SCHWEITZER ENGINEERING LABORATORIES®

Synchronous Measurement, Control, & Protection of Electric Power Systems

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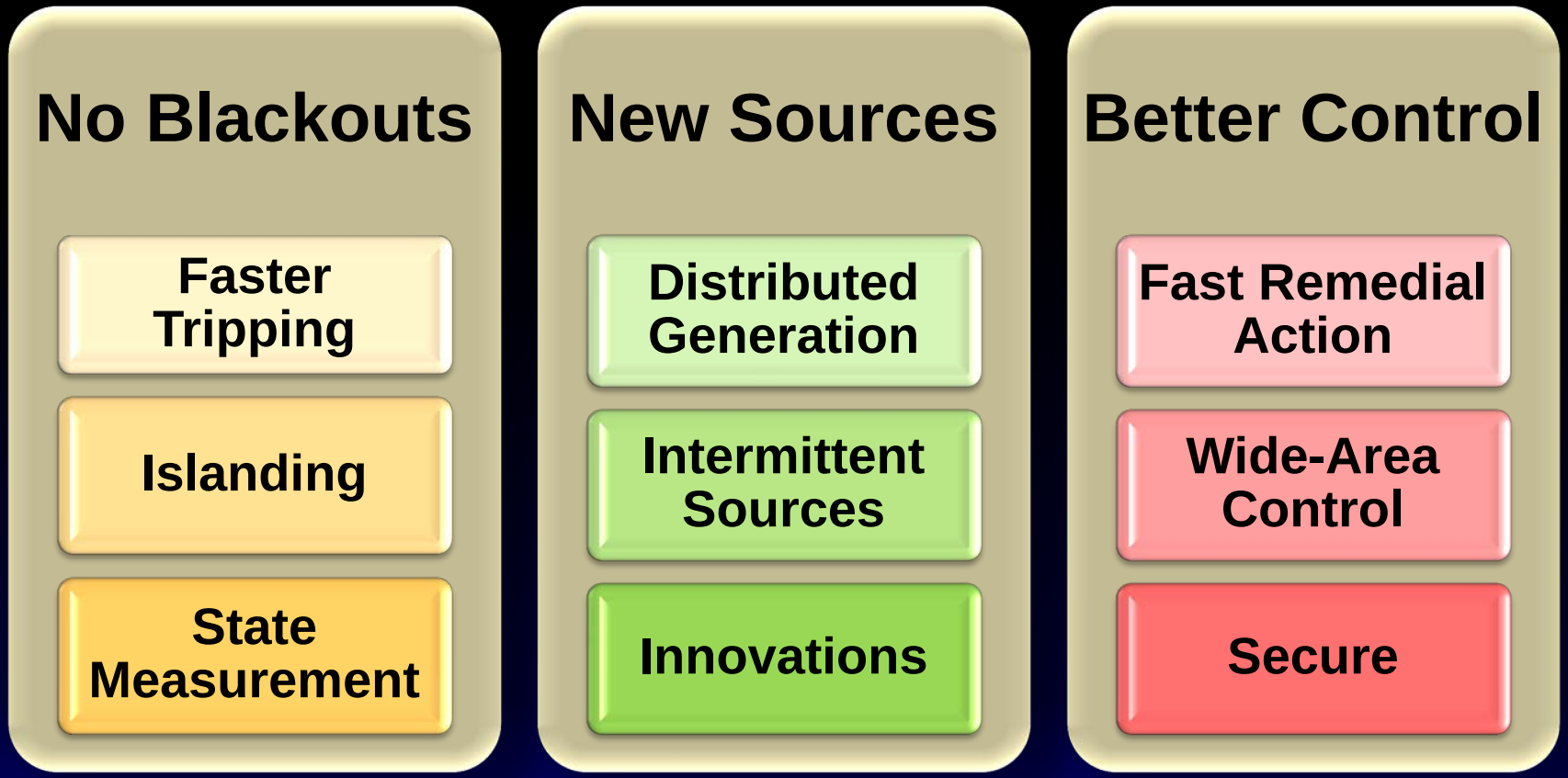
February 29, 2012

Making Electric Power Safer, More Reliable, and More Economical®

The Future of Power Systems



Solutions must be: efficient, low-cost, robust, reliable

Building Blocks and Solutions

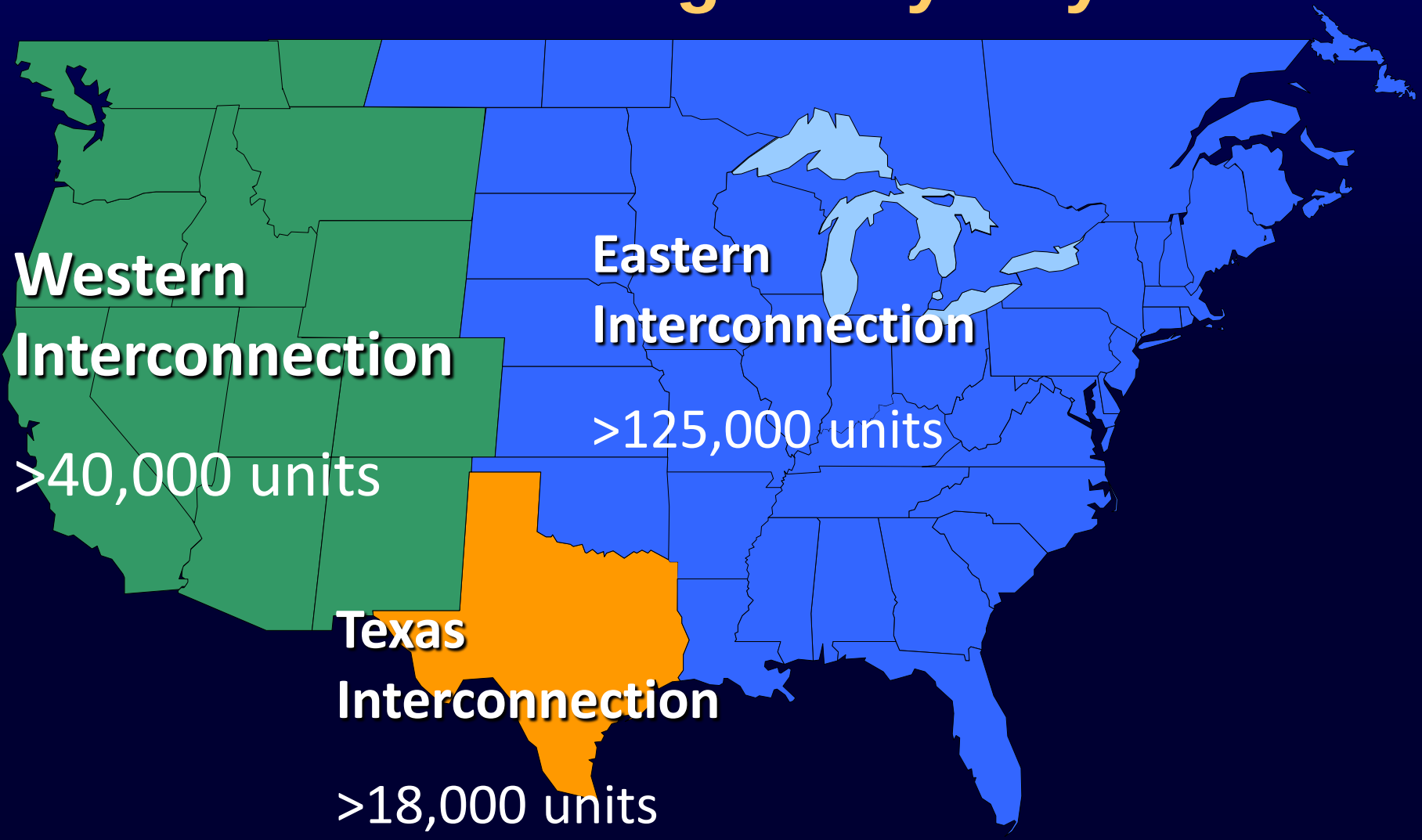
- Measure, control, protect
- Process information anywhere
- Dependable, deterministic, secure communications… utility rated
- Reliable, redundant precise time
- Real-time wide-area solutions for control, protection, and automation of electric power systems

Synchronous measurement, control, and protection capabilities are in your relays, meters, VRCs, …

TODAY,

for free.

