

The Global Vision and Path for Greener and Smarter Distribution Grid

by

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Outline

- Introduction
- The past, present and future of power and energy systems
- Challenges and opportunities for future
- The Modern Utility Environment: Evolution of Smart Grid
- Organizational and technical challenges
- Smart Distribution Grid: why and what?
- Practical Case Study # 1: Fault Location, Protection and Prediction of SCE's Circuit Of the Future (CoF)
- Integrated Distribution Management Systems (IDMS)
- Practical Case Study # 2: IDMS Implementation
- Summary and conclusion

Have you come to “Terms” with the following?

- Smart Grid
- New technologies
- New resources
- Green energy
- Carbon Sequestration

Prolog

- Electricity is the best invention of the 20th century.
- It is a changing world!
- Recent rapid developments demand attention.
- Electricity is a basic commodity.
- We are becoming more dependent on it for a better quality of life.
- Necessary for economic and social development.
- Meet optimal performance criteria.
- Proper regulations are required to respond to new challenges under the restructured environment.

Prolog (contd.)

- Power systems should be designed, planned, operated and managed in a coordinated way.
- True for both developed and developing countries.
- Opportunities and challenges are different for each country.
- All changes should ensure optimal and economic service to the consumers of electricity.
- So should the solutions proposed.

The Past

- 125 years of history since the advent of electric power systems.
- Several persistent problems with power systems lingered for many decades.
- did not get adequate attention under the regulated environment compared to generation and transmission.
- No coordination between planning, design, operation and management.
- Mistakes of the past led to the current state of affairs in many systems worldwide.

The Past and Present

- Electrical infrastructure is ageing rapidly
- Generation: New projects are out of phase
 - Too many plants were built in the seventies
- Transmission: Critically loaded resulting several significant blackouts.
 - No new lines were built during the last 20 years
- Distribution is gaining more attention since deregulation

The Present

- Restructuring has resulted in getting needed attention.
- Human resource imbalance: a very serious issue
 - Where will the new generation of engineers and professors come from?

The Present

- Performance optimization for efficiency, reliability and regulation and other performance measures are being addressed.
- Many public and private companies still experiencing very high T&D losses, in the range of 30-50%.
- Voltage regulation excessively poor, placing undue stress on the loads at this end.
- In many developing countries has added complex socio-economic dimension.
- Affordable electricity supply is an essential requirement of the modern society.

The Present

- Aging infrastructure of inadequate capacity are still supplying power though with poor performance.
- Example: Many underground cables and overhead poles installed in 1930's still in service throughout the world.
- Conservativeness of the design and operation may have prolonged their life expectancy.
- How long will they survive and at what cost to the utilities, or to the society?

The Future

- The outlook for the future is not all doom and gloom.
- Many positive changes rapidly occurring during the last decade due to restructuring of the industry.
- We are living at an exciting time in history to modernize future energy and power systems.

The Future (contd.)

- Electric power systems becoming larger and more complex in the last 60 years.
 - Unprecedented growth in the demand.
 - Population growth.
 - Higher standards demanded by society.
 - Increased customer expectations.

What is in Store for the Future?

- The real world is full of uncertainties
- Many needs of the society are geographically are imbalanced
- Energy demand and supply unbalance will continue to exist in the future
- Global population will increase by 30% to 9 billion in the next 40 years
- How do we prepare to meet the challenges and take advantage of the opportunities?

Global Issues of Concern (contd.)

