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Paper Title:

***Smart-Grid-Enabled Load and Distributed Generation as a
Reactive Resource***

Outline

- Motivation
- Definitions
- Proposed Control Framework
- Security Requirements
- Distributed Reactive Power Control Examples

Motivation

- Increased PMU deployment will improve monitoring capabilities
- Improved monitoring motivates improved control of resources
- Inadequate reactive power supply was a factor in most previous major North American blackouts

Goal of this work

- Improve control of resources using ...
 - A distributed reactive power support system
 - A comprehensive form of control
- Near real-time reactive control at residential level
- Coordinating communications must be secure

Definitions

- Q-C Buses –
 - transmission system level buses controlled to provide an amount of aggregated reactive power support
- Load Categories
 - Loads classified according to ability to provide support
 - CAT1 (most controllable) through CATN (least controllable)
 - Categories are not fixed

Definitions

- Reactive Support Regions
 - Buses chosen *a priori* to help each other
 - One main controller in each region can be responsible for obtaining the necessary reactive support for all devices in its region
 - Division allows focus on a subset of the controllers
 - Can also help make the framework extensible to decentralized control algorithms

Overview of Proposed Framework

- Centralized control – detects voltage problems
- Centralized control – computes required aggregate reactive power responses
- Regional controllers – receive requests for support directed to constituent Q-C Buses
- Q-C Buses – receive requests for an aggregate amount of support which they must obtain from devices in the distribution system
- Each party confirms its participation

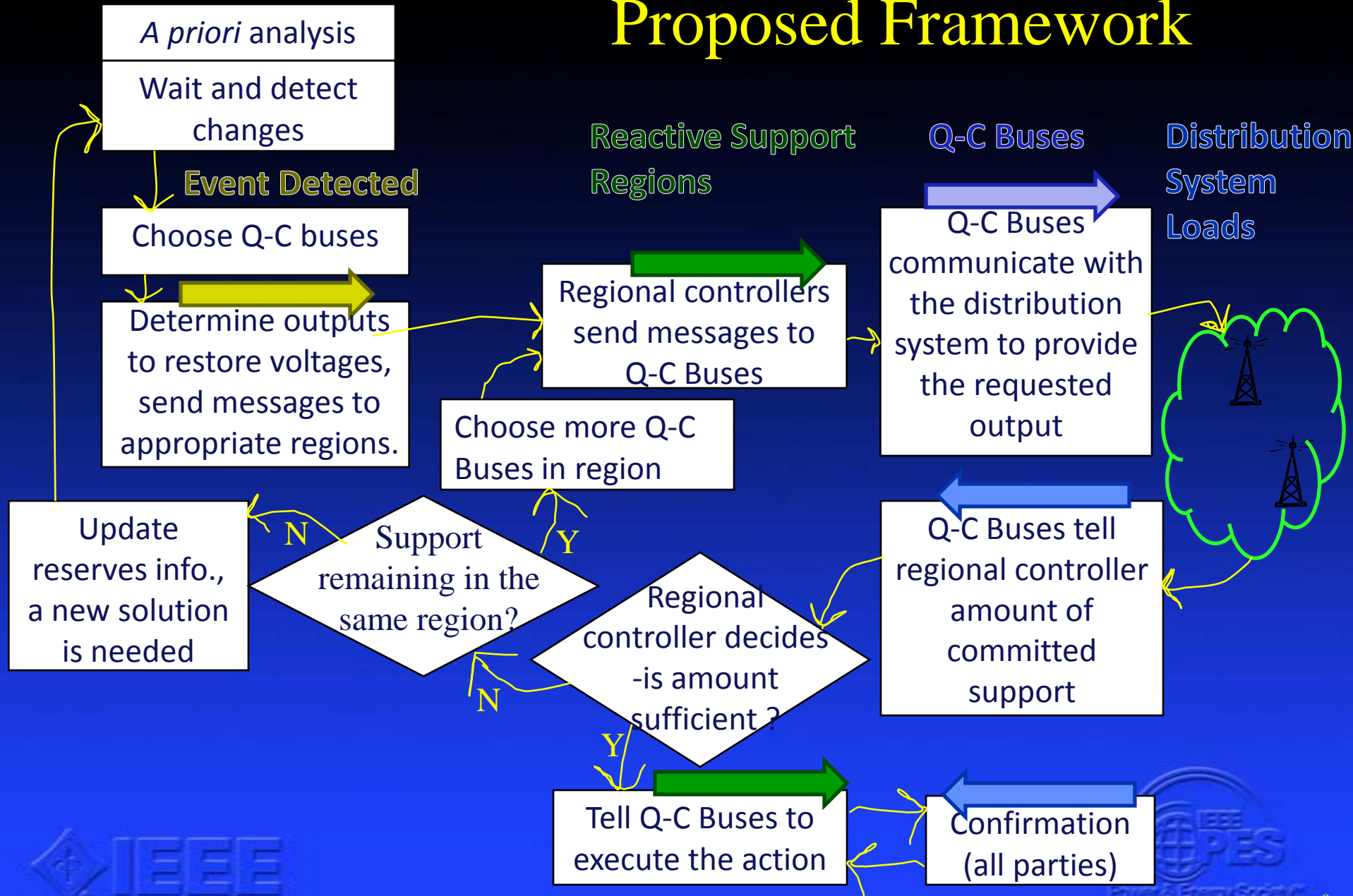
Overall Vision of the Proposed Framework

