GE Industrial Systems

American Superconductor

Grid Support and Power Quality Products

D-SMES Presentation to ESA Chattanooga, TN

American Superconductor Corp.
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American Superconductor: Corporate Background

- Founded 1987 After Initial HTS Discoveries
- Headquarters: Westborough, MA with Business Units in Middleton,WI and Dusseldorf, Germany
- 350+ Employees Worldwide
- Focus: Power Applications for Superconductivity
  - World Leader in HTS Wire Manufacturing
  - Strategic Alliances for HTS Technology Development (GE, EDF, Pirelli, Rockwell & others)
  - Existing Commercial Products Employing LTS/HTS Technology

Distributed SMES (D-SMES): A New Tool for Grid Stabilization

- Threats to Grid Stability Are Increasing
  - Sustained Load Growth & Population Shifts
  - Relatively Little Recent Grid Investment
- Changing Load Patterns Require Even More Rapid Response to Avoid Low Voltage and Voltage Collapse
  - Growth of A/C and Other Inductive Motor Loads Means Heavy Current Draw After Faults
  - Growth of Sensitive Silicon-Based Loads Means **It's Not Enough to Simply "Keep the Lights On"**

D-SMES Technology

“In a Nutshell”

GE Industrial Systems

Utility Problems That D-SMES Can Solve:

- **Voltage Stability** - Uncontrolled rapid decline in system voltage

- **Low System Voltage** - Steady state system voltage that is below the established acceptable criteria

- **Import/ Transfer Capability Restrictions** - Limited
  - ability to reliably import, export, or transfer power

AMSC performs full system analysis jointly with the customer to determine the least cost, best available solution

What is a SMES Device?

The SMES device stores electric energy in a superconducting magnet and can <u>instantaneously inject</u> both <u>real</u> and <u>reactive power</u> into the transmission or distribution network, to solve a wide variety of voltage related utility or industrial electrical distribution system problems.

SMES TECHNOLOGY/PORTABILITY

Typical SMES device leaving the factory….Highly Mobile, Expandable!

Easy to Install once it arrives on site, typically it takes just 2 days!

SMES Output Characteristics ***(trailer explanation on next slide)***

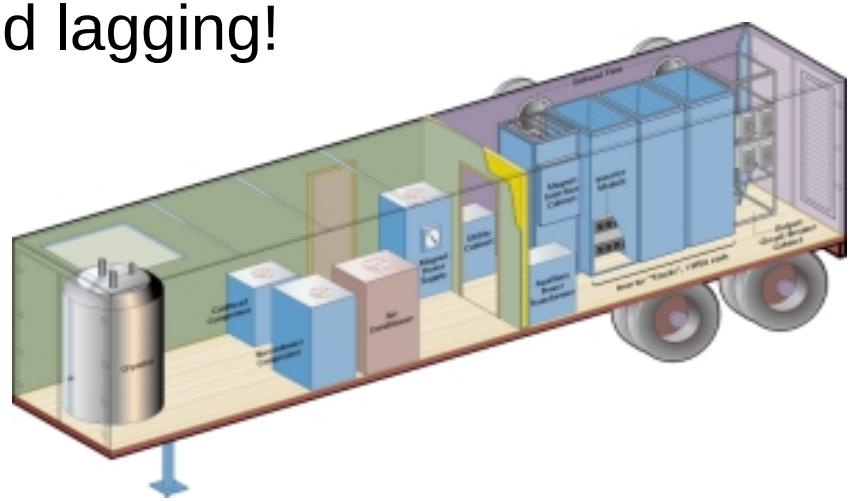
- 3 MW Instantaneous
  - Acts as controlled distributed generation
  - Protects Utility Grids and Industrial Plants

- Up to +/- 18 MVAR Instantaneously (inverter based)
  - Up to +/- 8 MVAR Continuous
  - Dynamic VARs instead of static VARs