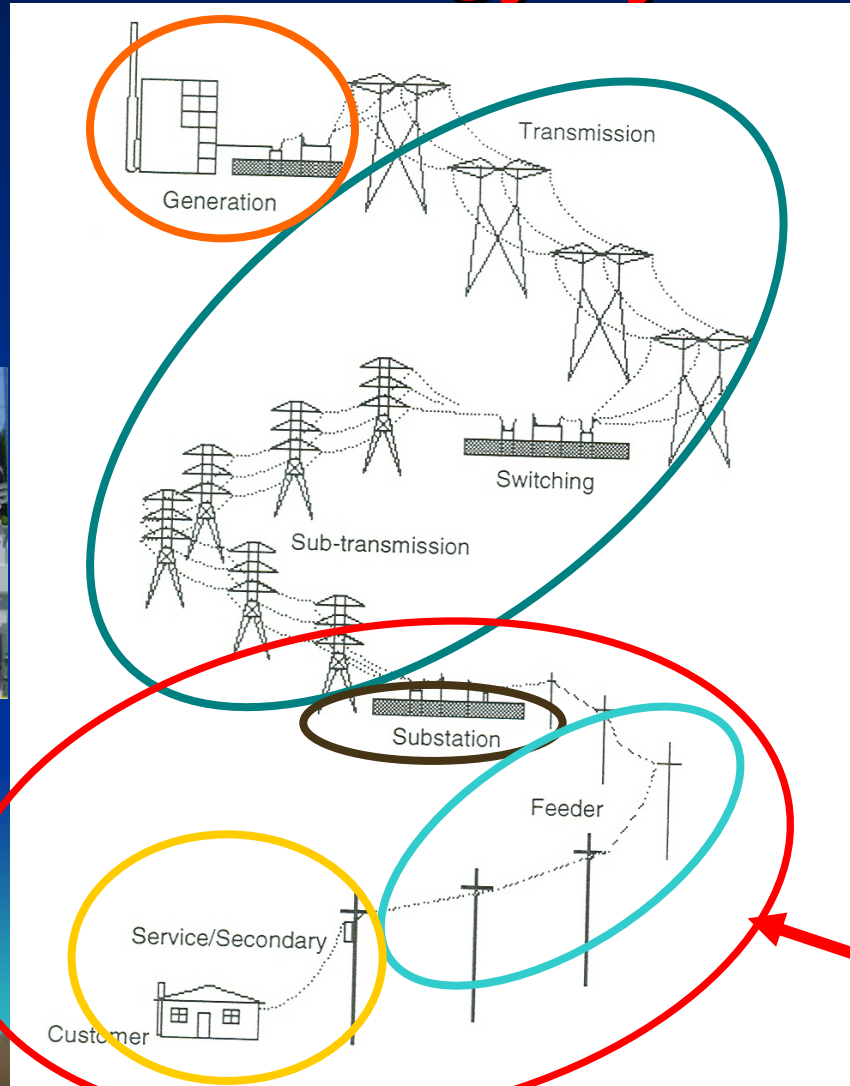
- Ecology and environment protection is essential
 - Global warming is one critical example
- Next to air and water, energy is the most important need of the society
- How to achieve balance between all conflicting forces?
- Seeking sustainable energy resources is the answer without sacrificing air and water quality

Need for Reduced Political Barriers

- Governments should aim for reduced bureaucracy
- Regulators need to balance societal and utility needs.
 - Reduced time for approval for new projects
- Utilities have to balance their internal enterprise management in the most efficient and effective ways

