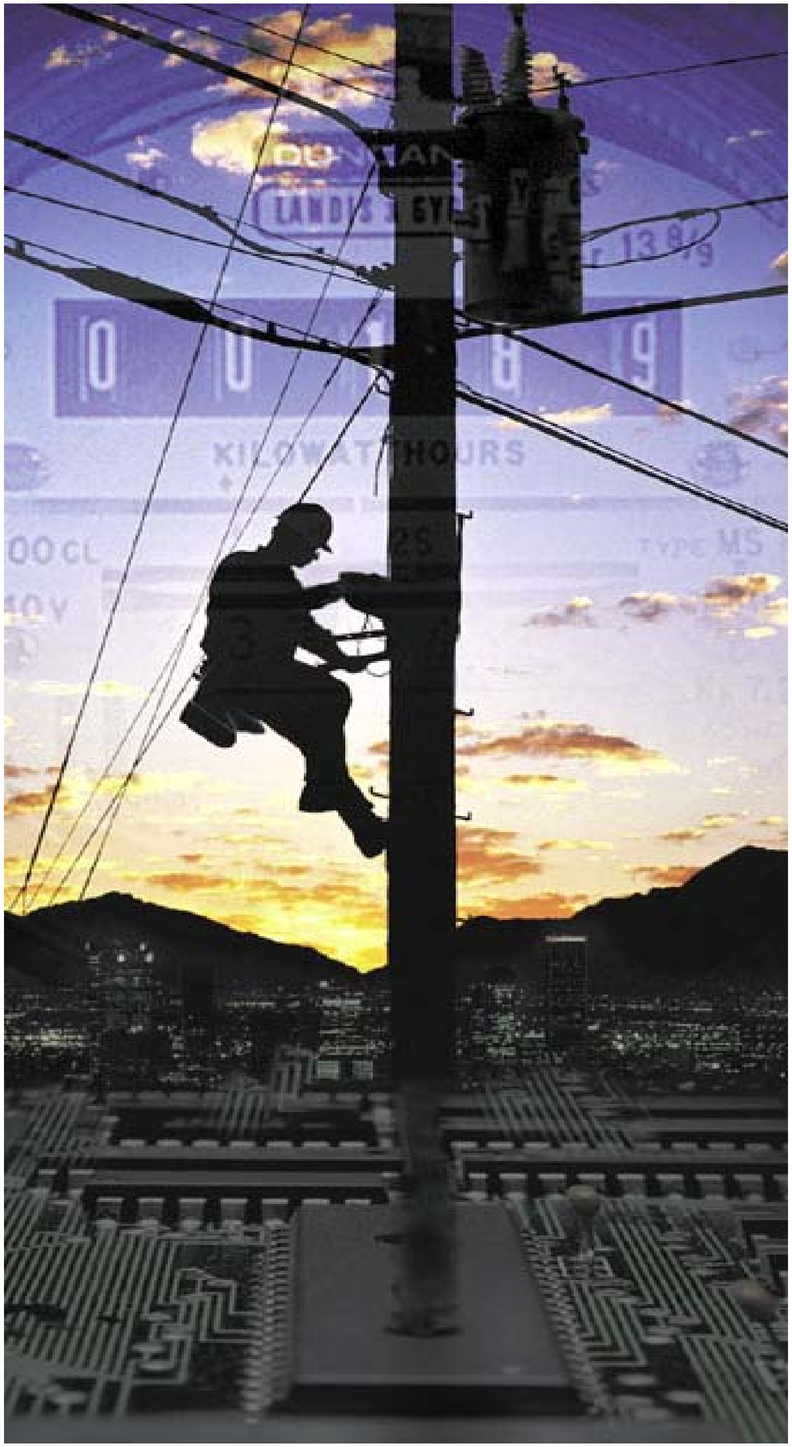

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Active Distribution Management Workshop

CIGRE Canada 2009 Symposium

Mark McGranaghan - EPRI
Roger Dugan – EPRI
Chad Abbey - IREQ

October 4, 2009
Toronto

Agenda

- Active Distribution Management Overview
- Modeling Considerations and OpenDSS
- Examples of Active Distribution Management and CIGRE C6.11 Activities
- IEEE Distribution Automation Working Group
- Demonstrations

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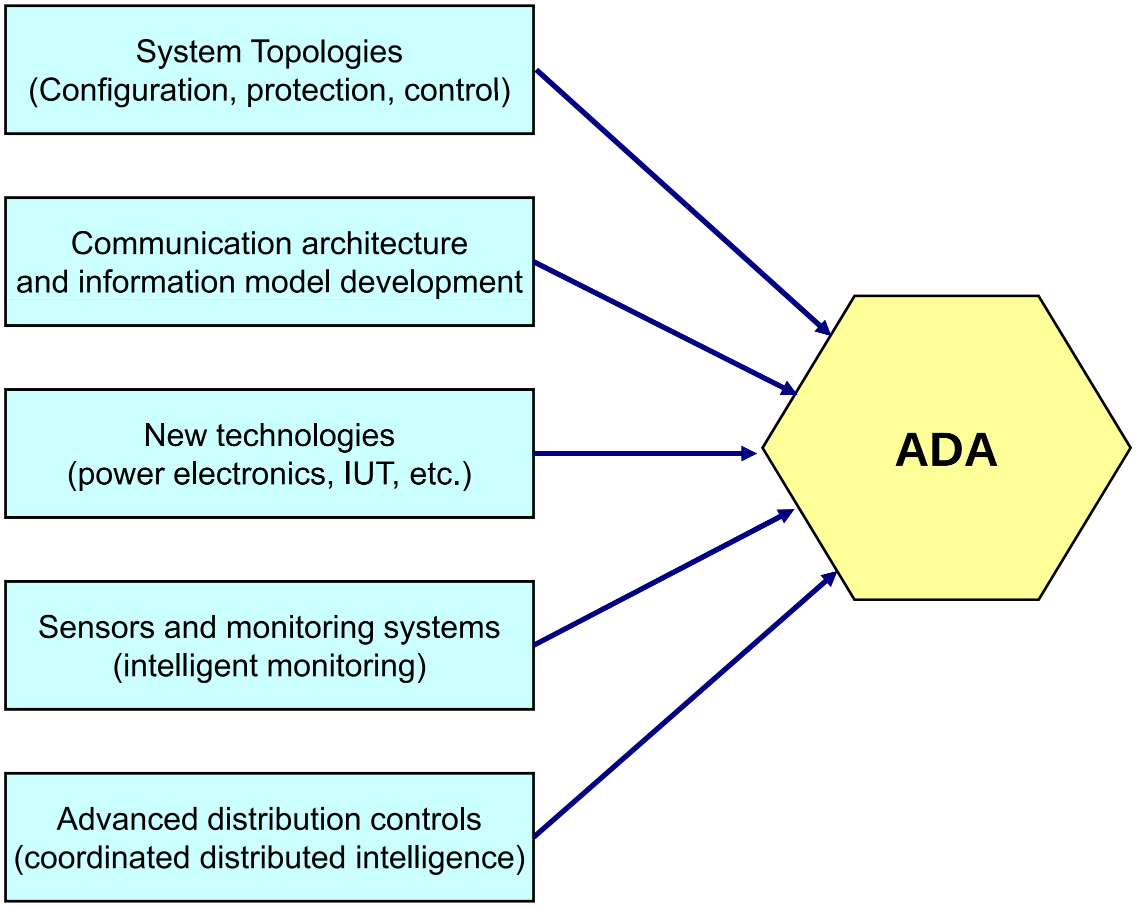
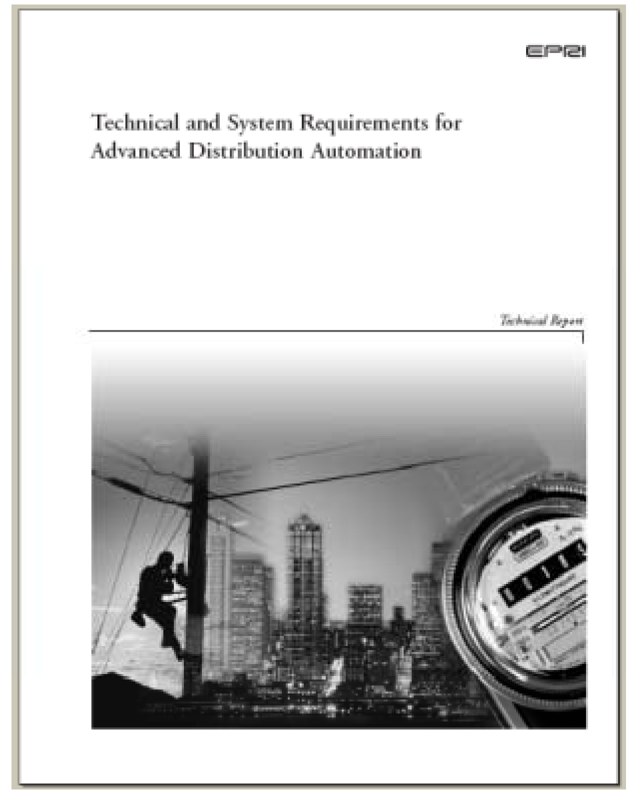
Active Distribution Management - Definition

- Distribution system operation and controls with the following characteristics
  1. Active monitoring of distribution system conditions
  2. Control of distribution system in real time
     - Protection functions
     - Reconfiguration after faults
     - Fault location
     - Voltage and var management
  3. Integration of distributed generation, storage, and demand response

Developing a Roadmap for Active Distribution Management





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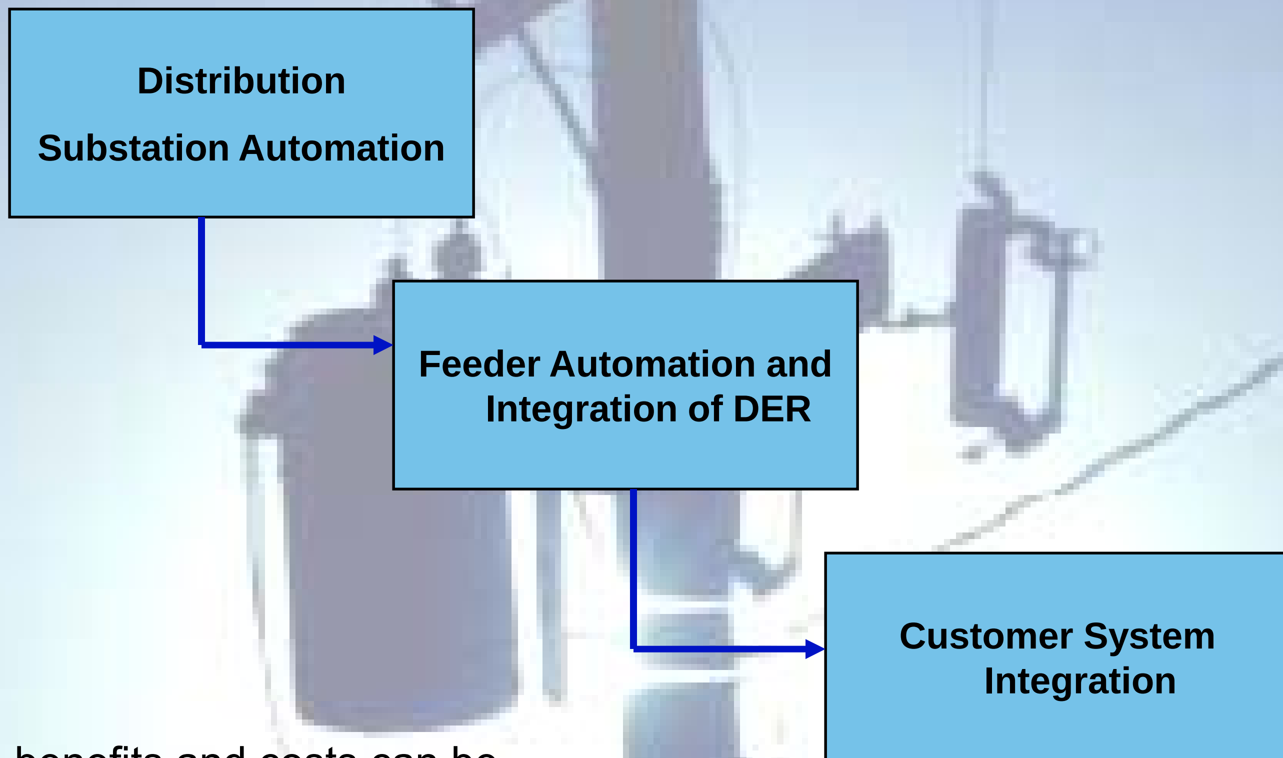
System Design Considerations

- Distributed Controls vs Central Controls
  - Local controls
  - Substation control
  - Central control
- Communication Infrastructure Requirements
  - What happens when communications are out?
- Distribution management system
  - Basic functions
  - Integration requirements
  - Maintaining the model
- Integrating distributed resources

Before Distribution Automation (courtesy of Alabama Power)

General flow of Distribution Automation Implementation



Automation benefits and costs can be evaluated in stages but consider infrastructure requirements for each stage and joint benefits for the infrastructure

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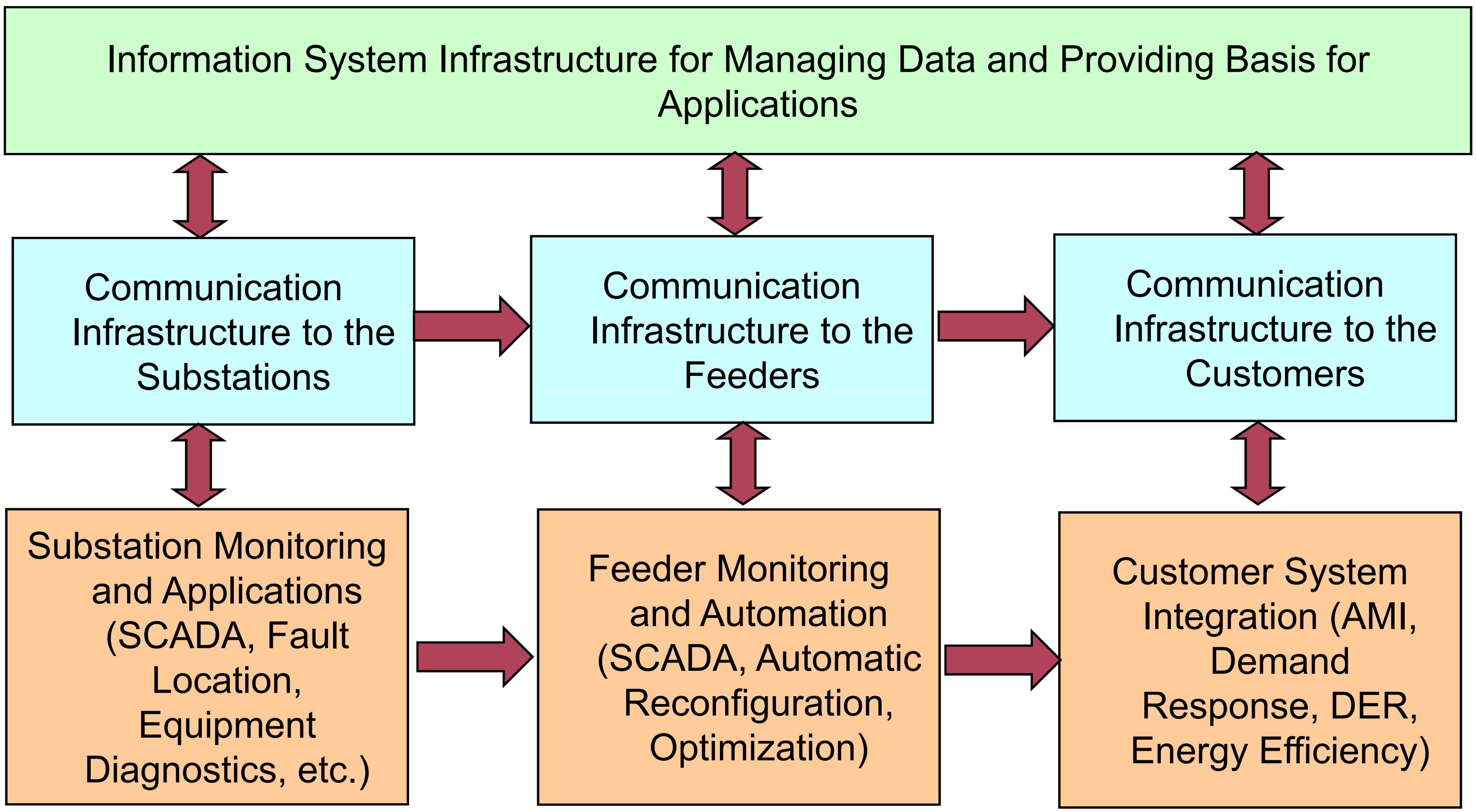
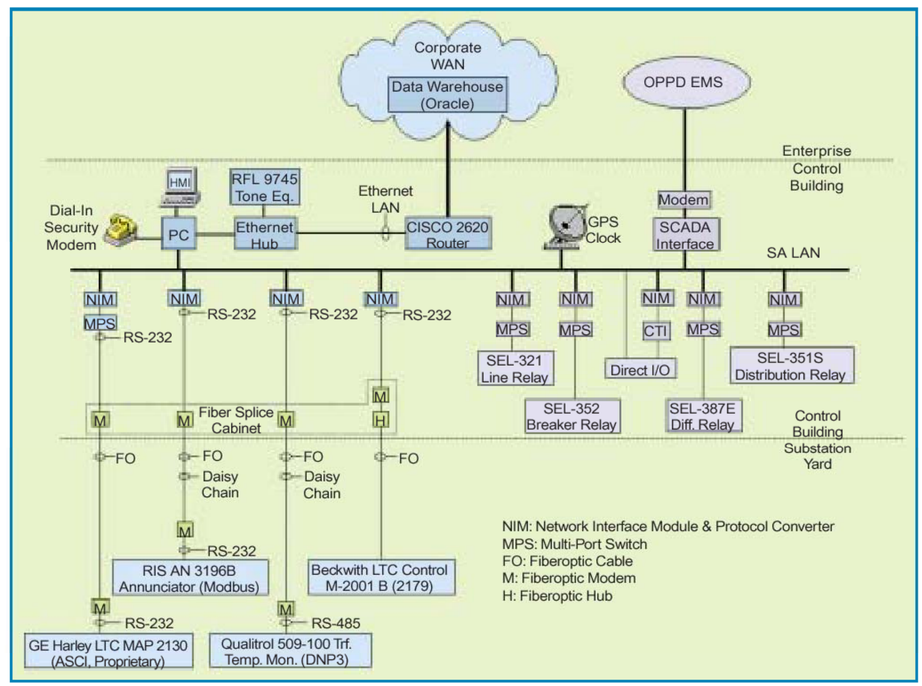
More detailed flow of implementation - roadmap



Substation Automation and Substation Integration

- Most significant implementation of automation today
- Many different communication technologies and protocols – migration to UCA/IEC 61850
- Significant improvement in operations and reliability is possible from substation automation alone.



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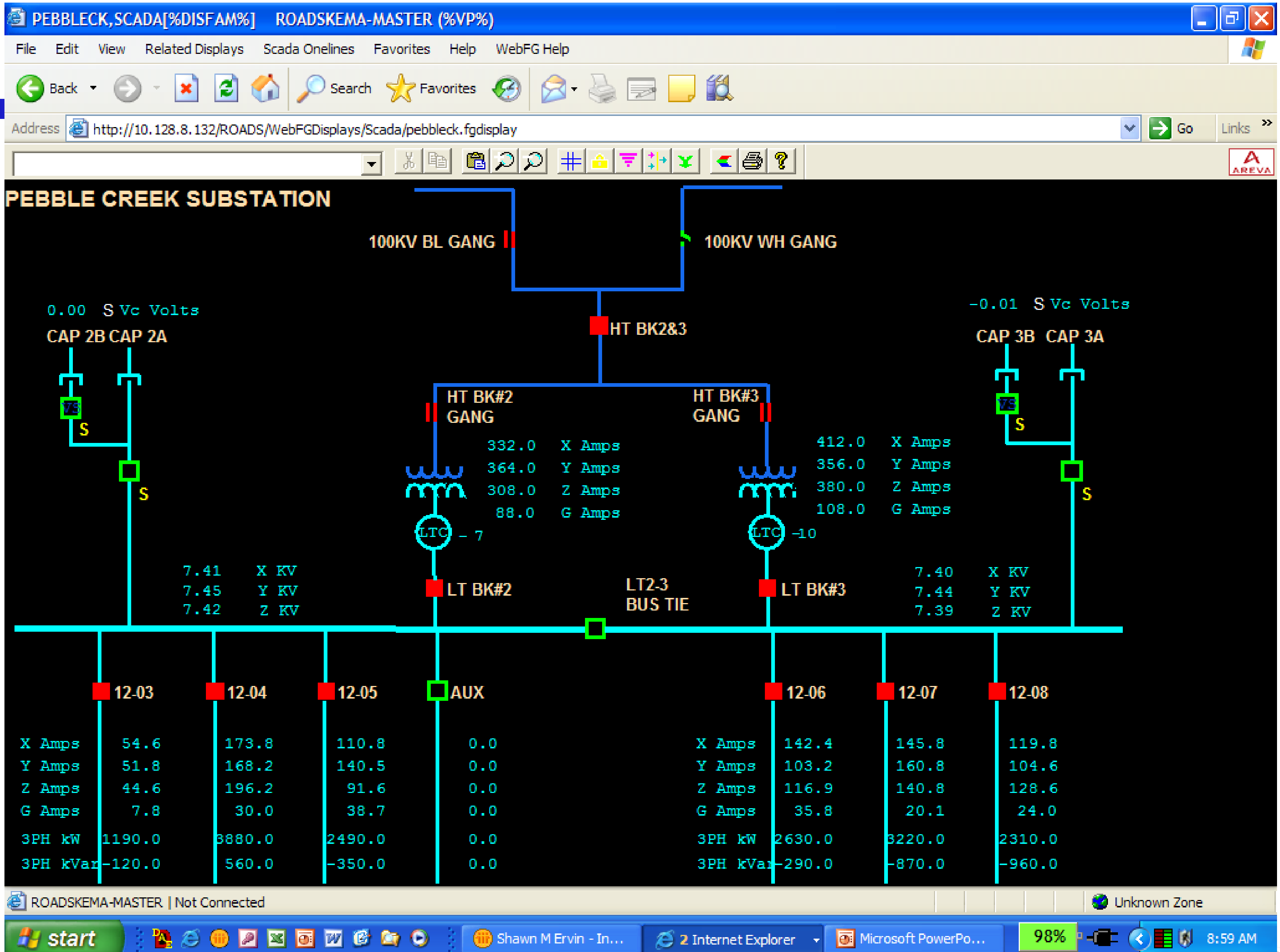
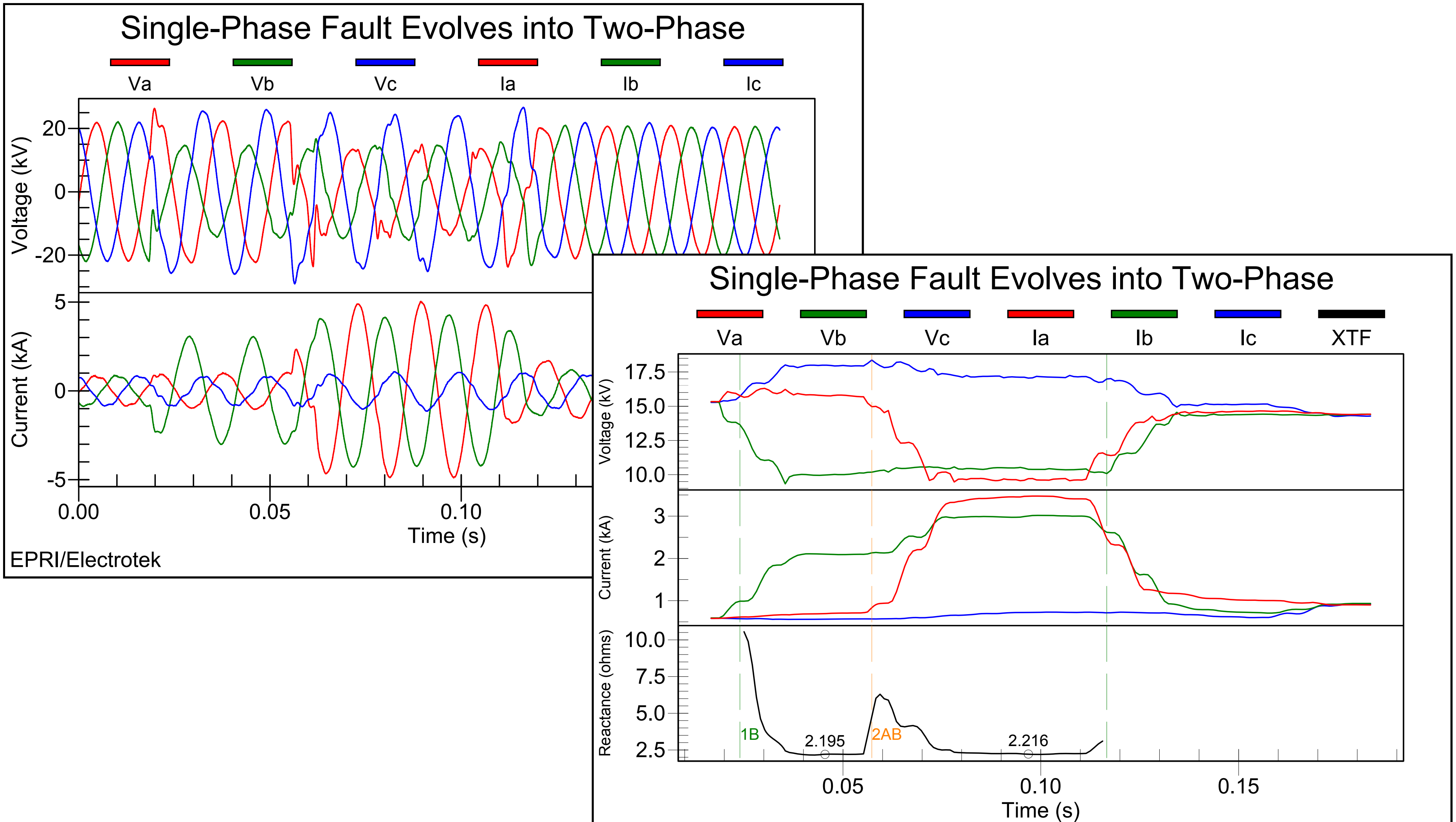
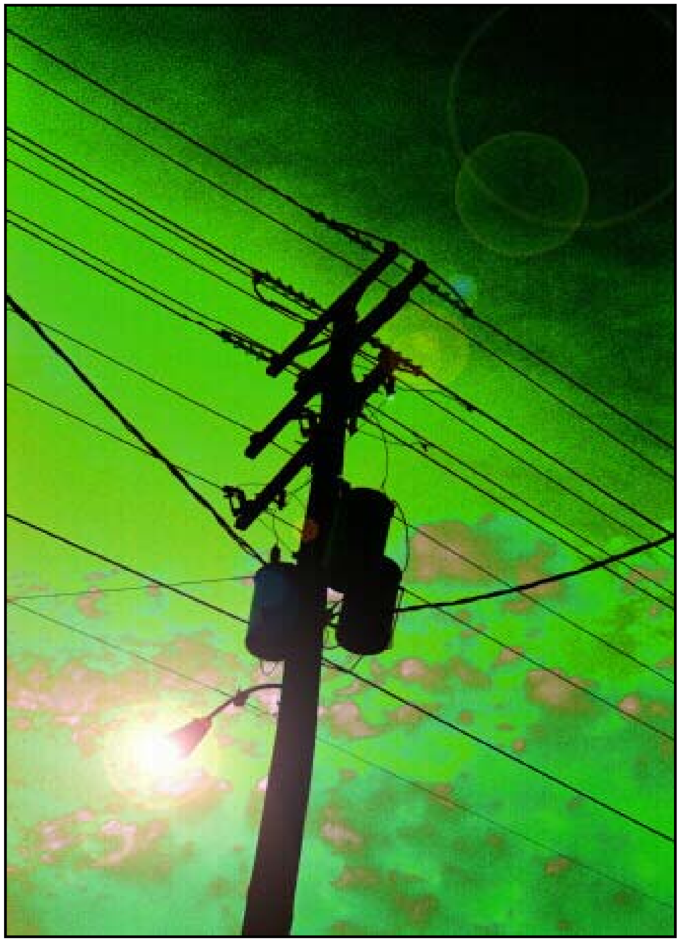

PEBBLECK,SCADA[%DISFAM%] ROADSKEMA-MASTER (%VP%)
File Edit View Related Displays Scada Onelines Favorites Help WebFG Help
Back Search Favorites
Address http://10.128.8.132/ROADS/WebFGDisplays/Scada/pebbleck.fgdisplay
Go Links
PEBBLE CREEK SUBSTATION
100KV BL GANG
100KV WH GANG
HT BK2&3
0.00 S Vc Volts
CAP 2B CAP 2A
-0.01 S Vc Volts
CAP 3B CAP 3A
HT BK#2 GANG
HT BK#3 GANG
332.0 X Amps
364.0 Y Amps
308.0 Z Amps
88.0 G Amps
412.0 X Amps
356.0 Y Amps
380.0 Z Amps
108.0 G Amps
LTC - 7
LTC -10
7.41 X KV
7.45 Y KV
7.42 Z KV
7.40 X KV
7.44 Y KV
7.39 Z KV
LT BK#2
LT2-3 BUS TIE
LT BK#3
12-03 12-04 12-05 AUX 12-06 12-07 12-08
X Amps 54.6 173.8 110.8 0.0
Y Amps 51.8 168.2 140.5 0.0
Z Amps 44.6 196.2 91.6 0.0
G Amps 7.8 30.0 38.7 0.0
3PH kW 1190.0 3880.0 2490.0 0.0
3PH kVar -120.0 560.0 -350.0 0.0
X Amps 142.4 145.8 119.8
Y Amps 103.2 160.8 104.6
Z Amps 116.9 140.8 128.6
G Amps 35.8 20.1 24.0
3PH kW 2630.0 3220.0 2310.0
3PH kVar -290.0 -870.0 -960.0
ROADSKEMA-MASTER | Not Connected
Unknown Zone
start
Shawn M Ervin - In...
2 Internet Explorer
Microsoft PowerPo...
98%
8:59 AM

Using substation monitoring for fault location



Automating Distribution Feeder Circuits – Benefits

- More flexible operation of distribution system
- Automated system response to disturbances and outages
- Improved reliability with multiple options for supplying load
- Optimized asset management and system efficiency
- Integration of DER to improve system performance and allow integration with energy management systems



Line Monitoring for RTUs

- Detection per phase
- Voltage, current and power factor per phase
- Standard distribution line design