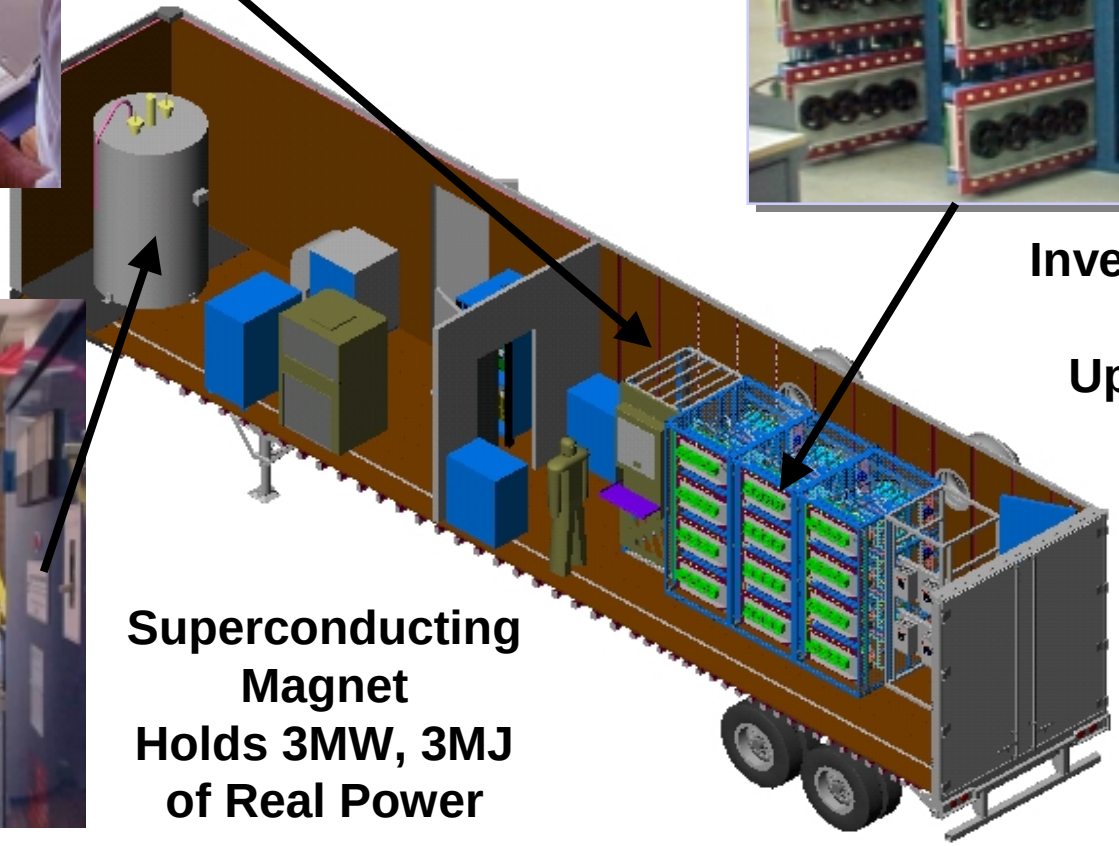
(The output of SMES (dynamic) VARS do not decrease in proportion to the square of the voltage like that of an SVC. SMES injects inverter based VARS not static VARS (like capacitors). SMES has excellent reactive power output! By adding additional capacitors we can improve output to 28 MVAR instantaneously and 16 MVAR continuous!

- VAR support is both leading and lagging!

- Reaction time of 0.5 cycles
- (Note: All information is on a per trailer basis)



State of the Art
DAS / Power Electronics
drive speed of
response and
high power output



Inverter Arrays Provide
Reactive Power
Up to 8 MVAR Cont.
And 18 MVAR
Instantaneous

Superconducting
Magnet
Holds 3MW, 3MJ
of Real Power

Inverter Example

GE Industrial Systems

4 quadrant stacked inverters, provide leading and lagging dynamic VARs to assist customers against voltage swells and dips. Master and 3 slaves shown (standard configuration). 250kW per inverter X 4 per stack @ 4 stacks = 4MVA shown.

Advantages - Fault Tolerance

- Inverter Array can Continue to Operate with Several Failed Inverter Modules
  - Only the power capability is reduced
- Inverter faults are isolated with Current Limiting Fuses for Catastrophic Failures
- Inverters are “Smart”
  - Slave Microprocessor for Diagnostics, Local High-Speed Fault Handling
- Small Size and Weight Yield 2 Hour MTTR

AMSC Confidential

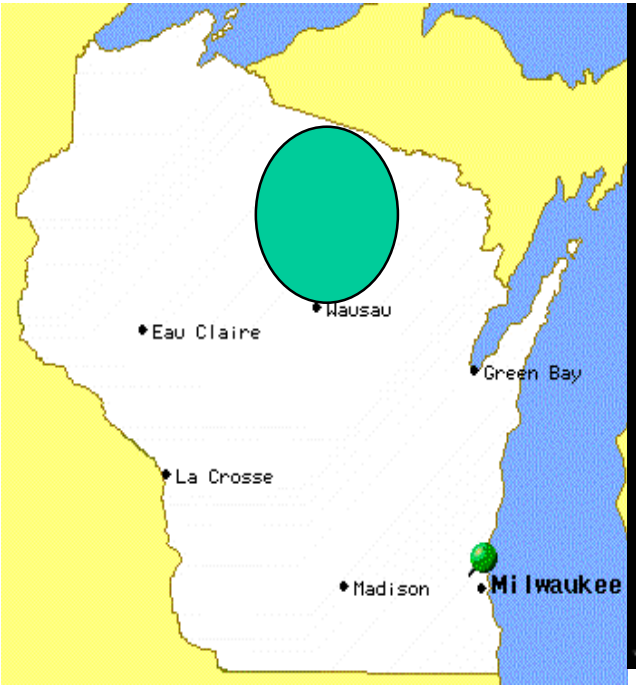
(mean time to repair)