SEL Synchrophasors Are Everywhere, and Growing Every Day!



RTAC & SVP:
Relay-Speed Processing, Anywhere

- State Equations: Stability, Thermal

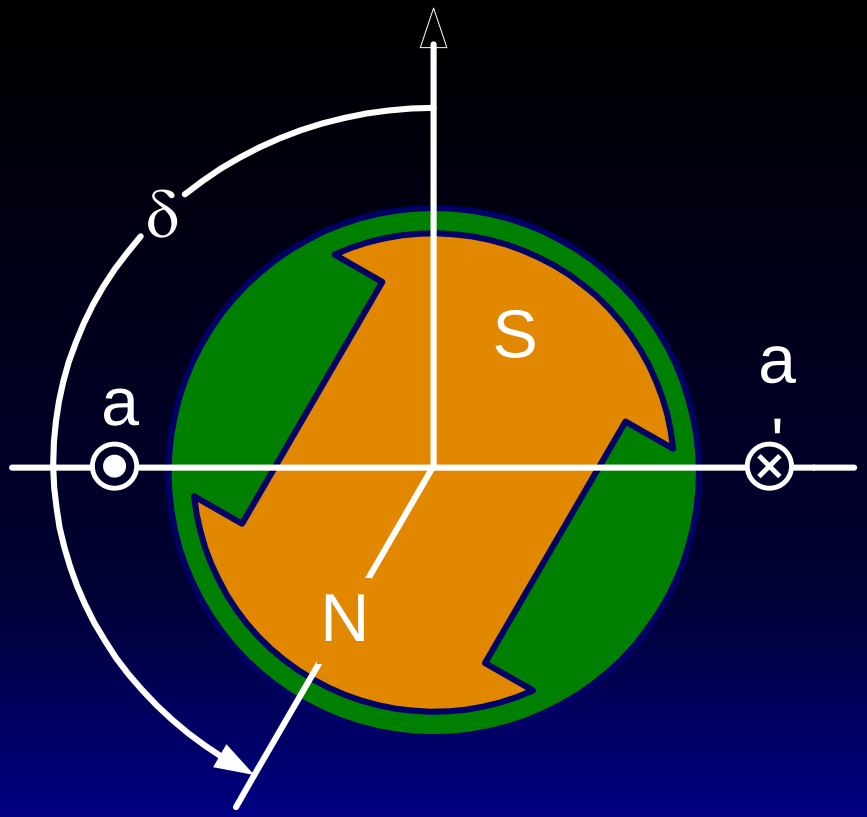
$$\dot{\underline{X}} = A\underline{x} + B\underline{u}$$

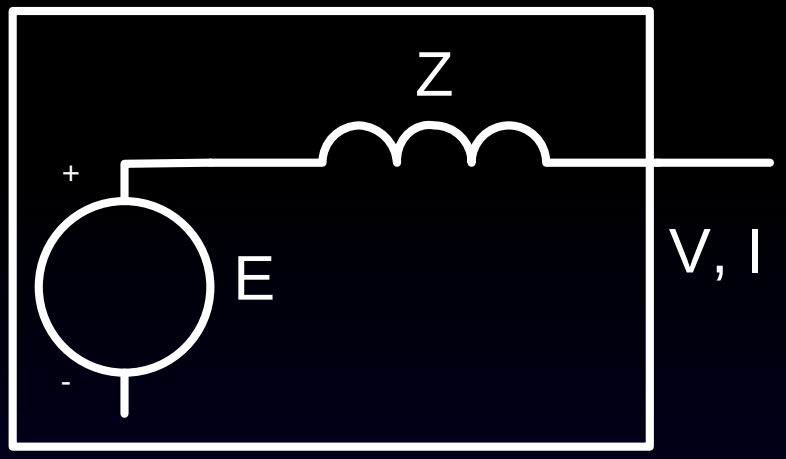
$$\underline{y} = C\underline{x} + D\underline{u}$$

- Phasor Math: Self-Checks, Interpolation

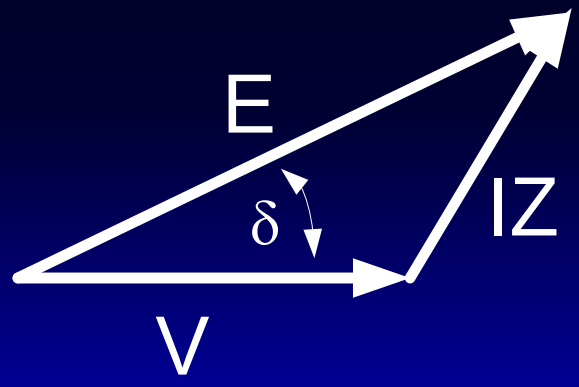
$$\vec{V}_m = \vec{V}_n + Z_{mn}\vec{I}_n$$

