SuperGrid-2 Workshop

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Systems Integration Issues

Bob Thomas

Cornell University

Traditional Electric Power Systems Expansion planning

- Done by engineers
- Separate generation expansion planning and transmission expansion planning activities
- Several alternate plans are created because of implementation uncertainty
- Planners take account of operations
  - Reliability!!!
  - Economics

Transmission expansion planning

- Begins with a load forecast and an expected generation mix.
- Dispatch assumed to be economical (marginal cost)
- AC power flow and contingency analysis simulation programs are primary tools
- Substations are part of the transmission expansion problem
- Supergrid will offer an alternative to adding conventional lines to the current US backbone consisting of 161-765 kV AC lines

Generation Expansion

- Planning a generation system that is both economical and reliable is a major responsibility
- Both energy (determines generation type) and demand (determines generation capacity) forecasts are needed
- Price and availability of fuel are primary factors in determining generation mix
- In the 80's and 90's environmental concerns increased in importance


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Lake Keystone Oct 1995

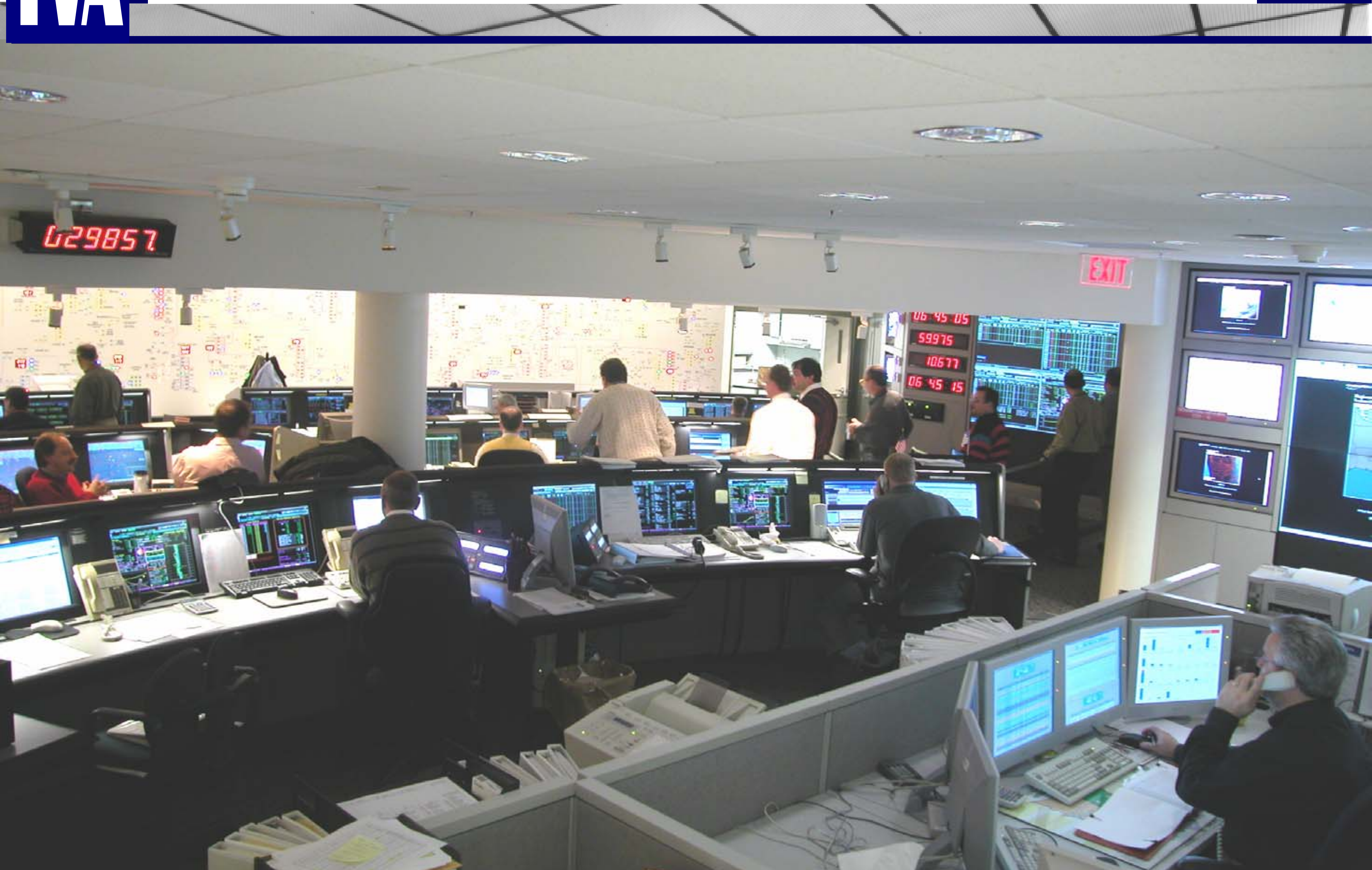
Protection

- Generation protection
  - not a system protection function (plant function)
  - Over-speed, reverse power, inadvertent energization, and out-of-step conditions
- Protection of transmission lines
  - protected on over-current, impedance and frequency
- Transformer protection
  - Over-current, temperature and pressure
- Bus protection
  - protect substations against fault conditions
- Other protection
  - controlled islanding schemes
  - load shedding such as under-voltage relaying to protect against voltage collapse

Operations

- Done in control centers
- Usually done by non-engineers with field experience and practical training
  - Jobs are boring and repetitive most of the time
  - Nuclear plant training thought to be desirable
- Job-one is reliability

To State of the Art



Transmission Operator

- Monitors actual system loading and voltage profiles
- Operates transmission facilities and directs generation to maintain voltage
- Manages switching schedules
- Monitors telemetry for failures