D-SMES Solution Attributes

- **Rapid Response:** 4-6 Months Contract to Installation
- **Ease of Permitting** (No ROW or Certification Required)
- **Low-Cost** Option Compared to Conventional Solutions
- **Speedy Integration into Grid** -- Two-Day Install Time
- **Indefinite Life** -- Solid State, Few Moving Parts
- **Enhances Competitive Opportunities** on Power Grid
- **Portability Allows Redeployment** -- No Stranded Asset Issues

CASE STUDY

WPS D-SMES Project: A Case Study



WPS

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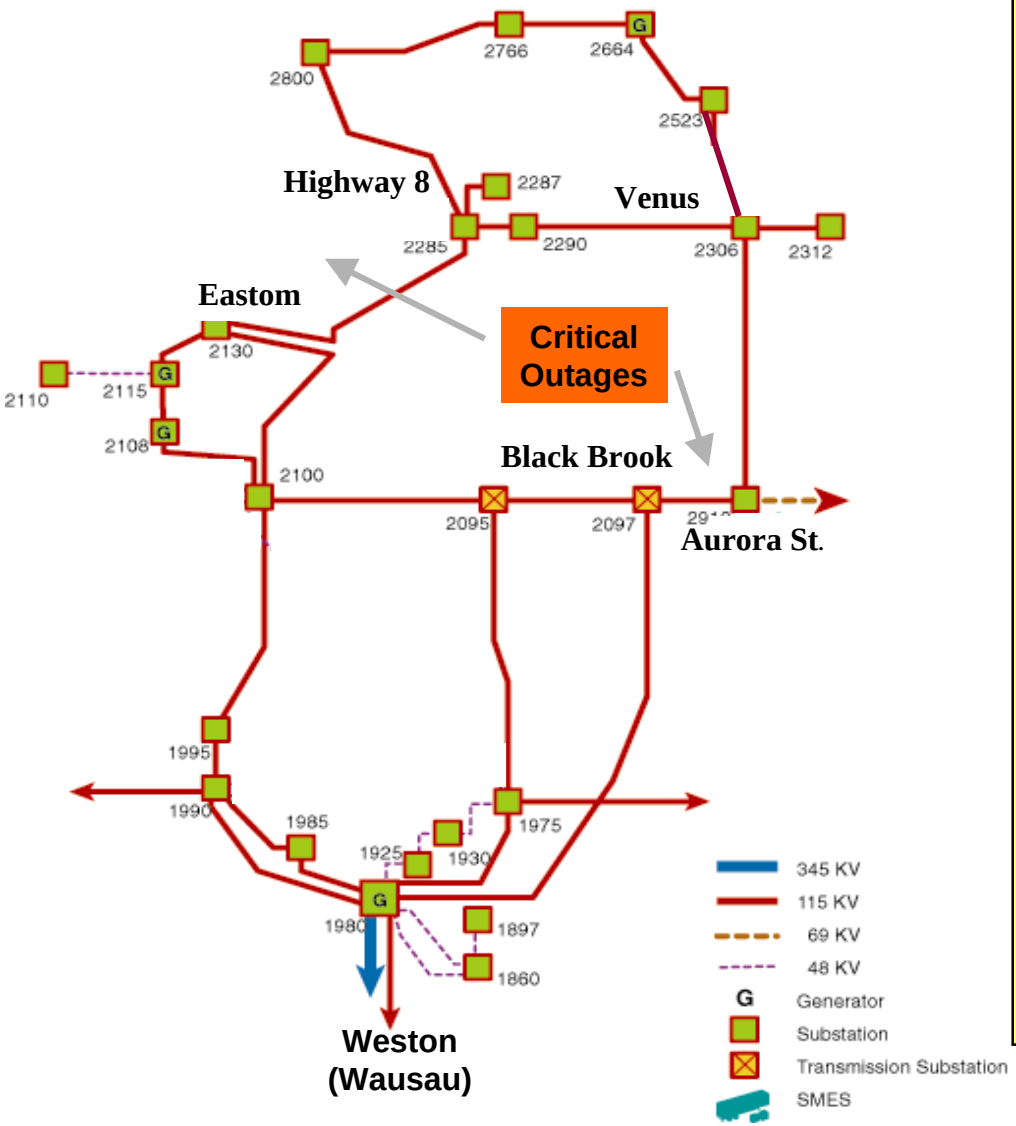
D-SMES WPS Project

