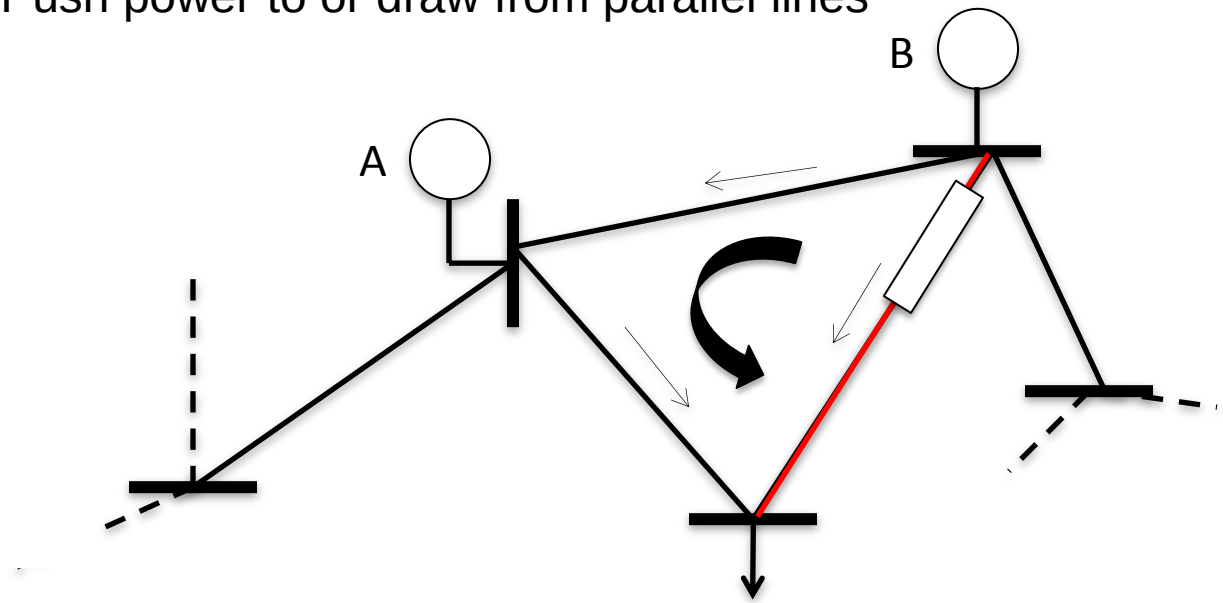
- Added benefit:
  - Balancing resource for variations in load/ renewable generation

Flexible AC Transmission Systems

Thyristor Controlled Series Compensators

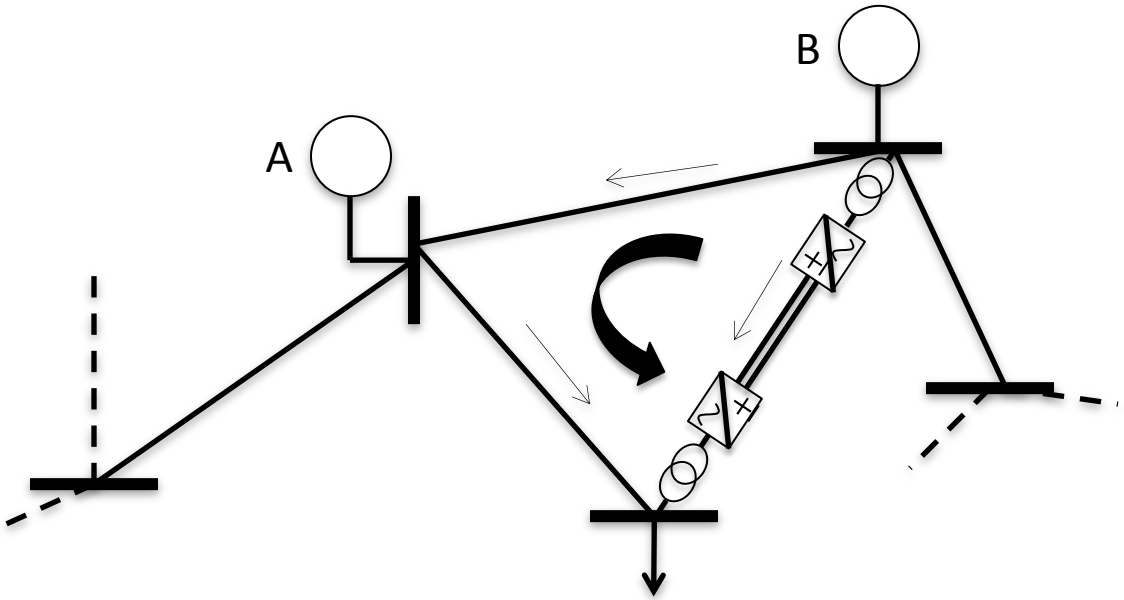
- Concept:
  - Based on power electronics
  - Influences line parameter
- Solution Approach:
  - Push power to or draw from parallel lines