Generator relays will directly measure δ

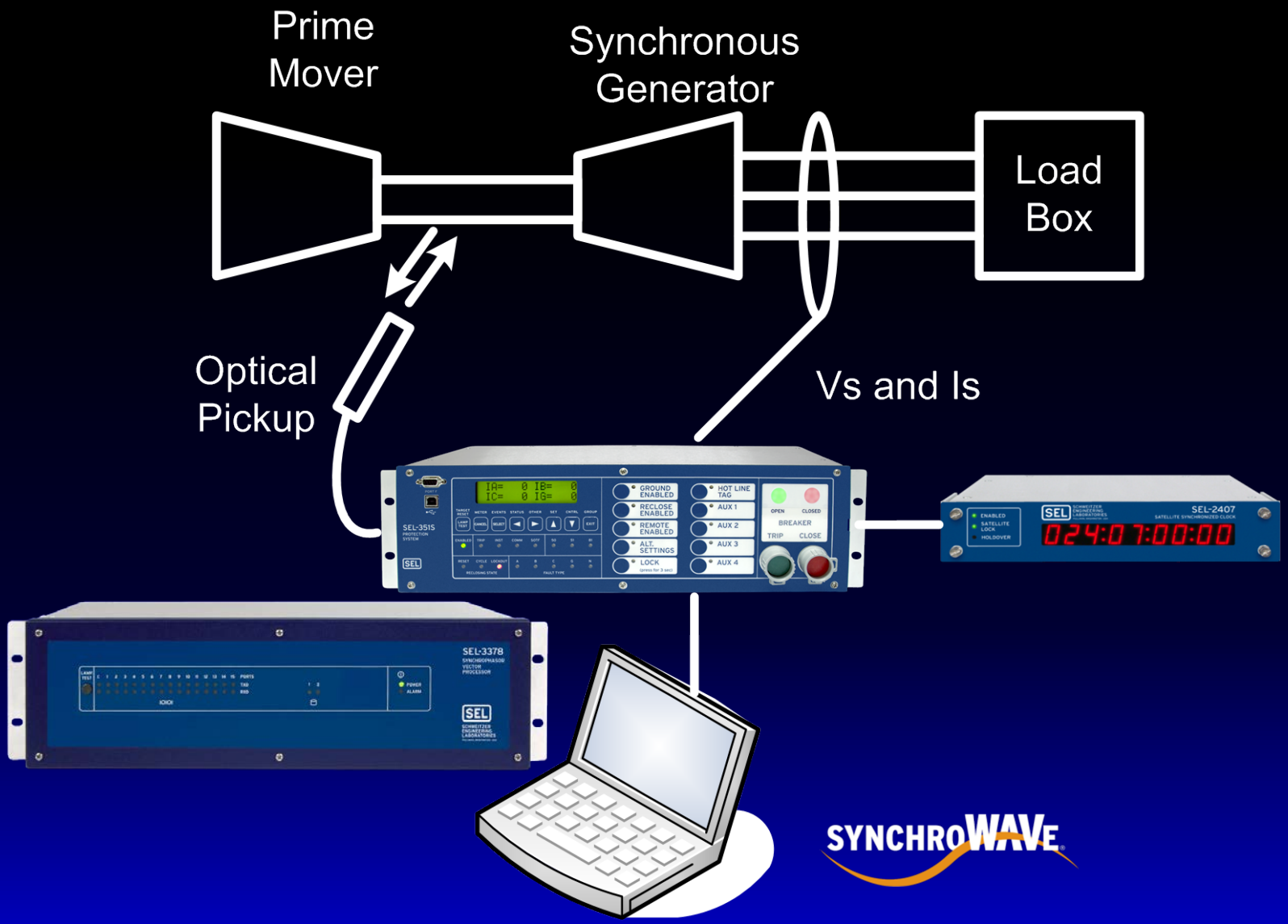




Generator

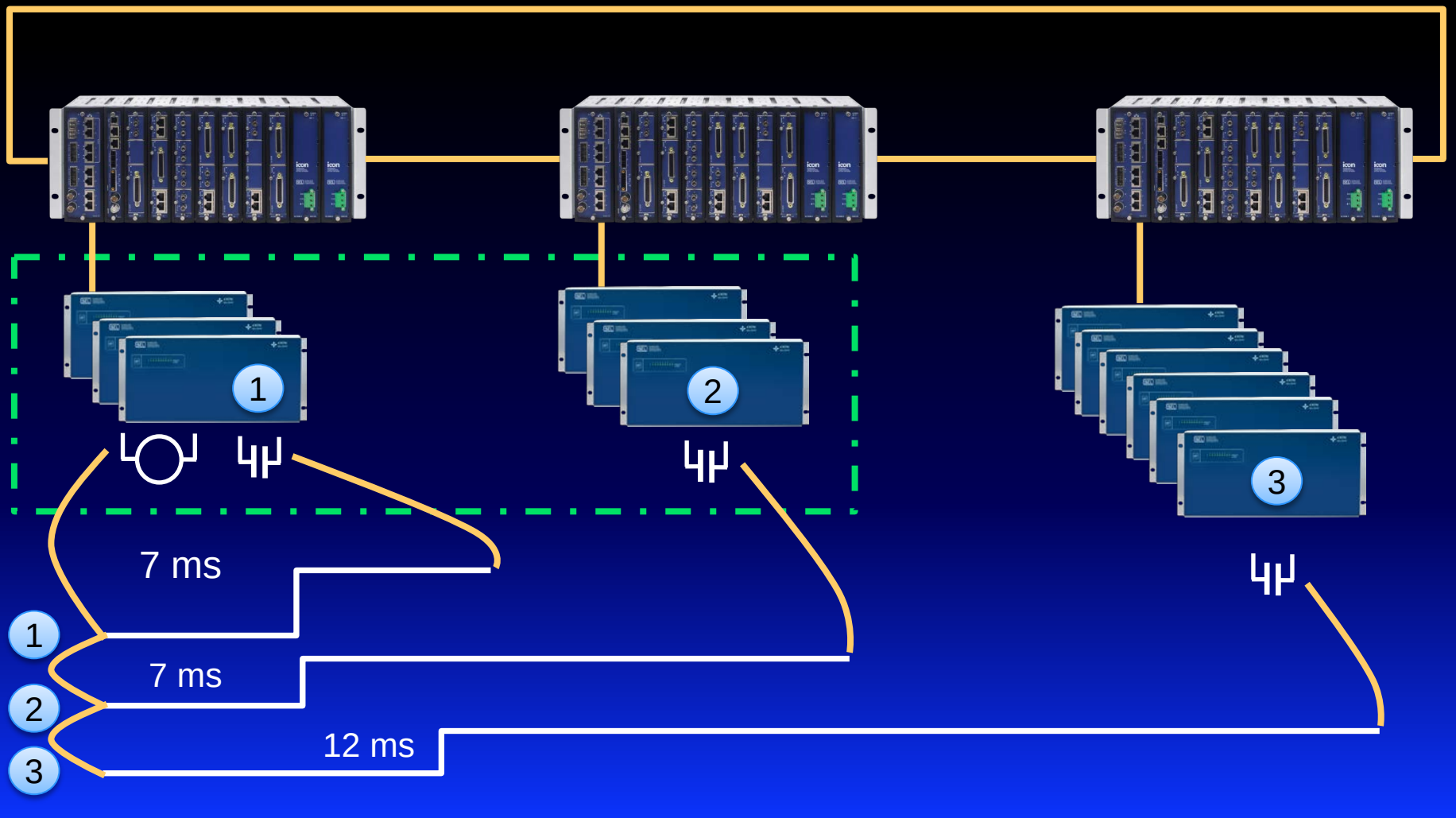


Rotor δ Test System

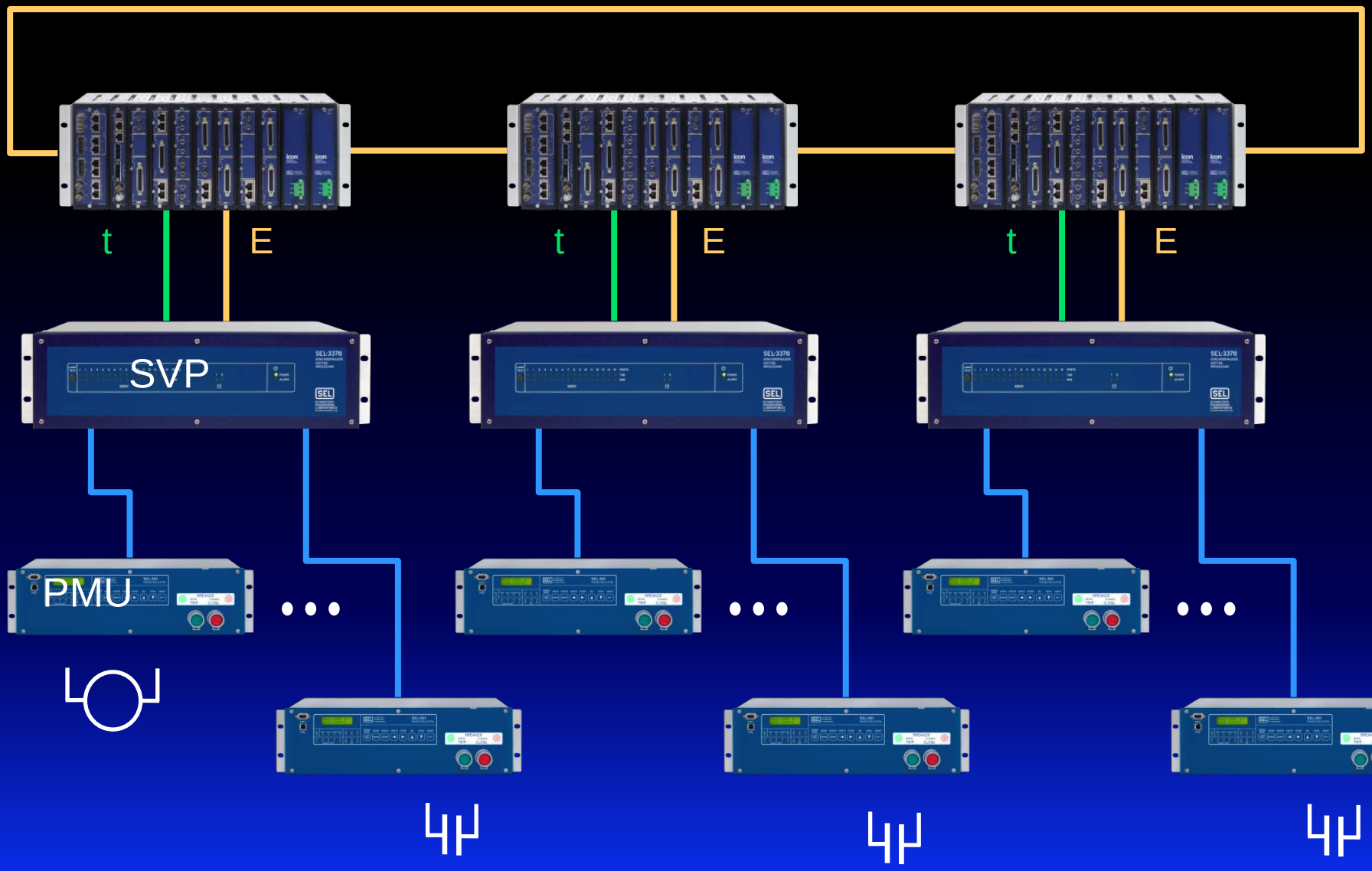


Communications for Critical Infrastructure

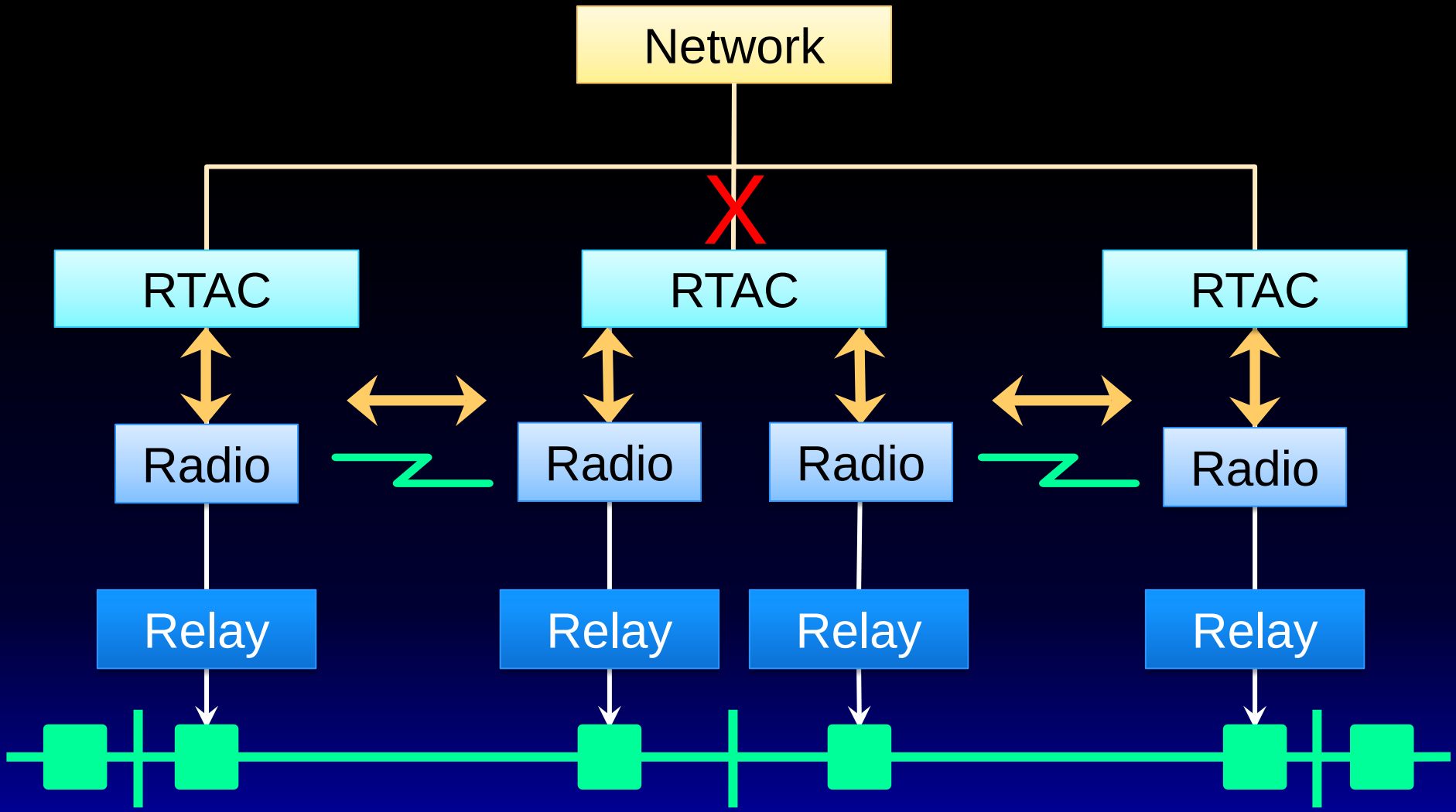
Secure, 5ms healing, reliable,
redundant, 0.5µs absolute time, deterministic.



Relay – SVP – ICON – SVP – Relay



Radios for POTT and Network Backup



GPS Time Is Not Guaranteed!