Voltage instability and Dips-Main Issue



WPS Northern Loop

(200 Mile Long Loop)

- **115kV Transmission Grid**
- **230 MW Total Load**
- **Highly Compensated w/caps**
- **3% Annual Load Growth**
- **Load: Industrial (paper mills)**

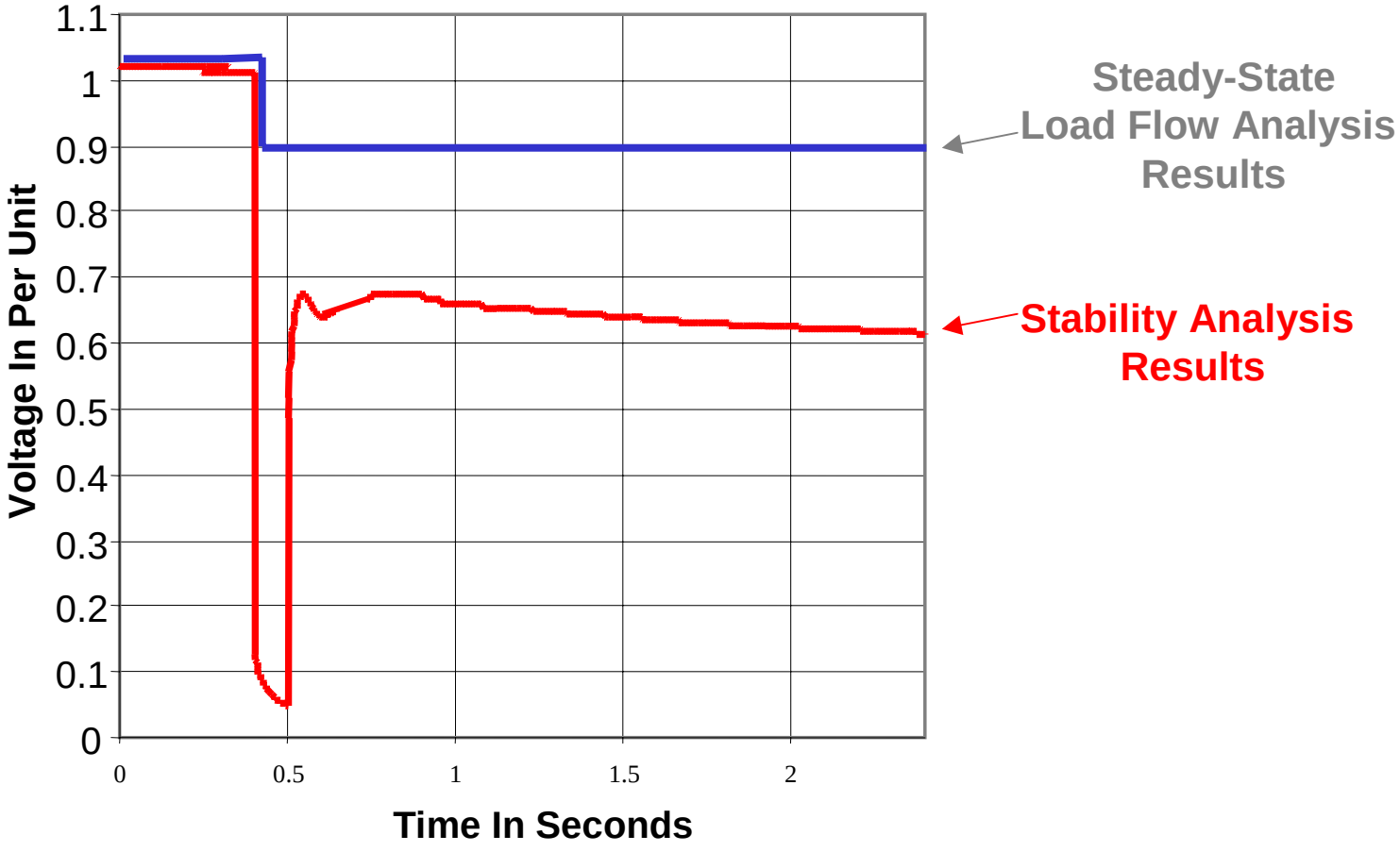
  Residential (vacation area)

The system is heavily compensated with switched cap banks which are subject to the Vsquared effect, decreasing their effectiveness.

