Segmentation

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Segmentation

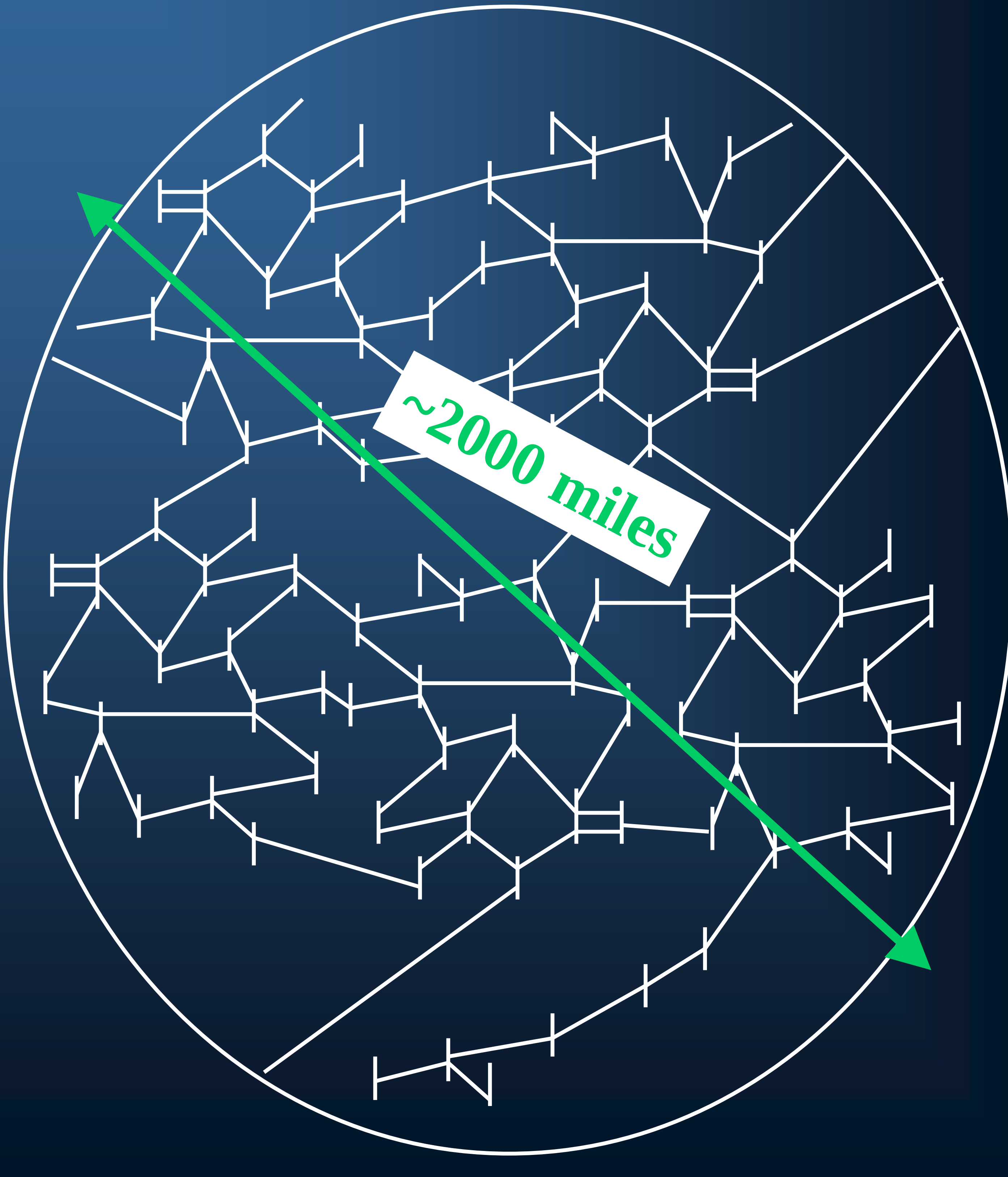
- Use dc to segment large ac grids into smaller synchronous ac segments