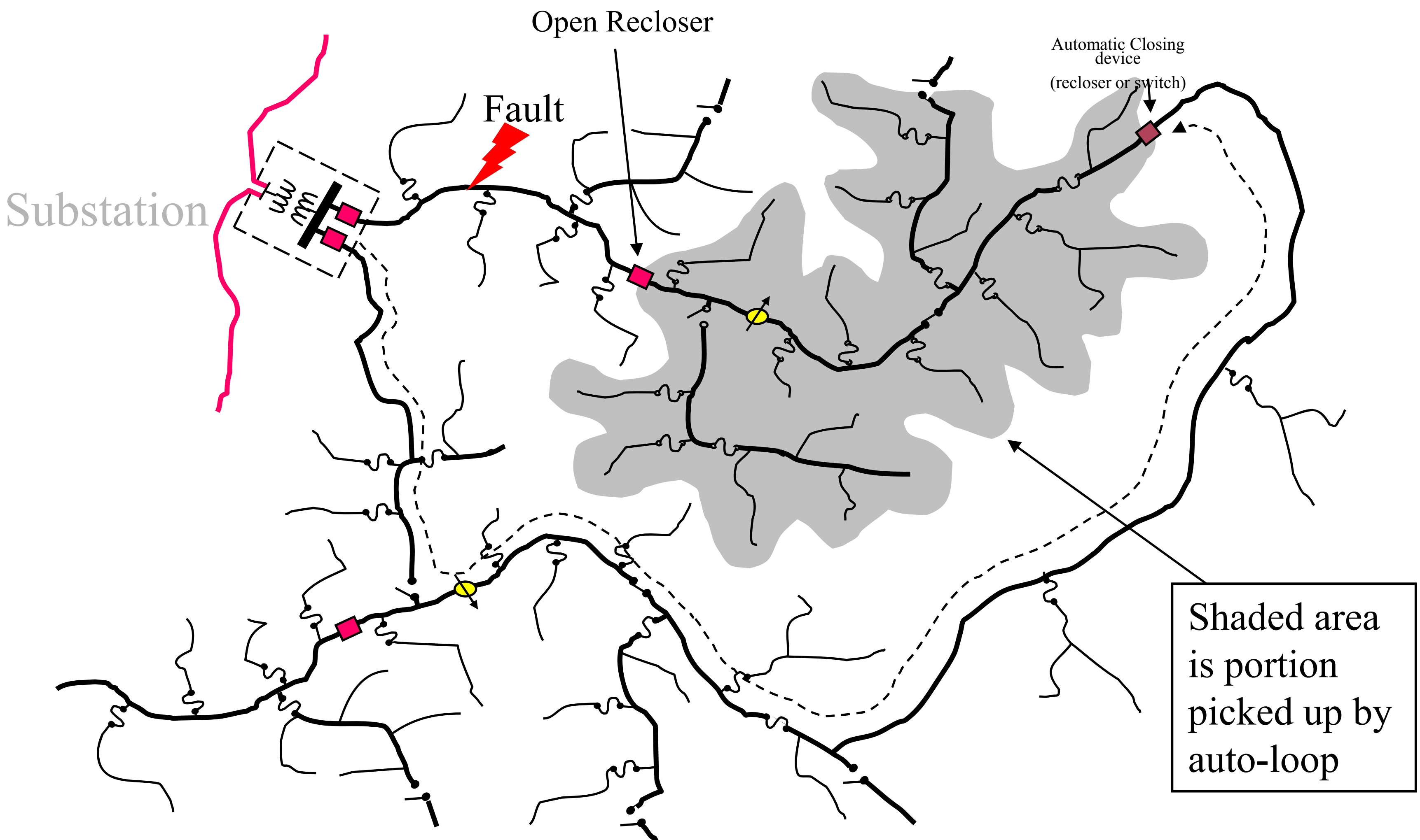
Fault Isolation & Restoration

- Primary Systems
  - Traditional utility first line of defense
  - Protective Relays & Reclosing Relays
  - Distribution Line Reclosers
- Secondary Systems
  - Operates after feeders have locked out
  - Gathers granular fault data from field devices
  - Determines fault location
  - Automatically isolate the faulted feeder section (if possible)
  - Automatically restore unfaulted feeder sections (i.e., customer load)

Automatic Sectionalizing & Restoration (ASR)

- ASR is a generic term for secondary fault isolation and service restoration
- Three types of ASR
  - Switch based
  - Distributed ASR (DASR)
  - Centralized ASR (CASR)

Automated reconfiguration opportunities



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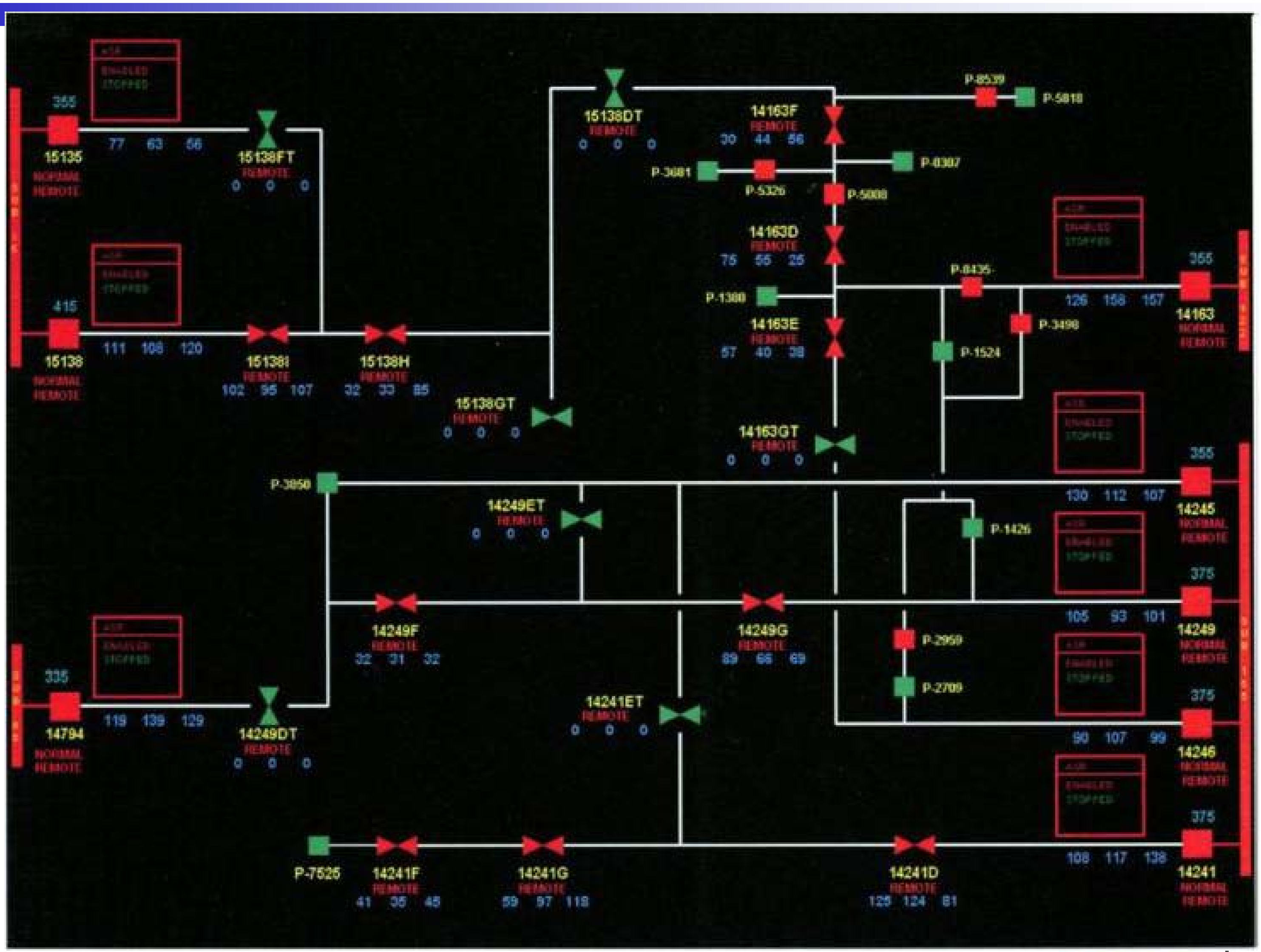
Example Operator View



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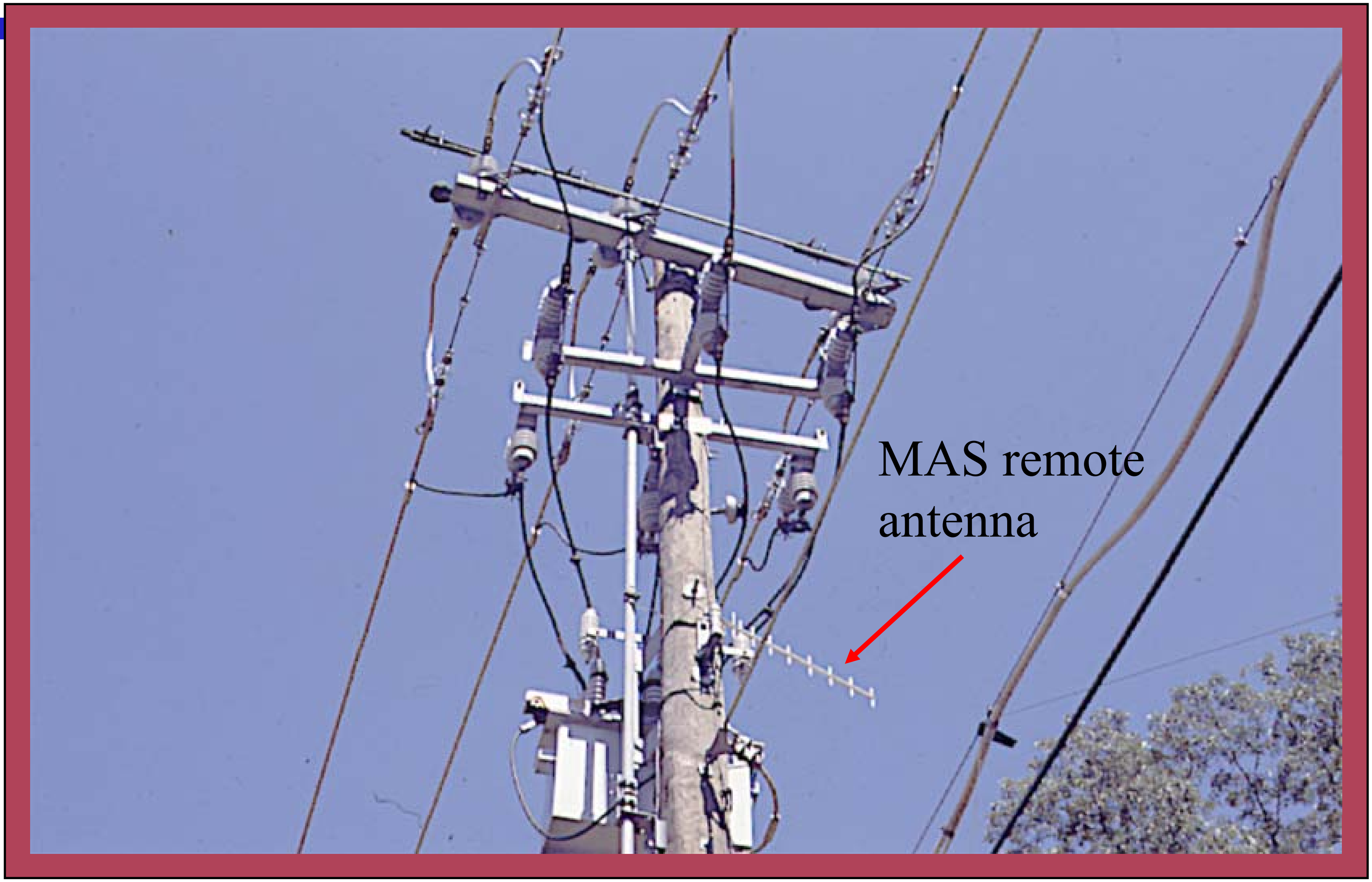
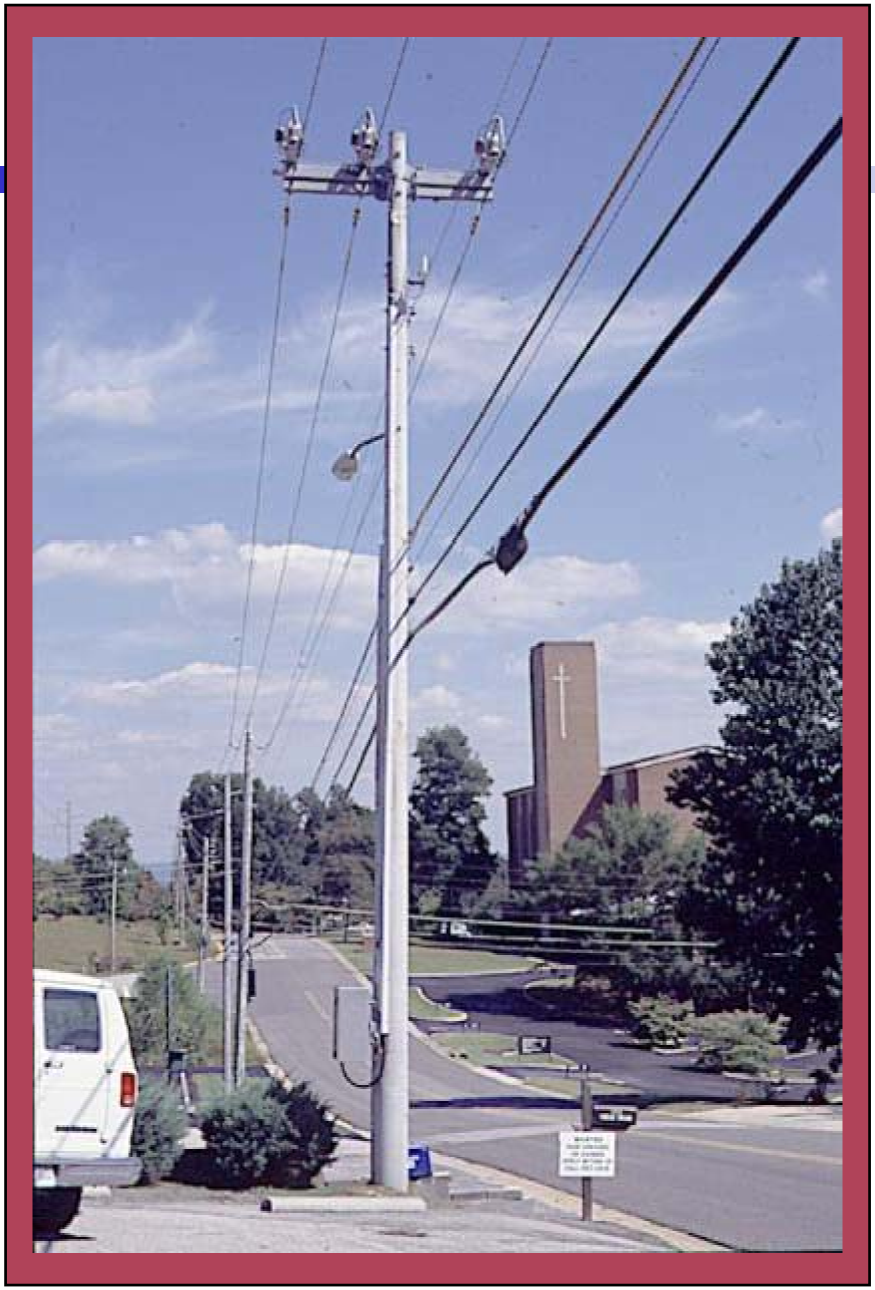
S&C Omni-Rupter flat-plane switch with Cleaveland/ Price motor operator

Pole-Mounted Recloser





SCADAMate Switch

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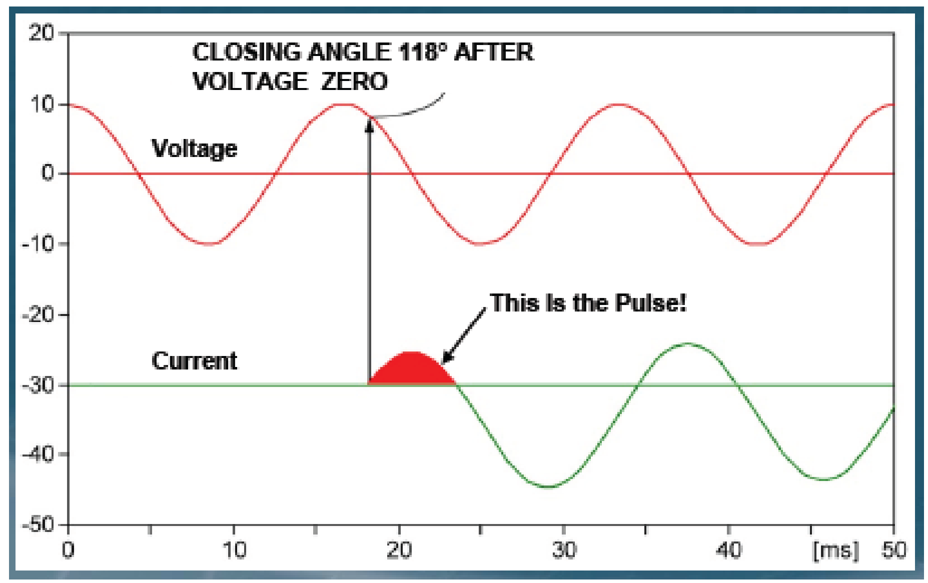
Pulse closing



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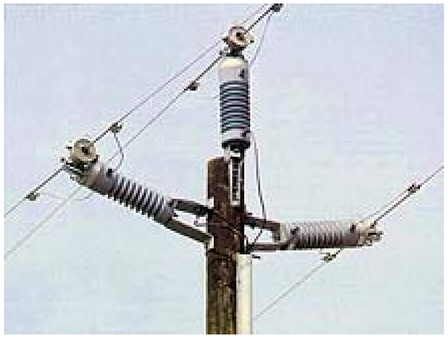
Sensors for Automation Applications

Piedmont Dielectric Line Sensors



Lindsey voltage and current sensors for OH and UG

Wireless communicating voltage and current sensors

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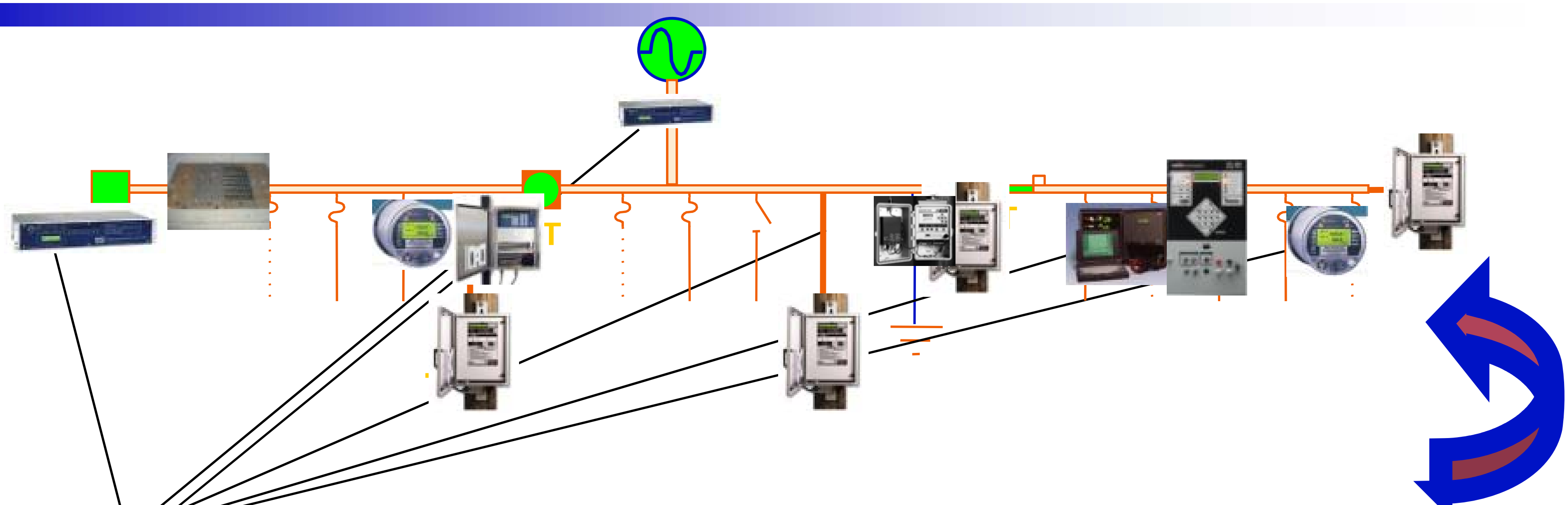
Hydro Quebec – $188M 6 year plan for automation (3750 switches)



DATA
(Using what?)

Voltage
Fault Currents
Load Currents
Temperature
Number of Operations
Alarms

Applications
(How?)

Voltage Control
Optimised Load Flow
Fault Location
Faulty Equipment
Power Quality Evaluation
…

Business needs
(Why?)

Energy Efficiency
Reliability
Distributed Resources
Power Quality
Customer Satisfaction

What Else?

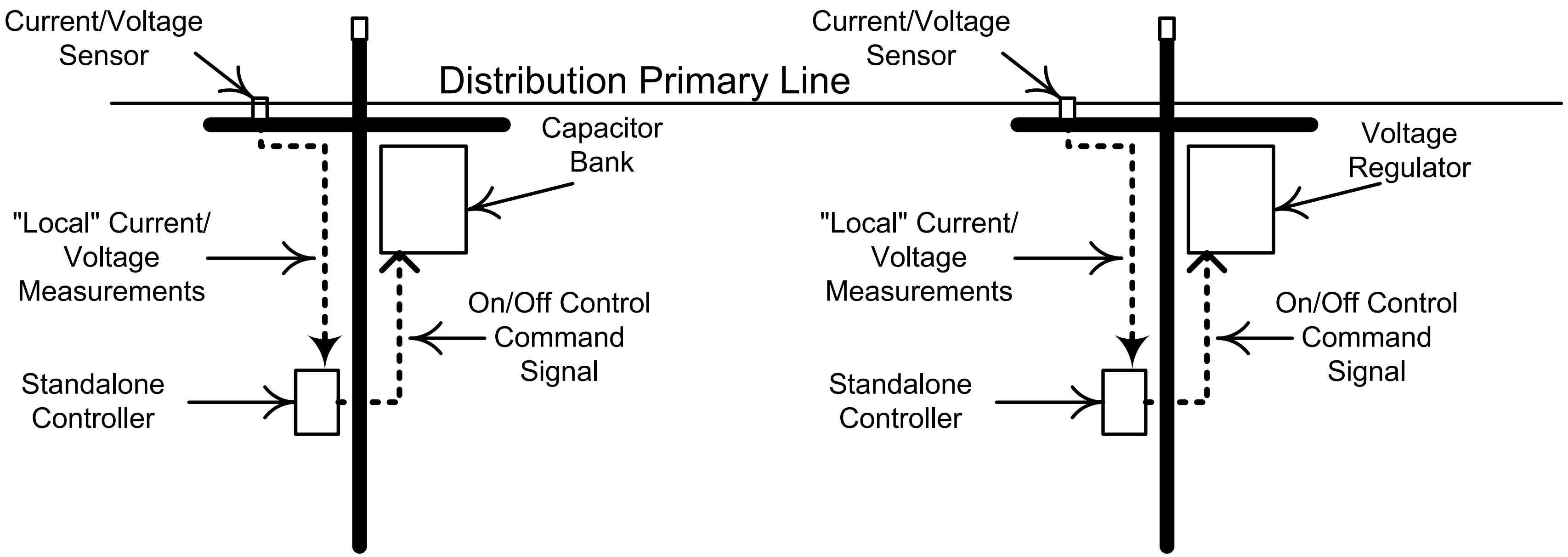
- Proactive load management
- Adaptive Volt/VAR control
- Demand response Integration
- AMI Integration
- Distributed generation integration

Coordinated Volt/Var Control

- Voltage regulators
- Capacitor banks
- Future – integrated operation of power electronics for
  - Storage
  - PV
  - Static compensators
  - …



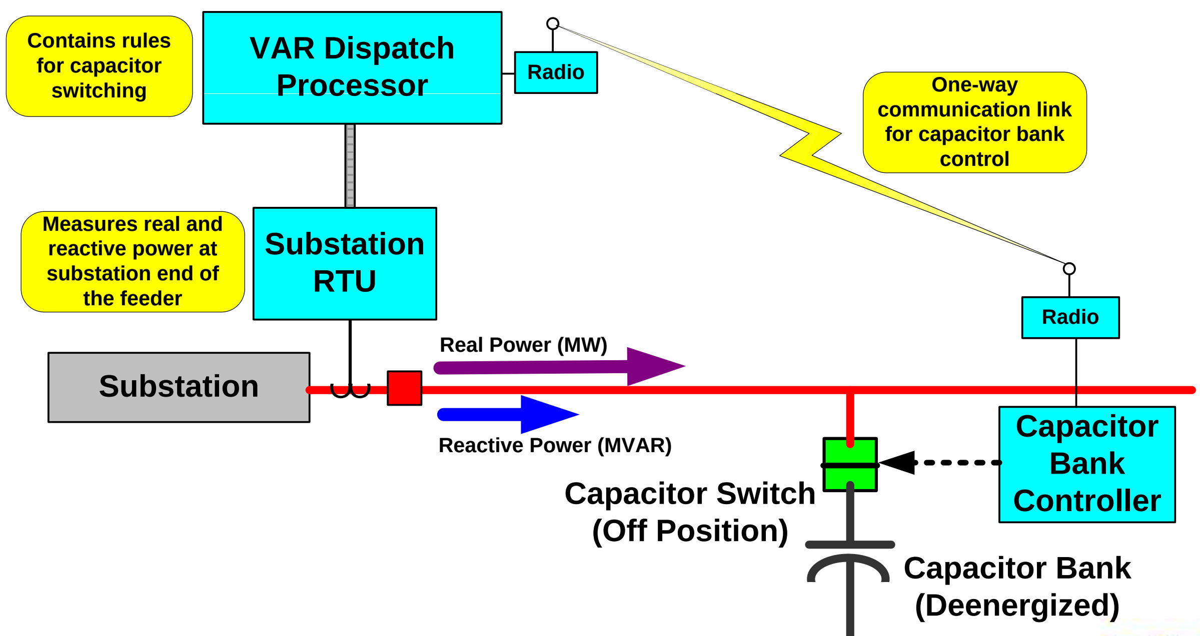

Traditional Volt-VAR Control



- *Volt-VAR flows managed by individual, independent, standalone volt-VAR regulating devices:*
  - Substation transformer load tap changers (LTCs)
  - Line voltage regulators
  - Fixed and switched capacitor banks

“SCADA” Controlled Volt-VAR

- Volt-VAR power apparatus monitored and controlled by SCADA
- Volt and VAR Control typically handled by **two separate** (independent) systems:
  - **VAR Dispatch** – controls capacitor banks to improve power factor, reduce electrical losses
  - **Voltage Control** – controls LTCs and/or voltage regulators to reduce demand and/or energy consumption (aka, **Conservation Voltage Reduction**)
- Operation of these systems is primarily based on a **stored set of predetermined rules** (e.g., “*if power factor is less than 0.95, then switch capacitor bank #1 off”)*



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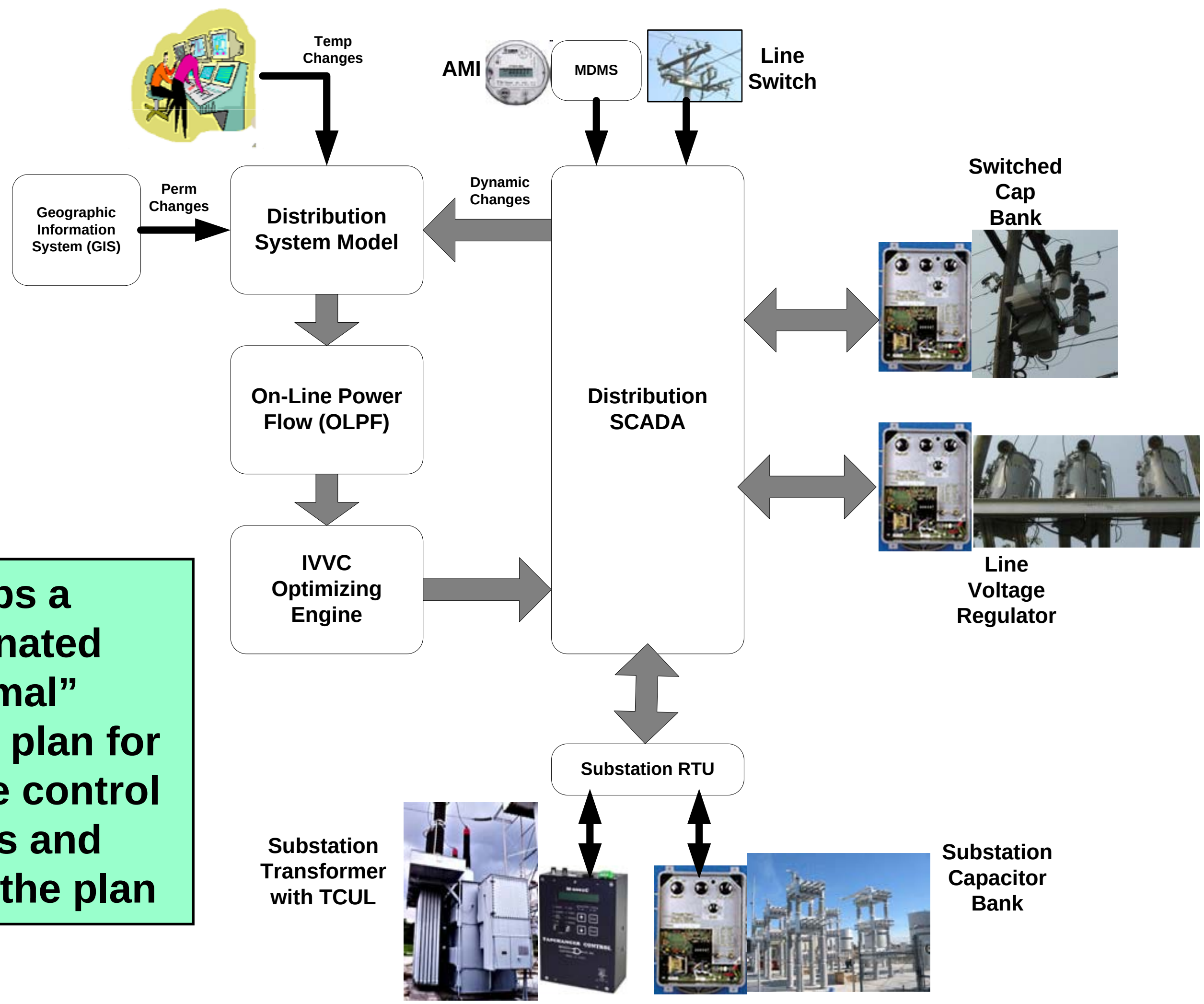
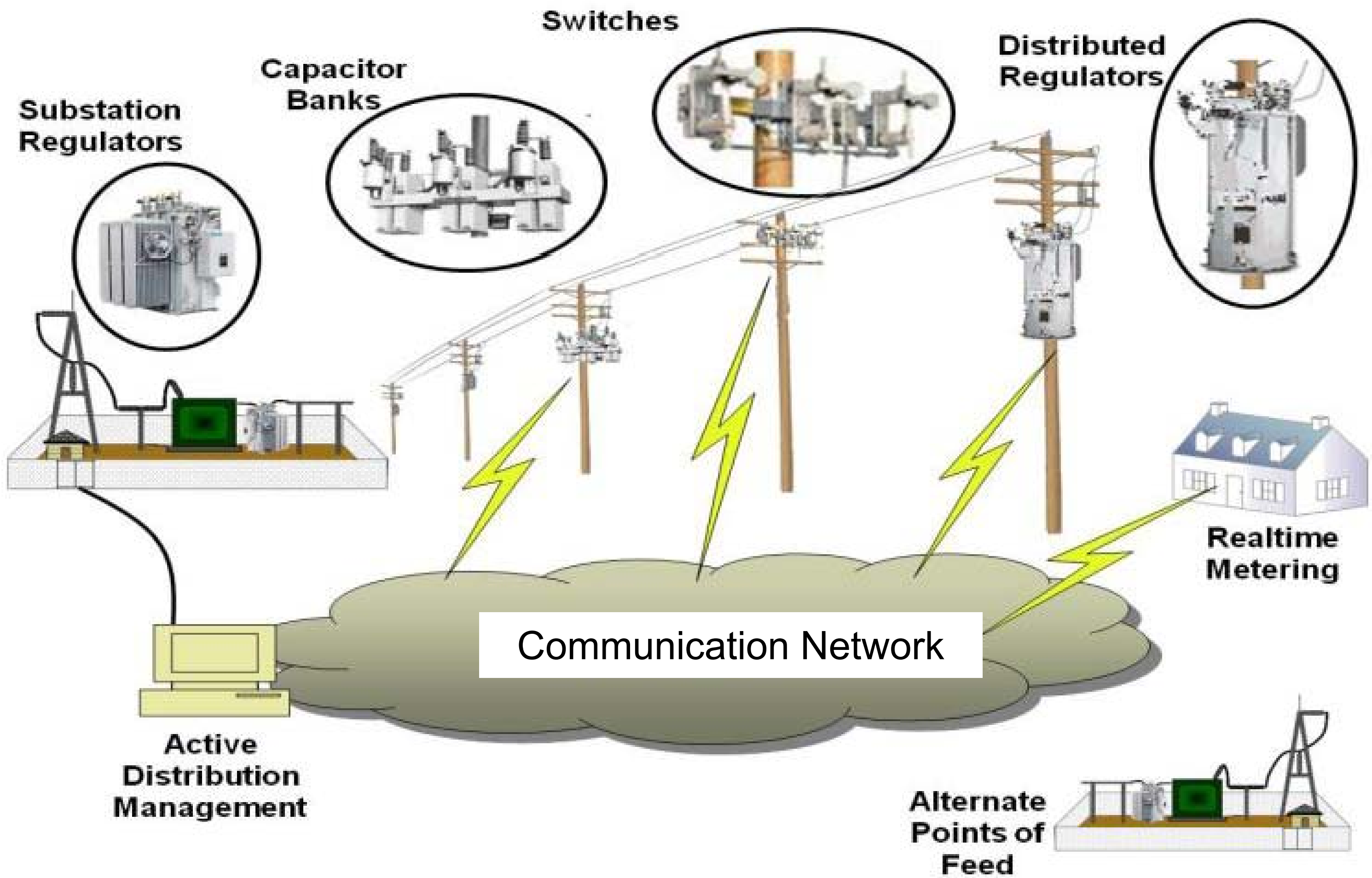
Integrated Volt-VAR Control (IVVC) System Configuration