- Jamming or interference (NAVWAR)
- Equipment failure
- DoD Control
- Solar flares

"On December 6, 2006, a solar flare created an unprecedented intense solar radio burst causing large numbers of receivers to stop tracking the GPS signal."

-- NOAA Press Release

Reliable and Redundant Precise Time

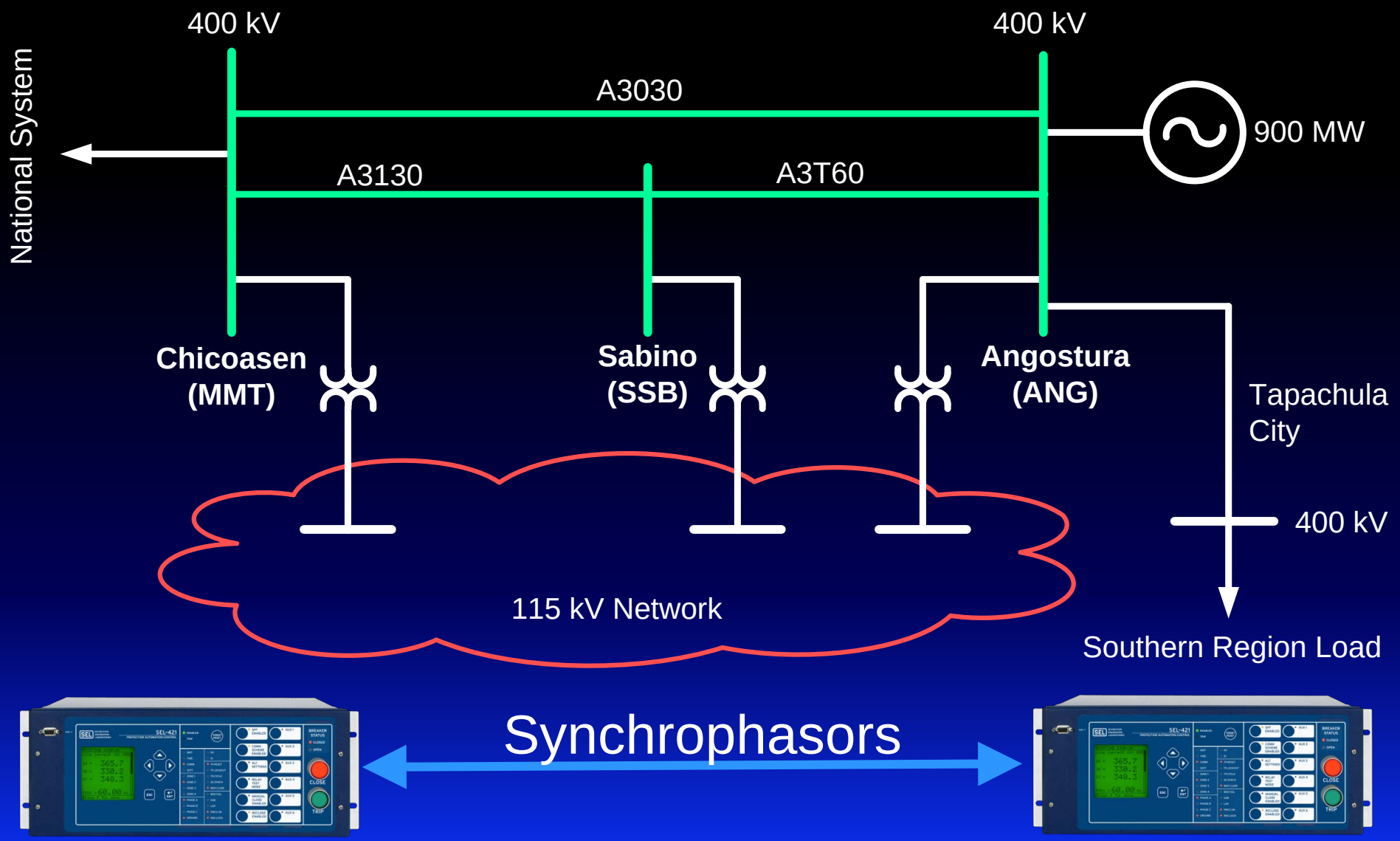
- Satellites: GPS is great when available
- ICON networks +/- 0.5µs of all nodes with or without GPS
- Rubidium and cesium standards
- WWVB?