Central Control

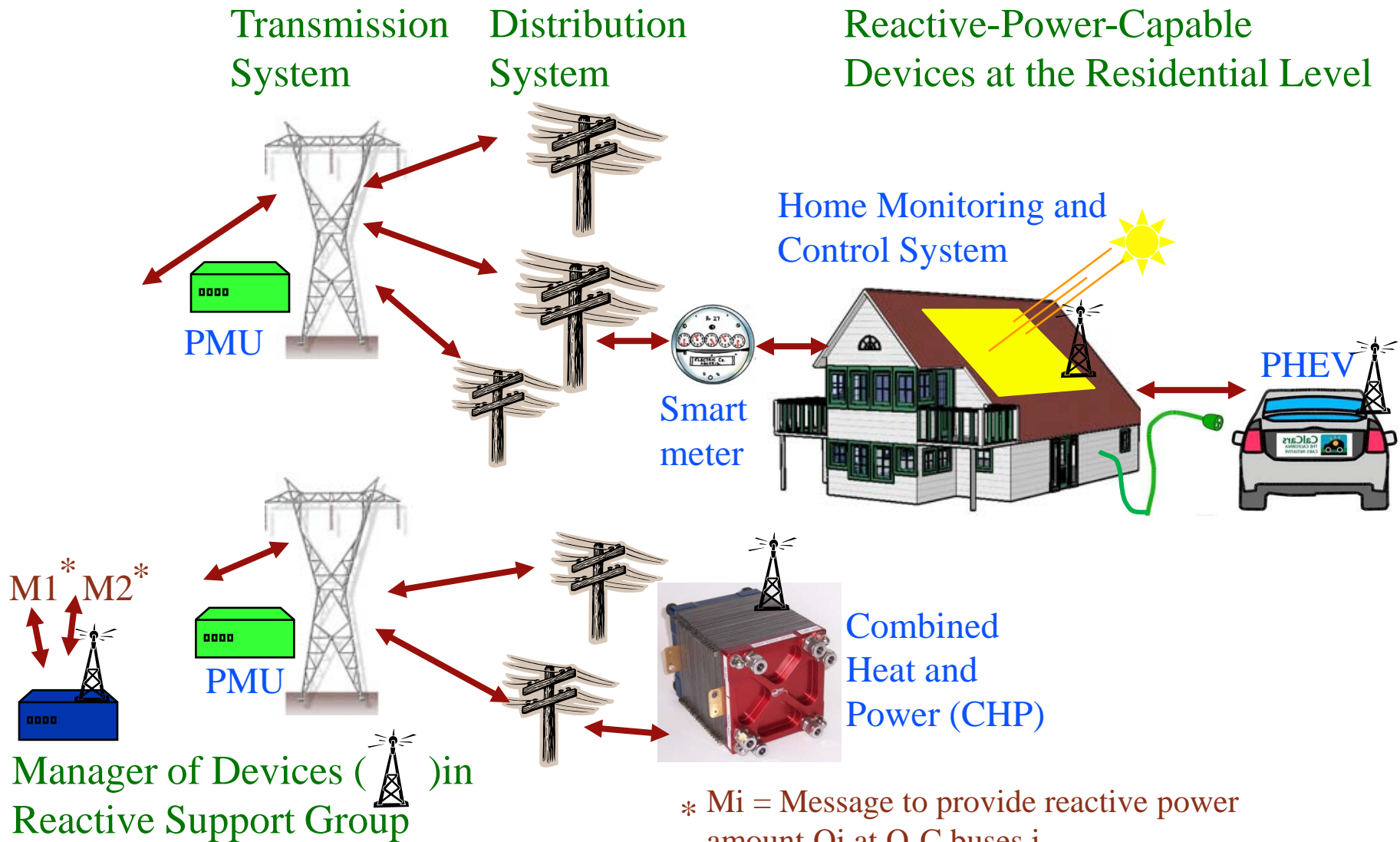
Reactive Support Regions

Q-C Buses

Distribution System Loads



Example - Constituents of a Reactive Support Group



Communications

- Secure communication framework to control reactive-power-capable devices at the end-user