- Defines operating limits, develops contingency plans and monitors operations
- Directs restoration
- Implements emergency procedures

Generation Operator

- Reviews generation commitments, maintenance plans, load forecasts
- Plans for operational reliability
- Approves and implements Interchange Transactions (ramping)
- Directs generators and loads to ensure balance in real time
- Provides frequency control
- Monitors control performance and disturbance recovery
- Implements emergency procedures as directed by RC

In summary – in the past

- Planning was easy - mostly load versus capability
- Generation was known
- Future loads were known
- Transfers were known
- New transmission facility construction was accepted
- Costs were low
- Tools were adequate

Assumptions for future planning

- There will always be a legacy system to integrate into
- Centralized planning
- Centralized operations
- Nuclear is a large-scale future generation choice
- Still need load following
- Large penetration of DR possible

The environment into which a plan for integration of Supergrid is needed

- Planning has become difficult – can't see the future as well
- No longer just load versus capability but voltage and transient stability issues as well.
- Generation patterns are changing
- Future loads are unknown.
- Transfers are unknown.
- New technology needs to be developed and applied.
- New transmission facilities are not accepted and are delayed. - Lead times are much longer thus presenting uncertainties.
- Costs are high thus presenting budget concerns and making lower cost alternatives (patch-ups) favorable.
- Tools for planning need to be more robust and comprehensive and focused on transient/cascading events
- Data and modeling concerns.

Vision for the Supergrid network

- A backbone with constant power delivery
- Primarily a DC system
- AC might be available
- Hydrogen is the coolant
- Hydrogen is a commodity for sale
  - DR fuel
  - Transportation fuel
- Substantial nuclear and renewable supply is needed in order to make the economics work

Note

- A meshed Supergrid must be considered for reliability reasons
- We have experience with radial HVDC – we have none with a meshed HVDC network
- We will likely continue the trend to open markets on both the supply and the demand side
- Decisions to add components to the grid will be based on reliability (contingency protection?) and economics (support market functions?)