Voltage vs time plot at Aurora St. 115 kV bus

Steady State Load Flow Response to Critical Outage

Three Phase 115 kV Bolted Fault - Stability Solution

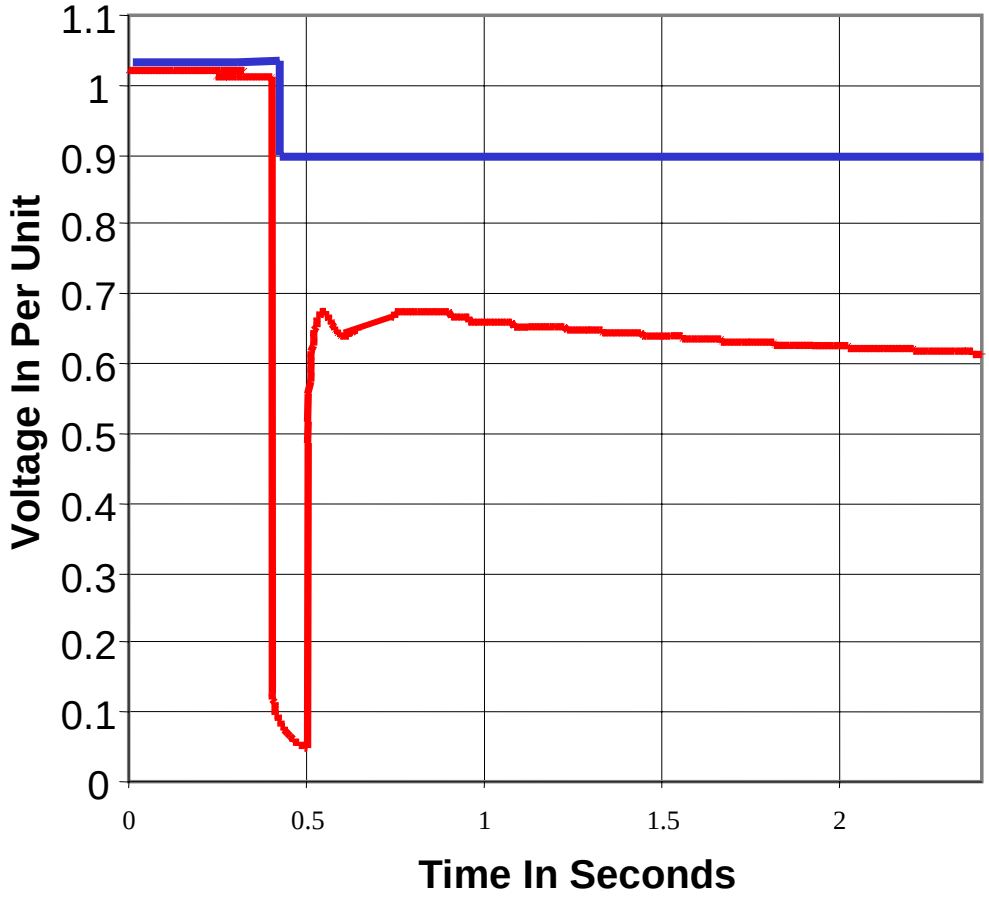


Aurora St. PU vs Time Plot

Red= Three Phase 115 kV Bolted Fault - Stability Solution

Blue = Steady State Load Flow Response to Critical Outage

115 kV Voltage Response



Voltage vs. time plot @ Aurora St.

Fault applied in 0.5 seconds Cleared in .10 seconds or 6 cycles

Switched caps @ 42% of nominal value due to V squared effect

Below 90% PU, motors begin to stall. Contactors open causing a loss of large amounts of load.

Criteria had to be evaluated!