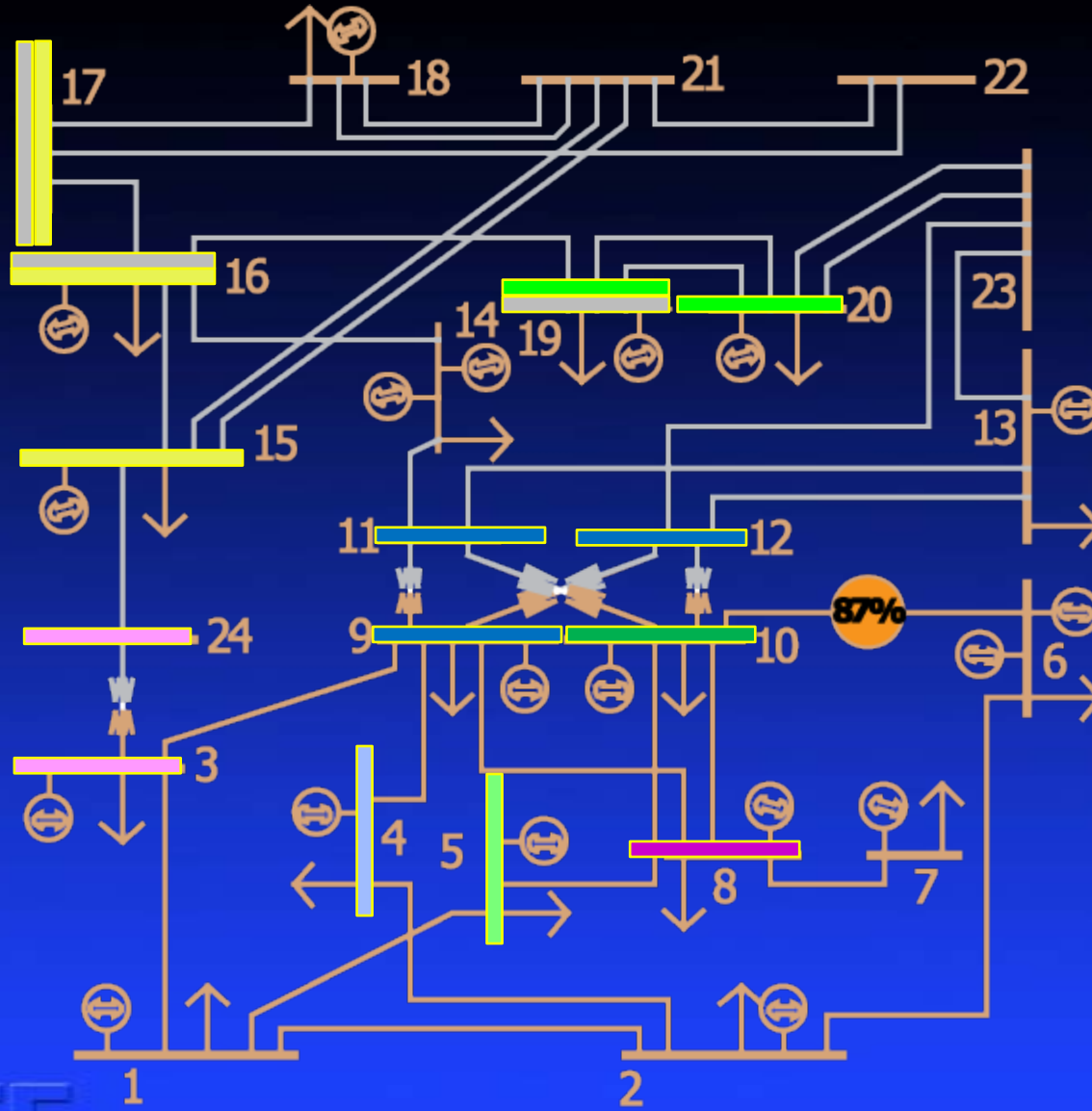


- Provides integrity, authentication, and protection against replay
- Just one option