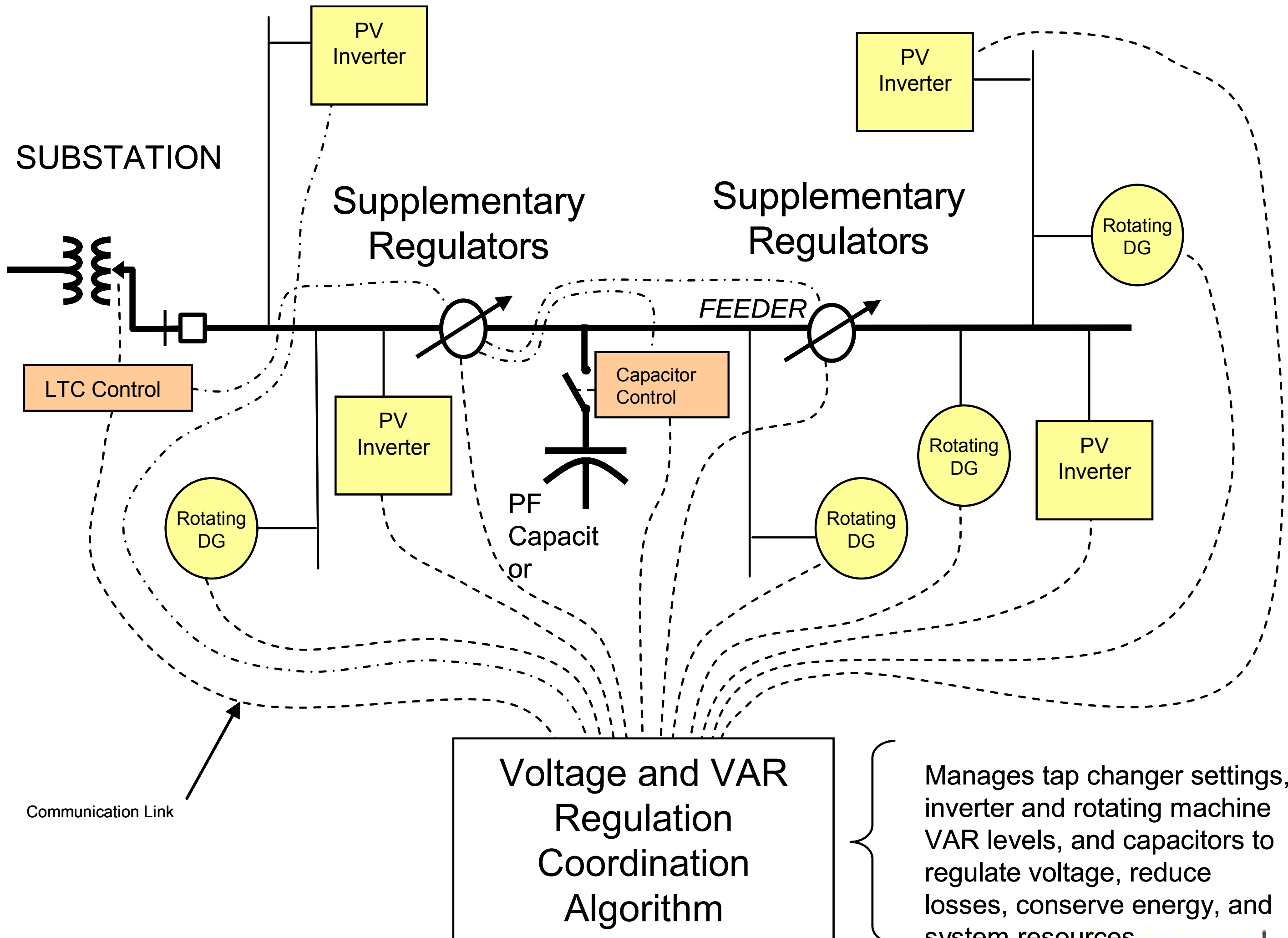


Develops a coordinated "optimal" switching plan for all voltage control devices and executes the plan

Integrated communication network for distribution management

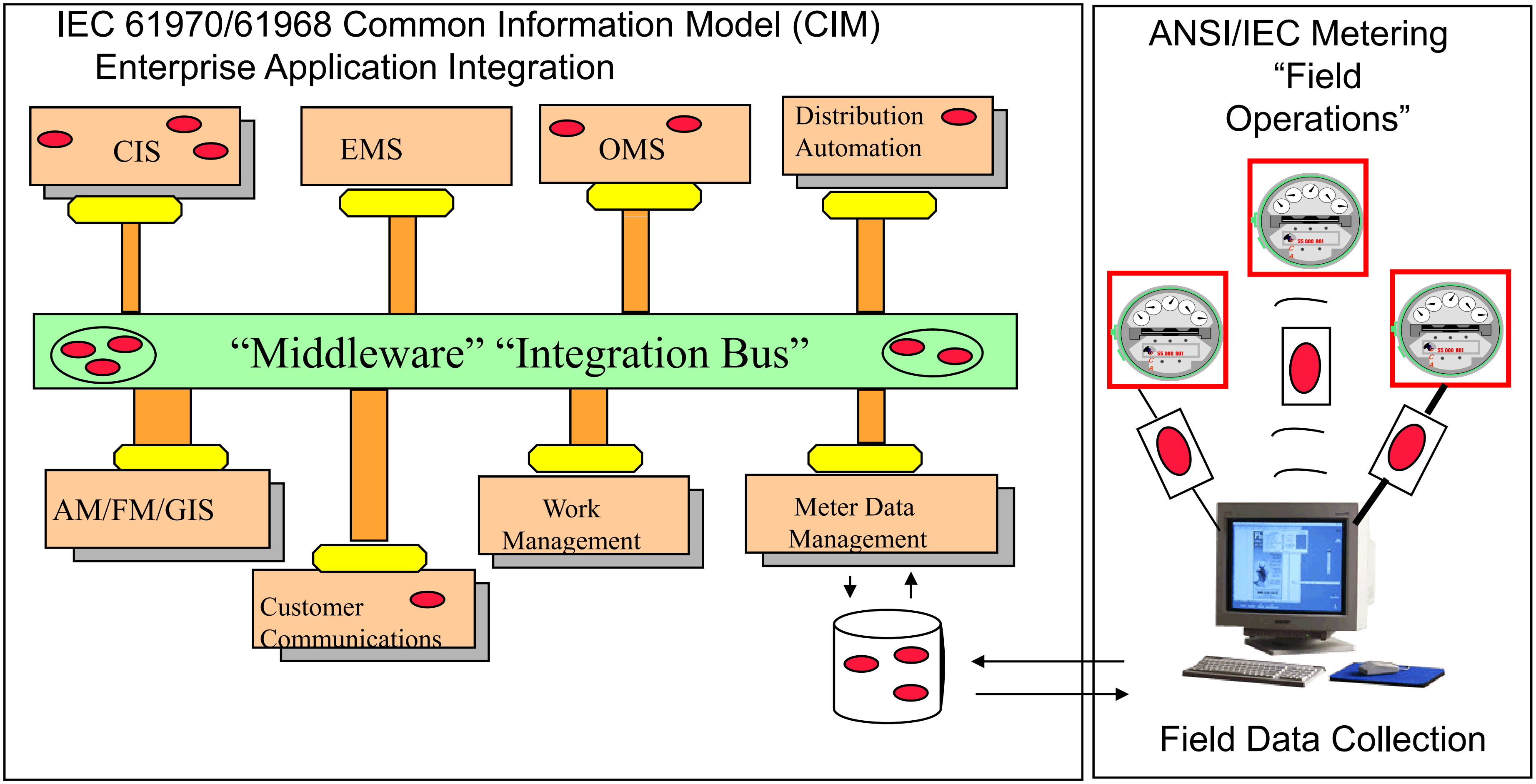


Integrated Volt VAR Control – DG Included



Manages tap changer settings, inverter and rotating machine VAR levels, and capacitors to regulate voltage, reduce losses, conserve energy, and system resources

Integrating AMI Data with Distribution Operations



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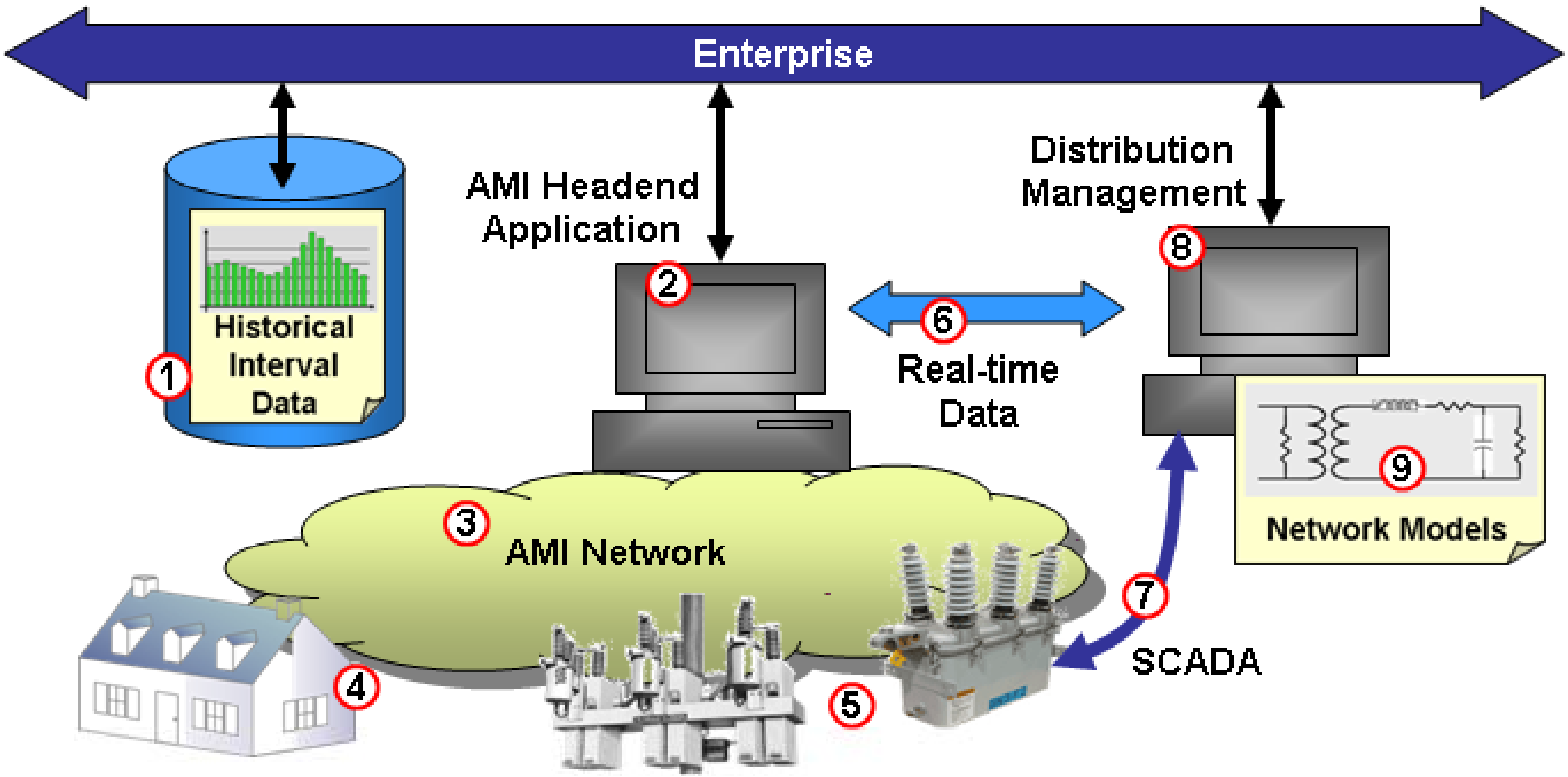
AMI Integration Options and Use Cases



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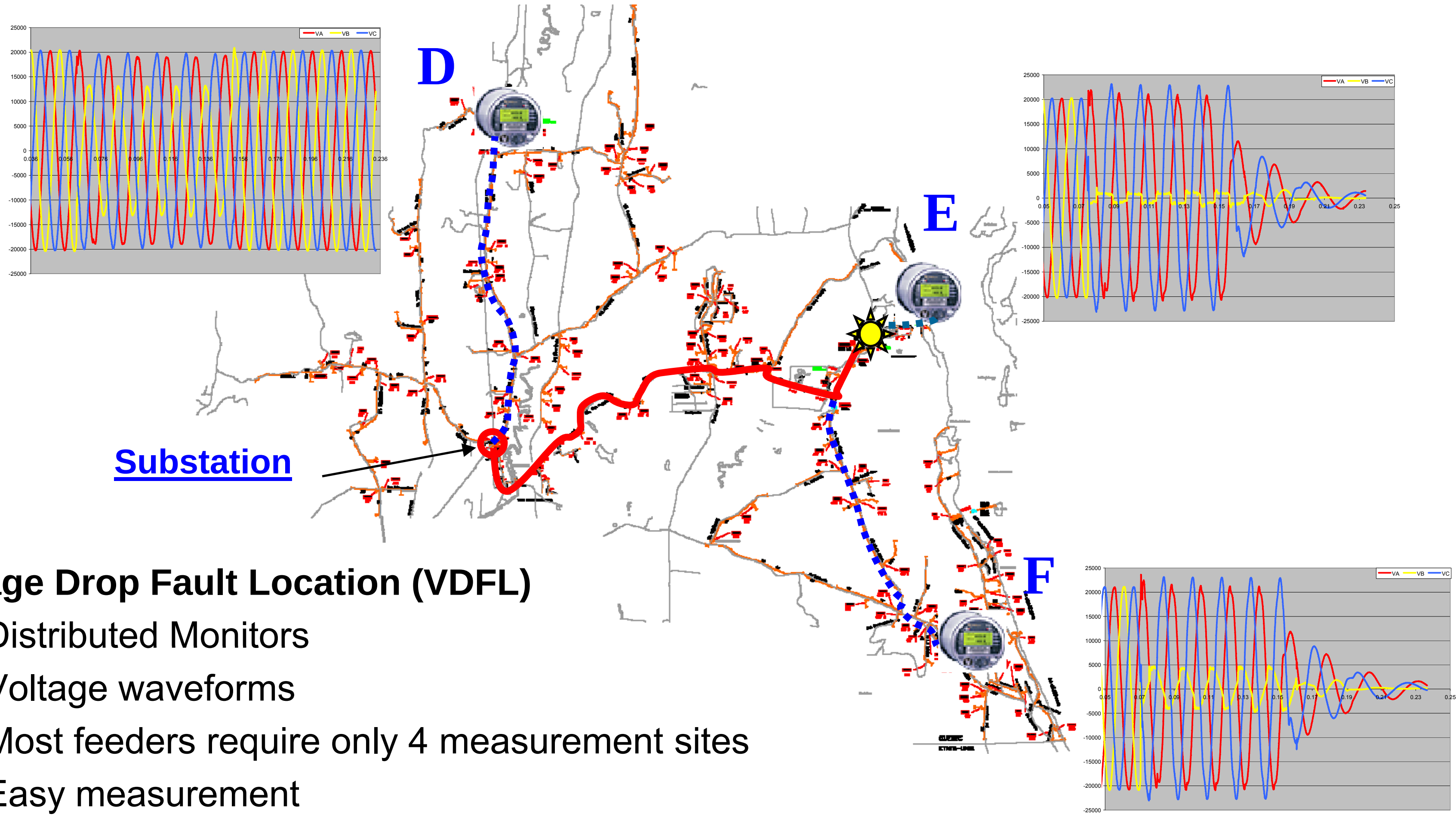
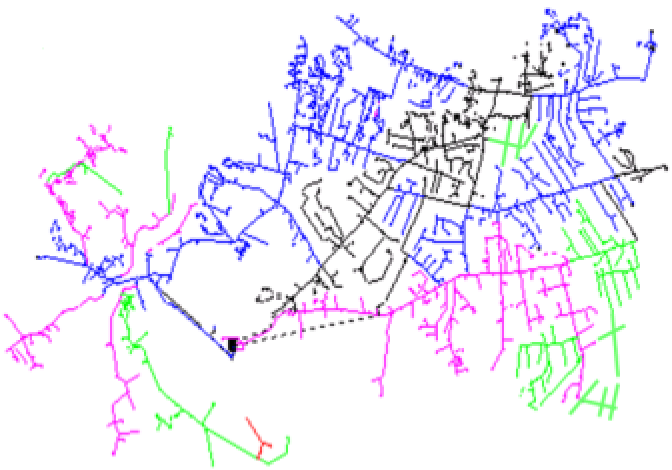
Fault Location with Distributed Monitors

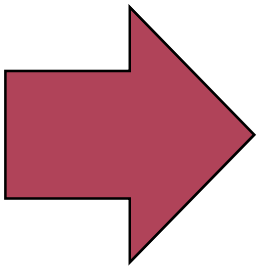


- **Voltage Drop Fault Location (VDFL)**
  - Distributed Monitors
  - Voltage waveforms
  - Most feeders require only 4 measurement sites
  - Easy measurement
    - Low voltage (customer side)
    - GPS not required (no precise synchronisation required)
    - Calibration not needed

New Distribution Models Open Up New Applications

New Models





Fault Location

Minimize Losses

Volt/Var Control

Transformer Load Management

Integration of Distributed Resources

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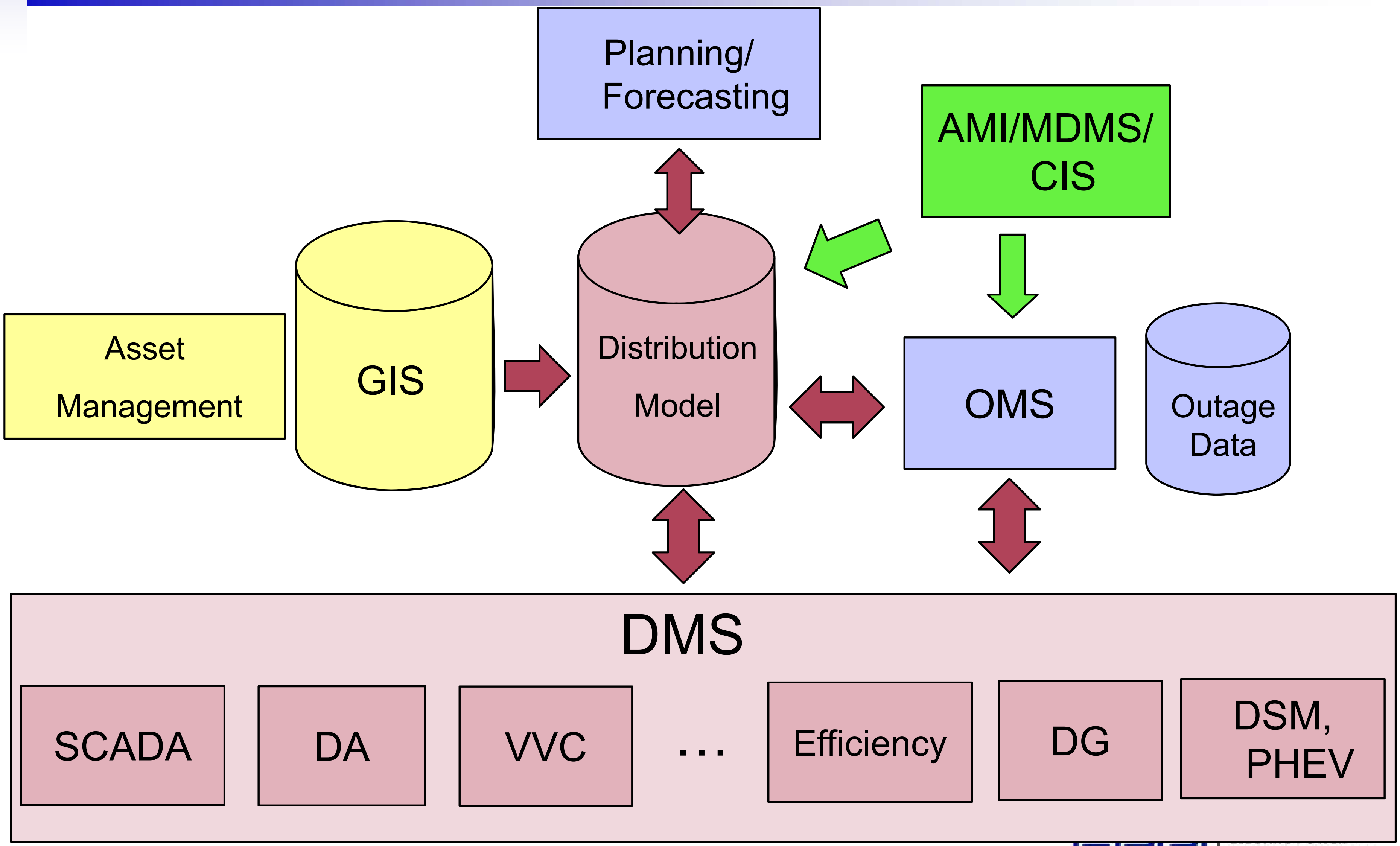
Vision for Distribution Management System integration with Smart Grid



Discussion of DMS Issues

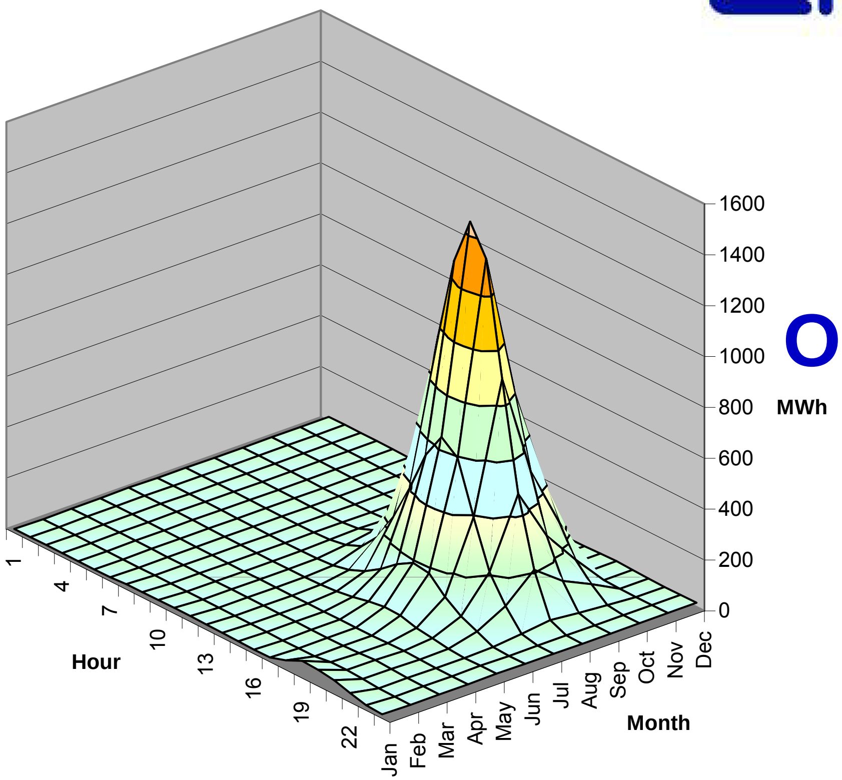
- DMS Applications
  - Volt Var Control
  - Loss Management
  - Reliability/reconfiguration
  - Asset management
  - Fault location/fault management
- Important Interfaces
  - GIS
  - OMS
  - Asset Management
  - Distribution Models
  - MDMS
  - CIS

- Distributed vs Central processing considerations
- Model management and complexity
- State estimators
- Operator interface requirements
- Cost/benefit assessment approaches
- Integration of distributed resources

Questions?

Agenda

- Active Distribution Management Overview
- Modeling Considerations and OpenDSS
- Examples of Active Distribution Management and CIGRE C6.11 Activities
- IEEE Distribution Automation Working Group
- Demonstrations



Open Source Software for Simulating Active Distribution Systems

Roger Dugan
Sr. Technical Executive
rdugan@epri.com

Active Distribution Management Tutorial

Cigre Canada
Toronto, Ontario

October 4, 2009

OpenDSS

- EPRI released its Distribution System Simulator (DSS) program as *open source* In Sept 2008
  - Source code is available to public
  - BSD License – basically no limitations

- Called "**OpenDSS**"

- Can be found at:

  - **WWW.SOURCEFORGE.NET**

    (Search for OpenDSS)

History

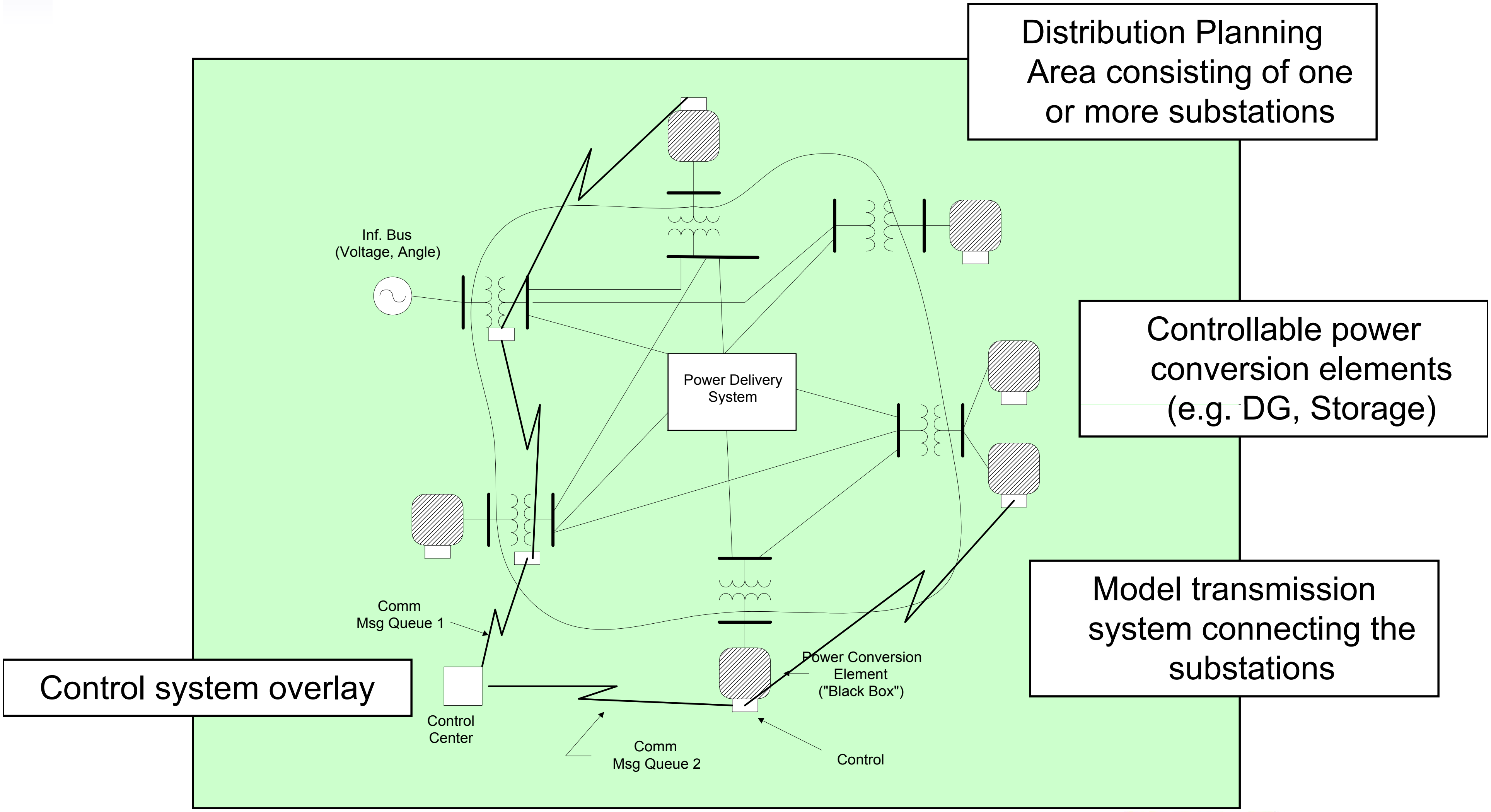
- DSS development was started at Electrotek Concepts in 1997 to provide
  - a very flexible and expandable research platform
  - a foundation for special distribution analysis applications
    - In particular, DG analysis

- Fills many of the gaps left by more conventional distribution system analysis tools
- For developing new approaches to distribution system analysis
- Acquired by EPRI in 2004

Time- and Location-Specific Benefits

- The DSS was designed from the beginning to capture both **Time- and Location-specific benefits** of
  - DG or other proposed capacity enhancements
- Most traditional distribution system analysis programs:
  - Capture only some location-specific benefits
  - Ignores time; Assumes resource is available
  - *This gets the wrong answer* for many DG and energy efficiency analyses
- Must do **time sequence analysis**
  - Over distribution planning area

Original Overall Model Concept circa 1997



Why Did We Make it Open Source?