Overview of
Distribution
System

Conceptual View of Power and Energy Systems

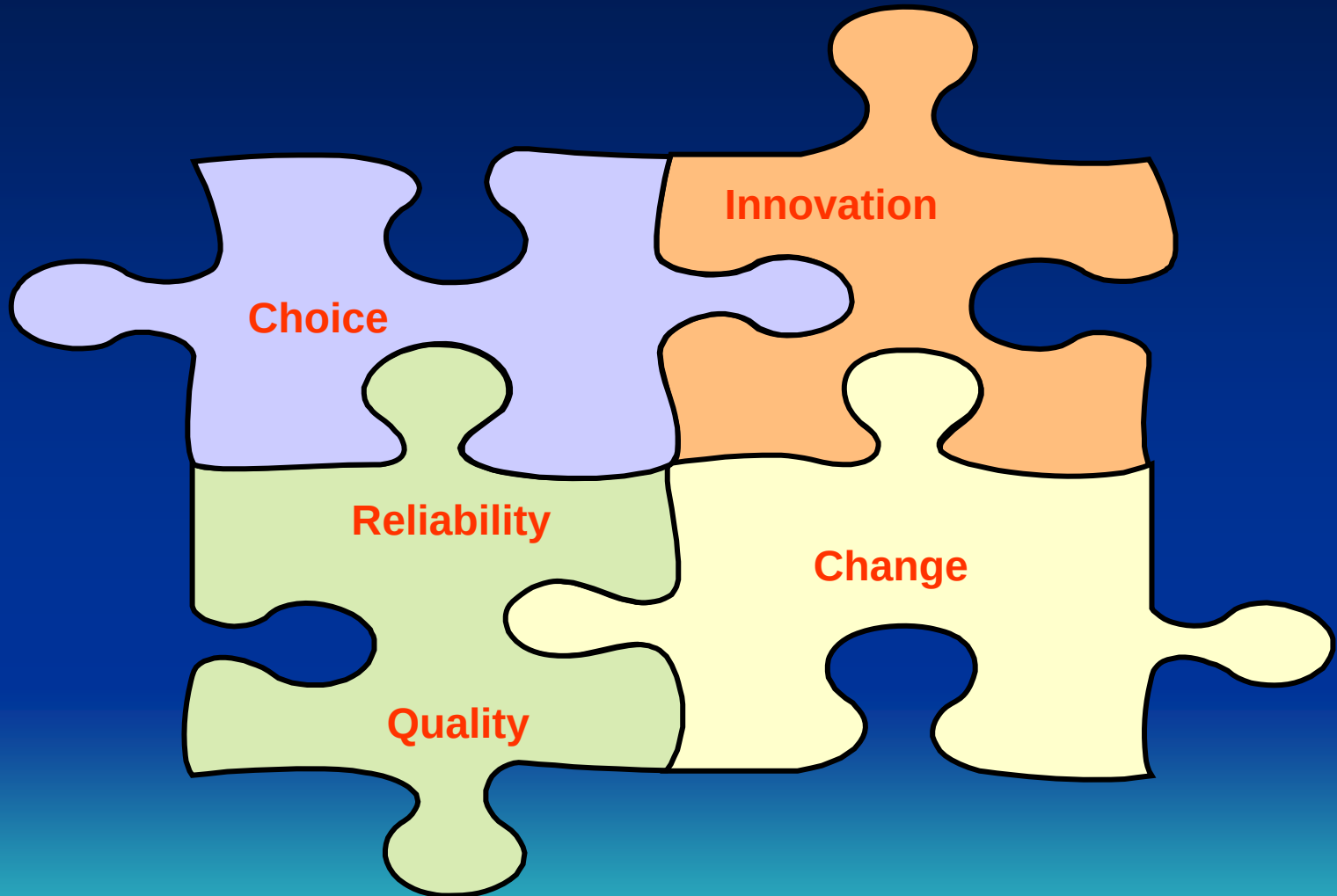


**Distribution
System**

Comparison of T and D Systems

<u>Characteristics</u>	<u>Distribution</u>	<u>Transmission</u>
Topology:	Radial	Network or Loop
Power:	100 MVA and Below	Bulk (100-20,000 MVA)
Voltage:	< 69 kV	>120 kV class
Components:	About 100 times more than in transmission	100 times less than in distribution
Capital Outlay:	40%	20%
Load:	Distributed	Concentrated (end points)
Unbalance:	< 5% - 30%	< 5%
# of Phases:	Both 1 & 3 (2 have been used)	3 or more, or HVDC

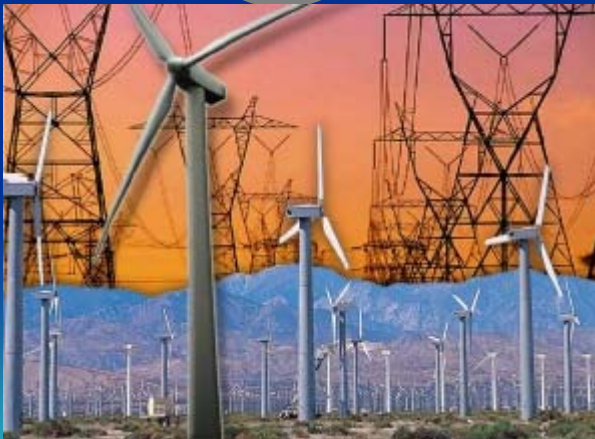
A Vision of the T&D Future



A Vision of the T&D Future

**You can't predict the future
but you can plan for it**

**What is Your
Image of the
T&D Future?**



**Global, Digital,
Mobile, Virtual,
and Personal**



Impetus for Smart Grid Development

- Deregulation (Re-regulation?)
- Development of new technologies
- Environment and ecology protection
- Customer satisfaction
- Birth of “Smart Grid” (Intelligent Grid)

What is Smart Grid?