High Voltage DC Line

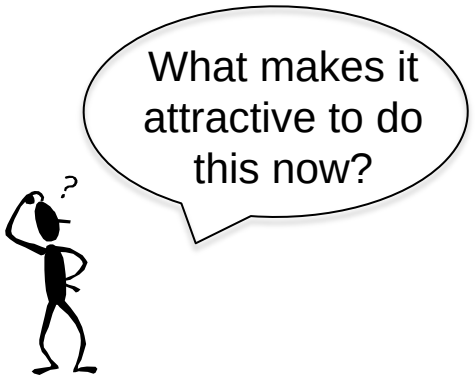
- Concept:
  - Connect DC line via converters to AC system
  - Converters can control power flow
- Solution Approach:
  - Push power to or draw from parallel lines



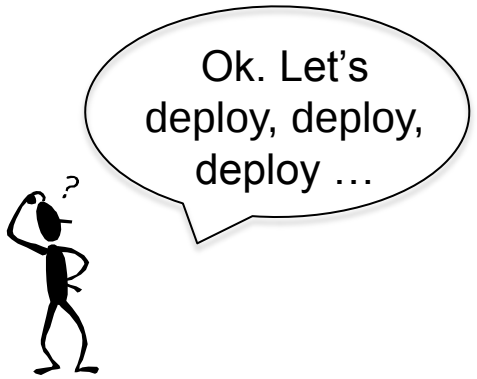
Opportunities

Increase in Grid Flexibility

- Increased Need:
  - More variable flows due to
    - Moving from bulk power to distributed generation
    - Fluctuating renewable generation input
    - Market operation
  - Improve usage of existing infrastructure
    - Increase in demand > grid expansion
    - “Not in my backyard” mentality



- Maturity of Technology
  - New technologies being developed
  - Issues with DC being resolved



Not so fast …

Challenges

- Reliability
  - More possibilities for failures
- Coordination of devices
  - Avoidance of unintentional interactions
- Protection
  - Possible need to change concept
- Security
  - More possible points for attack
- Financial Implications
  - Cost of devices and who should pay for them
  - Impact on market outcomes

Conclusion

Moving towards flexible infrastructure

- Flexibility added by grid technologies can serve as an enabler for a more sustainable power grid
- Problems particularly with respect to interactions are still not entirely known
- Challenges need to be addressed and carefully thought through as power grid operation becomes even more complex

Discussion

Now it's your turn …

Some provocative statements to start:

- "Utilities are not interested in such innovations because they are too conservative and believe the grid is fine as it is"

  => Utility people speak up!

- "Vendors of these devices and other grid solutions are just too lazy to solve challenges caused by their devices because they can make money off of unsolved problems"

  => Vendors speak up!

- "Academics do not provide any useful contributions to solve the problems because everything is purely simulation based – what do they know of the real world?"

  => Academics speak up!