WPS Transmission Planning Criteria

- **Restore Transmission Voltage to 0.9 Per Unit Within 1/2 Second**

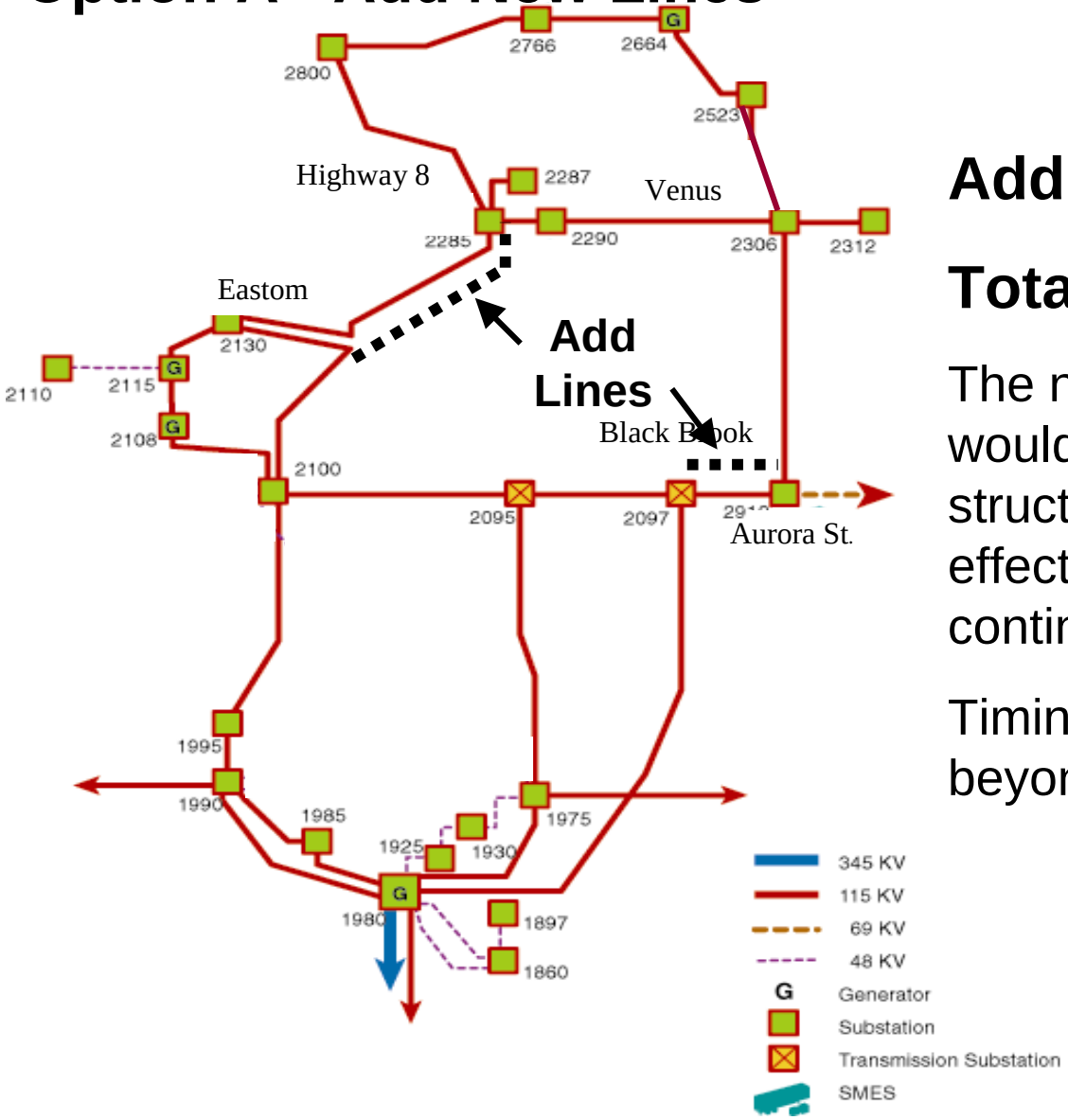
- **Restore Transmission Voltage to 0.95 Per Unit Within 5 Seconds and retain**

Reason: Below 0.9 PU @ 1 second or greater duration, paper mills begin seeing problems. WPS chose .5 seconds.

At 0.95 PU for more than 5 seconds, motors stall, causing cascading events and slow voltage collapse due to LTC operation of system.