You can build systems today that enjoy the precision of GPS and provide wide-area synchrony even when GPS is lost.

We Must Operate, Control, Protect Our Wide-Area Systems Better

- Quicker loop times
  - Cycles or seconds…vs…minutes
  - Automation / operators
- State-based control
  - Measure the state
  - Drive the system to desired state
- Distributed control/successful islanding

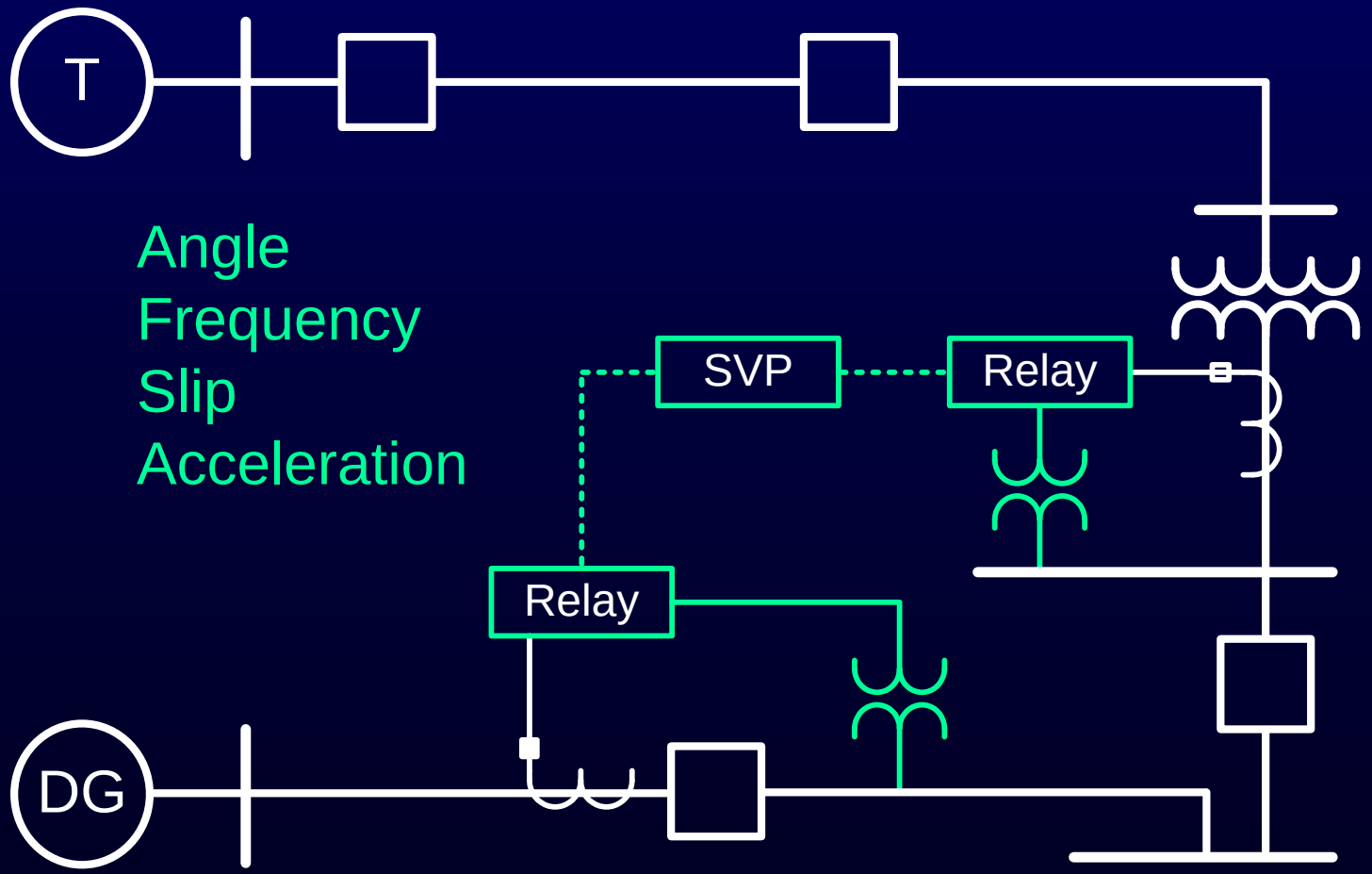
CFE (Mexico): Generation Shedding



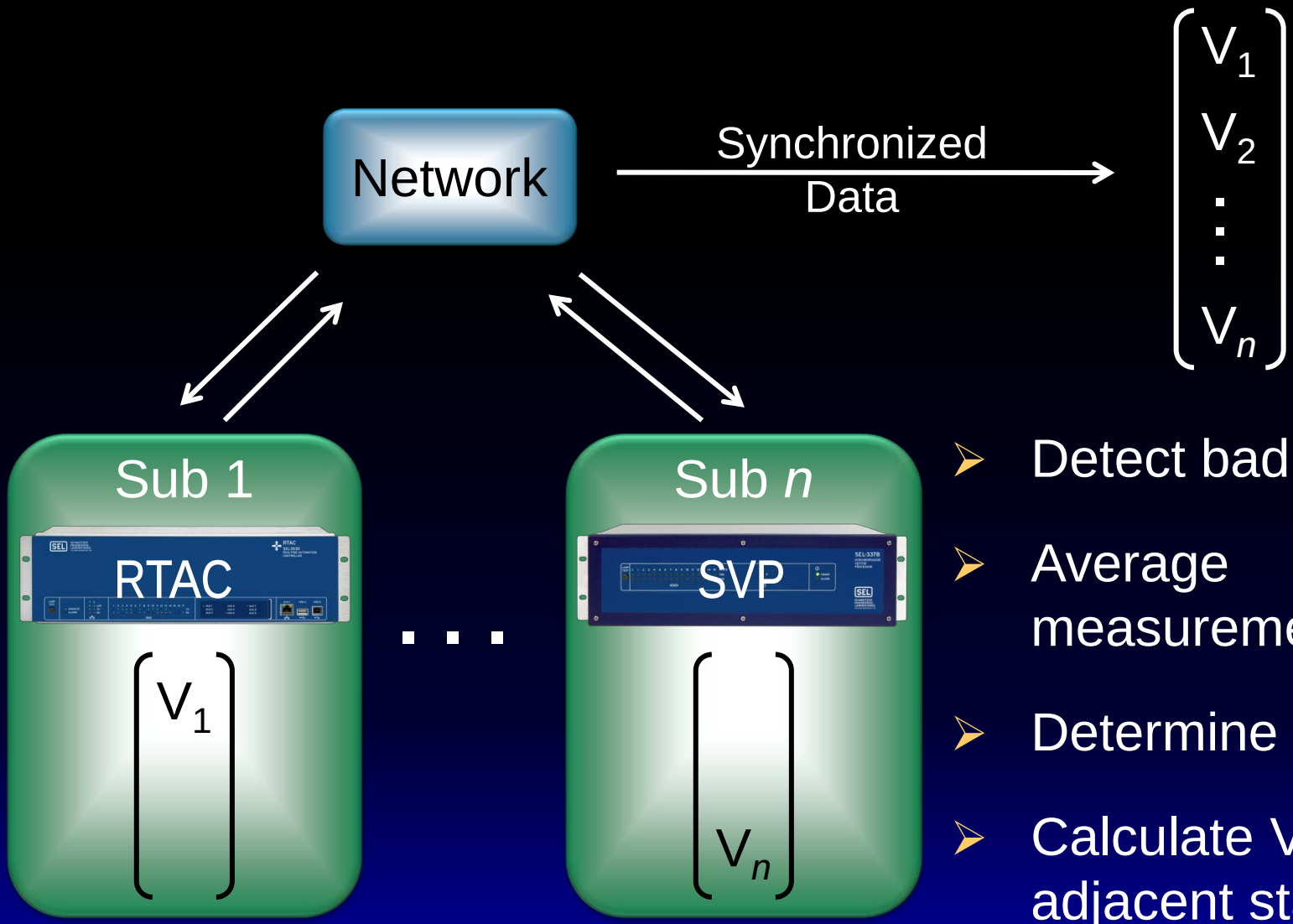