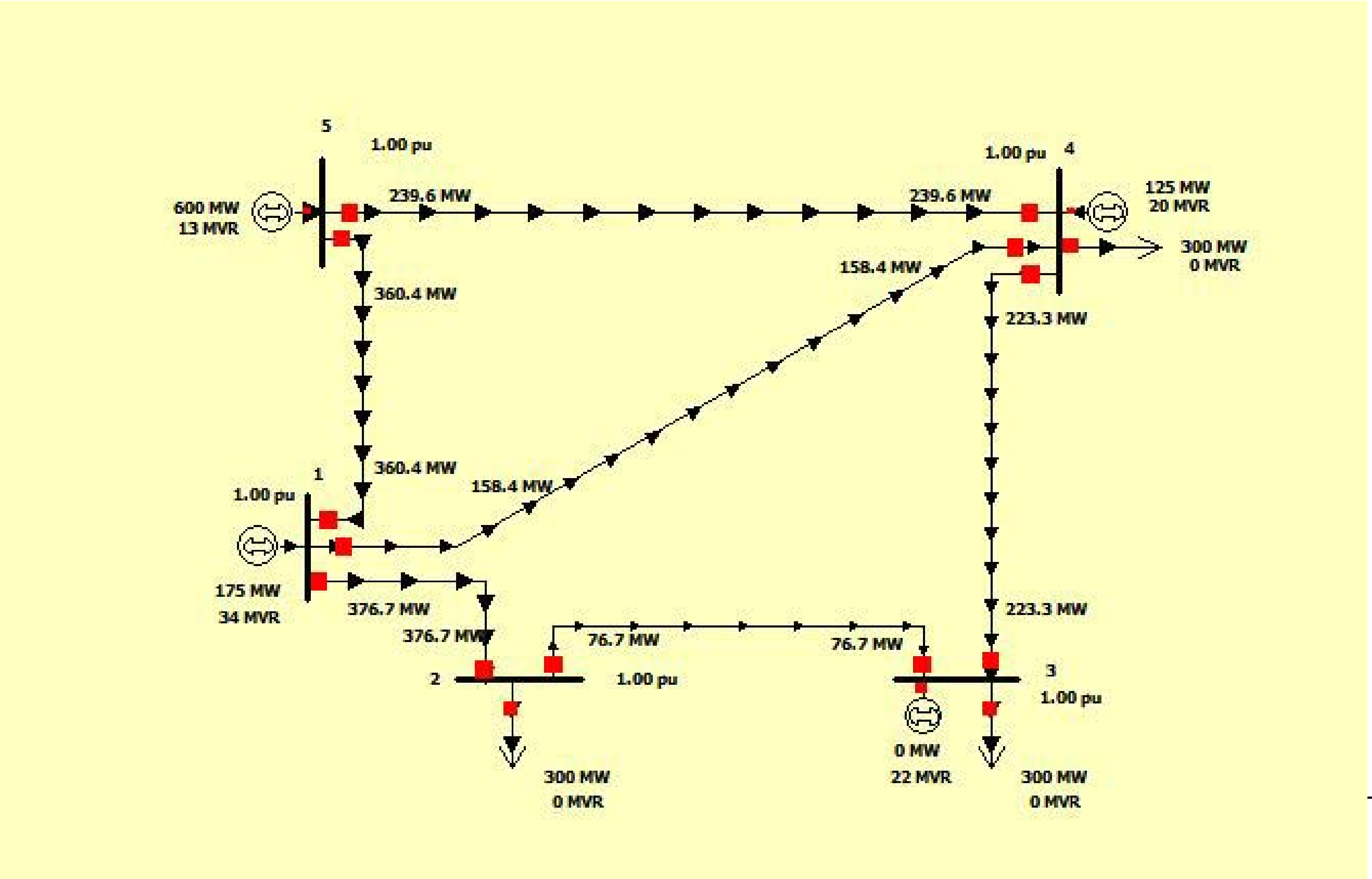
Most probably

- Supergrid, if it is DC, will be thought of by planners as adding baseload generation at certain points in the grid.
- Supergrid as envisioned will not be able to load follow. Most DR cannot load follow without local storage unless embedded in a “Microgrid”.
- Sufficient conventional generation capacity will still be needed unless there is a breakthrough in storage technologies.