- EPRI has made the DSS open source to:
  - Cooperate with other open source efforts in the USA in Smart Grid research
    - Gridlab-D at PNL, for example
  - To encourage new advancements in distribution system analysis
    - We've already seen proof of this
  - To provide Smart Grid researchers a tool for testing and developing distribution control algorithms

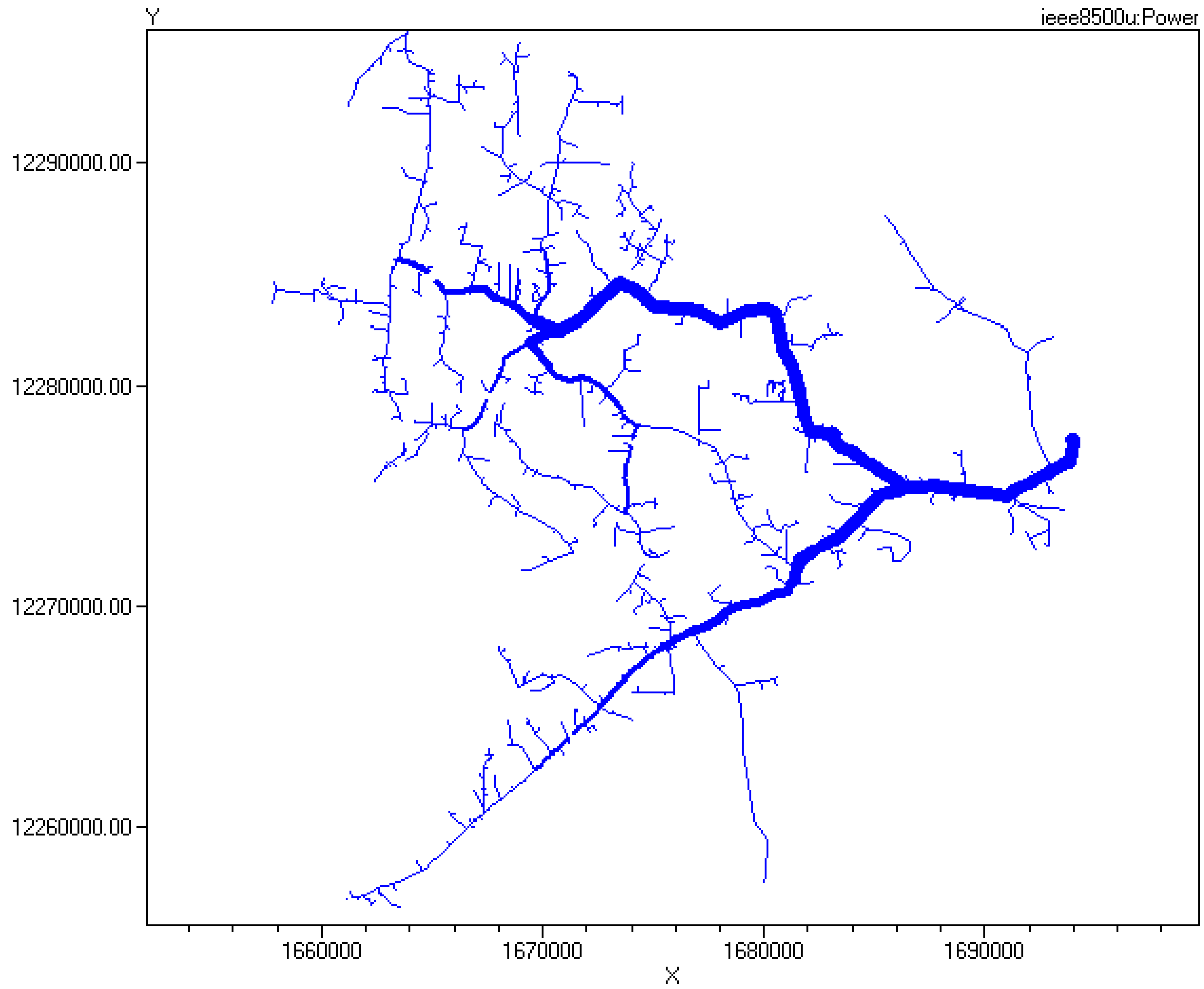
Example DSS Applications (the more exotic ones)

- Neutral-to-earth (stray) voltage simulations.
- Loss evaluations due to unbalanced loading.
- Development of DG models for the IEEE Radial Test Feeders.
- High-frequency harmonic and interharmonic interference.
- Losses, impedance, and circulating currents in unusual transformer bank configurations.
- Transformer frequency response analysis.
- Distribution automation control algorithm assessment.
- Impact of tankless water heaters on flicker and distribution transformers.
- Wind farm collector simulation.
- Wind farm impact on local transmission.
- Wind generation and other DG impact on switched capacitors and voltage regulators.
- Open-conductor fault conditions with a variety of single-phase and three-phase transformer connections.

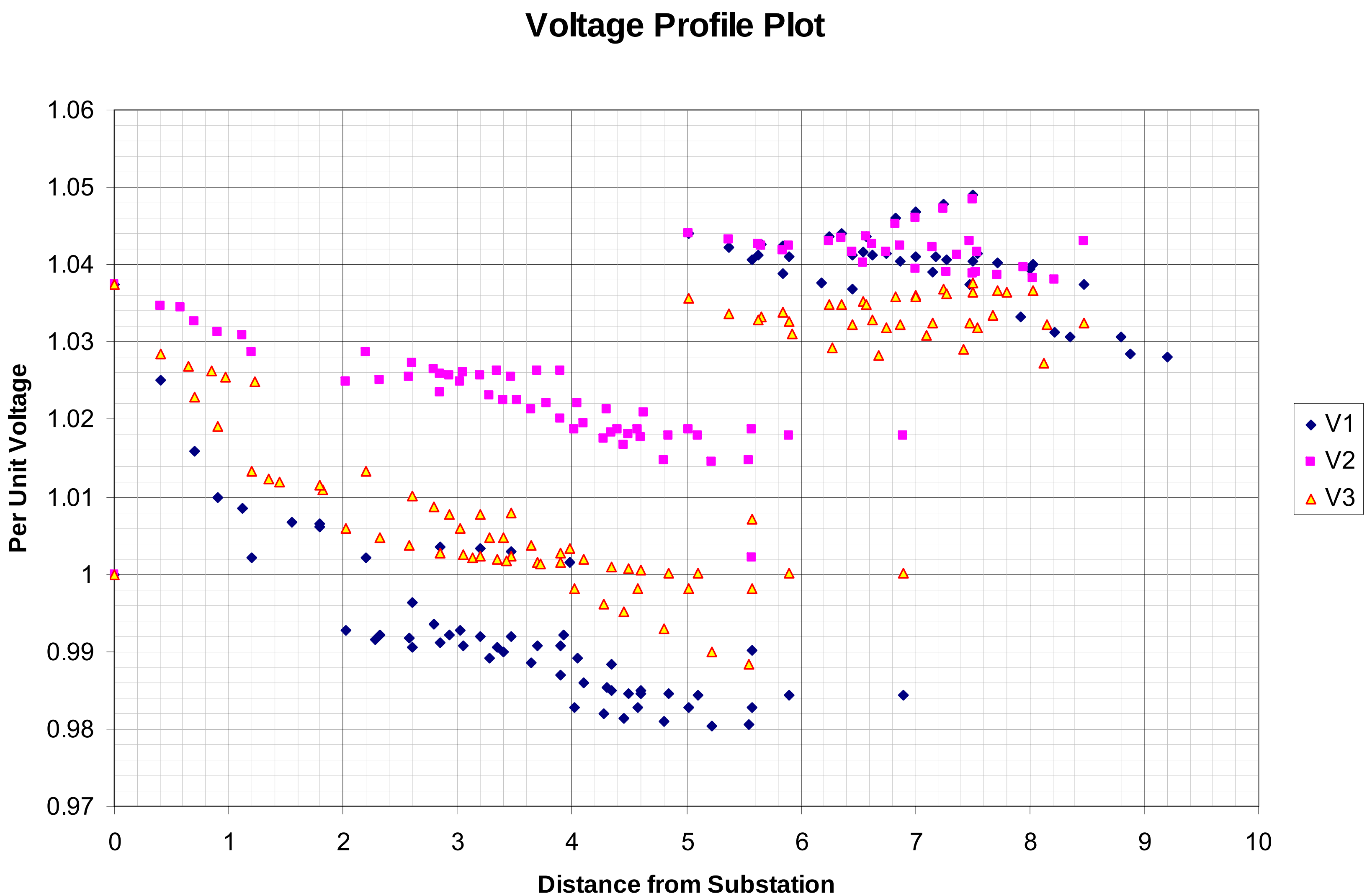
What Can It Do?

Examples of Results

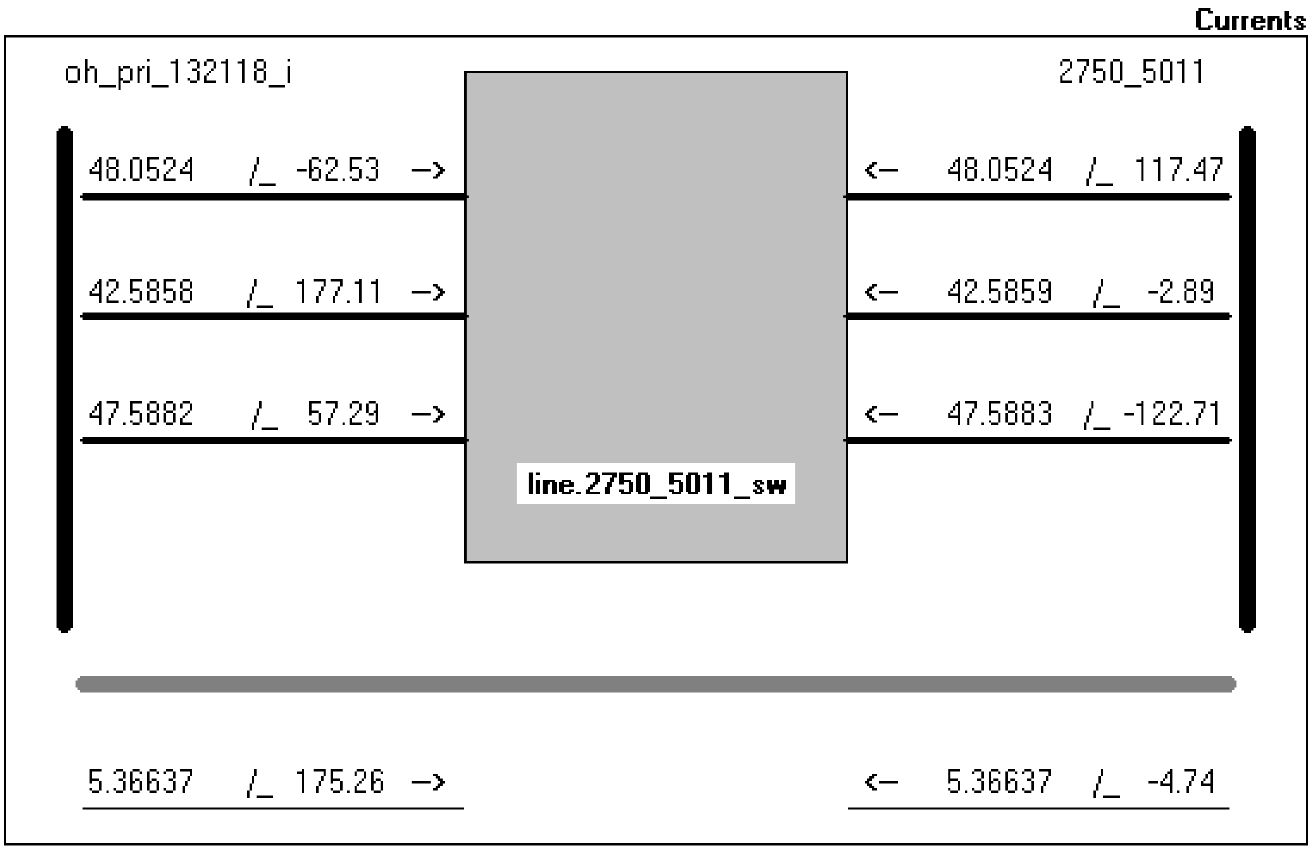
Power Flow Visualization



Power Flow Visualization

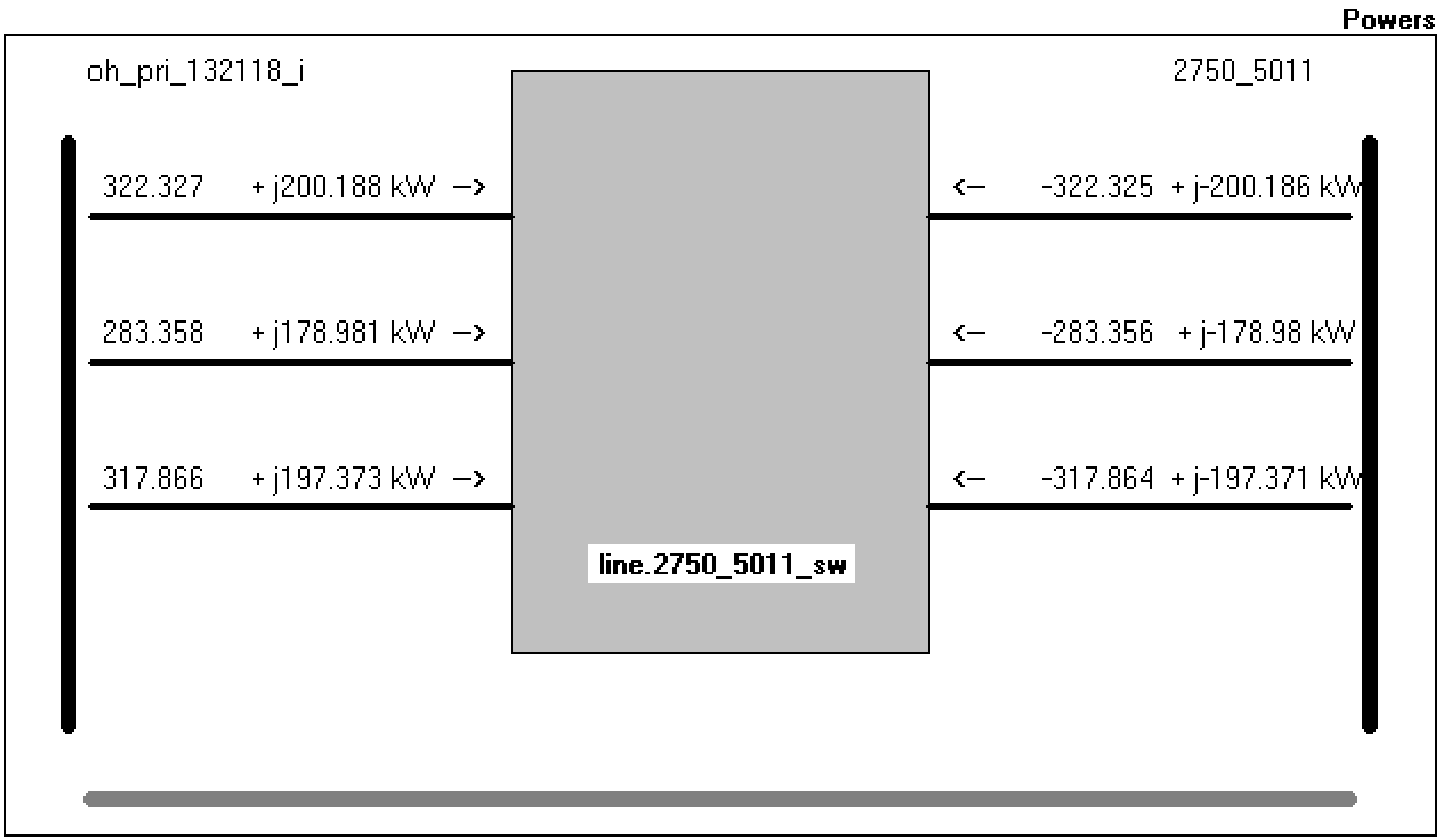


Current

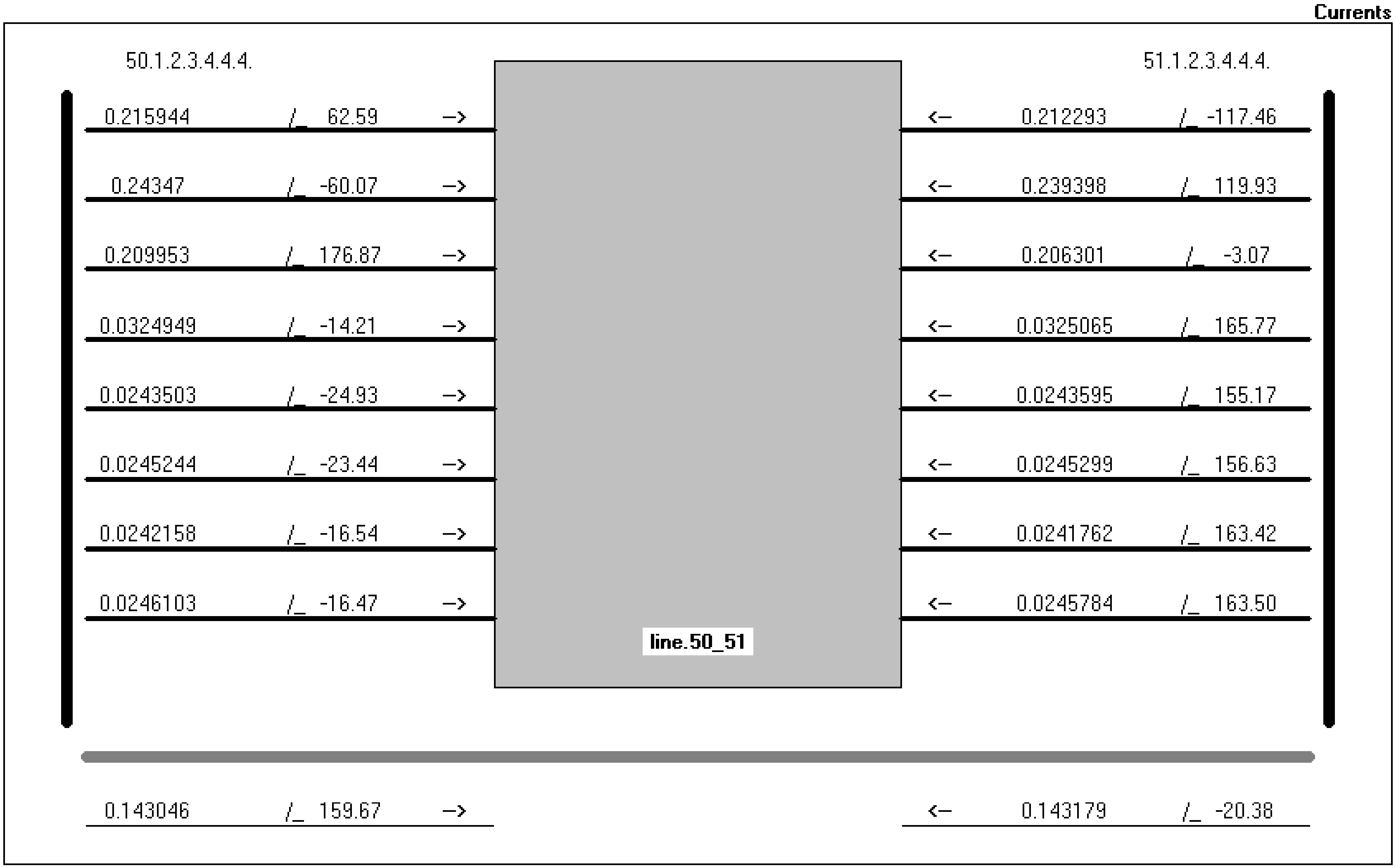


Currents
oh_pri_132118_i
2750_5011
48.0524 /_ -62.53 ->
<- 48.0524 /_ 117.47
42.5858 /_ 177.11 ->
<- 42.5859 /_ -2.89
47.5882 /_ 57.29 ->
<- 47.5883 /_ -122.71
line.2750_5011_sw
5.36637 /_ 175.26 ->
<- 5.36637 /_ -4.74

Power

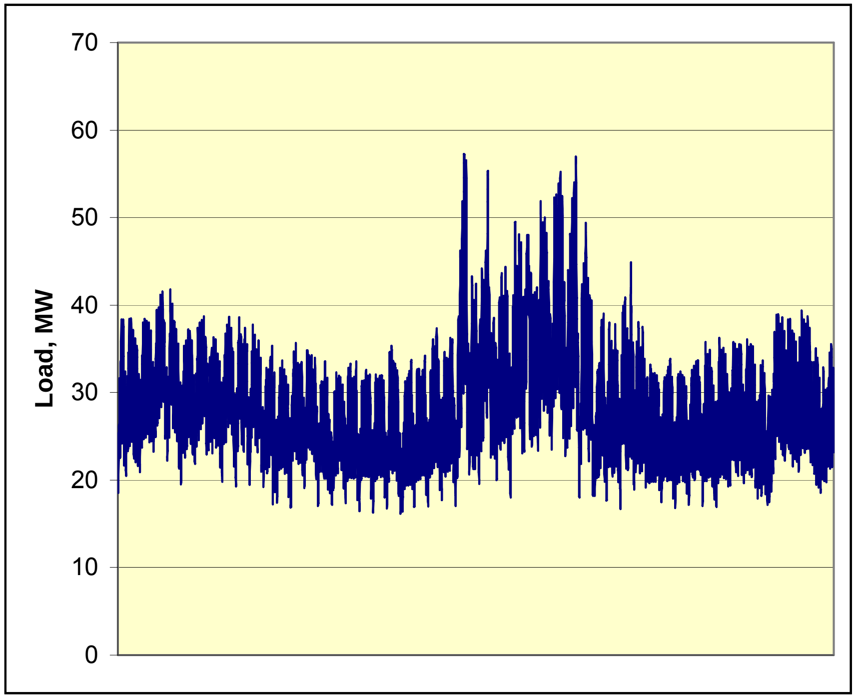

Powers
oh_pri_132118_i
2750_5011
322.327 + j200.188 kW ->
283.358 + j178.981 kW ->
317.866 + j197.373 kW ->
<- -322.325 + j-200.186 kW
<- -283.356 + j-178.98 kW
<- -317.864 + j-197.371 kW
line.2750_5011_sw

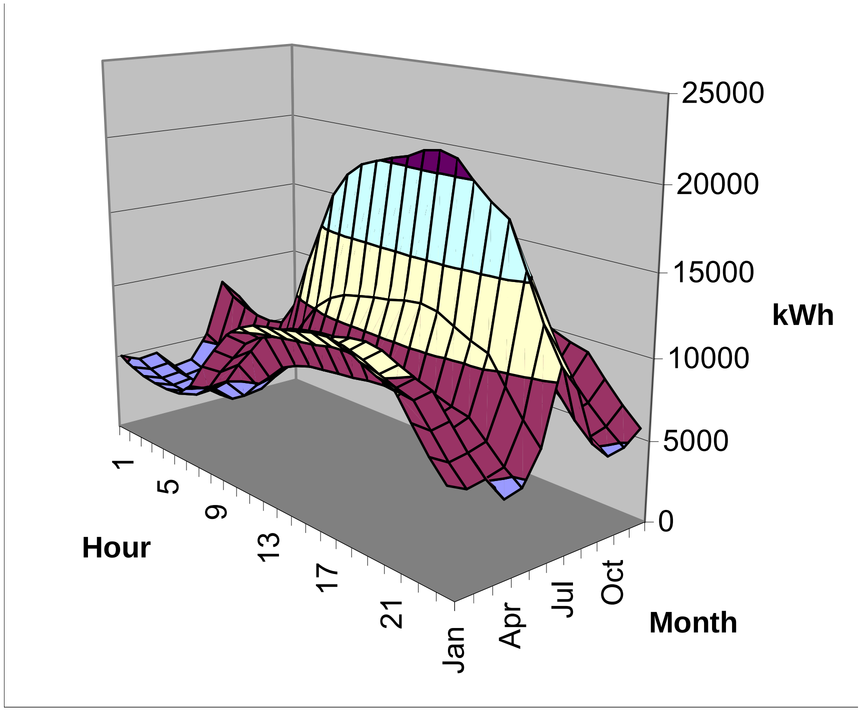
A Bit More Complicated …



Annual Losses

Peak load losses are not necessarily indicative of annual losses





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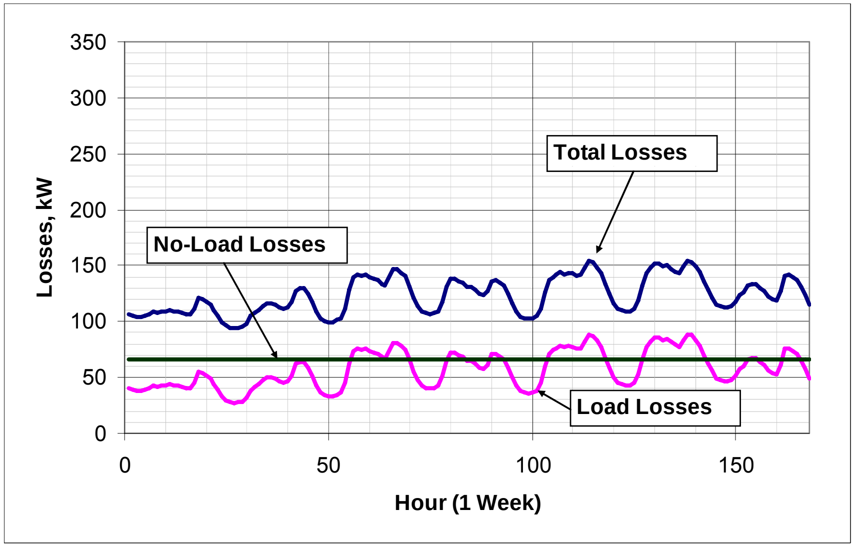
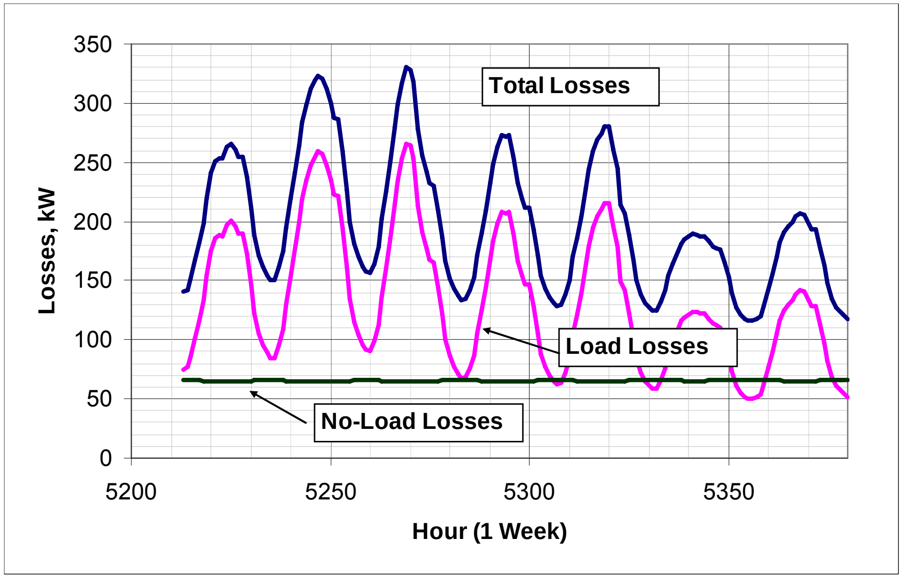
Power Distribution Efficiency (EPRI Green Circuits Project)