Georgia: Tiblisi Relies on Enguri Dam

Line Loss Requires Load Shedding

Florida Power & Light Anti-islanding



Directly Measure the State

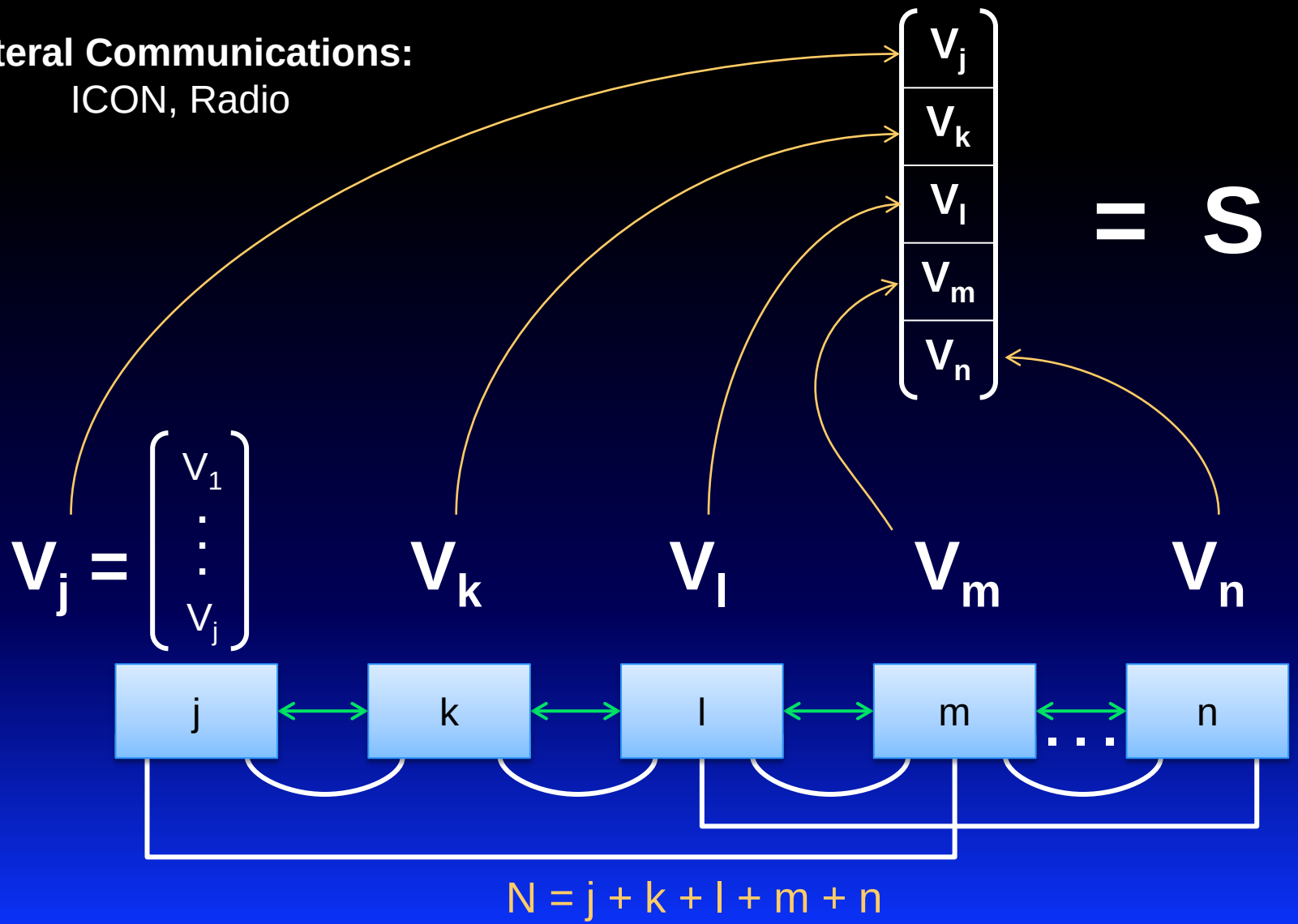


- Detect bad data
- Average measurements
- Determine topology
- Calculate V at adjacent stations:
  $V' = V + ZI$

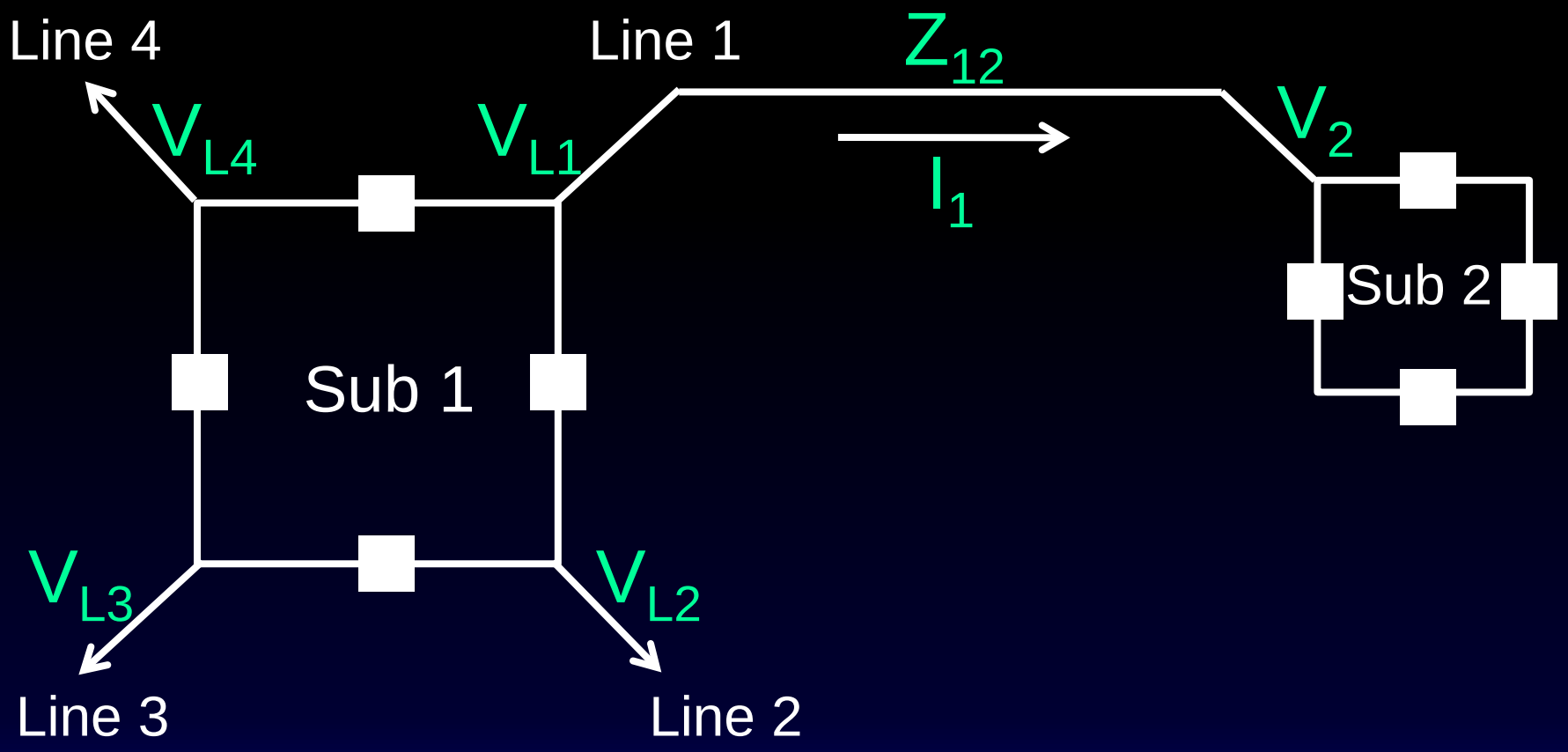
Complete State Vector, S

Every Location Gets the State Vector

Lateral Communications:
ICON, Radio



State Interpolation or “Linear Estimation”