- The entire power system viewed in a holistic manner
- Includes business enterprise, generation, transmission, distribution, utilization and customer satisfaction
- Utilize new technologies to the best advantage
- Designed, planned and operated to realize utmost performance

Smart Grid

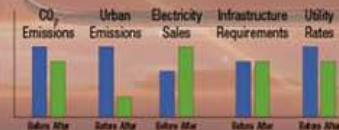
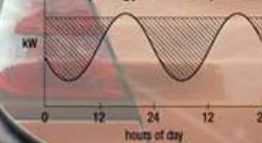
Source: Department of Energy

The Smart Grid Can Deliver

BENEFITS

- Enhanced energy security
- Reduced greenhouse gases
- Improved urban air quality
- Increased grid asset utilization

"Valley Filling"
(Energy for PHEVs)



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National Laboratory
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Smart Grid Characteristics

Source: Department of Energy

- Self-healing from power disturbance events
- Enabling active participation by consumers in demand response
- Operating resiliently against physical and cyber attack
- Providing power quality for 21st century needs
- Accommodating all generation and storage options
- Enabling new products, services, and markets
- Optimizing assets and operating efficiently

Other Definitions of Smart Grid

- Smart Grid is universally understood to be the key enabling technology for the nation's ambitions for renewable energy development, electric vehicle adoption, and energy efficiency improvements.

Source: <http://www.gridwise.org/pdf/SmartGridMASTER.pdf>

The Smart Distribution Grid will Support and Enable

**Sustainable Energy
Development**

- Renewable resources and demand response integration and management
- Enhanced reliability, power quality, and system self healing
- Empowers customers with new technology value added products and services
- Economic benefits through innovation and efficient energy management
- Asset management and utilization optimization

Why Smart Distribution Grids are Needed?

- **Distribution system deficiencies**
 - Little flexibility and intelligence
 - Outdated legacy network
 - Unacceptable performance measures
- **Consumer cost of service issues**
- **Environmental issues**



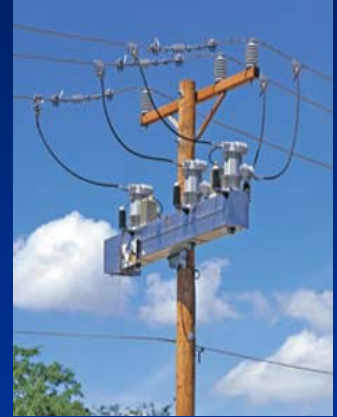
Why Smart Distribution Grids are Needed?

- Capitalize on new technology advancements
 - Advanced metering
 - Power electronic devices
 - Changing end-use loads (nonlinear)
 - Communication networks
 - Advanced computing systems
 - Plug-in hybrid vehicles
- Reduce the cost of distributed energy sources
- Dispersed Generation Integration



What will Smart Distribution Grids Look Like ?

- They will be characterized by:
 - Low cost sensors and smart meters
 - Distributed information and intelligence
 - Smart customer appliances
 - Distributed energy resources
 - New materials such as high temperature superconducting materials
 - High efficiency transformers
 - Improved fault limiting and protective devices
 - New storage devices



Goals and Requirements

- Customer Satisfaction
- Efficiency
- Reliability
- Voltage and frequency regulation
- Power Quality
- Economy
- Environment and ecology
- Regulatory
- Security (system and cyber)
- Safety