Light Load Week

Peak Load Week



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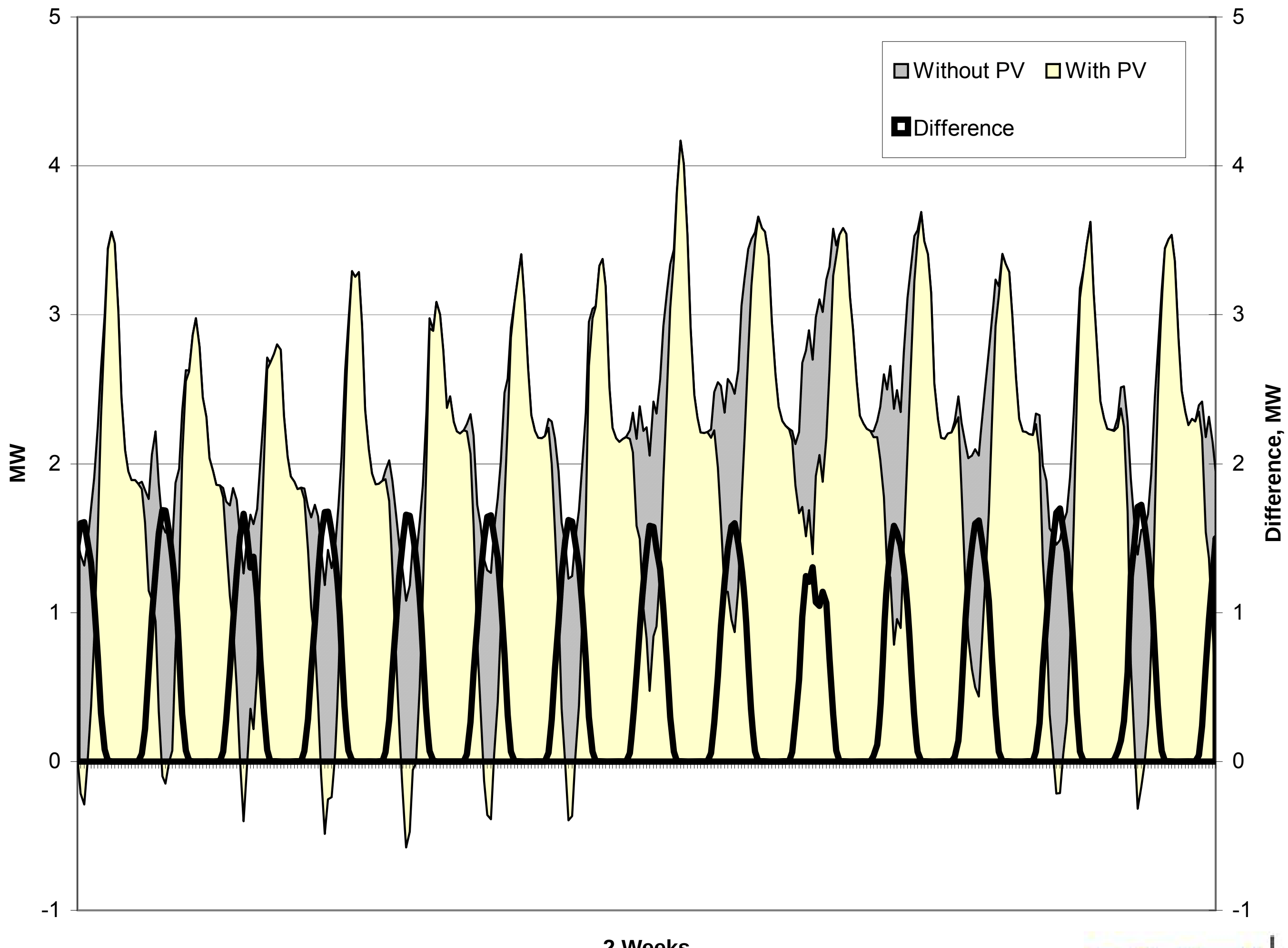
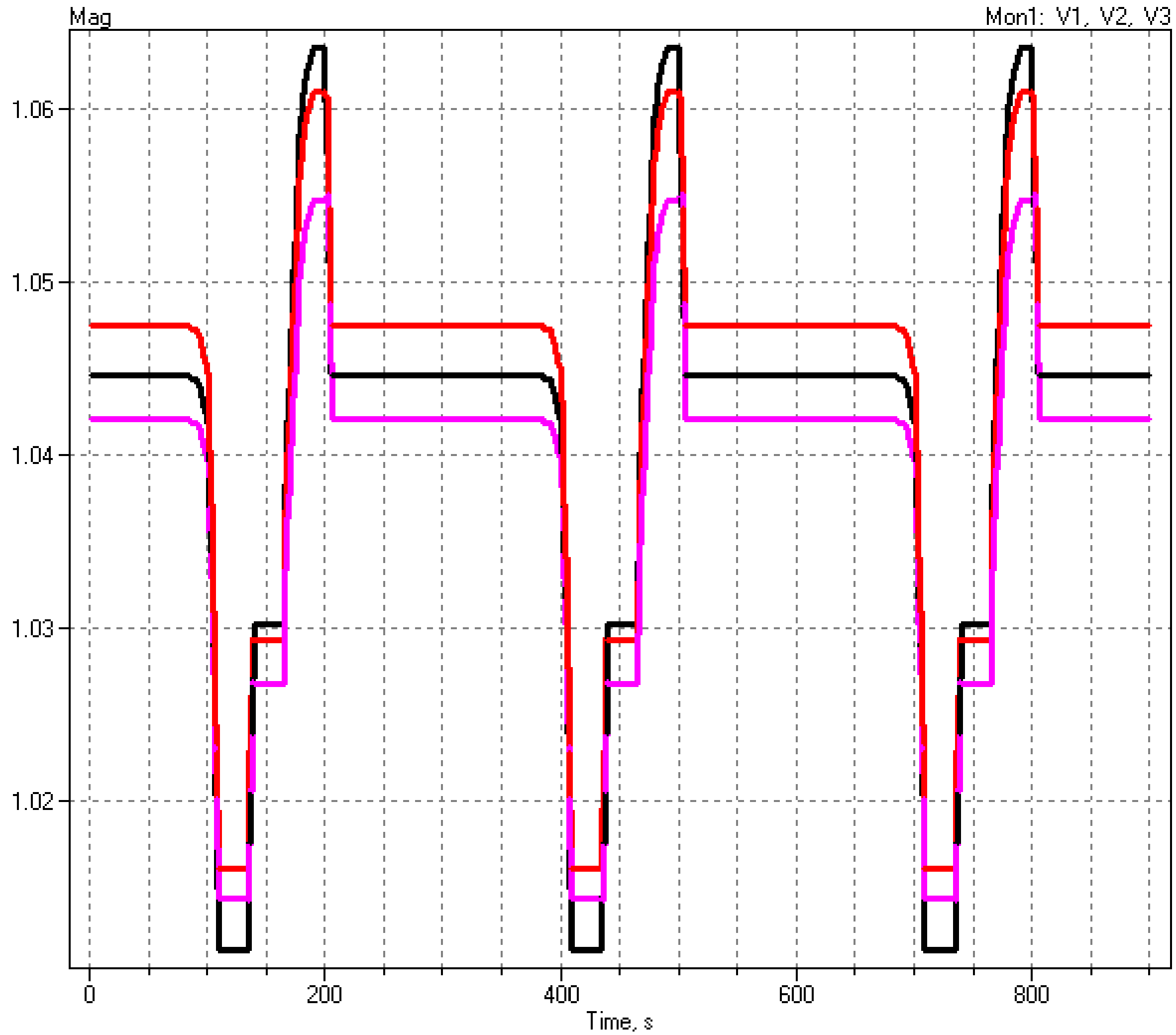
Solar PV Simulation



Solar Ramp Simulation – Regulator Impacts



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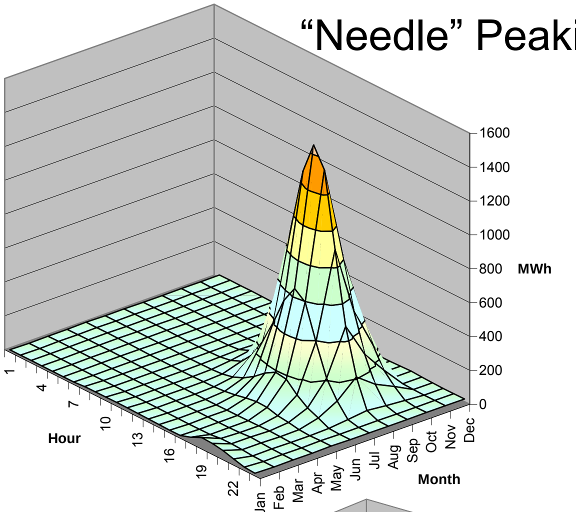
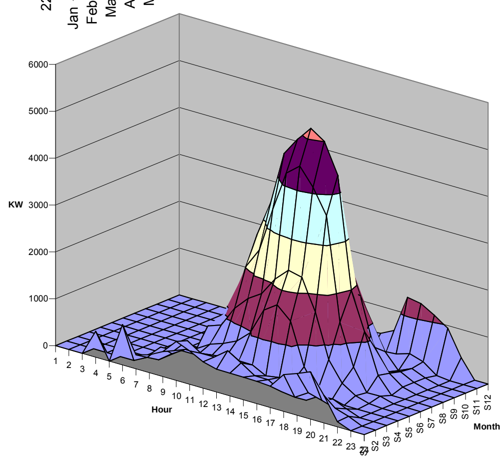
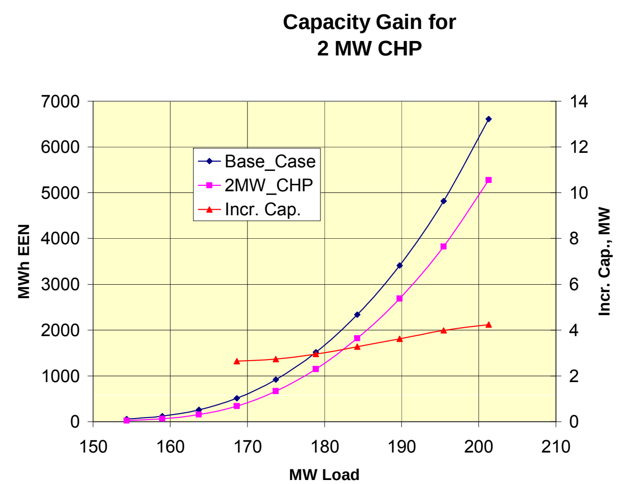
Using DSS to Determine Incremental Capacity of DG

“Needle” Peaking System





Broad Summer Peaking System



“How much more power can be served at the same risk of unserved energy?”

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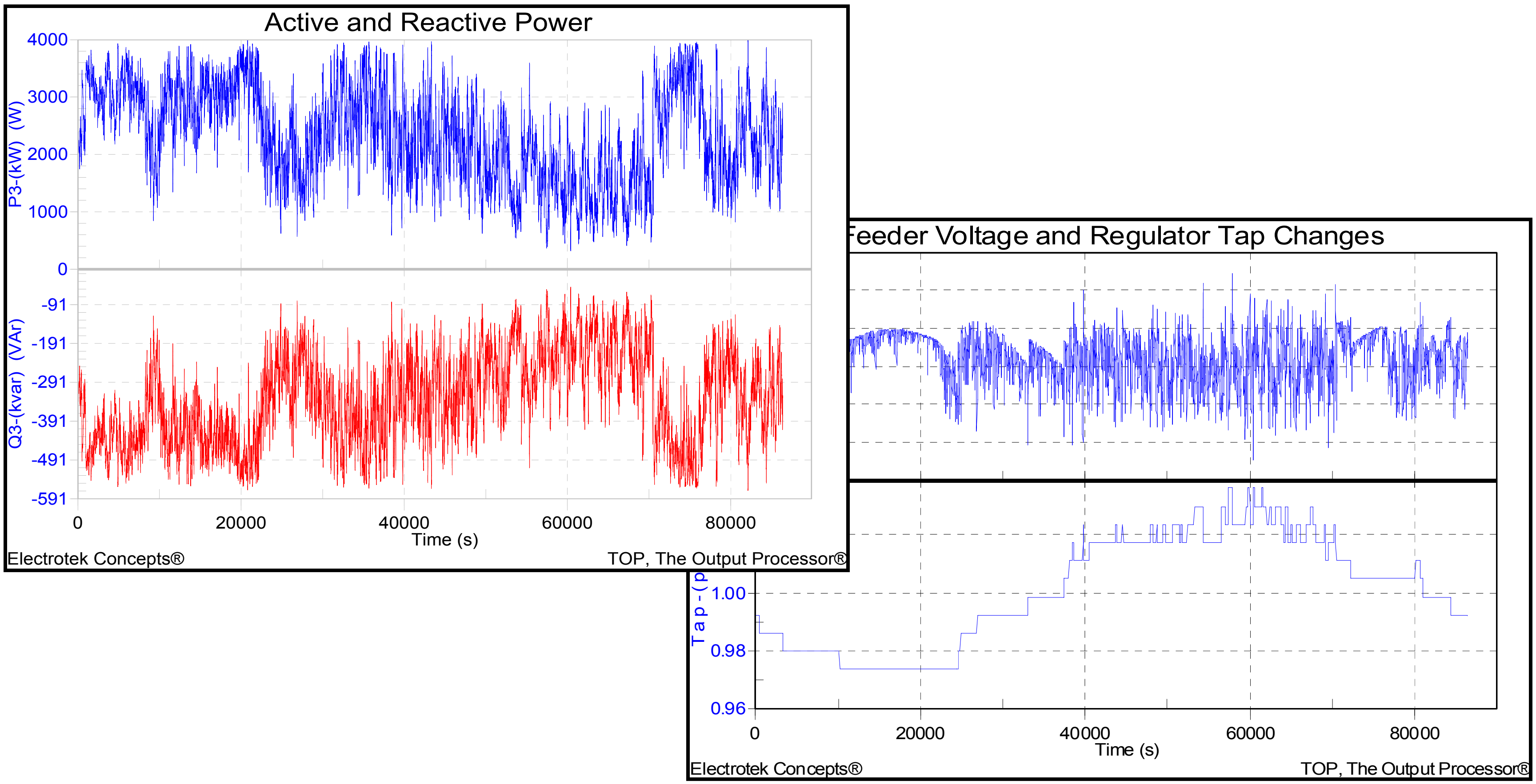
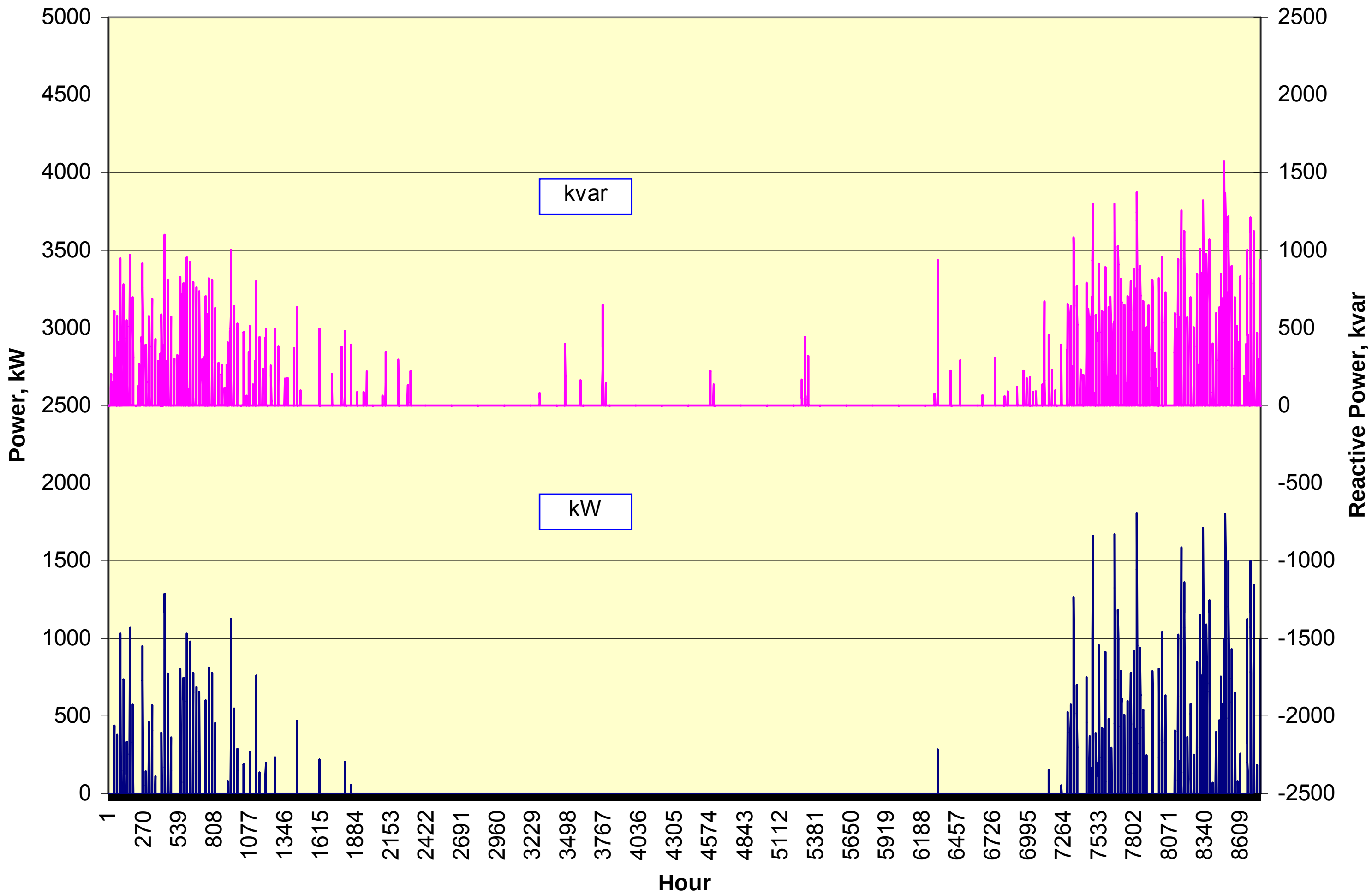
Wind Plant 1-s Simulation

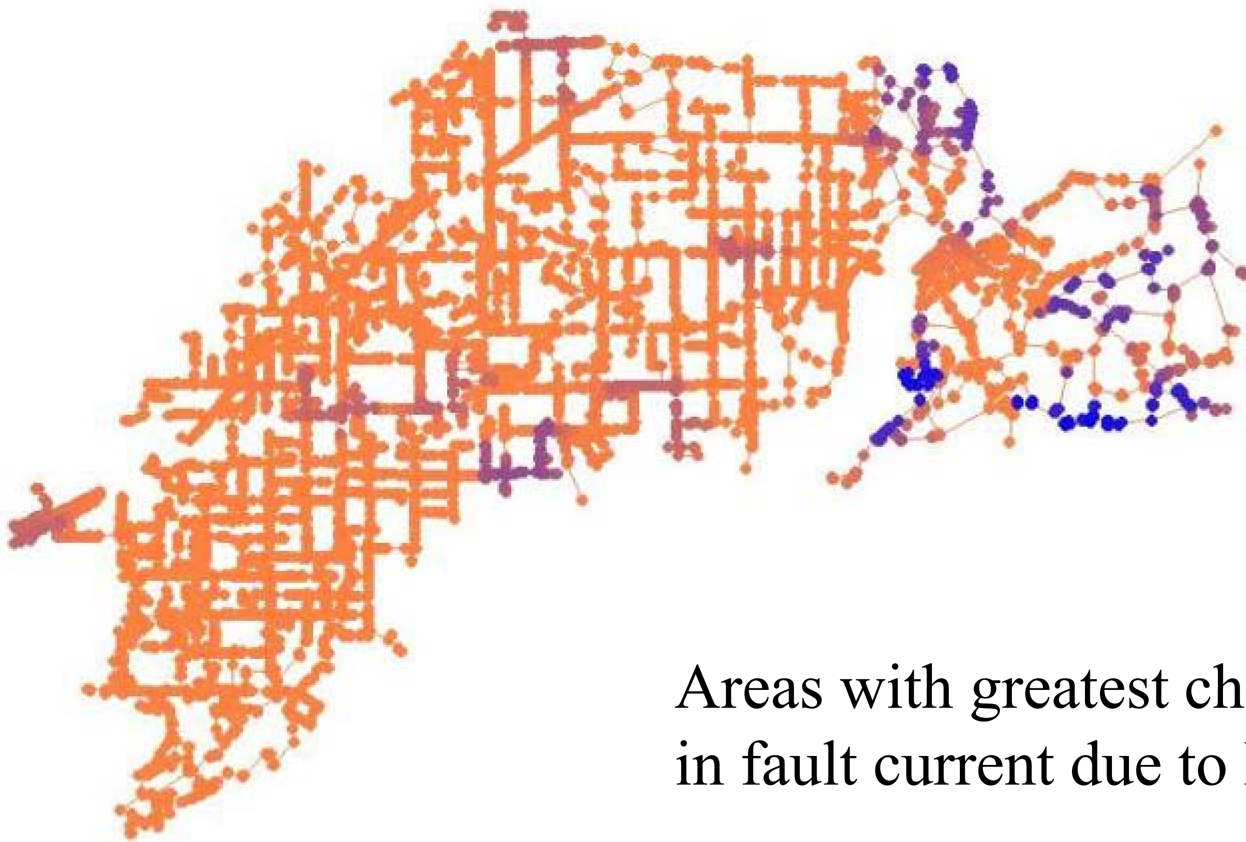


DG Dispatch



kvar
kW
Power, kW
Reactive Power, kvar
Hour
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
1
270
539
808
1077
1346
1615
1884
2153
2422
2691
2960
3229
3498
3767
4036
4305
4574
4843
5112
5381
5650
5919
6188
6457
6726
6995
7264
7533
7802
8071
8340
8609

DG Impact Visualization



Areas with greatest change in fault current due to DG

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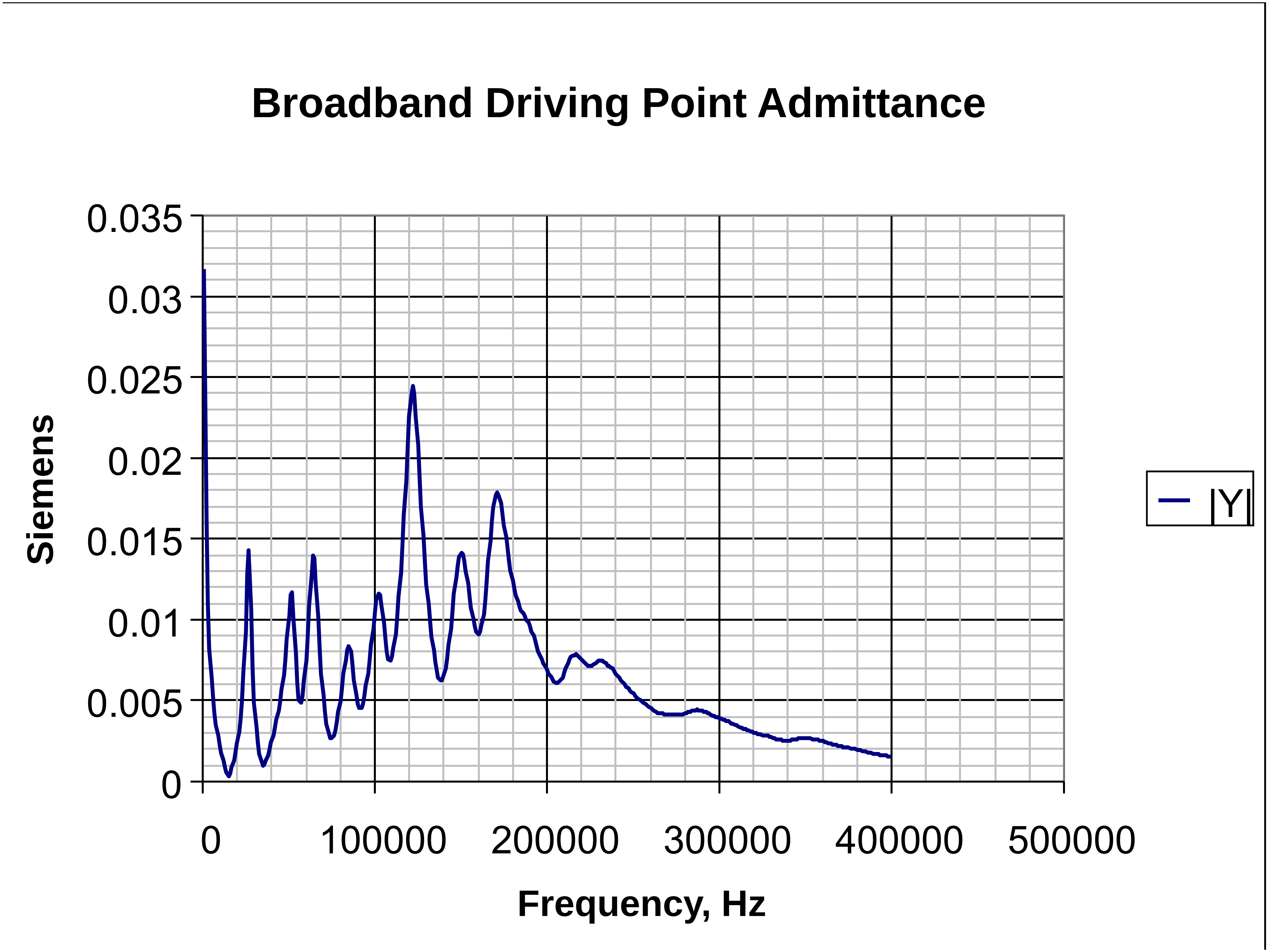
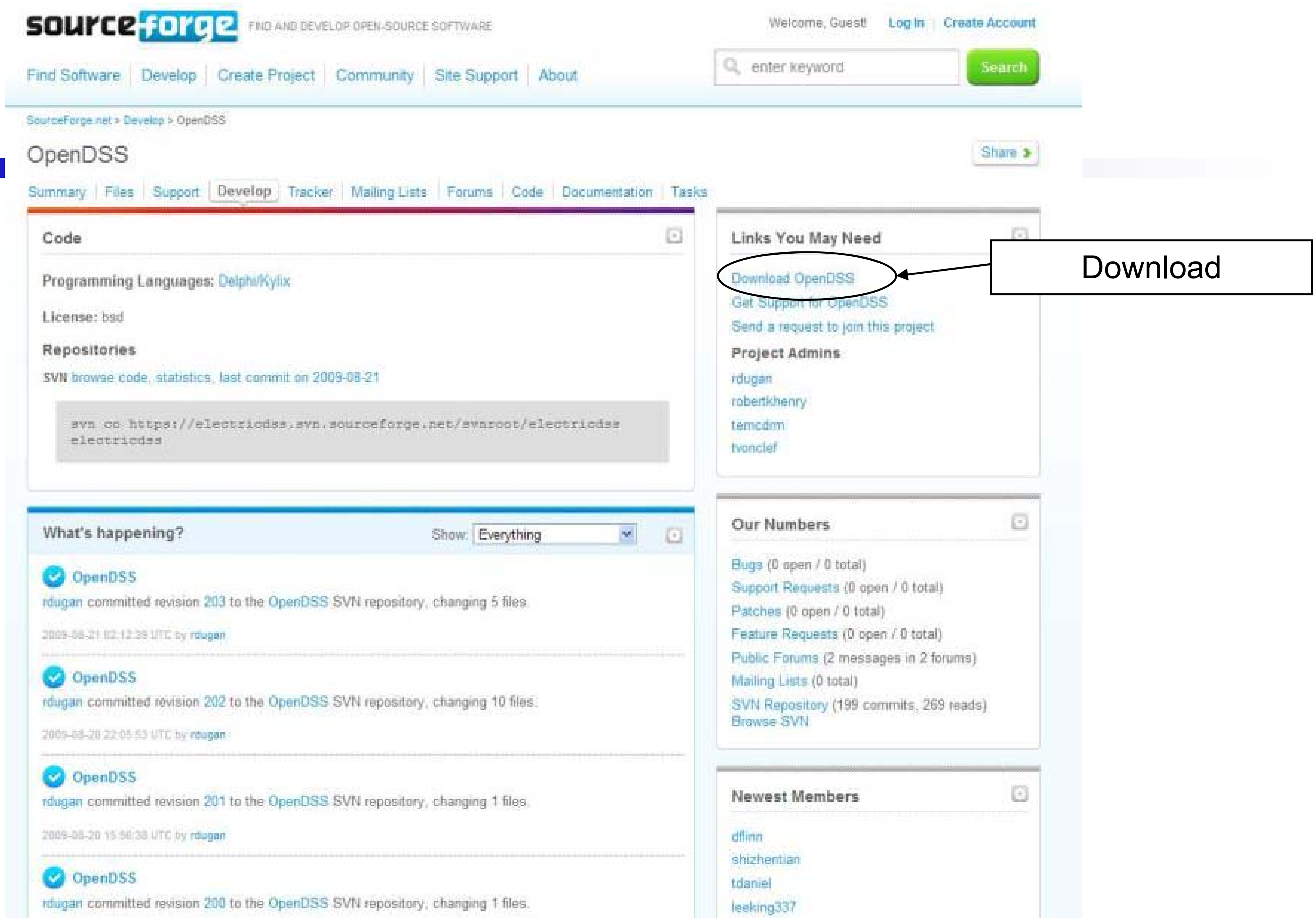


Broadband Driving Point Admittance
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Siemens
0
100000
200000
300000
400000
500000
Frequency, Hz
|Y|

Where Can I Find It?

http://sourceforge.net/projects/electricdss/develop

(Or go to Sourceforge.net and search for “OpenDSS”)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enter keyword
Search
SourceForge.net > Develop > OpenDSS
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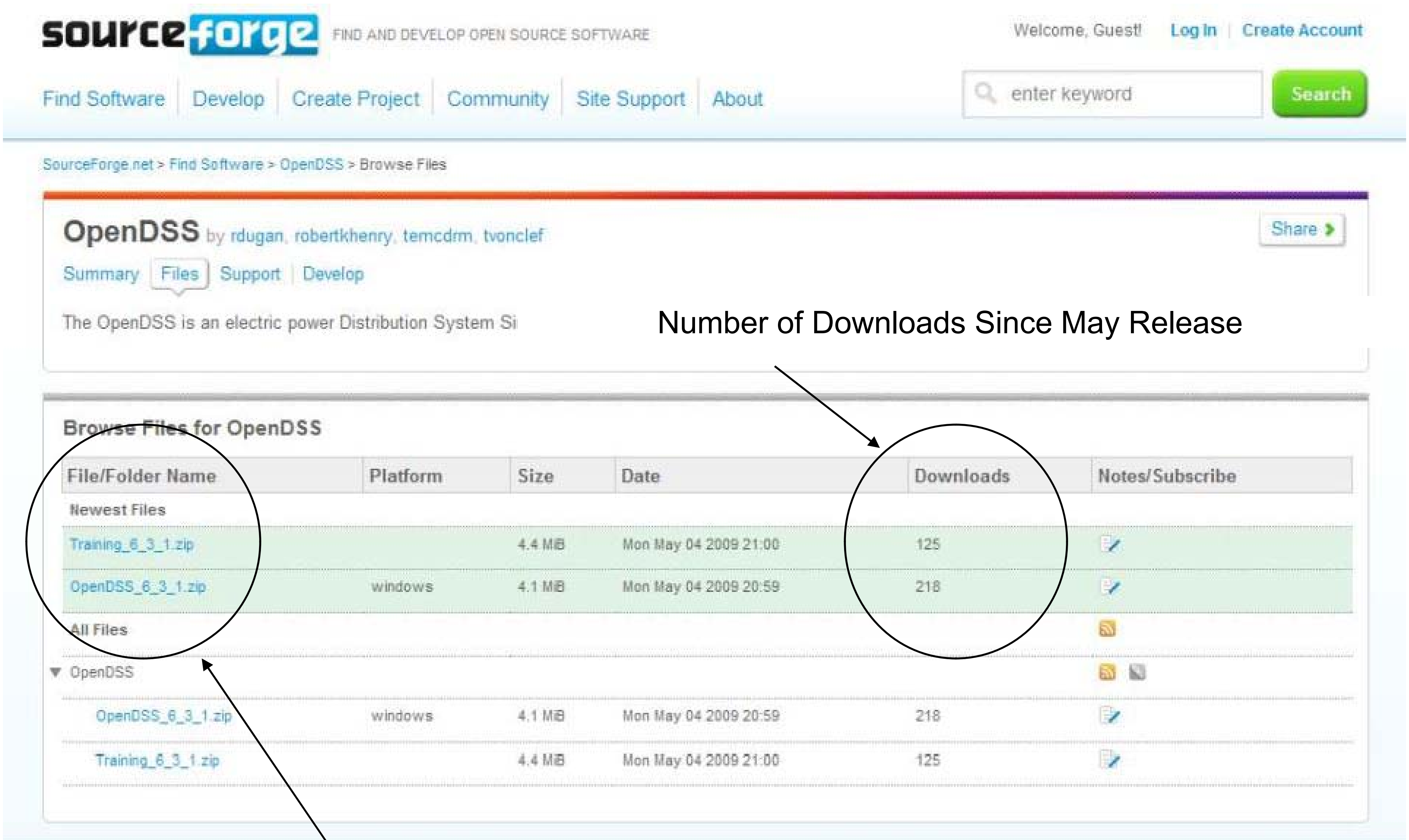
Share
Summary | Files | Support | Develop | Tracker | Mailing Lists | Forums | Code | Documentation | Tasks
Code
Programming Languages: Delphi/Kylix
License: bsd
Repositories
SVN browse code, statistics, last commit on 2009-08-21
svn co https://electricdss.svn.sourceforge.net/svnroot/electricdss electricdss
What's happening?
Show: Everything
OpenDSS
rdugan committed revision 203 to the OpenDSS SVN repository, changing 5 files.
OpenDSS
rdugan committed revision 202 to the OpenDSS SVN repository, changing 10 files.
OpenDSS
rdugan committed revision 201 to the OpenDSS SVN repository, changing 1 files.
OpenDSS
rdugan committed revision 200 to the OpenDSS SVN repository, changing 1 files.
Links You May Need
Download OpenDSS
Get Support for OpenDSS
Send a request to join this project
Project Admins
rdugan
robertkhenry
temcdrm
tvonclef
Our Numbers
Bugs (0 open / 0 total)
Support Requests (0 open / 0 total)
Patches (0 open / 0 total)
Feature Requests (0 open / 0 total)
Public Forums (2 messages in 2 forums)
Mailing Lists (0 total)
SVN Repository (199 commits, 269 reads)
Browse SVN
Newest Members
dflinn
shizhentian
tdaniel
leeking337
Download



sourceforge FIND AND DEVELOP OPEN SOURCE SOFTWARE

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enter keyword Search

SourceForge.net > Find Software > OpenDSS > Browse Files

OpenDSS by rdugan, robertkhenry, temcdrm, tvonclef

Share

Summary | Files | Support | Develop

The OpenDSS is an electric power Distribution System Si

Browse Files for OpenDSS

File/Folder Name	Platform	Size	Date	Downloads	Notes/Subscribe
Newest Files					
Training_6_3_1.zip		4.4 MiB	Mon May 04 2009 21:00	125	
OpenDSS_6_3_1.zip	windows	4.1 MiB	Mon May 04 2009 20:59	218	
All Files					
▼ OpenDSS					
OpenDSS_6_3_1.zip	windows	4.1 MiB	Mon May 04 2009 20:59	218	
Training_6_3_1.zip		4.4 MiB	Mon May 04 2009 21:00	125	

Number of Downloads Since May Release

Installation files on SourceForge.Net

Known Active* Users Outside EPRI

- Strathclyde University
- University of Tennessee
- Tennessee Tech / NES
- GE
- KEMA
- (Student in Poland)
- PNNL
- Arizona State Univ
- Cal Tech
- EnerNex
- IEEE Test Feeders WG

(Based on queries about program usage)

* - Active includes those using OpenDSS to benchmark their own tools

EPRI Usage

- Green Circuits
- PHEV Impacts
- Wind plant and solar power simulations
- DG interconnection studies
- Harmonics studies
- Stray voltage/NEV
- As basis for renewable DG screening apps (e.g., P174)
- Support for Smart Grid Demos (P124)
- Distribution State Estimator development (w/ EDF)
- Lab support
- General studies
  - Distribution power flow, Loss evalution, etc.
  - Atypical faults, transformer connections, etc.