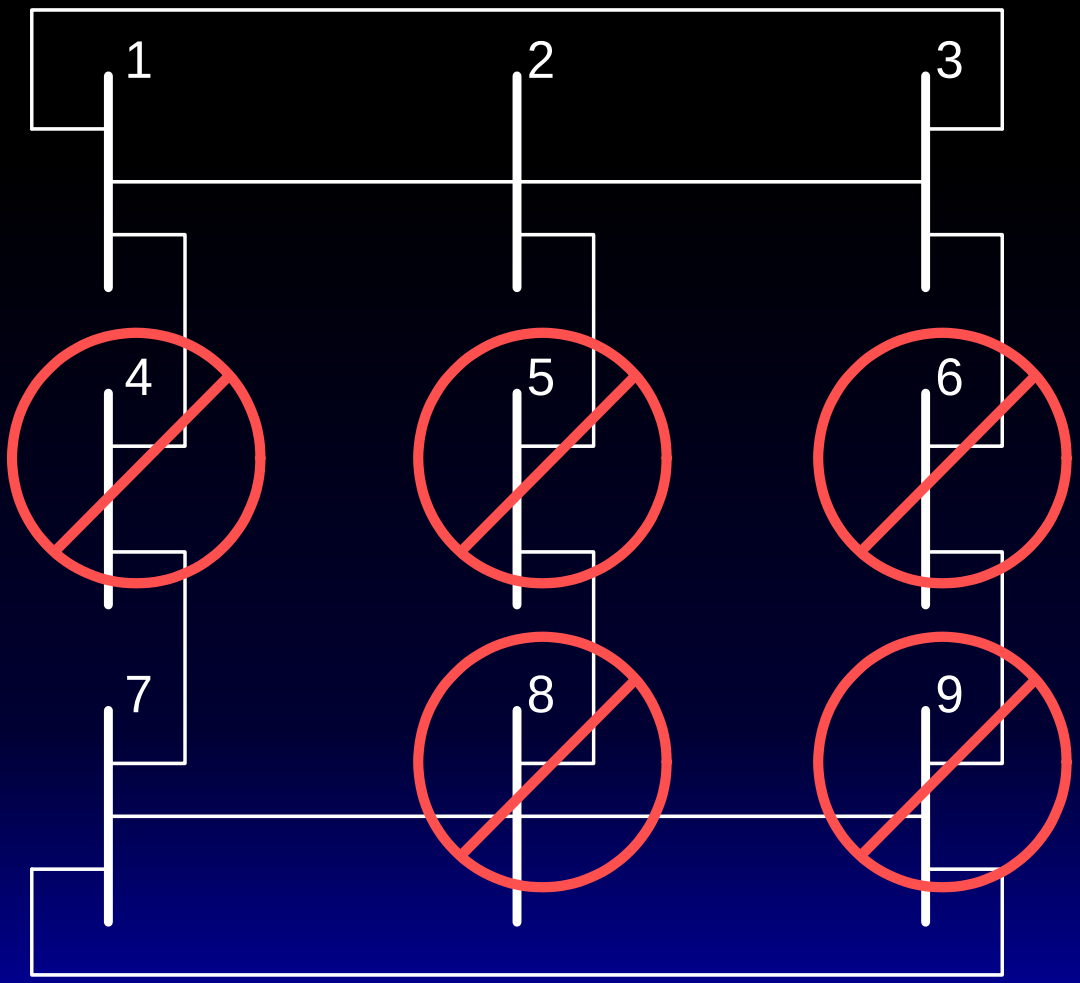


$$V_1 = \tfrac{1}{4}\left(V_{L1} + V_{L2} + V_{L3} + V_{L4}\right) \qquad V_2 = V_1 + Z_{12}\, I_1$$