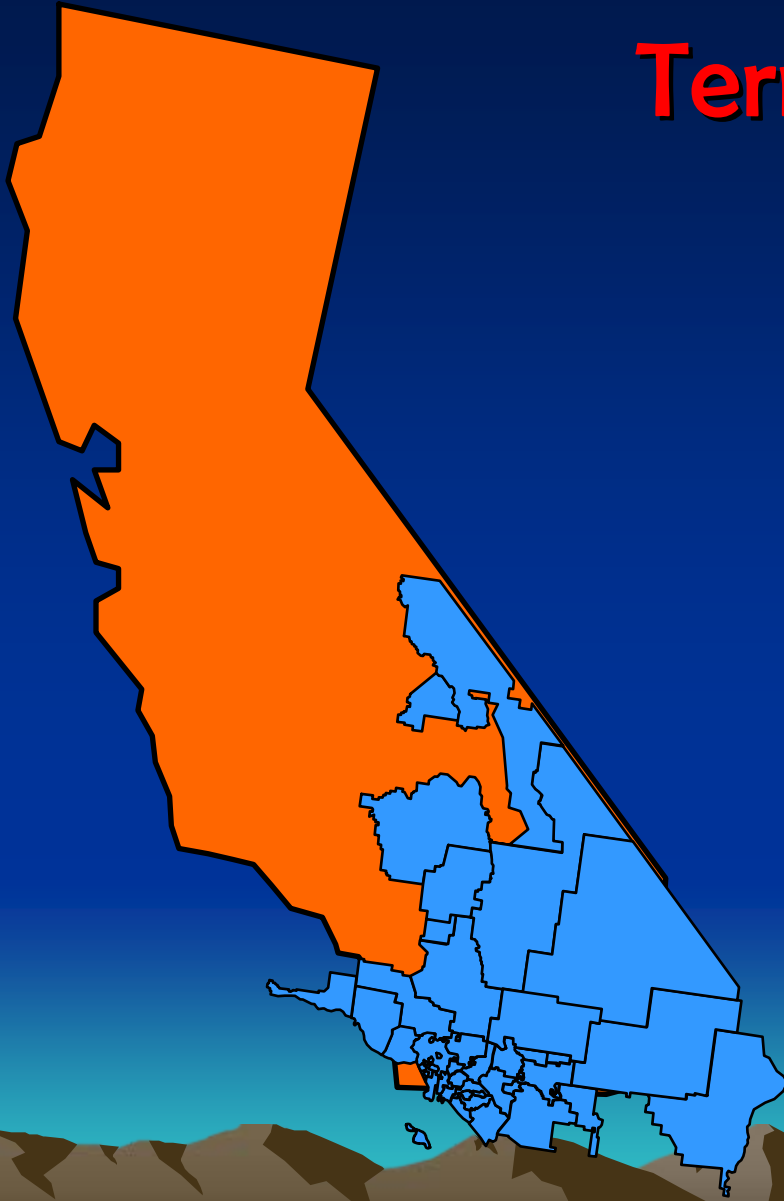
What is Advanced Distribution Automation (ADA)?

- “ADA is revolutionary approach to managing and controlling distribution systems. It achieves a fully controllable and automated distribution system including the integration of Distributed Energy Sources (DER) to optimize system performance. “
- Source: EPRI

Practical Case Study: Fault Location, Protection and Prediction of SCE's Circuit of the Future (CoF)

Goal: To promote ADA through new
technologies

Southern California Edison (SCE) Territory



- 50,000 square miles
- ~23,000 MW peak demand
- 5 million customers
- 11 million people served
- 845 cities and communities

DOE Project Goals

- **Advanced protection Methods on the Circuit of the Future (CoF)**
- **Three goals over 3 years:**
 - Design and test new protection scheme
 - Design and test protection scheme with fault current limiter
 - Investigate, design and test advanced fault location, sensing and prediction methods
- **Team: SCE, KEMA, Virginia Tech**

Potential Benefits

- Reduce number of customers seeing outage
- Reduce duration of outages for most customers
- Better locate faults and dispatch crews to problem quickly
- Reduce equipment cost
- More flexible protection to help with integration of DG/Renewable Sources

Details on Goals

- **Goal 1 – New Protection Scheme**
 - Comprehensive literature search and survey
 - Initial operation of the CoF in 2007
 - Continue to monitor the performance of the protection system
- **Goal 2 – Protection with and without Fault Current Limiter (FCL)**
 - PSCAD Model Development for FCL
 - Energized Zenergy FCL on March 6, 2009
- **Goal 3 – Advanced Protection**
 - New and creative ideas explored