OpenDSS Strengths

- Arbitrarily detailed n-phase circuit model - Few limitations
- Extensible
  - Can add new models or drive from another program
- Can solve large problems
  - Upper limit? (We don't know yet)
- Solution speed is competitive with commercial programs (does some things better than many)
- Designed to do time series simulations:
  - Annual simulations (15 min – 1 hr steps)
  - Daily simulations (15 min – 1 hr steps)
  - Duty cycle simulations (1 s – 1 min steps)
  - Dynamics simulations (step size in ms)

OpenDSS Limitations

- Frequency domain only
  - Does not currently do electromagnetic transients
    - There have been several requests to add it
  - Sufficient for >90% of its intended purpose supporting distribution planning
- Is a solution engine, not a complete distribution planning support system
  - Sufficient for research and consulting environment
    - Or a commercial software developer
  - Lacks graphical circuit data editor and database
    - Relies on commercial vendors for that function

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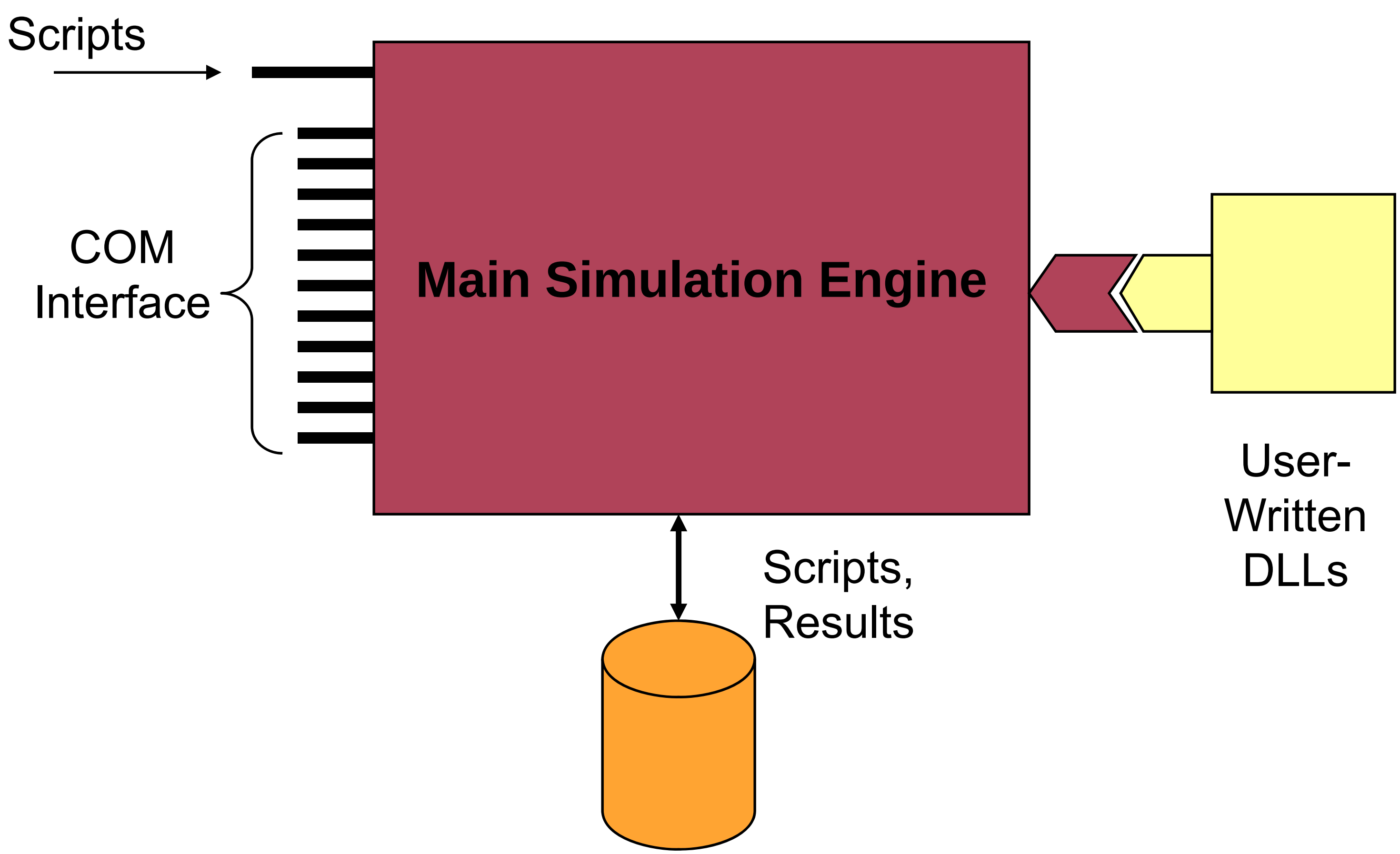
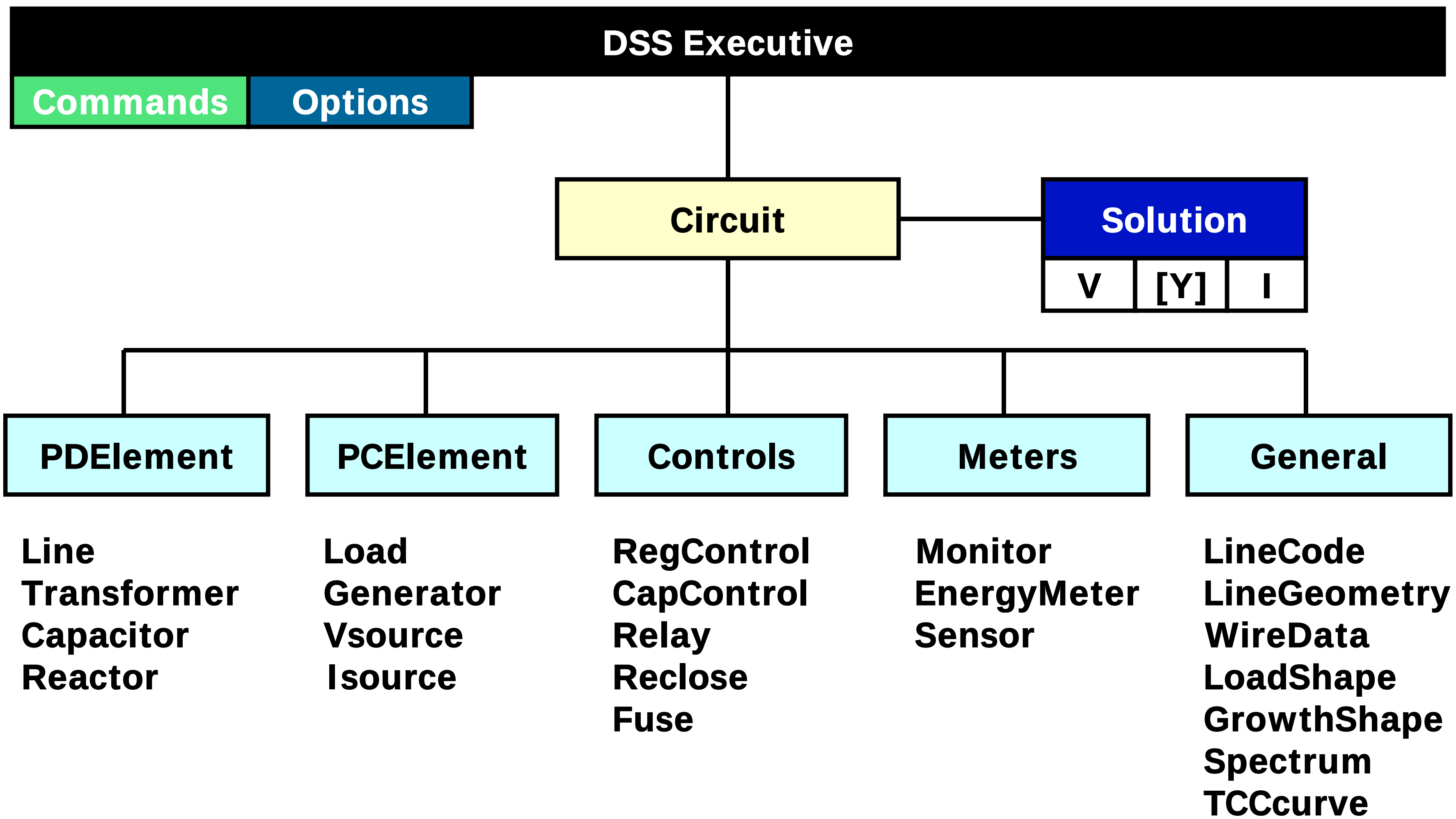
DSS Architecture

DSS Structure



DSS Object Structure



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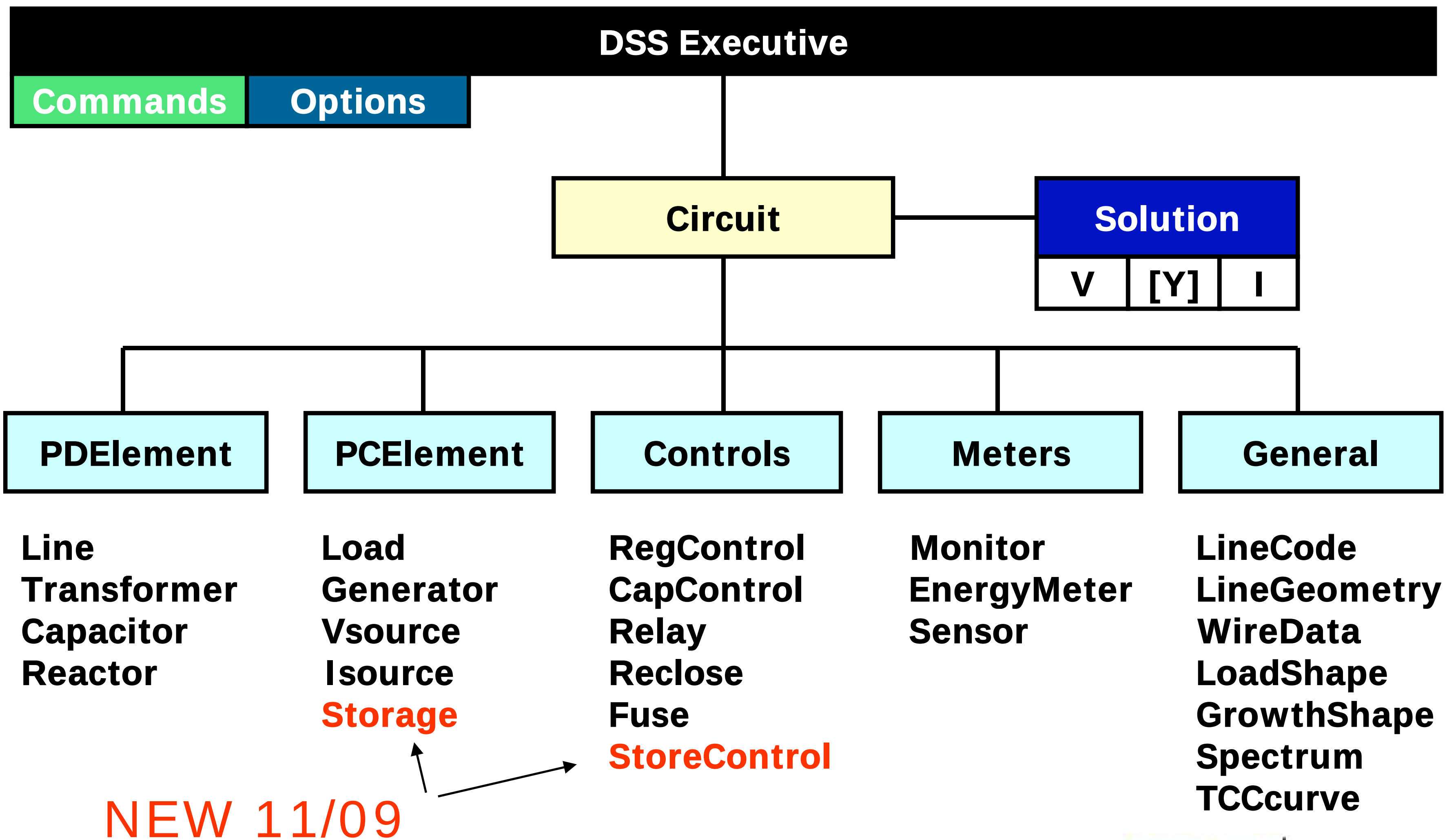
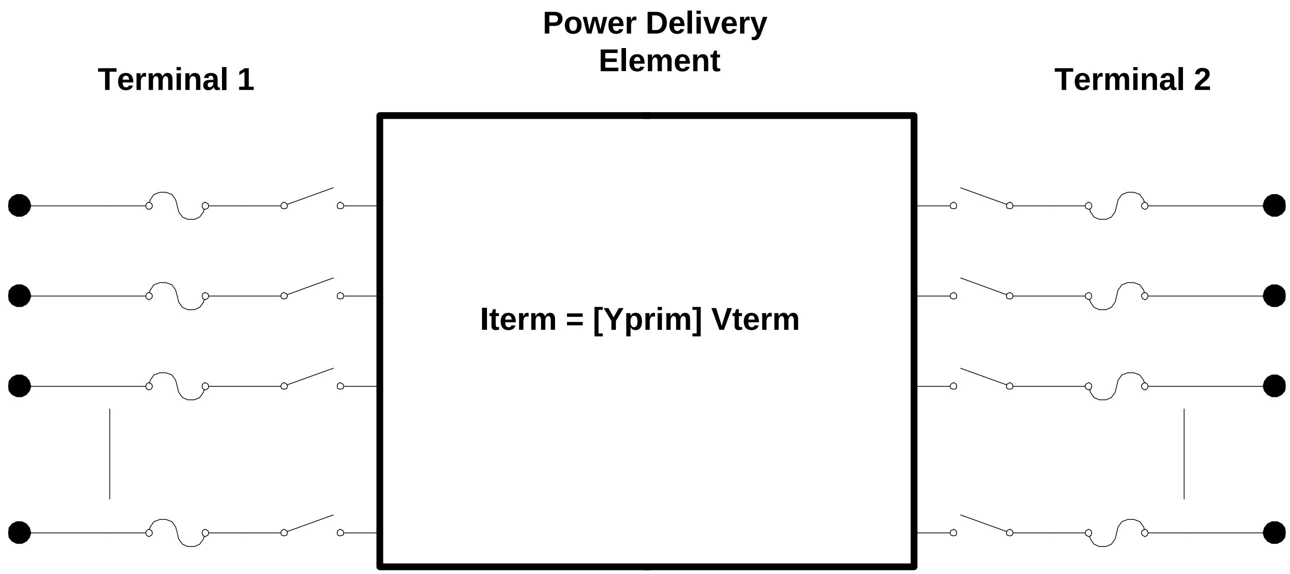
DSS Object Structure

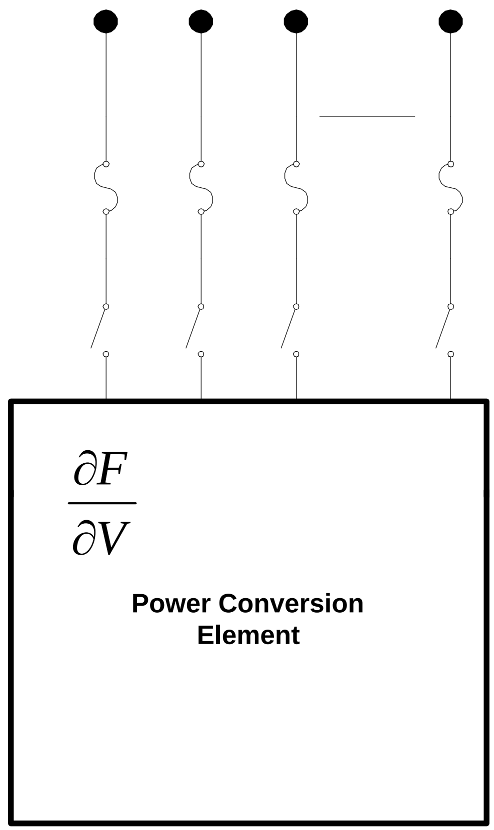


Power Delivery (PD) Elements

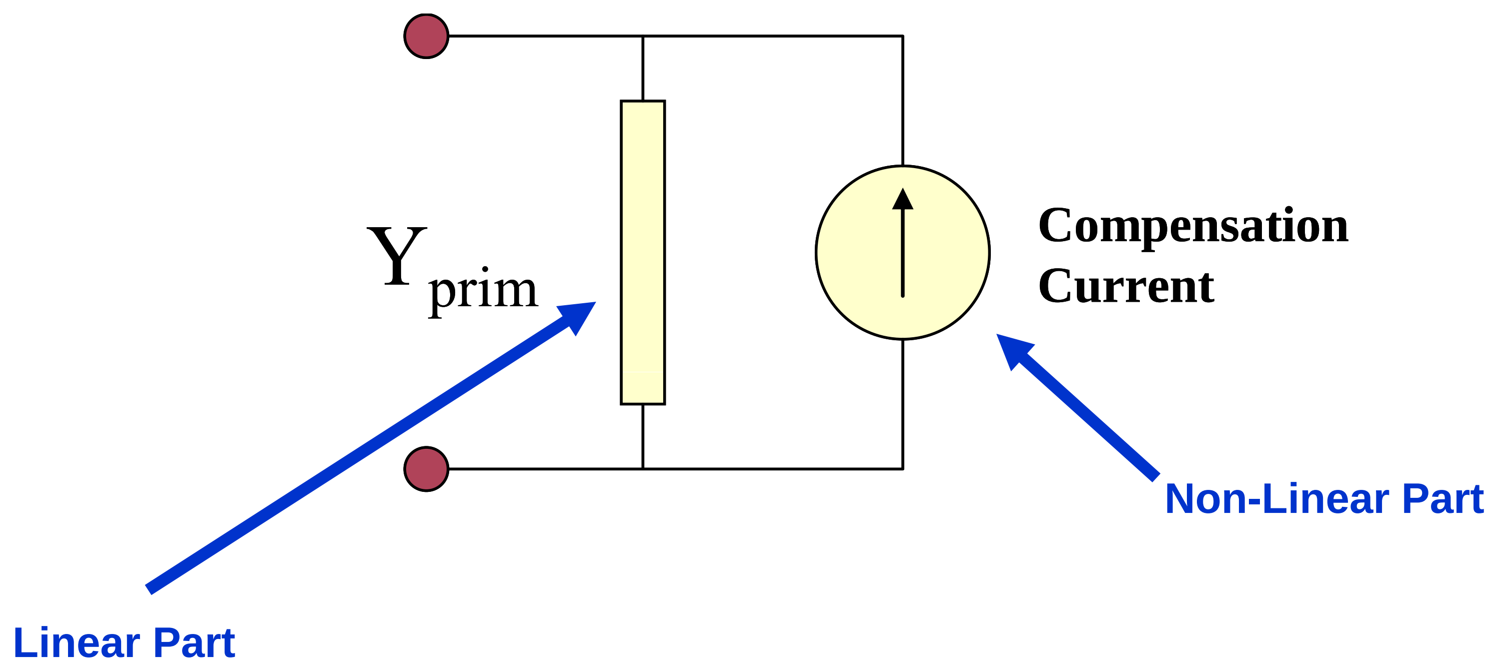


Power Conversion (PC) Elements

$I_{Term}(t) = \mathbf{F}(\mathbf{V}_{Term}, [\text{State}], t)$

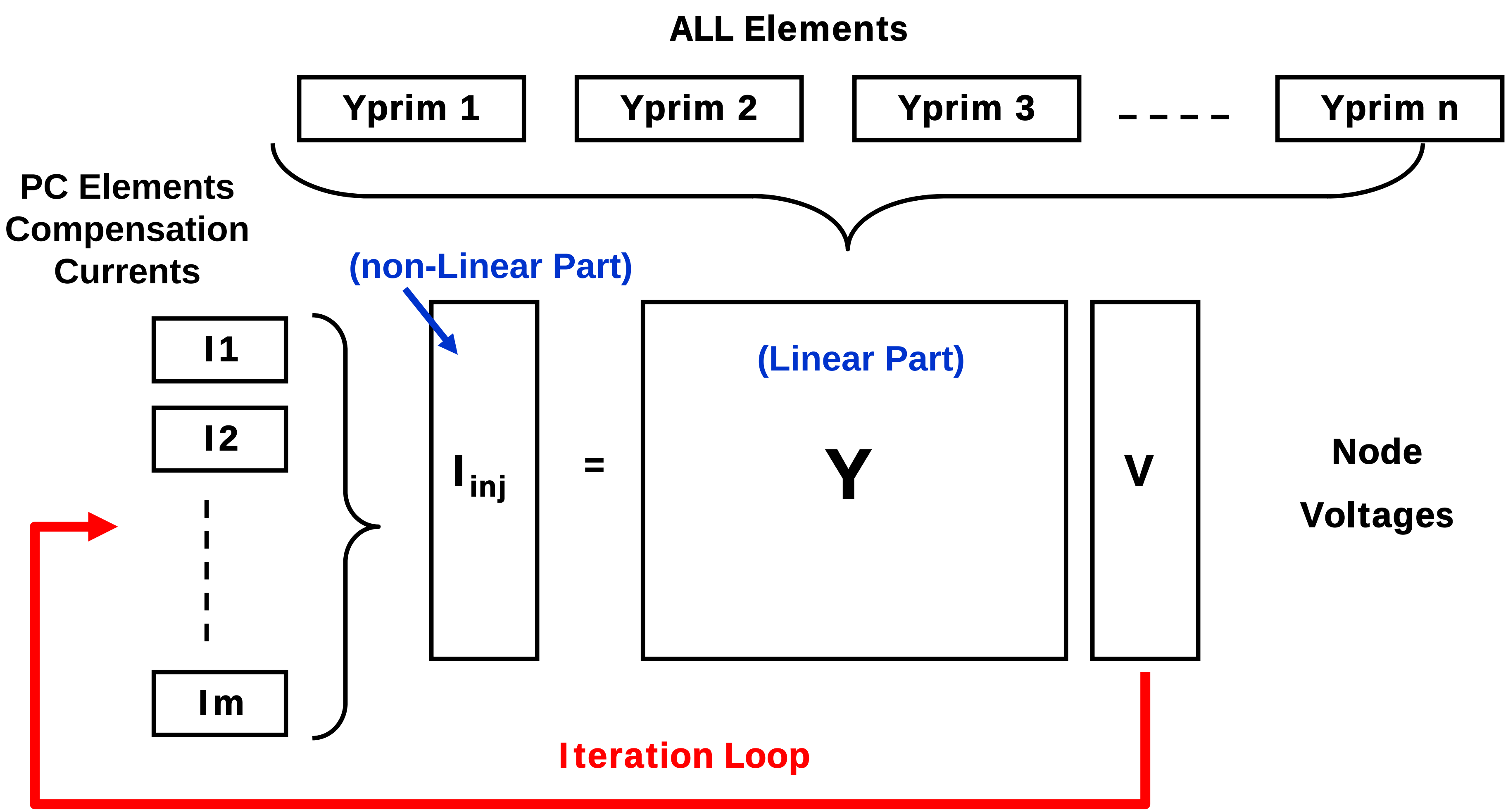


Load (a PC Element)



(One-Line Diagram)

Putting it All Together

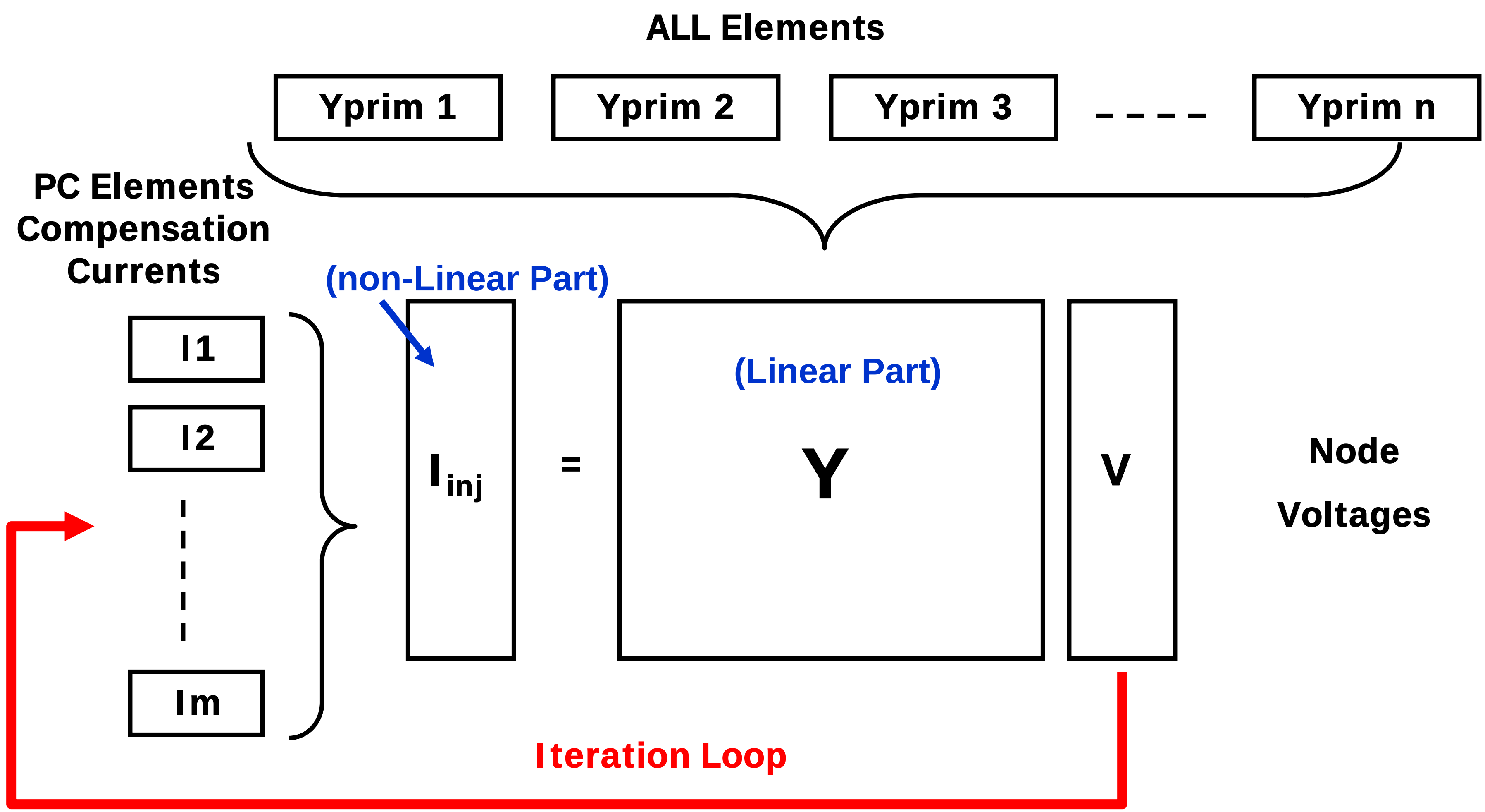


Questions I Get …

What Kind of Power Flow does OpenDSS Use?

- The DSS is not a traditional power flow as power engineers tend to think of power flows
  - It is a *Simulator*
- Its heritage is harmonics analysis and dynamics analysis
  - *It is a power flow in the sense that you can model loads connected to buses and get a solution that matches traditional power flow programs*
- The "Normal" solution mode is a fixed point iterative solution that works fine for >90% of distribution systems
- There is a "Newton" solution method for circuits that are difficult to converge with the Normal method.
  - *Not to be confused with the traditional Newton-Raphson method in power flow programs*

The Fixed Point Solution Algorithm ...



Solution Speed

- Distribution systems generally converge quite rapidly with this method.
- The OpenDSS program seems to be on par with the faster commercial programs – or faster
- It is set up to run annual simulations easily
  - Our recommendation:
    - ***Err on the side of running more power flow simulations***
    - That is, don't worry about the solution time until it proves to be a constraint
    - This reveals more information about the problem.

How Do You Get Currents and Power If You Only Solve for Node Voltages?

- One thing that troubles some users who are accustomed to other ways of solving power flows is how the branch currents (and powers) are determined when only the Node voltages and “Compensation” currents are known.

- If the Y matrix is properly formed, and convergence is achieved, the currents will be correct
  - Trust Kirchoff’s Current Law at nodes!!

Where Does OpenDSS include Mutual Coupling?

- **It Always Includes mutual coupling!**
  - All circuit element models provide the DSS executive with an Admittance **MATRIX**
    - That is, every model may have coupled phases
  - Units on admittance matrix are actual siemens (S)
    - OpenDSS may report values in per unit, but internally works in actual volts, amps, siemens
    - A necessity to model unbalances, e.g,
      - 120/240V split-phase distribution transformer
      - Fault where 69 kV falls on 12.47 kV

Can it solve network systems as well as radial?