IEEE 24-Bus RTS Example

Possible Reactive Support Groups

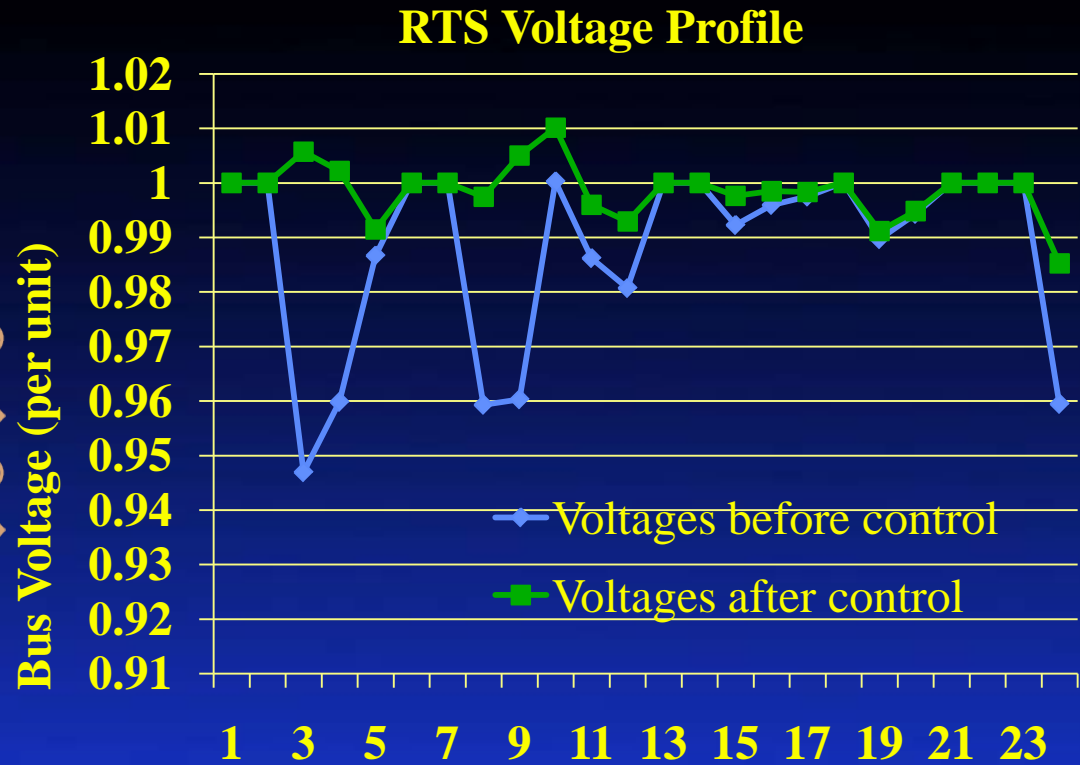
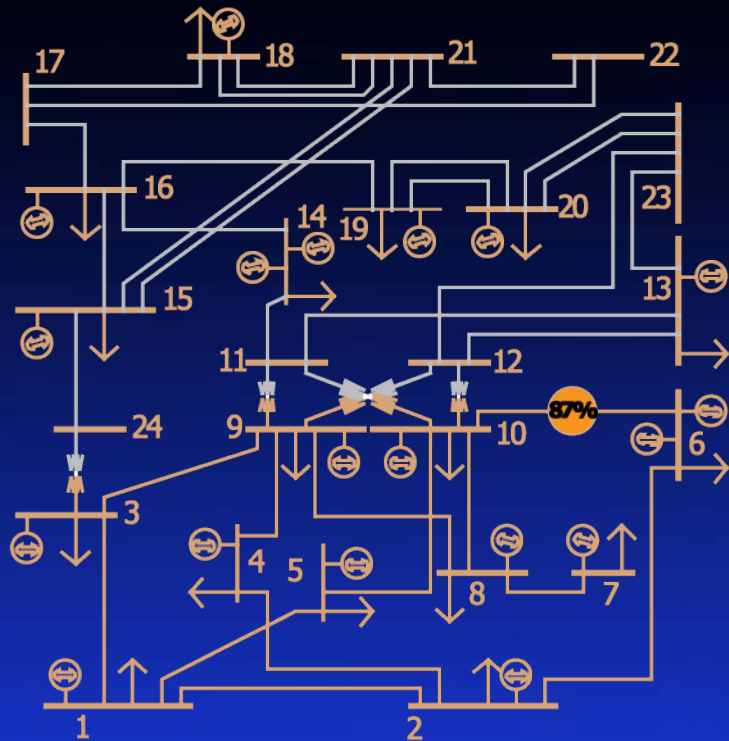
and 5 Chosen Supporter Buses for Each Group