- Precedent:
  - Texas
  - Hydro Quebec
  - WECC-Eastern Interconnection
  - Norway
  - India
  - Australia (Tasmania)

Segmentation

- Propose ac islands of (roughly) 10GW to 60GW
  - Convert existing longer regional ac ties to HVDC
    - Bipole
    - Tripole
  - Insert back-to-back dc converters in remaining ac ties
    - Conventional dc
    - Voltage Source Converter, or
    - *Variable Frequency Transformers*

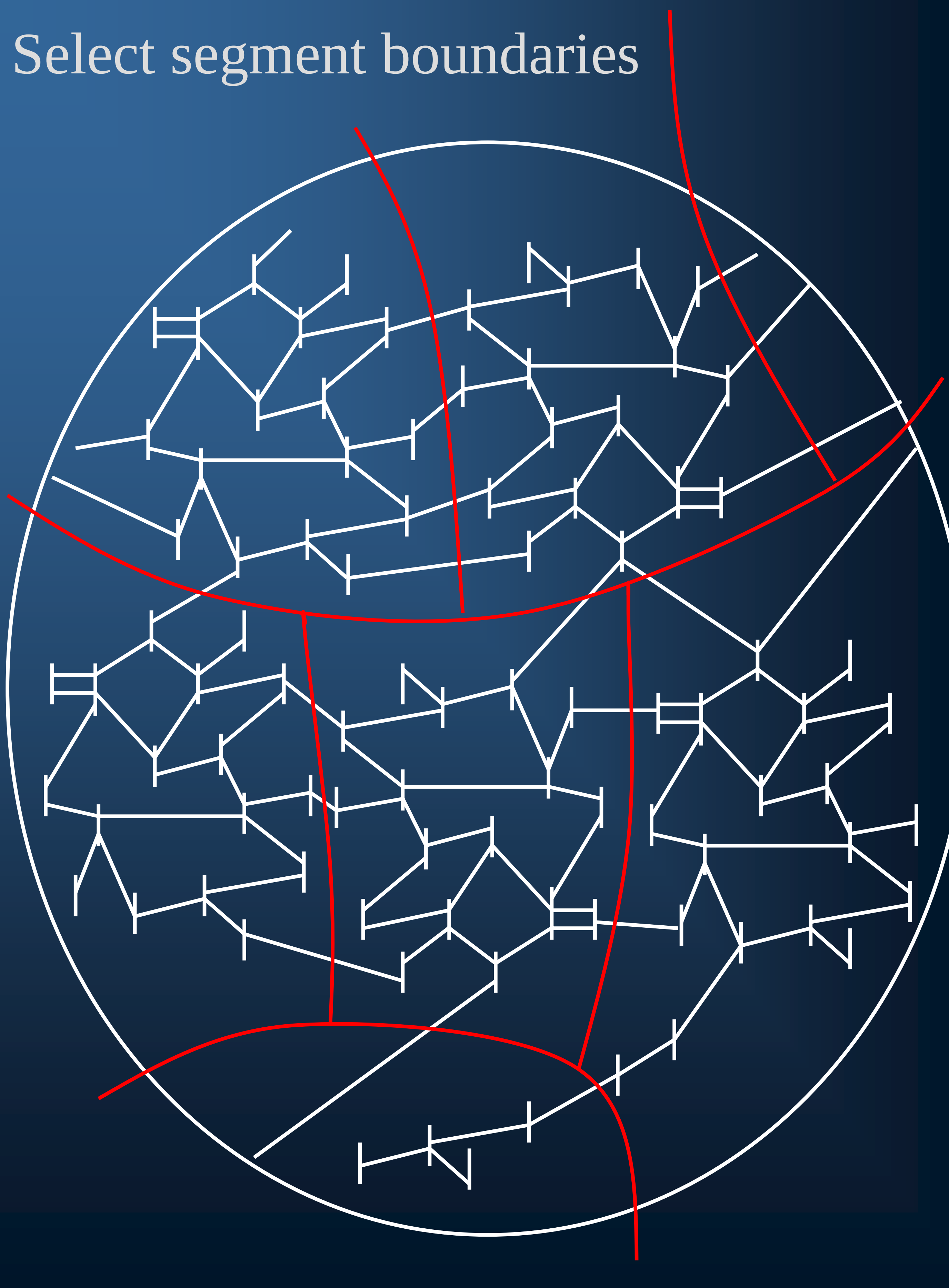
Example



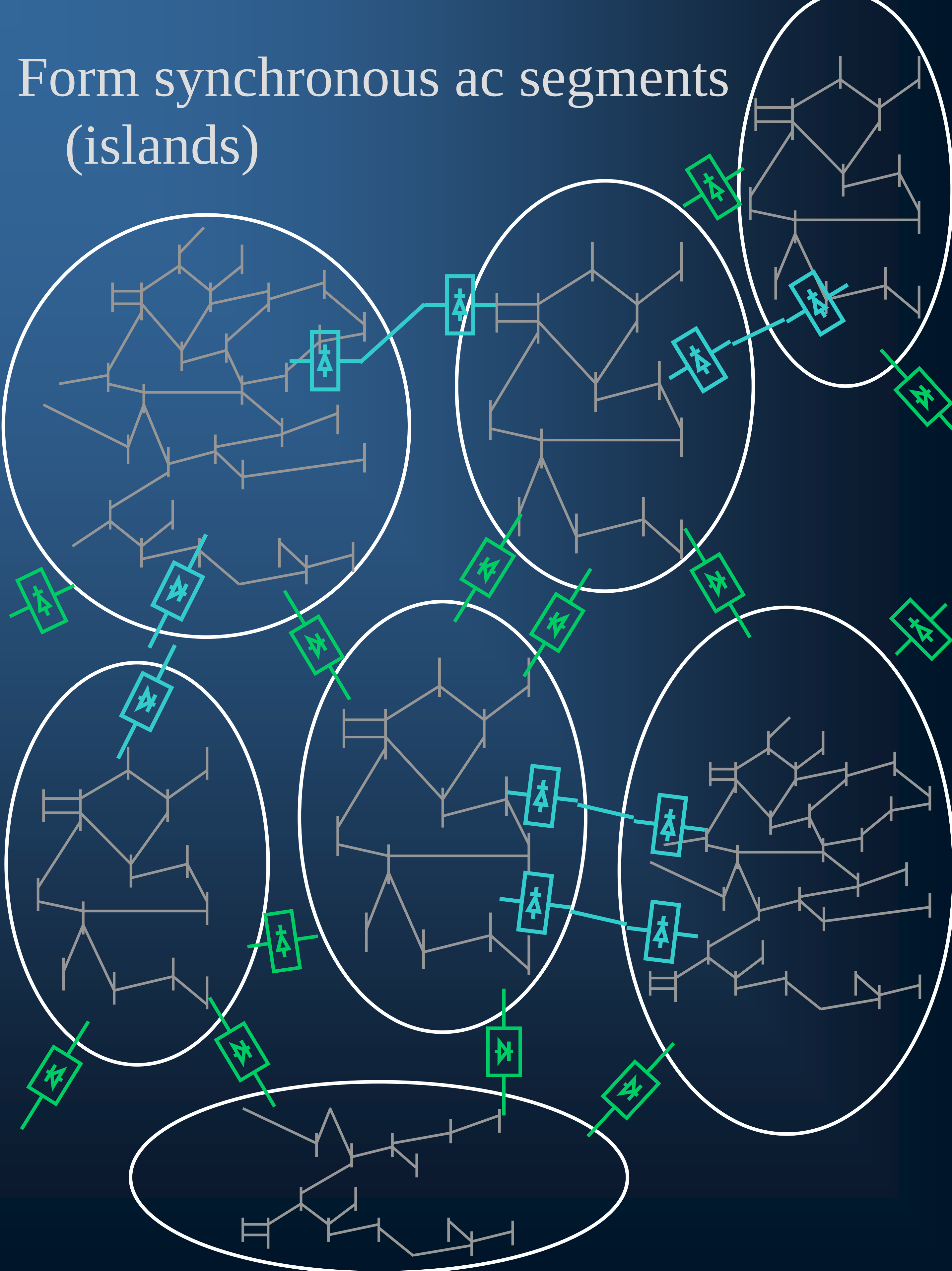
Boundary Selection Criteria:

- Boundaries formed according to:
  - Locations that require least back-to-back MVA
  - Locations that break up stability limited paths
  - Congested paths that need more transfer capability
  - Where longer DC lines can be formed from existing ac lines
  - Political boundaries where practical
- An optimization problem!

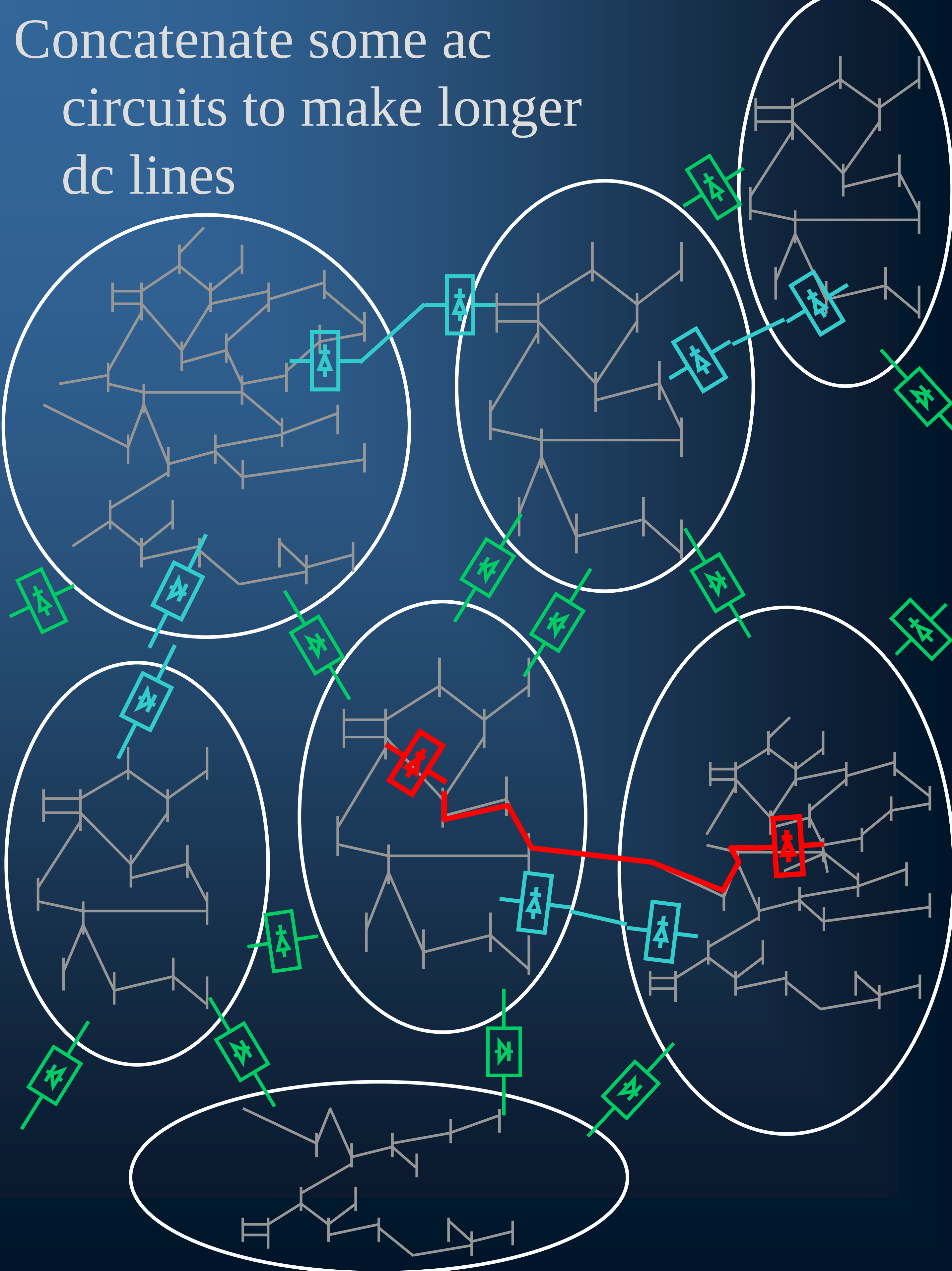
Select segment boundaries

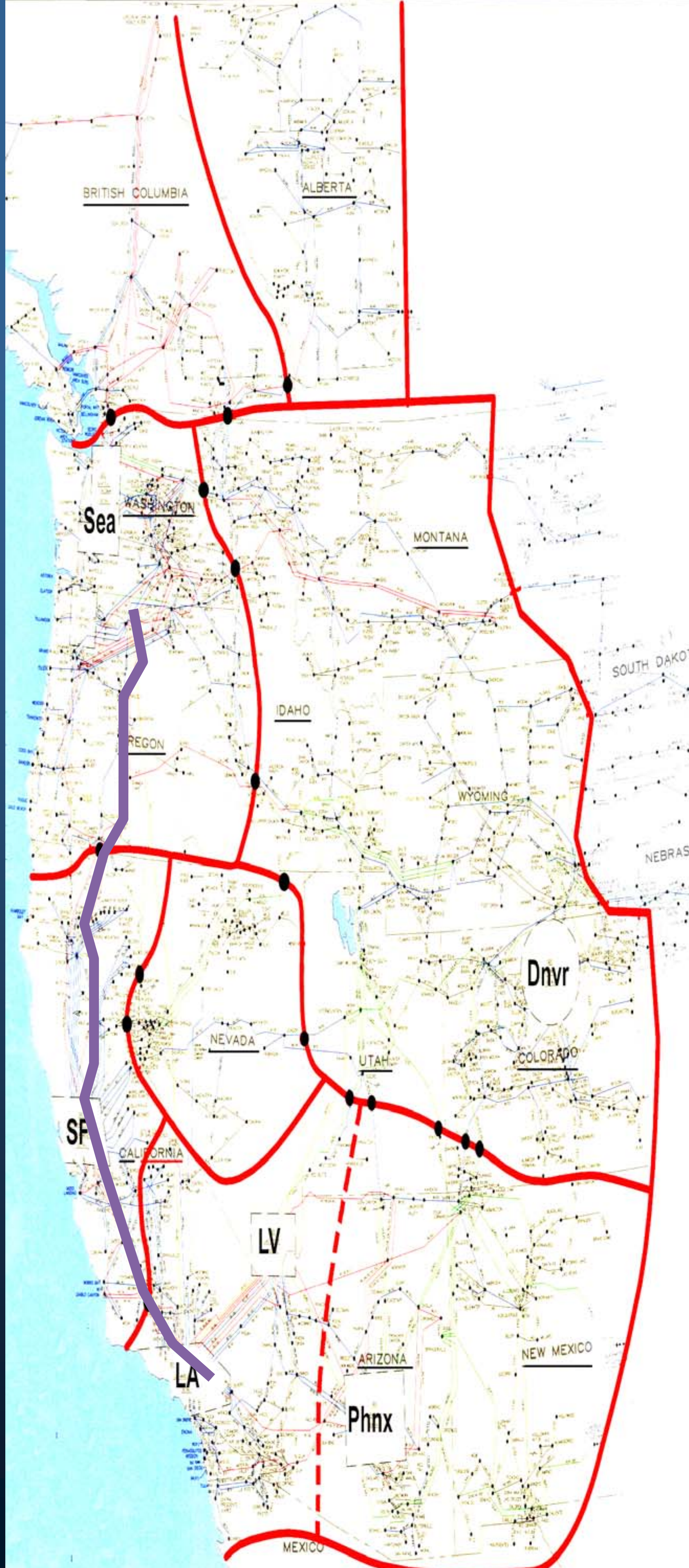


Form synchronous ac segments (islands)