Systems Issues for Supergrid

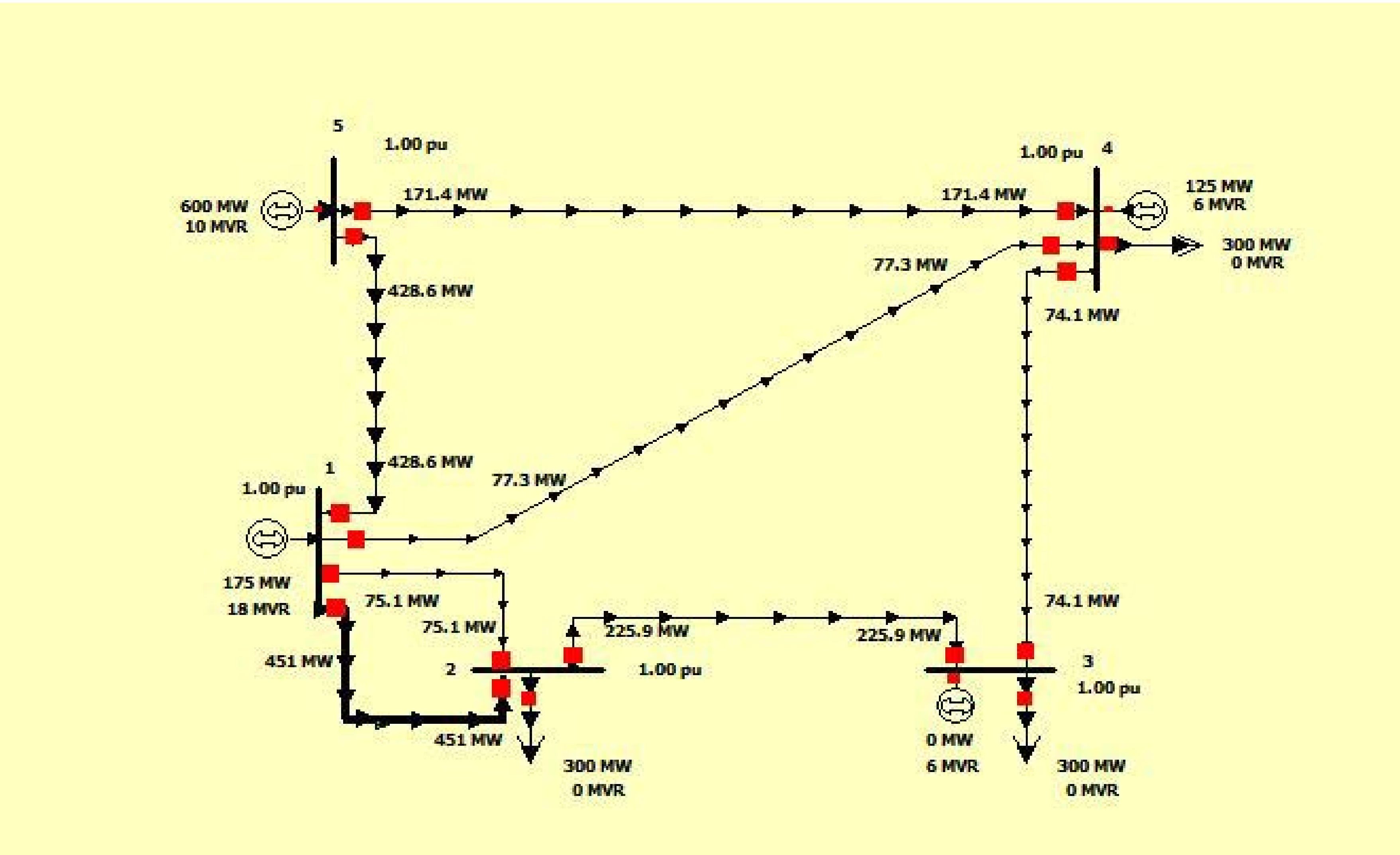
- Loss of high density corridors on contingency
- Protection if DC - don’t yet have DC circuit breaker – how is a “zone of protection” determined?
- Storage
- Nuclear plant sighting?
- Grid control? (ramping for load following or loss of units not possible with nukes. Fast storage helps)
- Integration of low-Z cables if AC

BaseCase



5
1.00 pu
600 MW
13 MVR
239.6 MW
239.6 MW
1.00 pu
4
125 MW
20 MVR
300 MW
0 MVR
158.4 MW
360.4 MW
223.3 MW
360.4 MW
1
1.00 pu
158.4 MW
175 MW
34 MVR
376.7 MW
376.7 MW
76.7 MW
76.7 MW
223.3 MW
2
1.00 pu
3
1.00 pu
300 MW
0 MVR
0 MW
22 MVR
300 MW
0 MVR

Adding a AC superconducting cable from bus 1_2



Research Issues

- New sensors for high DC current
- New circuit breakers
- Dual substation functions (electrons plus hydrogen)
- Use of hydrogen as an effective storage mechanism
- Maintenance outages need careful planning
- Contingency outages may require far more locational reserves than currently needed (Loss of largest unit)
- New planning and operation models are needed