4
5
8
10
9,11,12
15,16,17
16,17,19
19,20
3,24

4,9,3,8,24
5,10,8,9,4
8,9,10,4,3
10,5,8,9,4
9,4,3,8,24
15,24,16,19,3
19,16,15,20,24
19,20,16,15,24
3,24,9,4,15

IEEE 24-Bus RTS Example Results



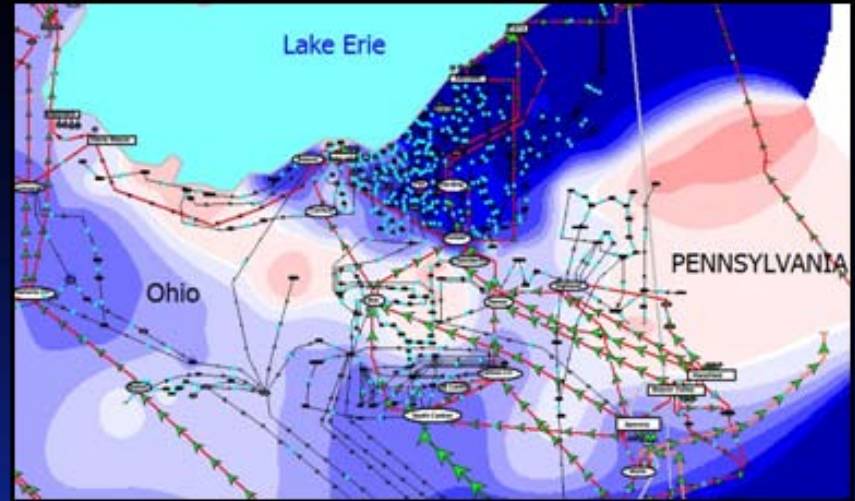
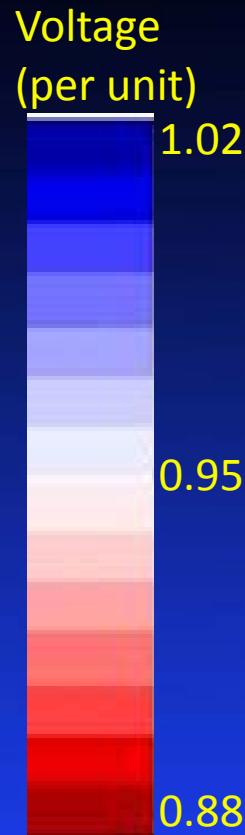
Bus #	Initial Q_{net}	Final Q_{net}	Initial voltage	Final voltage
3	-37 MVar	37 MVar	0.9469	1.0057
4	-15 MVar	15 MVar	0.9598	1.0022
8	-35 MVar	35 MVar	0.9593	0.9975
9	-36 MVar	36 MVar	0.9603	1.0050
24			0.9594	0.9852

Bus Number

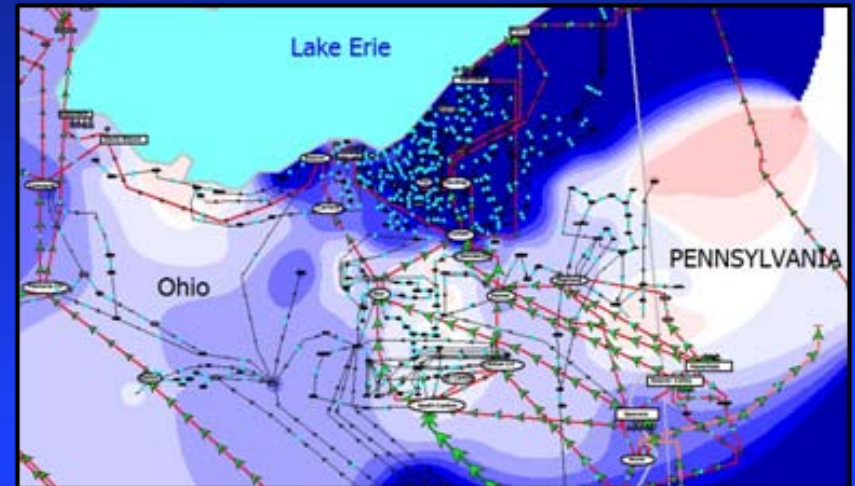


2003 Blackout Example

Power factor correction at just 5 buses results in appreciable voltage improvement



Reconstructed pre-blackout state with low voltages



After power factor correction of 5 buses

Thank You

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