Concatenate some ac circuits to make longer dc lines




BRITISH COLUMBIA
ALBERTA
Sea
WASHINGTON
MONTANA
SOUTH DAKOT
IDAHO
REGON
WYOMING
NEBRASK
Dnvr
NEVADA
UTAH
COLORADO
SF
CALIFORNIA
LV
LA
ARIZONA
Phnx
NEW MEXICO
MEXICO

Future – add long haul HVDC lines

Why Segmentation?

- Difficulties with Existing Large ac Grids:
  - Disturbances can propagate across ac grids
  - Vulnerability to simple sabotage strategies
  - Transfer capability limited by:
    - Angular stability, voltage stability
    - Loop flows
    - N-1 and N-2 contingencies
  - Limited ROW power densities (relative to dc)

Benefits of Segmentation

- Reduced risk of widespread blackouts
- Intra-segment blackout risk is lower
- Cascading/collapse is limited to one segment
- Reduced operational complexity & uncertainty
- Inter-area power flows where it is directed
  - Schedule for lower ac losses
  - Schedule for best use of ac line capability

Benefits of Segmentation

- Substantial increases in transfer capability
  - Conversion of ac to dc
    - Bipole
    - Tripole
  - Back-to-back converters control flow on upstream and downstream ac system
    - Back-to-back tie and dc line power can be stepped down to cover upstream and downstream ac contingencies
      - By operator for N-1 (prepare for next N-1)
      - By SPS for N-2 (automatic)
      - Allows higher loadings of adjacent ac circuits

Benefits of Segmentation

- Facilitates grid planning & investment decisions
  - More predictable capability of upgrades
  - More predictable impacts & usability of upgrades
  - Stability is no longer an issue (some intra-segment)
- Market benefits
  - Enhanced commodity values and trading opportunities
  - Simpler and more easily applied and policed market rules
  - Less uncertainty over rights to transmission upgrade capacity

Benefits of Segmentation

- Makes WAMS easier and more effective
- Intelligent/self-healing grid becomes feasible
- State Estimators perform much better
  - Finite segments
  - Simple neighboring system model (boundary flows)
  - SE based applications far more useful & reliable

Existing Interconnection Benefits Remain

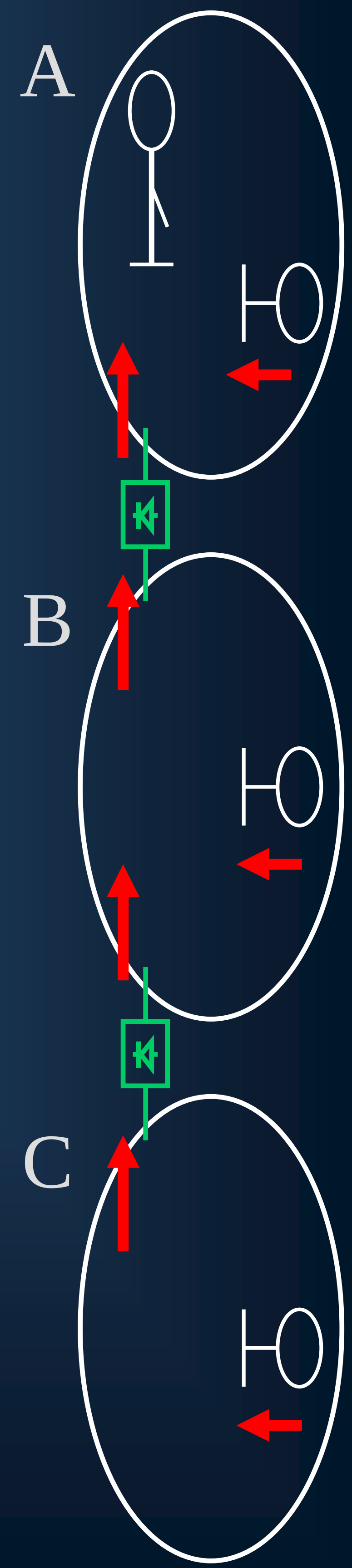
- Traditional benefits:
  - Generation sharing
  - Reserve sharing
  - Emergency response
  - Firm transfers
  - Economy transfers
- Most are increased or improved