WPS OPTIONS

Option A - Add New Lines



Add 2 New 115 kV lines

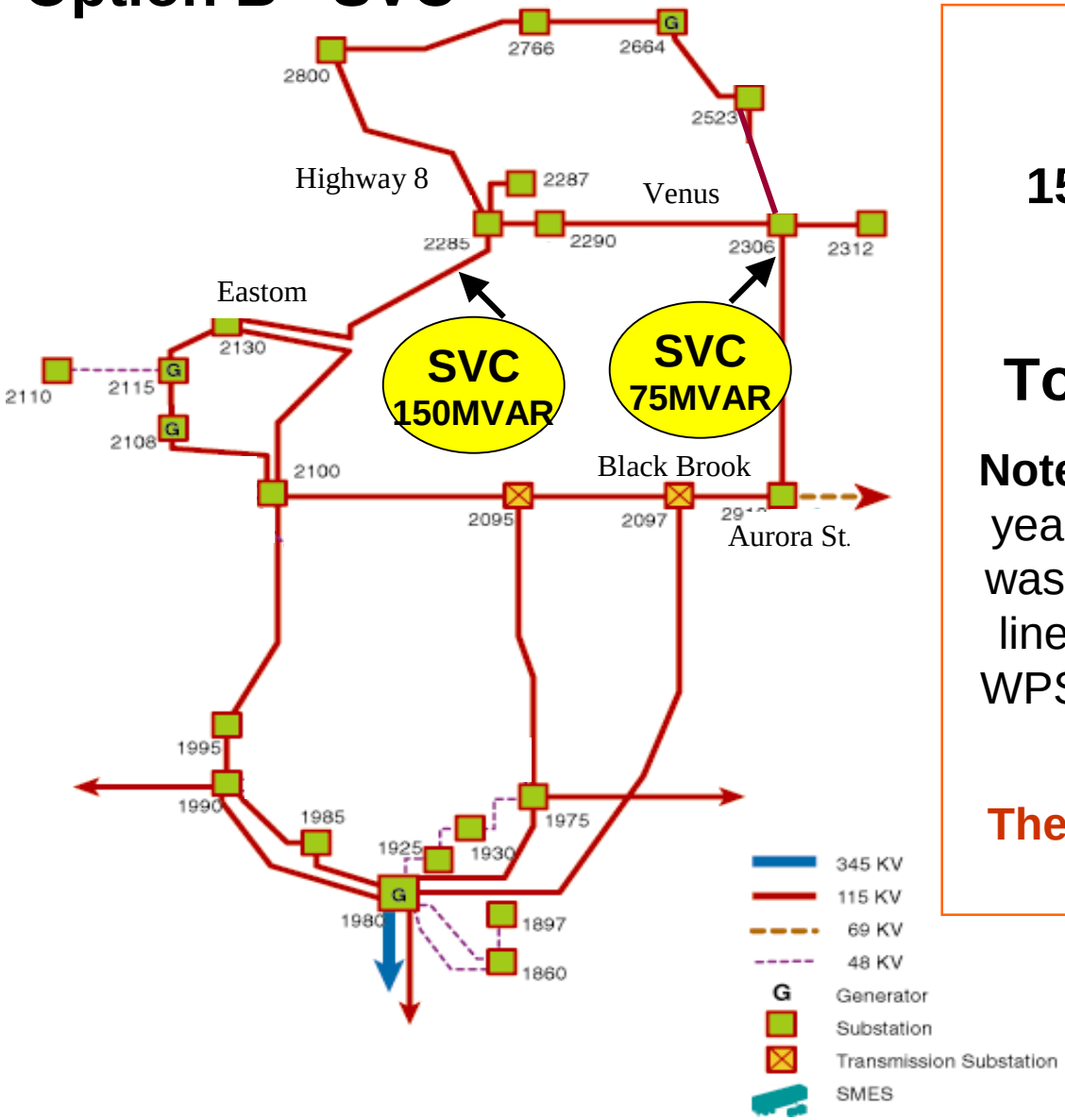
Total Cost: $12M

The new double circuit lines would be run on a single structures and could be effected by the same contingency.

Timing brought them out beyond the 2000 deadline.

WPS OPTIONS

Option B - SVC



Add 2 SVC

150 MVAR @ Highway 8

75 MVAR @ Venus

Total Cost: $11.125M

Note: SVC had to be oversized 5 years out into the future. If WPS was successful in getting 115 kV line in from MN in 3 years, then WPS paid out 2 years for nothing for the SVC.

The SVC becomes a stranded asset!