- The use of the word “Distribution” in the name of the program conjures up ideas of radial circuit solvers in North America
  – (but not necessarily in Europe)

- The DSS circuit solver is completely general
  – It has no idea whether the circuit is radial or not.
    - Stemming from its harmonics analysis heritage

- The EnergyMeter class is presently the only class that cares about radiality.

Load and Buses

- There is a subtle difference in the way the DSS treats loads that is confusing to many power engineers:
- Traditional power flow programs
  - “A Bus has load”
- OpenDSS
  - “A Load has a bus”
- This allows connection of a multitude of different loads and load types to the same bus
- Much more flexible and powerful

Load Models (Present version)

1: Standard constant P + jQ load. (Default)

2: Constant impedance load.

3: Const P, Quadratic Q (like a motor).

4: Nominal Linear P, Quadratic Q (feeder mix).

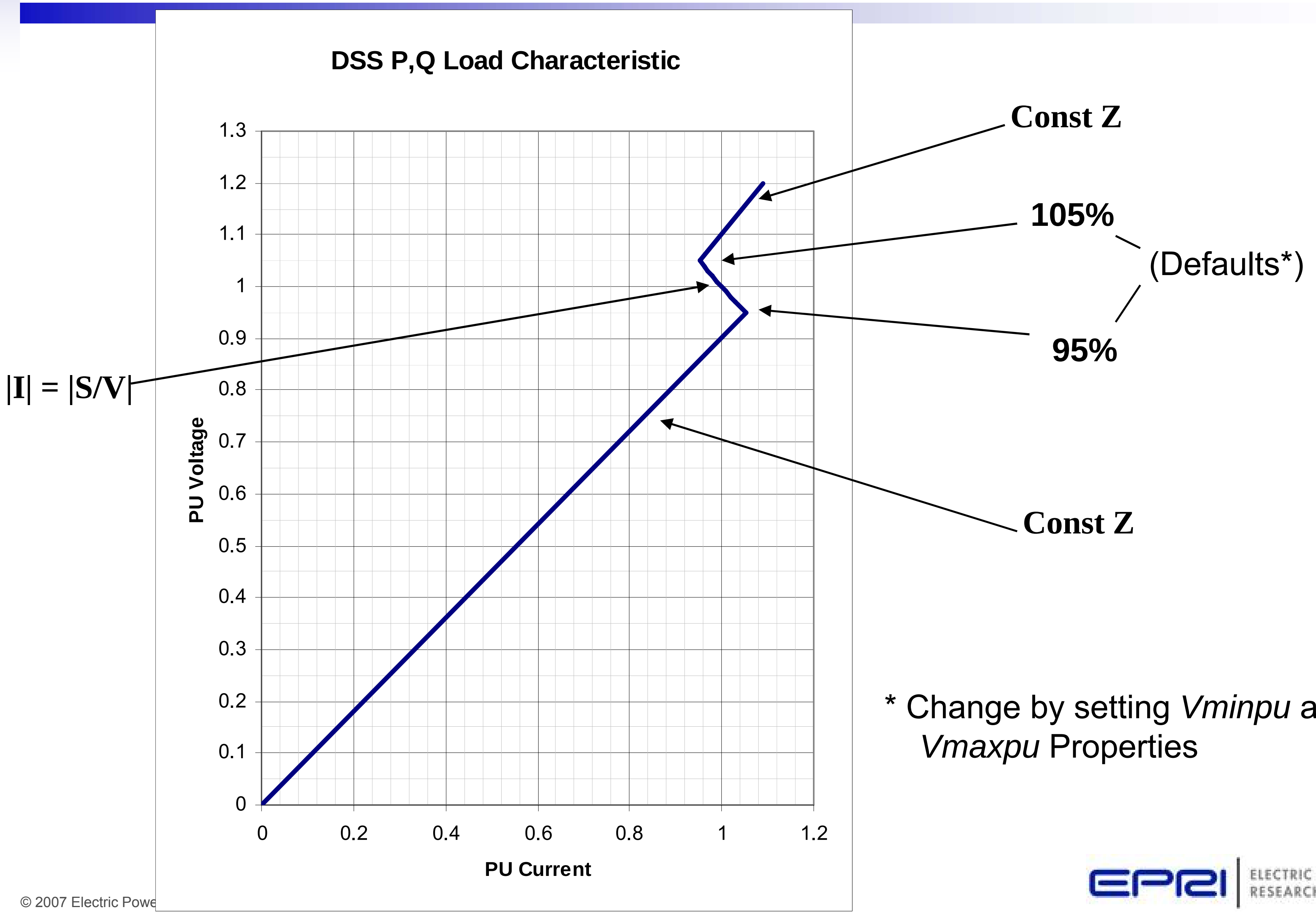
(Use this with CVR factor)

5: Constant Current Magnitude

6: Const P, Fixed Q

7: Const P, Fixed Impedance Q

Standard P + jQ Load Model (Model=1)



* Change by setting *Vminpu* and *Vmaxpu* Properties

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Why Do I Need This Kind of Load Model?

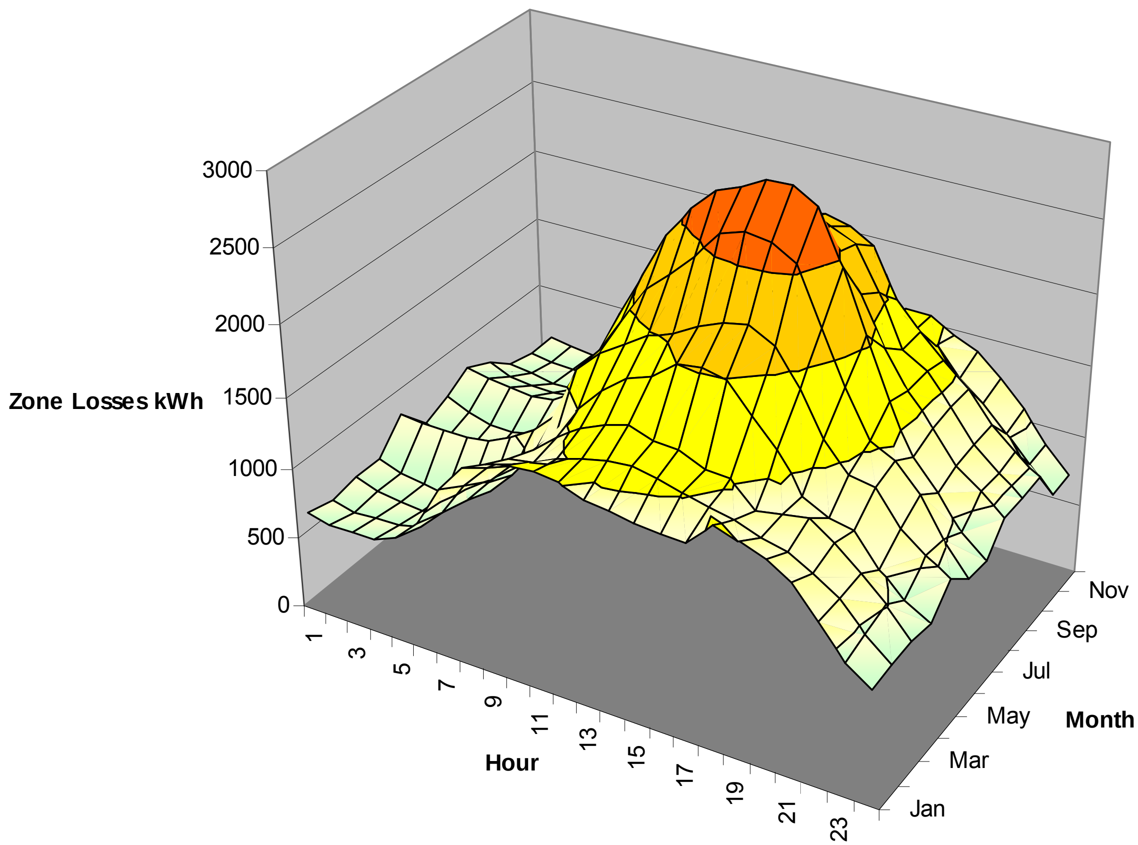
- So annual simulations can be executed with less concern for lack of convergence
- What happens when the DG trips off and the voltage drops really low because the regulators are bucking?
  - Solution does not break
  - Solution may not be correct, but will be when the regulators bring the voltage back to normal
- Faults can be simulated during a run and the solution will still converge
  - Gives the DSS the ability to solve difficult problems

Where is the P-V bus type?

- Buses do not have special types in OpenDSS
  - Buses are simply connection points for circuit elements
- A Generator can control (or attempt to) power and voltage
- *This question usually arises with regard to modeling DG on distribution systems*
  - *Fortunately, one seldom needs this model unless the DG is quite large with respect to system capacity*
  - *Most DG is controlled by Power and Power Factor while interconnected*

How Do I Make One of Those 3-D Plots?

Maximum of value for each hour over the month.



We call this an "E-3" plot after the San Francisco economics firm who taught us how to do it (see http://ethree.com)

This is done in MS Excel by post-processing CSV files from annual simulations

OpenDSS Application Workshop - Nov 2-3

OpenDSS Introduction and Basics
Setting up the model
Modeling control systems
Example Applications - Case Studies

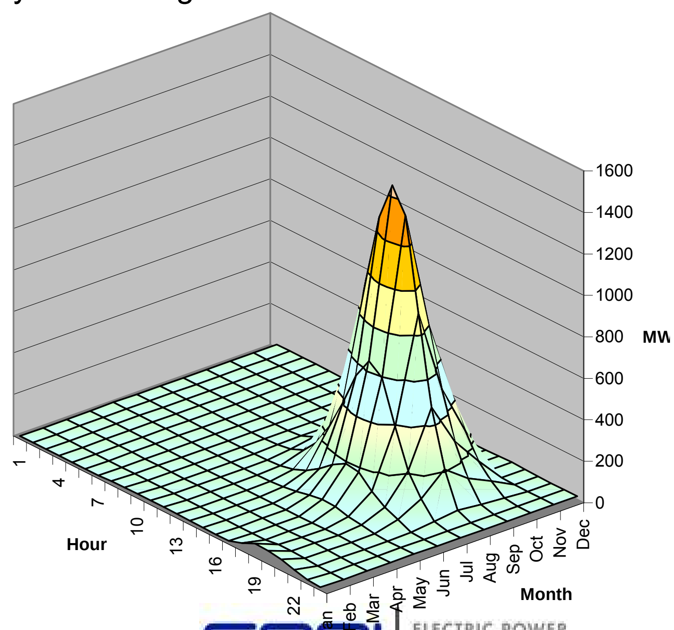
- Distribution Loss Studies - Green Circuits, Program 172B
- Modeling distribution automation and distribution controls - Program 124C
- Integration of Plug-In Hybrid Electric Vehicles
- Distributed Energy Resources Integration with the Smart Grid - Smart Grid Demonstration Initiative
- Evaluation of PV and other renewables integration with the distribution system - Program 174
- Energy storage integration - e.g. community energy storage
- Using OpenDSS for Harmonic Analysis
- CIM Interface for OpenDSS

Ongoing development plans

- Coordination with other development efforts

Bring your own Windows laptops for hands-on experience
Webcast of workshop for those that cannot attend (attendance limited to 25)

Nov 2-3, Knoxville, TN
Half day Monday
Full day Tuesday



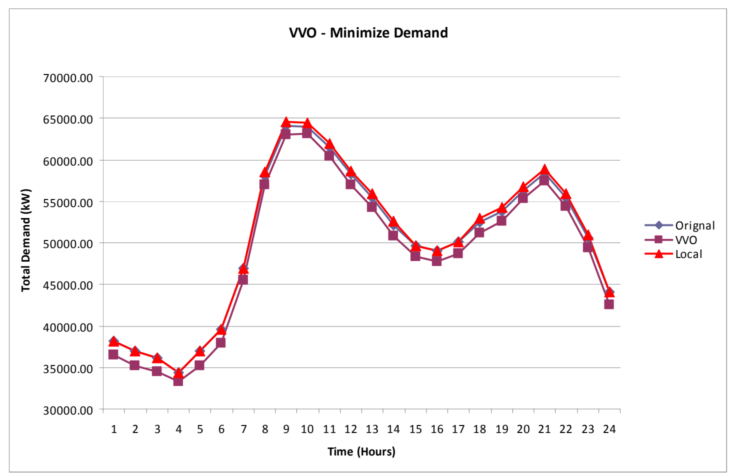
New Project – Develop Industry Library of Load Models with Voltage Dependency Characteristics

Equipment Response to Voltage Changes (laboratory testing and selected field testing)

Preliminary Customer Response Models

Customer Classification Development based on important characteristics

Assessment and refinement based on field deployments (AMI, etc.)



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Questions?

Agenda

- Active Distribution Management Overview
- Modeling Considerations and OpenDSS
- Examples of Active Distribution Management and CIGRE C6.11 Activities
- IEEE Distribution Automation Working Group
- Demonstrations

Summary of CIGRE and Canadian Activities

EPRI Active Distribution Network Workshop

Chad Abbey
October 4, 2009

Hydro Québec

Overview

- **CIGRE activities**
- **Canadian Initiatives**
  - Utility projects
  - Industry collaborations
  - NRCan activities
  - Testing facilities
- **Summary**

C6.11 Development and operation of active distribution networks

Overview of activities

C6.11 Achievements

> **Preparation of a survey on active distribution networks**
>
> - Define *Active distribution network* concept and main features
> - Review actual status of implementation and barriers
> - Review actual operational rules for DG
>
> **Definition of 5 sub-WG and review of questionnaire responses**
>
> **Published survey result in Electra and at CIRED**

Active Distribution Network Definition

Active networks are distribution networks with Distributed Energy Resources **(generators and storage) and** flexible loads **subject to** control**.**

DERs and participating loads take some degree of responsibility for system support, which will depend on a suitable regulatory environment and connection agreements**. The DSO may also have the possibility to manage electricity flows using a** flexible network topology.

Future Activities

- Summarize results from EPRI events
- Document innovative pilot projects using standard template
- Classify active distribution network projects
  - Objectives and drivers
  - Distribution system operator, private producer, and societal benefits
  - Enabling technologies
  - Barriers, catalysts / triggers
  - Research needs
- Help update EPRI distribution roadmap

Sources of Information

- > **International events – EPRI Workshops, conferences**
- > **EU projects - More Microgrids, ADDRESS, ADINE**
- > **Smart Grid Demos**
- > **Other National Programs**
  - Australia, Canada, Korea, Japan
- > **Active Network Management database**
  - http://cimphony.org/cimphony/anm/

Technical Report Outline

> Introduction
> Survey results and definition
> Present level of development of ADN
  - Methodology
  - Pilot project results
> The way to the future
  - Conclusions
  - Recommendations

Active Distribution Networks in Canada

Overview

Smart Grid and DG Drivers

> **Distribution System Automation**
- Reliability
- Ageing infrastructure – grid modernization
- Smart meter initiatives
- Energy efficiency

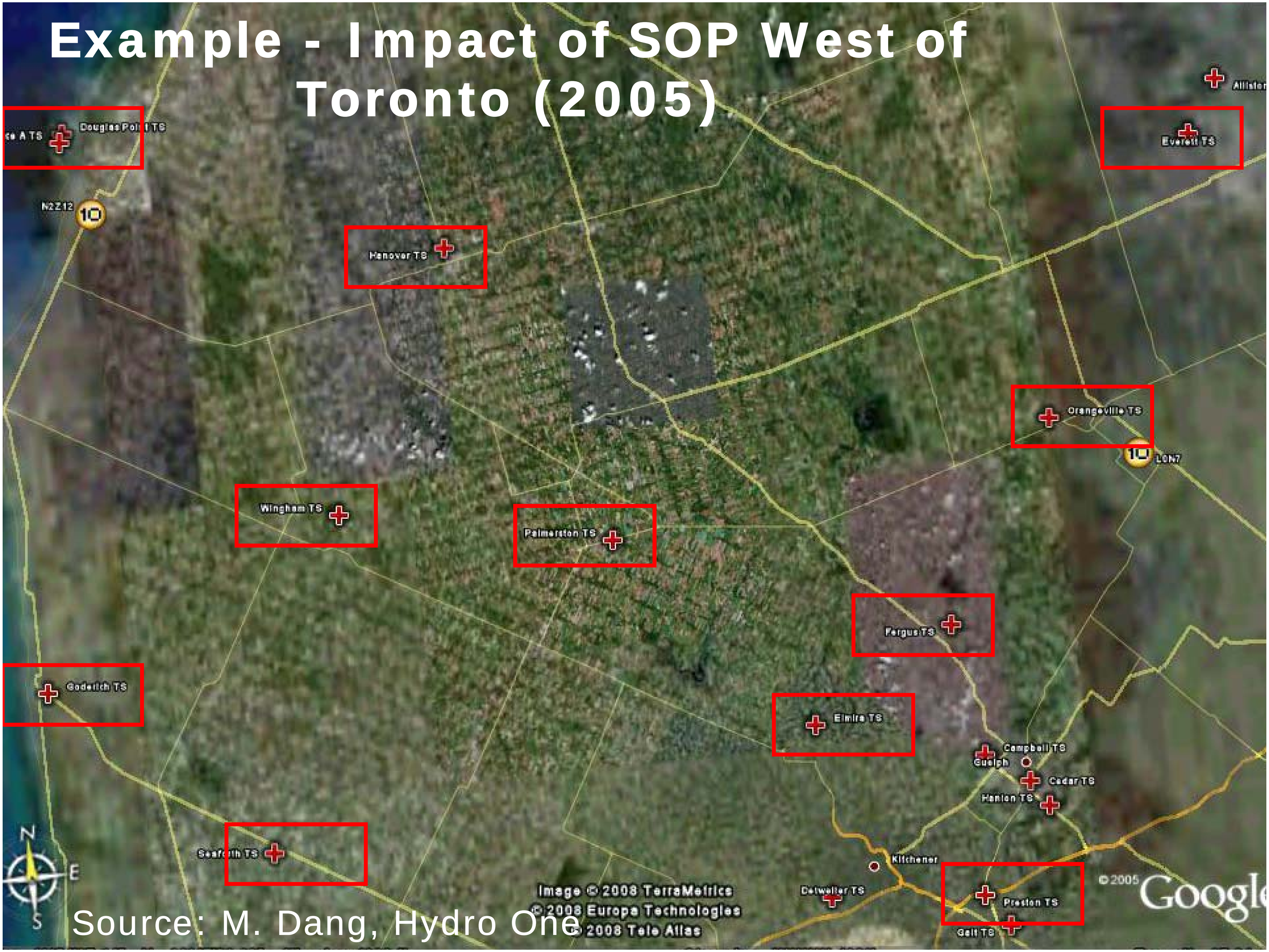
> **Distributed Energy Resources**
- Predominantly policy push
- Secondary drivers: reliability, capacity

Distributed Generation in Canada

> **Technologies**
- Wind, small hydro, PV, biogas

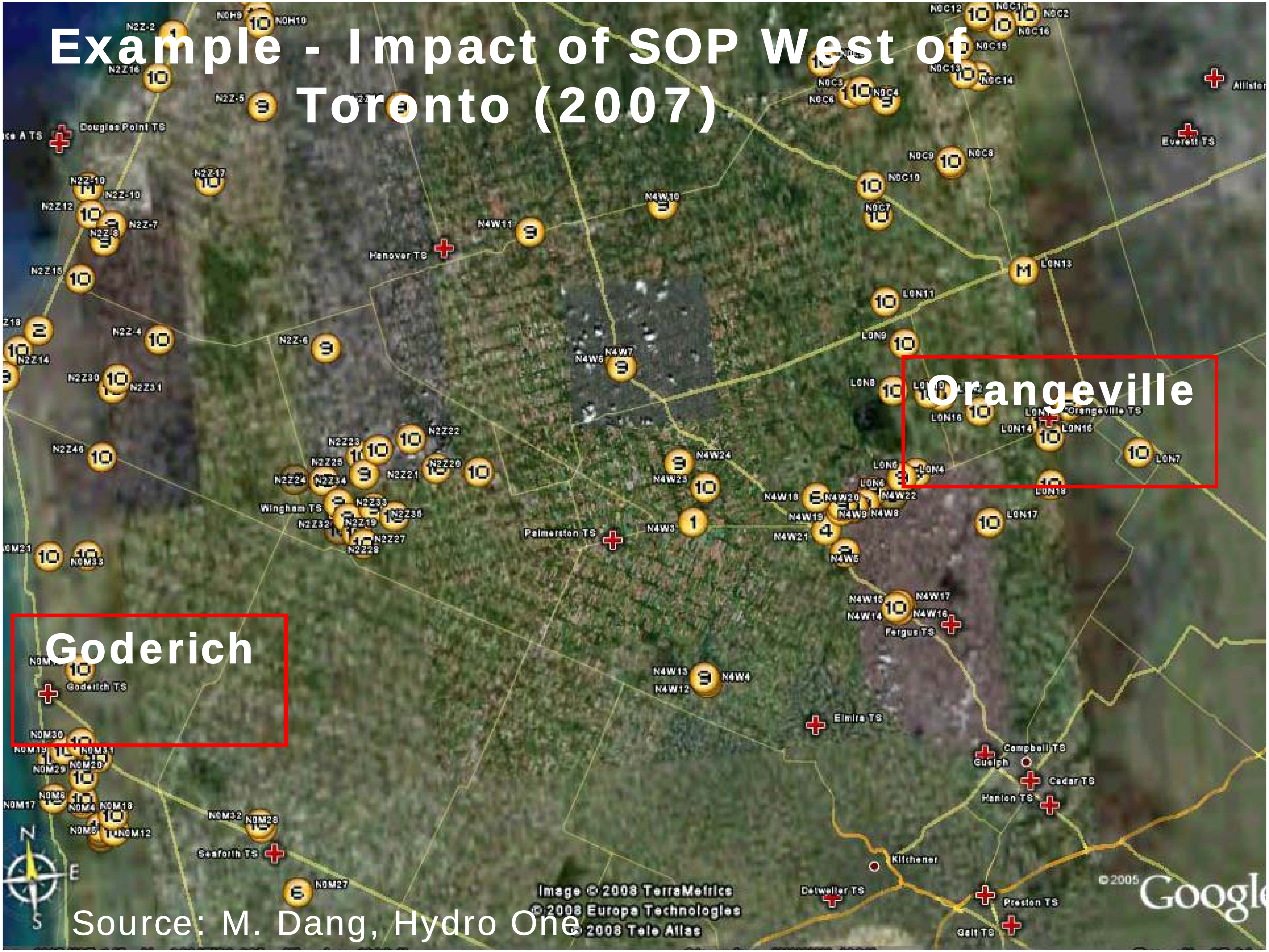
> **Regions**
- BC – small hydro, request for proposals
- Alberta – Distributed wind, biogas
- Manitoba – Distributed wind
- **Ontario** – Green Energy Act
- Québec – small hydro, wind, programs coming

Example - Impact of SOP West of Toronto (2005)



Source: M. Dang, Hydro One

Example - Impact of SOP West of Toronto (2007)



Source: M. Dang, Hydro One

Smart Canadian Utility Projects

Smart Grid Technology	Utilities / Region
AMR / AMI	BC Hydro, Ontario, Hydro-Quebec
Automatic Fault Location	Hydro-Quebec
Fast Reconfiguration	BC Hydro, ENMAX, Burlington, Toronto Hydro
Voltage Reduction Schemes	BC Hydro, Hydro-Quebec
Remote Monitoring	Milton Hydro, Hydro-Quebec
Planned Islanding	BC Hydro, Hydro-Quebec

CEATI Smart Grid Working Group

> **Centre for Energy Advancement through Technological Innovation (CEATI) International**

> **Objectives**

- Definition of Smart Grid
- Action plan for development of the Smart Grid
- Identify technology gaps
- Share successful strategies for implementation of the Smart Grid

> **Initiated in 2008**

Ontario Smart Grid Forum

> **Participation**
  - Led by IESO
  - Utilities, suppliers, government

> **Objectives**
  - Develop a high level vision of Ontario Smart Grid
  - Educate industry leaders on drivers, technologies
  - Identify enablers and barriers

> **Outputs**
  - Report on findings and recommendations
  - Website: www.theimo.com/imoweb/marketsandprograms/smart_grid.asp

Ontario – Encouraging Smart Grid and Renewables

> **Smart Grid Forum releases its finding – February 2009**
> **Green Energy Act created – feed-in tariffs for renewables – May 14, 2009**
> **Ontario Energy Board (OEB) - draft guidelines on planning for smart grid architecture - June 16, 2009**
> **Important elements:**

- Creation of new deferral accounts for capital investments incurred related to the development of a smart grid or the accommodation of new renewables.
- Introduction of a mechanism to provide advance funding for expenditures to accommodate new renewables or develop a smart grid.
- Initial guidance to distributors on planning to accommodate new renewables and a smart grid.

NRCan DG Study Group

> **Membership**
- Utilities: BC Hydro, Hydro Quebec, NB Power
- Manufacturers: GE Multilink, SEL
- Private producers

> **Activities**
- Review of utility interconnection guidelines (Hydro One)
- Provide advice on cost effective DG interconnection technology
- Linking Smart Grid with DG
  – Remote monitoring and control, advanced protection

NRCan Clean Energy Fund

- **Renewable Energy and Clean Energy Systems Demonstration Projects**
  - Deadline – September 14, 2009
  - Project selection - mid-November
- **Large Scale CCS Demonstration Projects**
- **Research and Development Projects**
  - Integration of renewable energy
  - Multi-stakeholder and Canada-US collaborations encouraged

Canadian Test Facilities

> **Low voltage test facility (CanmetENERGY):**

- Multiple inverters and interconnection testing

> 120-kVA, 3ph Grid simulator

> 5kW/15kW Solar Simulator

> Adjustable RLC loads

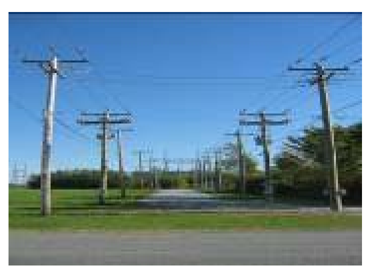
> **Medium voltage test facility (IREQ-HQ):**

- Distribution automation network testing

> A radial 25-kV feeder (35 poles, 370m)

> 300-kW, 600 V, resistive, inductive and motor loads

> Induction and synchronous generators



IREQ Feeder Layout

- 3 feeders (common source)
- Dedicated 47-MVA 25-kV transformer at the substation Completely independent from the distribution network
- 2 x 3 167-kVA transformers - 14.4 kV/347 V
- Internet and phone lines to all equipment
- Auxiliary power 3 x 120 V

3 Small buildings :
- Load
- Control and acquisition
- Distributed generation

IREQ's test line

Distribution Automation Equipment

> **25 kV reclosers, breakers**

> **Automation equipment**

- Remote monitoring
- Smart meters

> **Switchable capacitor banks**

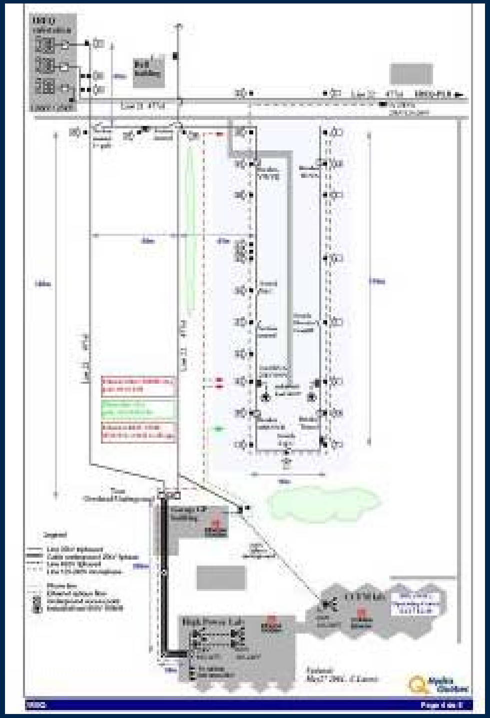
> **25 kV in-line voltage regulator**

Voltage regulator – 3 phases

CL-6A regulator control

Cooper VWVE recloser

25 kV measuring station (voltage and current)



Map of line

Schweitzer SEL-351R for Recloser

Acquisition computer

DC measurements
Voltage and current

25-kV voltage and current transformers

Acquisition and storage unit

600-V current measurements

Load Banks

> **3-phase resistive / inductive loads**

- (DELTA or/and STAR)
- (Independently controllable phases, distortion, PF adjustment)
- Total of 400 kW resistive

> **Induction motor**

- AC drive, variable load of 150 kW
- Drives DC alternator

Resistive and inductive loads

Load for motor

AC Drive for induction motor

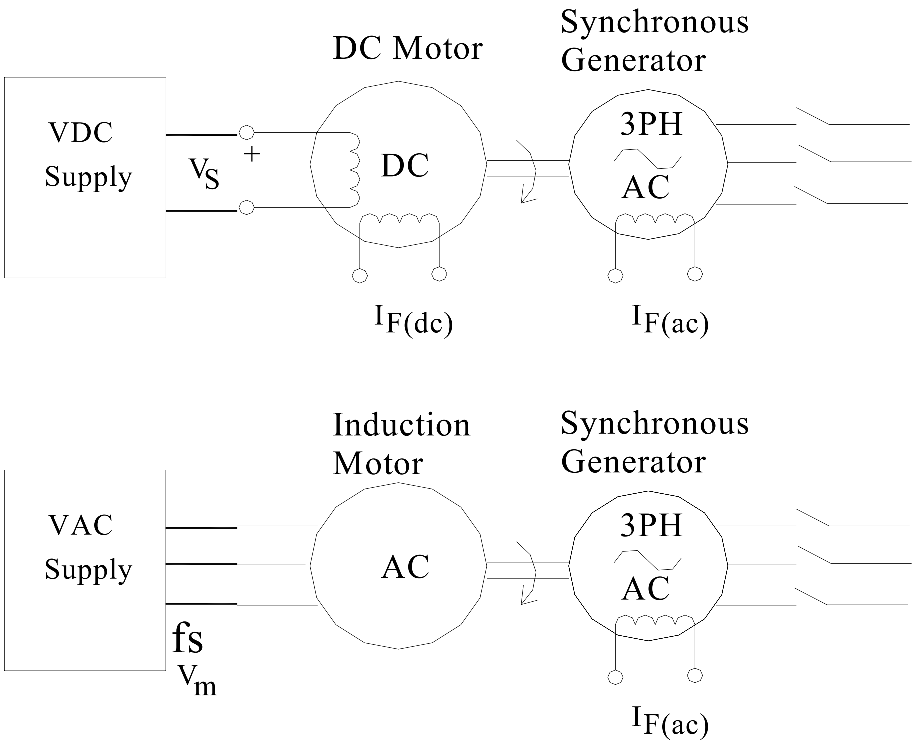
AC induction motor and DC generator

Load and acquisition control room

Distributed Energy Resources

> **DG technologies**
- Induction machine
- Synchronous machine
  - Diesel generator
  - Motor driven synchronous generator

> **Future considerations**
- Inverter interfaced
- Wind turbine nacelle



Contactors and breakers

Speed relay

DC power supplies

Soft Start for induction generator and Beckwith relay

Other protection relays under tests

measurements and aux. power

Induction generator

Coupling of machines

DC motor

500-kW Cummins DIESEL Synchronous generator with synchronizing control (Power Rent - Onan)