Power Can Be More Precisely Scheduled:

- For lowest losses
- Where intra-segment line capacity is available
- Where total transfer can be maximized
- To accommodate intra-segment maintenance
- Power can be routed via multiple segments
- For market management
- Involves multiple segments … requires coordination

How it Works

- “Governors” on dc lines and back-to-back converters replace Kirchoff’s laws, synchronizing power, power-angle, etc.
  - Loss of generation in segment A
  - Frequency drops in segment A, generators in A respond, ties to adjoining segments ramp up
  - Segment B frequency decays, generators in B respond, ties to adjoining segments ramp up
  - Segment C frequency decays, generators in C respond, ties to adjoining segments ramp up, etc.
  - UFLS may occur in segment A; might also be allowed in segment B for a problem in A



How it Works

- More and larger frequency excursions
  - A bad thing?
  - No, a good thing!
  - Just ask the folks in Texas
  - When system frequency excursions occur …..
    - Generator governors and firing systems are exercised
    - Generator response problems are identified and fixed
    - Governing and boiler equipment is adjusted for best performance
  - Generator response is more predictable and reliable

How it Works

- dc tie governors limit assistance to neighbors;
  - Within spinning reserve and/or UFLS tolerance
  - Within thermal/voltage capability of ties and associated ac circuits
  - Different limits for each direction
- Bottom line -- Provide as much assistance as you can without jeopardizing your own system
- Neighboring segment allowed to collapse without taking neighboring segments with it

How it Works

- Automatic central control?
  - Not essential, but interesting possibilities
  - Local controls must backup central controls
    - Pre-set tie governor dp/df and maximum power
- Many central control possibilities
  - For steady state optimization
    - Minimize losses
    - Maximize total flow capability (normal or emergency assistance)
    - Accommodate intra-segment constraint(s)
  - For emergency response (fast, automatic)
    - Reroutes power upon local problem
    - Responds to requests from neighboring segments
      - More or less transfer (before frequency decays)
      - Different route (to accommodate grid problems in neighboring segment)

Cost

- Huge cost, huge benefits
- Who pays?
  - Private party investment for incremental transfer capability
    - a business opportunity
  - Public investment for increased reliability
    - Resistance to malevolent attack (Federal)
    - Social benefits of fewer and lesser blackouts
  - Market benefits?

More to Think About … Is grid reliability dropping?

- Every line and transformer addition or upgrade loads upstream, downstream, and parallel lines and transformers more heavily;
  - Average line loading is thus increasing over time, and this
  - Increases stress on the grid, making N-1 events more likely
- The same additions/upgrades also lead to uniformly heavily loaded lines thus;
  - Leading to multiple limiting N-1 contingencies
  - And multiple "most heavily impacted" elements
- This combination leads to;
  - The system is "tested" more frequently
  - Each test has higher risk of compounding events and cascading
- Beyond the above, an increasing share of N-2 events are troublesome

More to Think About . . . .

- Heavily loaded systems
  - Huge reactive supply and losses
  - Increasingly difficult reactive balance
  - Greater increase in I^2X losses upon N-1 events

More to Think About . . . .

- Criteria/Standards are not being adjusted to accommodate these effects

- Can we halt the reliability decay?
- Is Segmentation the answer or part of the answer?

- Questions?