if all breakers closed and
if all voltages about the same

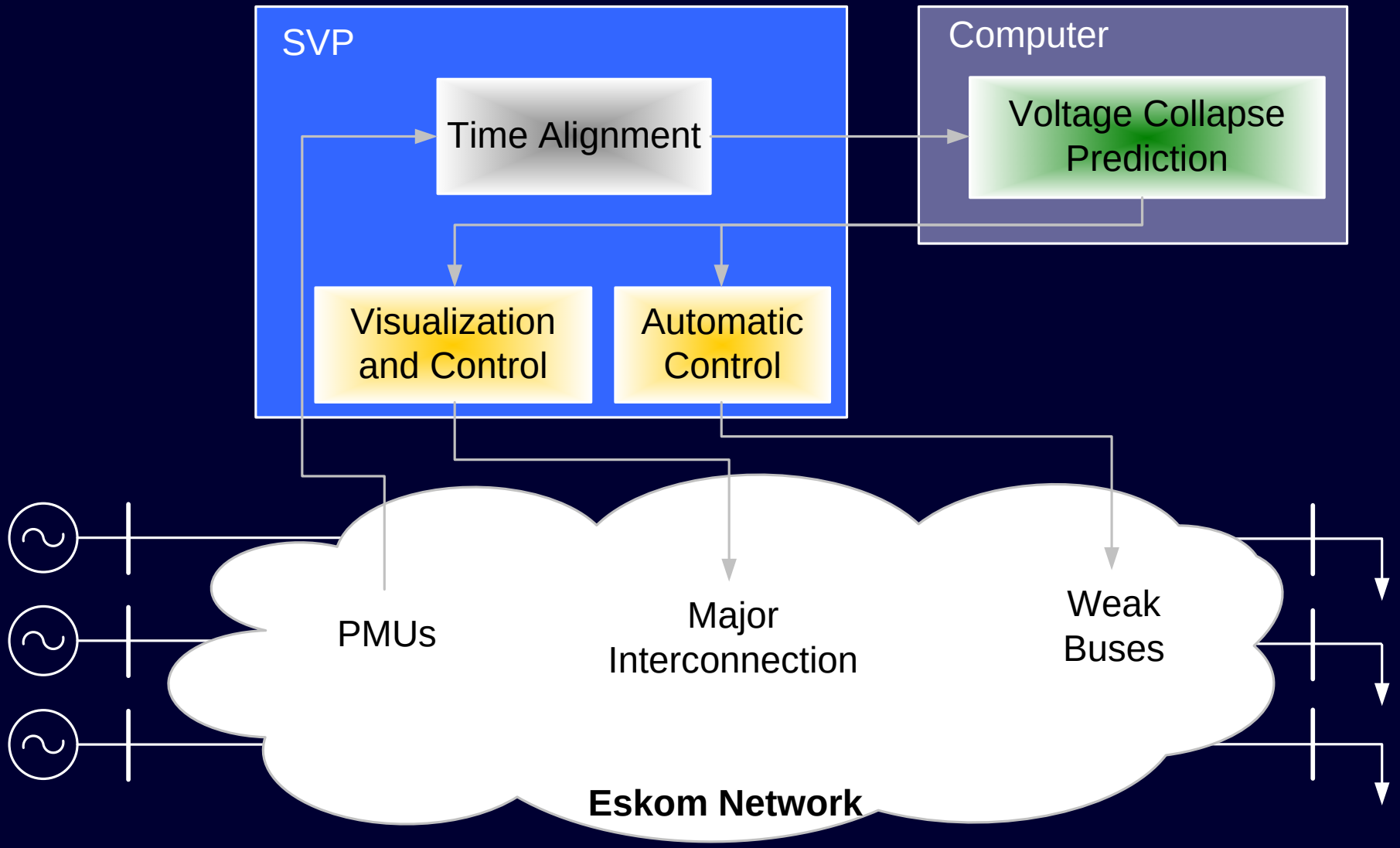
Determining Wide-Area Voltages

Use Local V and I to Determine Remote V

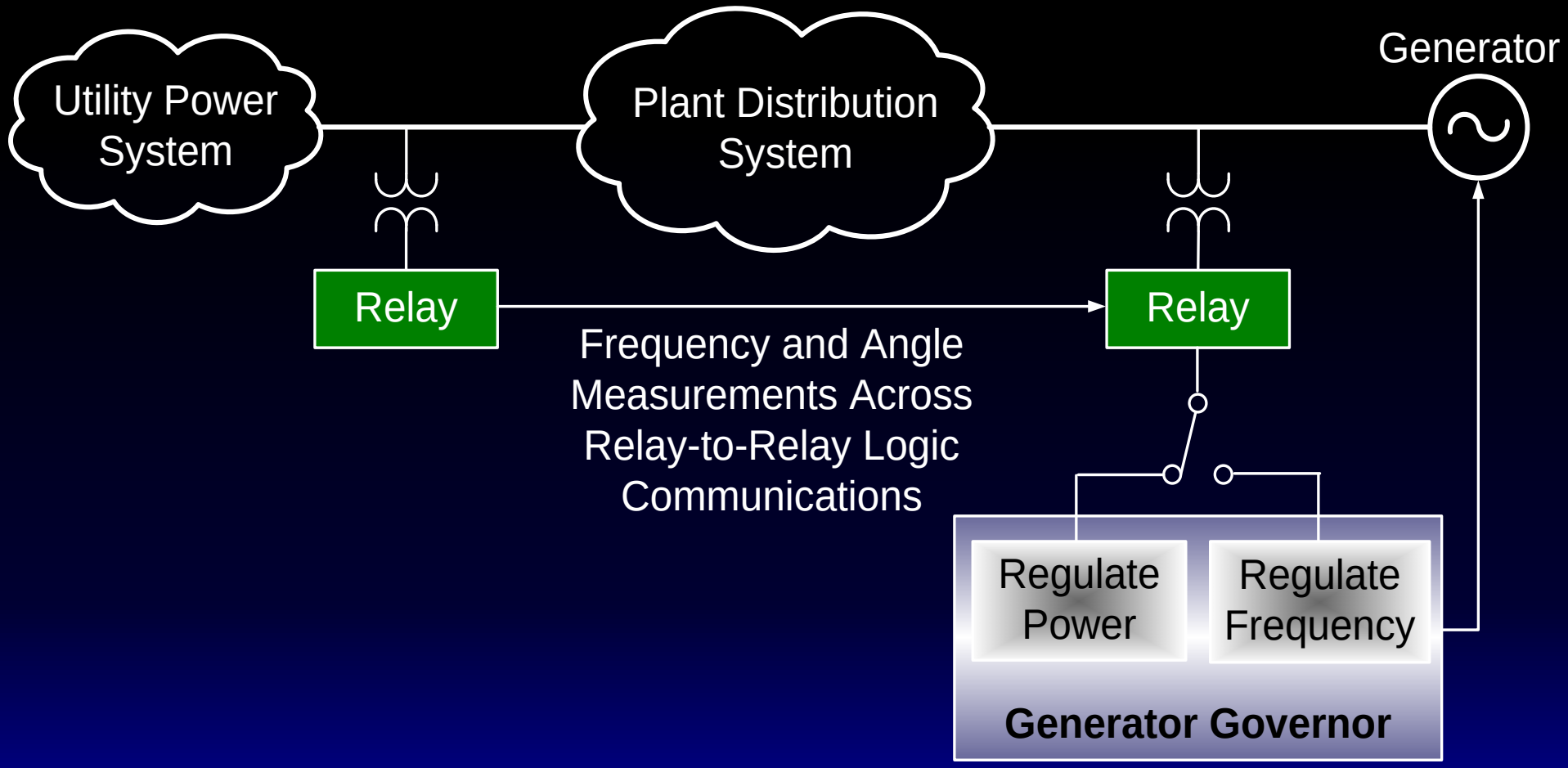


$$V2' = V1 + Z12 \bullet I12$$

Voltage Stability Assessment System



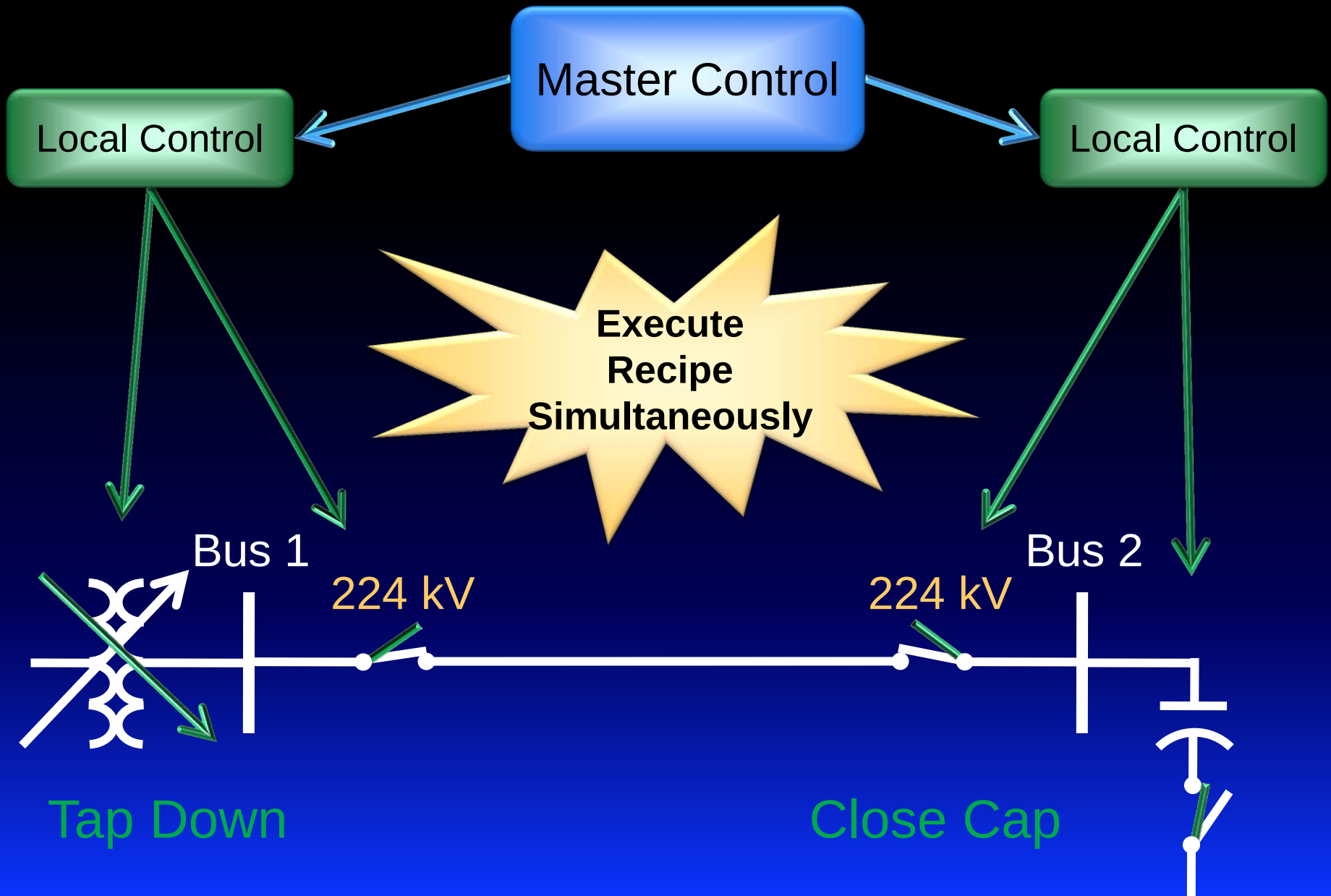
Governor Mode Control



Traditional Control to Isolate Line

Master Control

Synchronized Recipes Execute at Precise Instant



Conclusions

- Measurement, control, protection
- Dependable, deterministic communications
- Reliable, redundant precise time
- Distributed state and vector processing
- Demand-driven solutions are emerging
- Soon we will see traditional SCADA replaced by fast, distributed, automated, synchronized measurement & control.