WPS OPTIONS

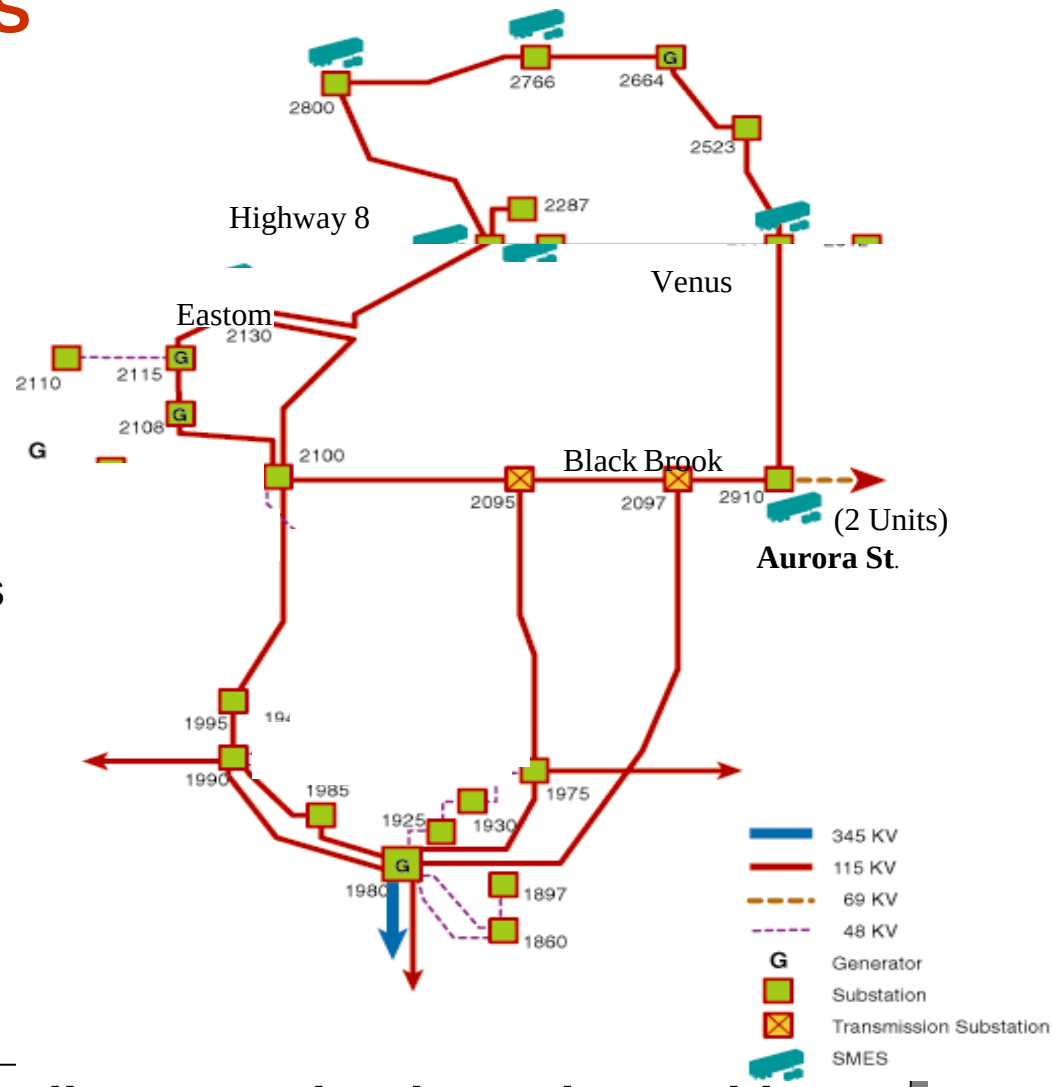
Option C - Add D-SMES

Add 6 D-SMES

Note: 2 units placed at Aurora St. 20 MW load, where there was greater consequences for a contingency!

The units are monitored 24/hrs day by (DAS) data acquisition system.

Total Cost: $ 8-9MM!



6 D-SMES Strategically Located Solves The Problem

Summary of Solution Alternatives

- **New 115 kV line Construction - 20 miles at a cost of $12,000,000**
- **Install 150 MVAR SVC at Highway 8 and 75 MVAR SVC at Venus at a cost of $11,125,000**
- **Series Compensation on 115 kV System- 4 Locations (Rejected)**
- **Install 6, 3MVA D-SMES Devices at a cost of less than $9,000,000**

D-SMES is the least cost solution

Financials And Delivery

Solution	Cost	Lead-time
8 D-SMES w/ Caps	$8-9M	8 Months
200 MVAR STATCOM	$16-18M	9-12 Months
250 MVAR SVC	$12-16M	9-12 Months
New 230 kV Tie	$7-10M	3-4 Years

The least cost solution that meets in-service requirements

D-SMES Applications

- Load Growth: Maintain or Improve Overall System Stability
- Planning Uncertainty: Facilitate Interconnection of New IPP Generators, Orderly Retirement of Older Units
- Congestion: Address Contingencies to Increase ATC Over Congested Interfaces
- Load Pockets: Ease Reliance on RMR Generators -- Improve System Economics & Environmental Performance

Our View

- HTS technologies revolutionize how electrical power is *created*, transmitted, stored, managed, and *utilized*
- HTS-based designs fundamentally change the value proposition for electrical products
- HTS technology has attained a proven level of maturity that is suitable for bringing high quality commercial products to market TODAY

AMSC is investing in its technical lead…the products being designed today will be the springboard for the portfolio of next-generation products

Thank you for listening!

Questions?

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