Diesel-generator controler

Remote control

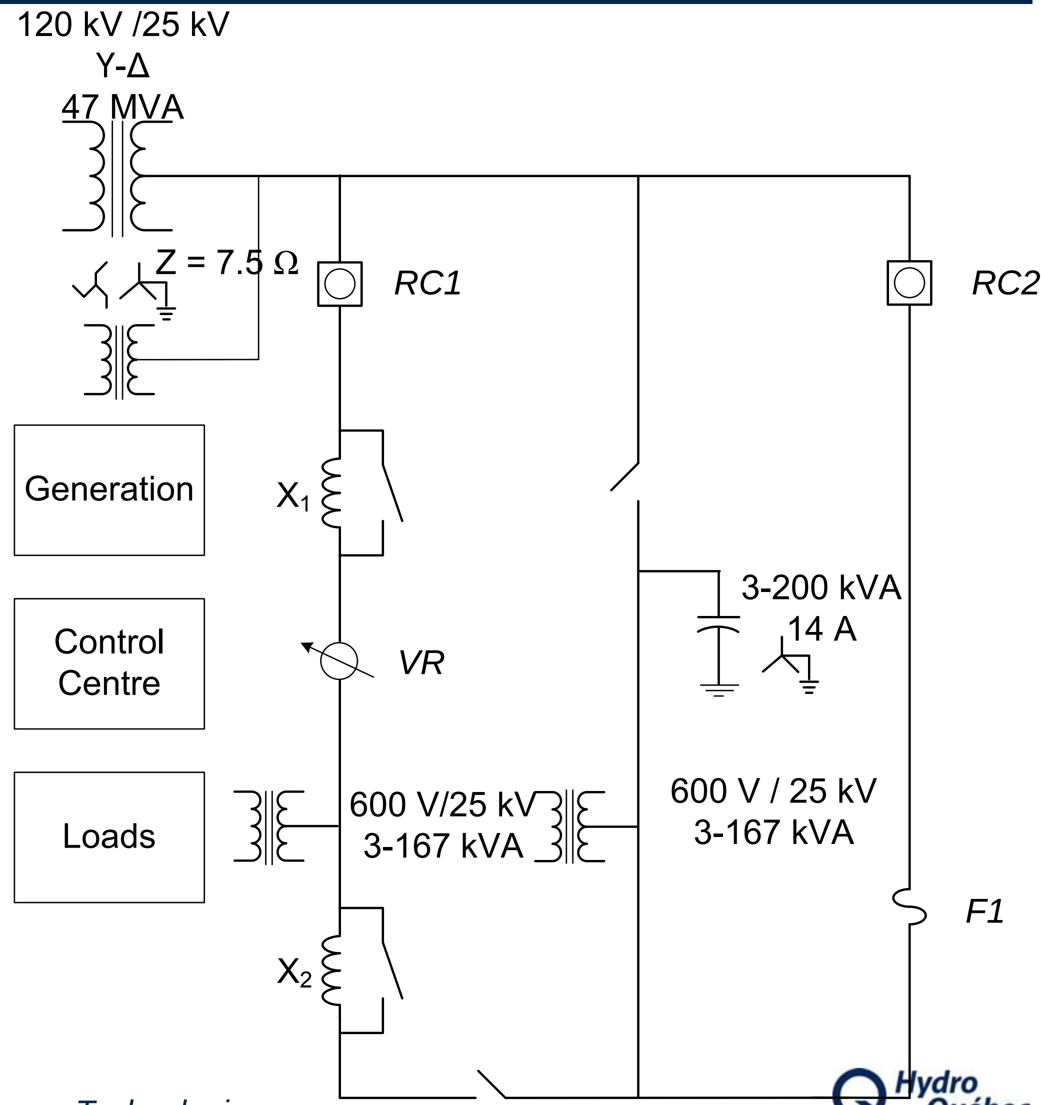
Breaker and contactor
for diesel interconnection

Testing Capabilities

- > **Capacitor switching**
- > **Reverse power flow characteristics of distribution transformers**
- > **Evaluation of protection relays for anti-islanding**
  - Diesel synchronous generator
  - Asynchronous machine to emulate a Wind generator
- > **Behavior of DG in a remote grid**
- > **Testing of reclosers during faults**
- > **Operation of in-line voltage regulator in the presence of distributed generation**

Feeder Configurations

- > Radial or meshed
- > Adjustable line impedance
- > Multiple feeders

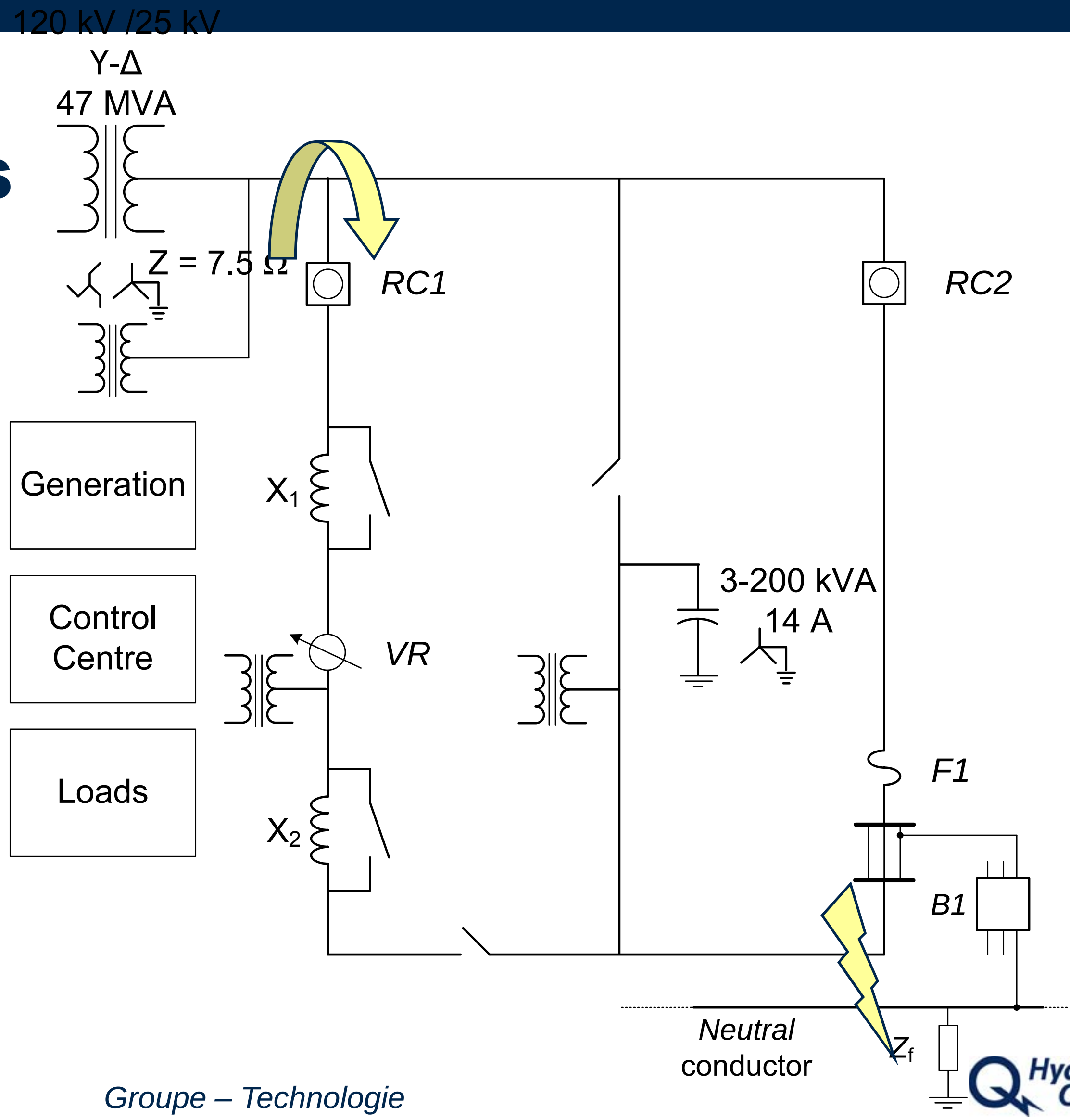


Abnormal Events

> Feeder faults

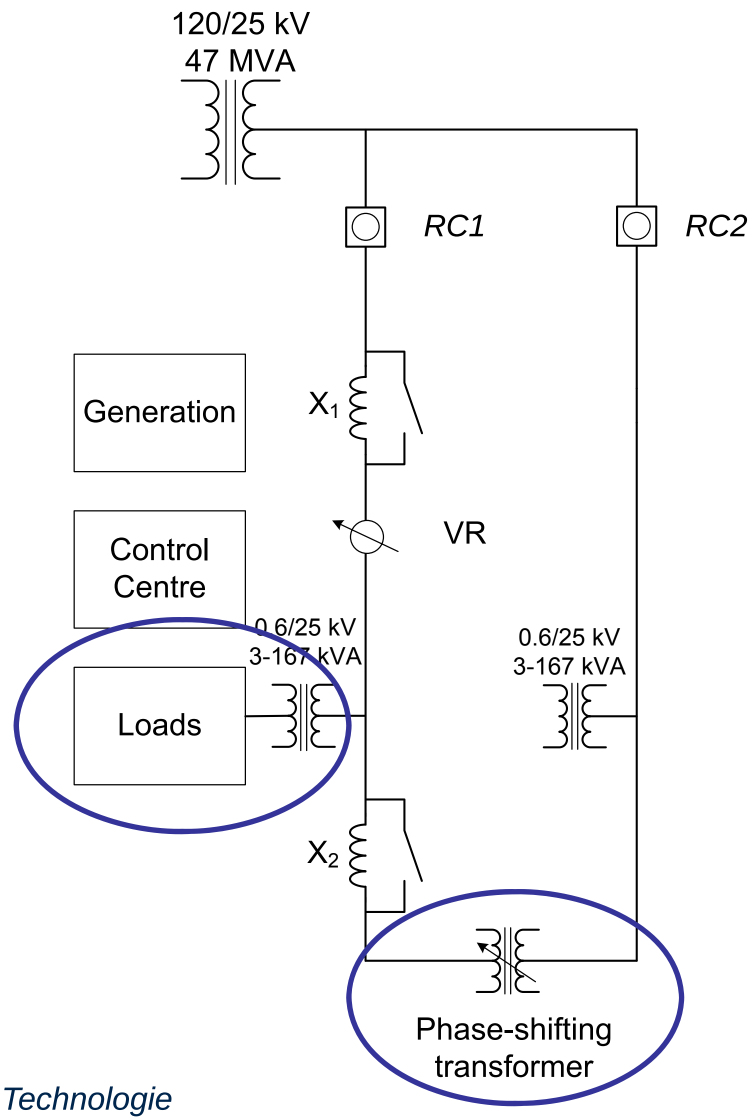
> Islanding

> LVRT



Emulation of Distribution System Load

> Controllable loads for basic tests
> Phase-shifter to emulate larger loads (future)



Summary

- > **CIGRE C6.11 - collaboration on active distribution networks**
- > **Investments in Canada's power systems**
  - Maintain / improve reliability
  - Improve energy efficiency
  - Integration of renewable energy
- > **Coordinated research and demonstration projects**
  - Test facilities – CanmetENERGY, IREQ test line
  - Demonstration projects

Contact Information

Chad Abbey - IREQ

E-mail: abbey.chad@ireq.ca

Tel. +1 450-652-8499 ext 2188

David Beauvais – CanmetENERGY, NRCan

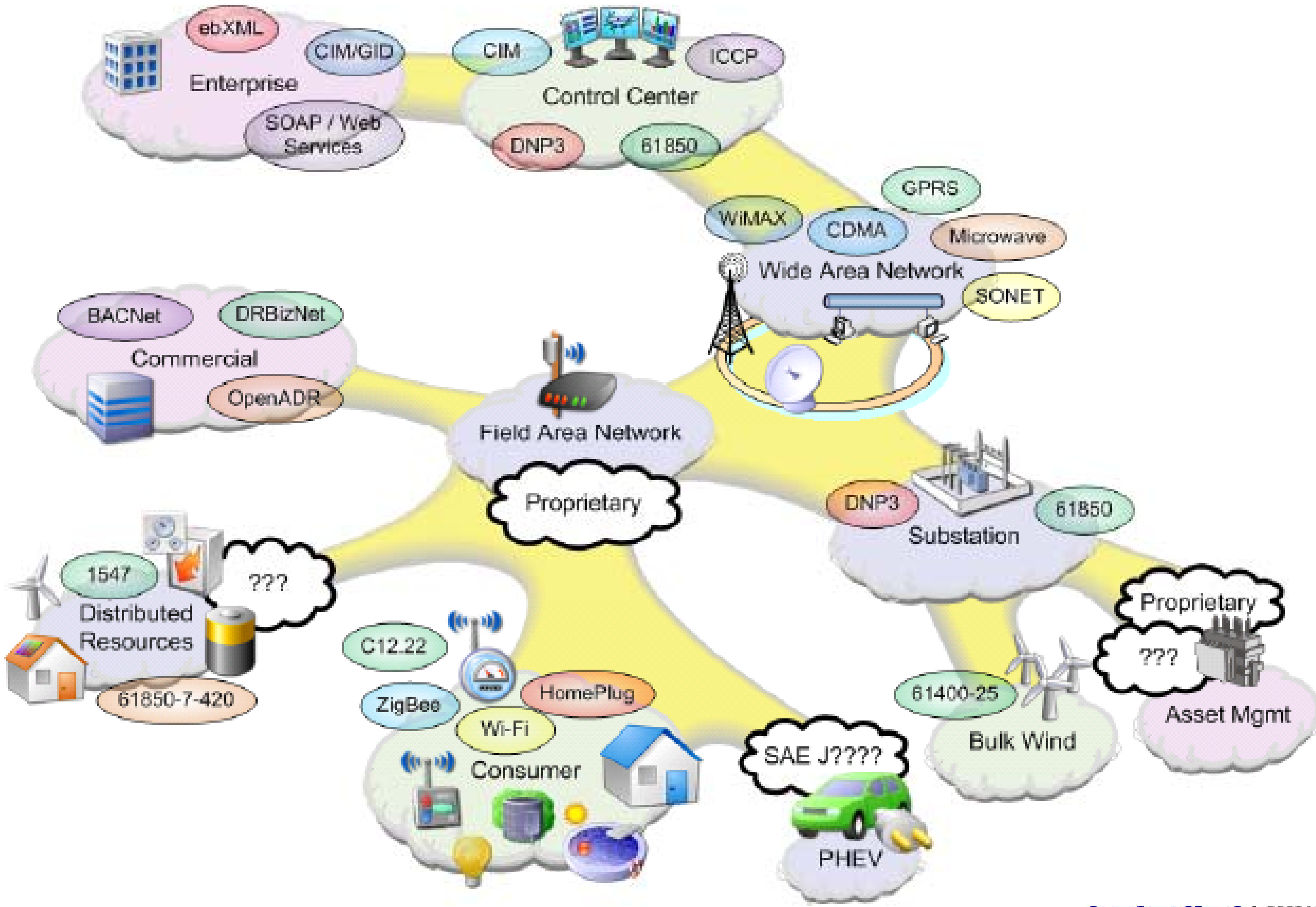
E-mail: dbeauvai@nrcan.gc.ca

Tel. +1 450-652-5995

Agenda

- Active Distribution Management Overview
- Modeling Considerations and OpenDSS
- Examples of Active Distribution Management and CIGRE C6.11 Activities
- IEEE Distribution Automation Working Group
- Demonstrations

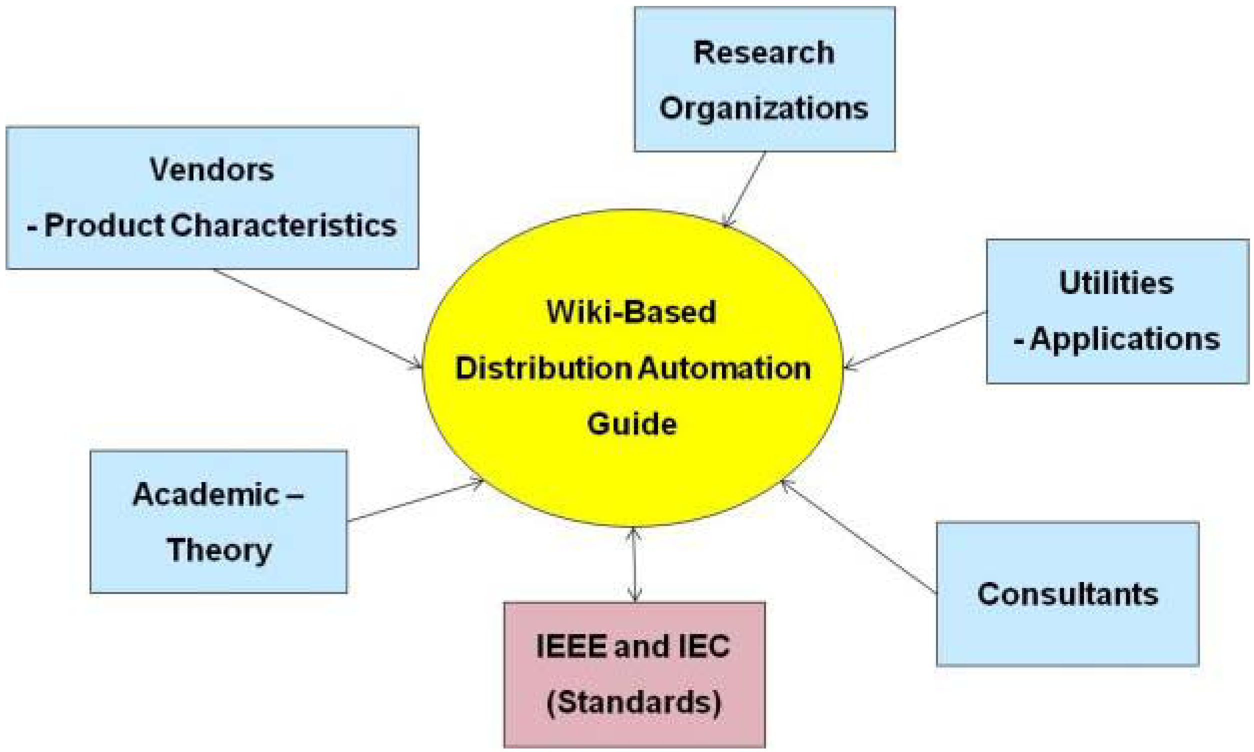
The Standards Landscape for the Smart Grid



POWER RESEARCH INSTITUTE

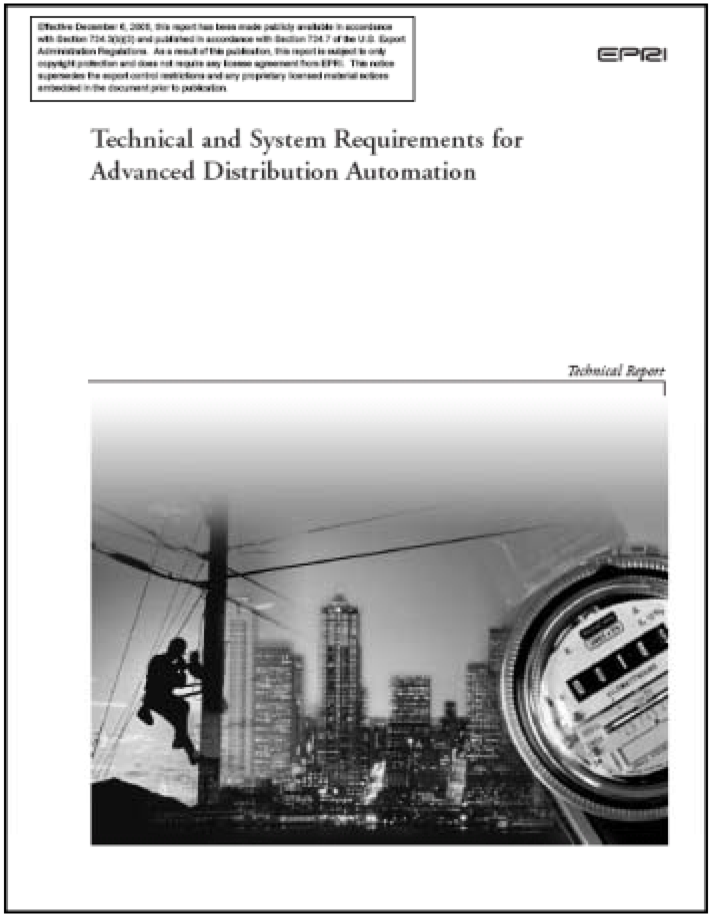
Application Guide for Smart Distribution

- Joint development with IEEE Distribution Automation Working Group
- Wiki.powerdistributionresearch.com

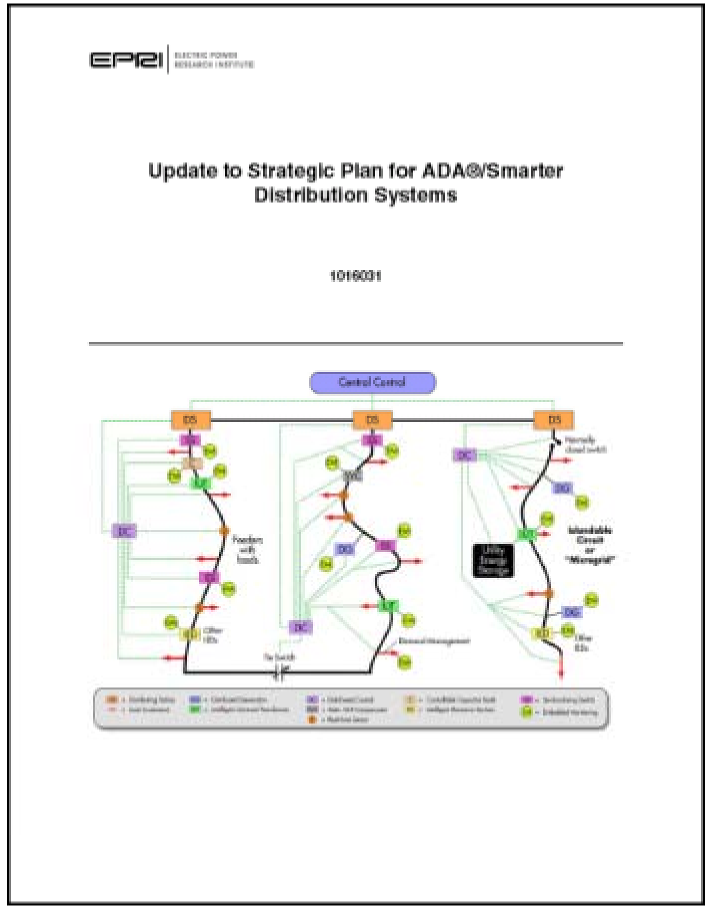


Roadmap for Smart Distribution

2004



2008



2010

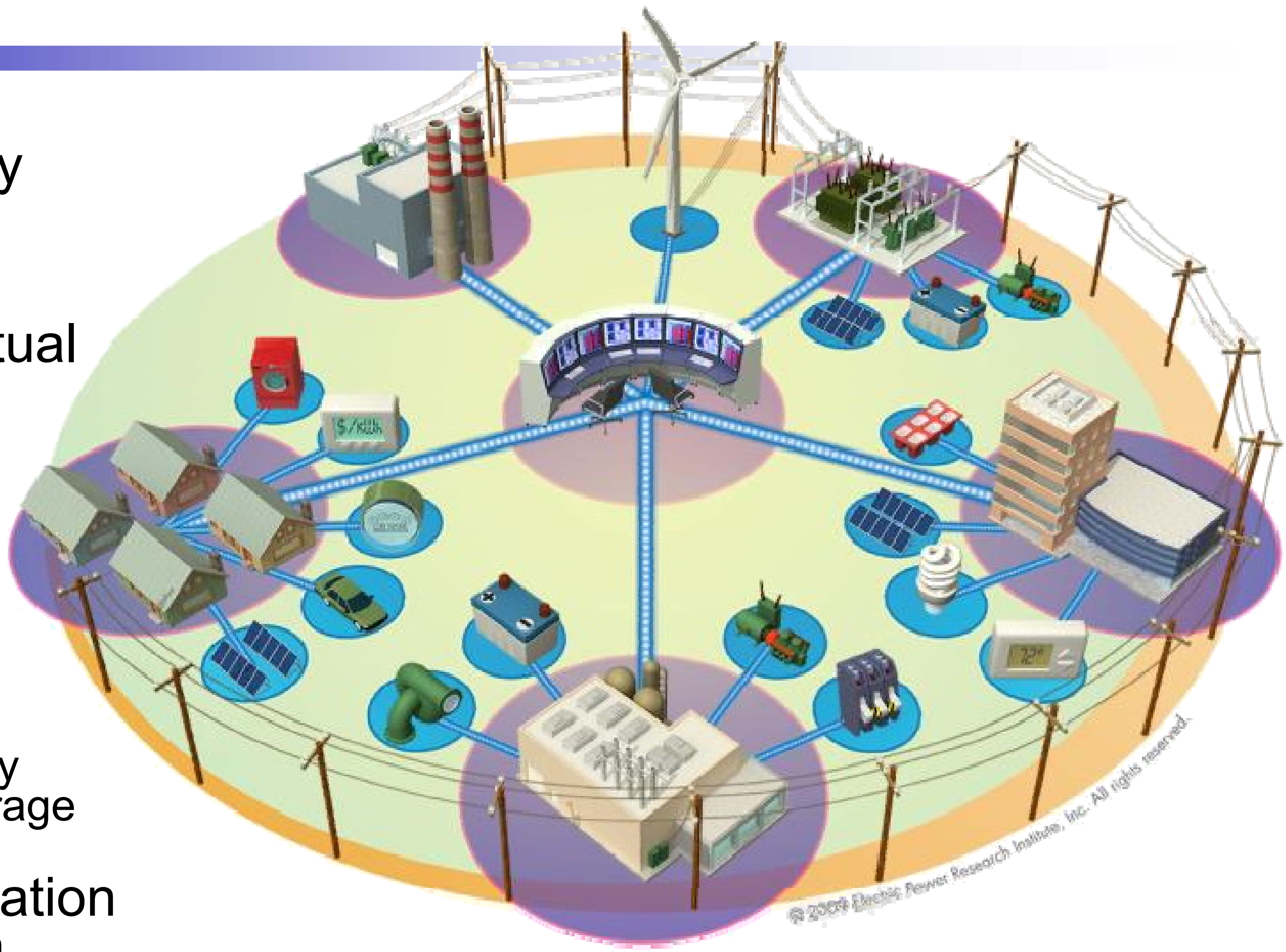
Other developments with IEEE Distribution Automation Working Group

- Volt and Var Control Task Force formed in 2009, 1st meeting in January 2010
- Other groups in discussion
  - Task Force on Distribution Communications for Smart Distribution Systems
  - DMS Interest Group
- DAWG Web site

  http://grouper.ieee.org/groups/td/dist/da/

EPRI Smart Grid Demonstrations

- Integration of Distributed Energy Resources (DER)
- Deploying the Virtual Power Plant
- Several regional demonstrations
  - Multiple Levels of Integration
  - Multiple Types of Distributed Energy Resources & Storage
- Leverages Information & Communication Technologies



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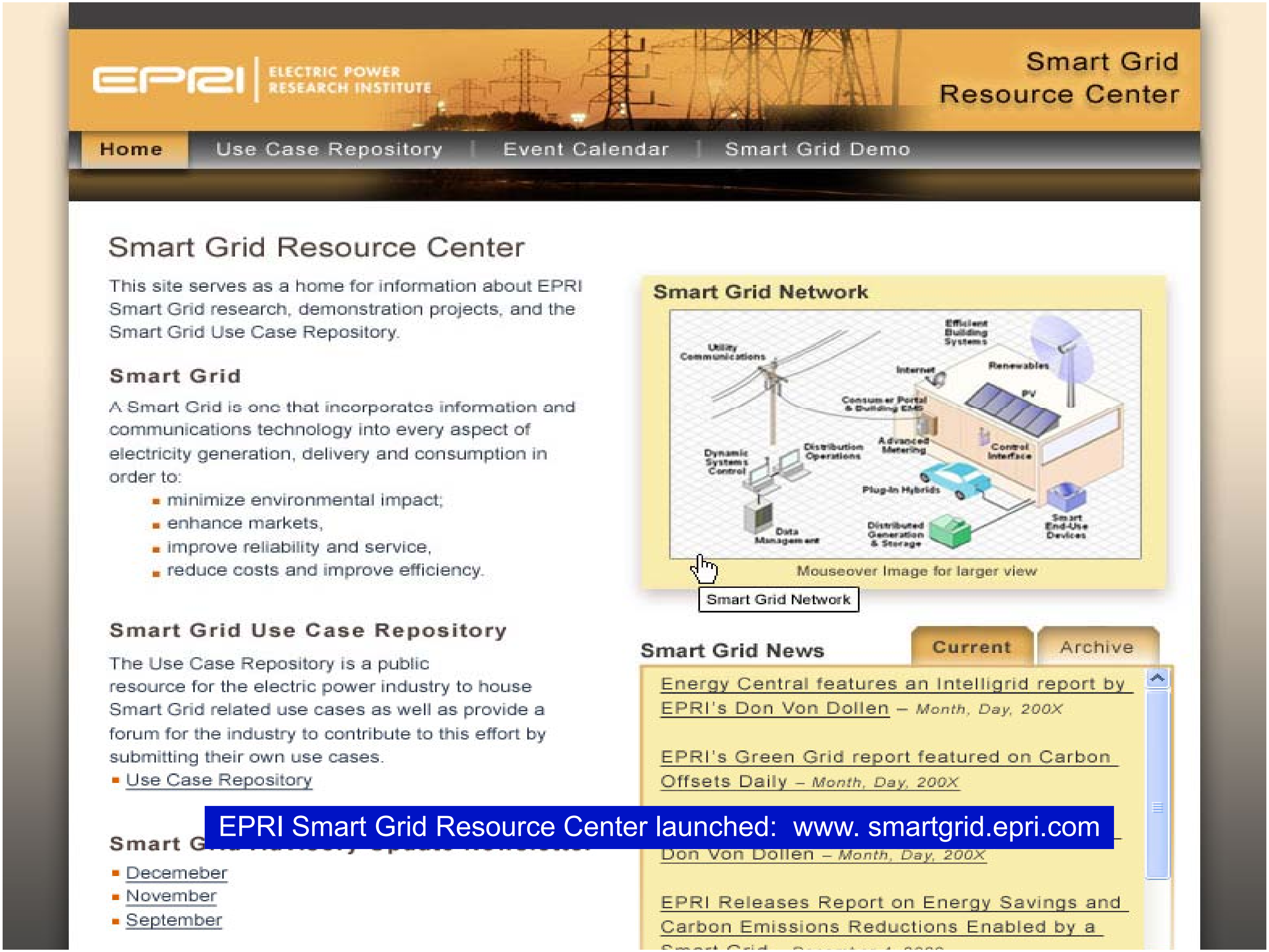

EPRI Smart Grid Resource Center launched: www. smartgrid.epri.com

Questions and Discussion