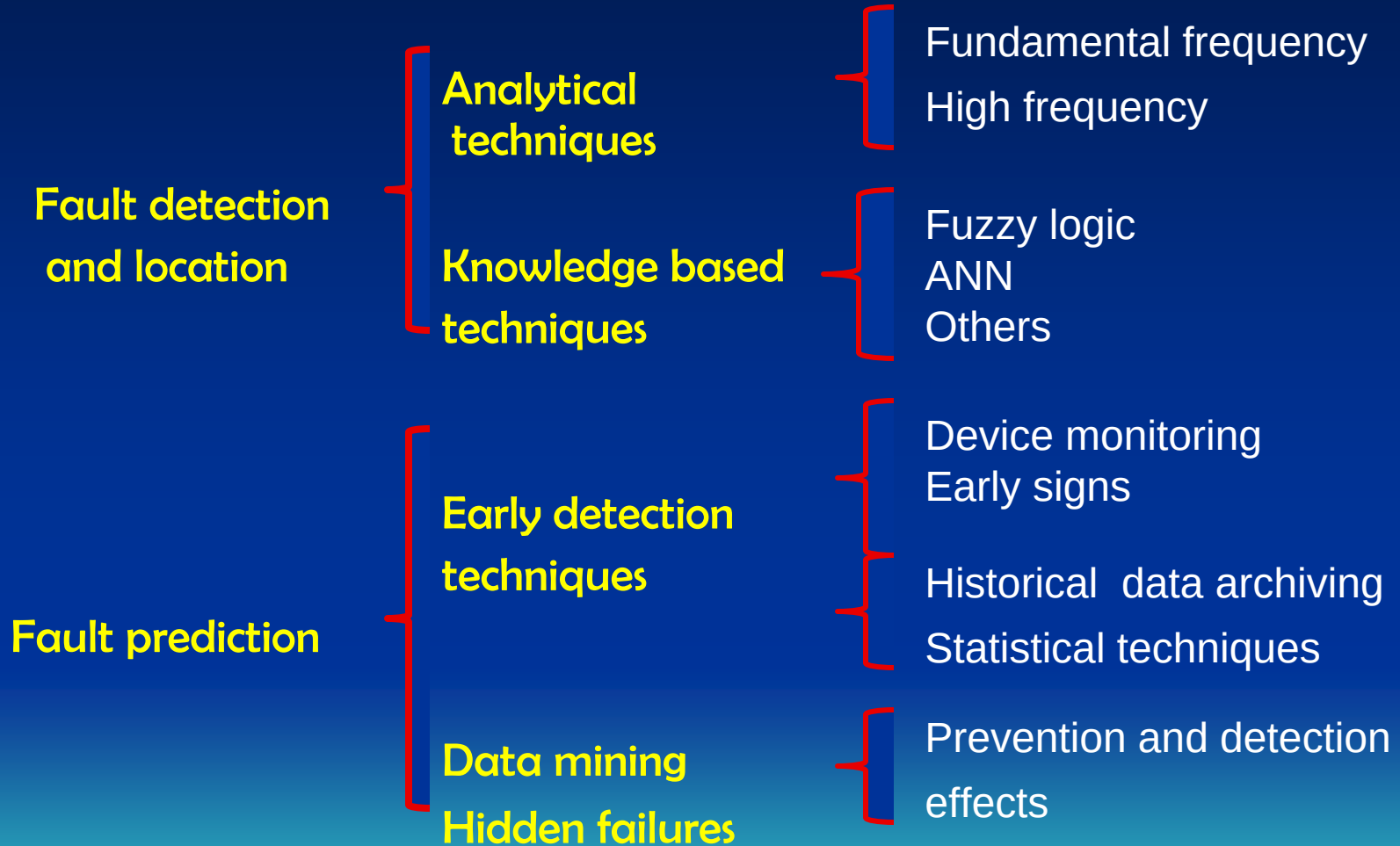
Goal 1 – Protection on the CoF

- Literature review work by KEMA and Virginia Tech completed
- Questionnaire is on the street about advanced protection practices and projects
- Summary is being prepared
- Install advanced fault detection and isolation system on the SCE Circuit of the Future

Literature Review

- Fault location, prediction and detection
- Also included distribution automation and fault current limiting and high impedance faults topics
- 1990 to present
- Criteria:
 - Level of development
 - Theoretical, lab. testing, commercial
 - Applicability to distribution systems
 - Adaptable, enhancement

Literature Review



Survey - Key Observations

- Replacing old relays with microprocessor based ones
- Developing in house protection schemes such as Special Integrated Protection Scheme (SIPS) for back up power supplies and OverLoad Scheme (OLS) for grid protection
- Deploying decentralized Feeder Automation System Technology (FAST) using switching logic in a programmable controller that feeds in data to master SCADA and can do protection functions independently

Survey - Key Observations

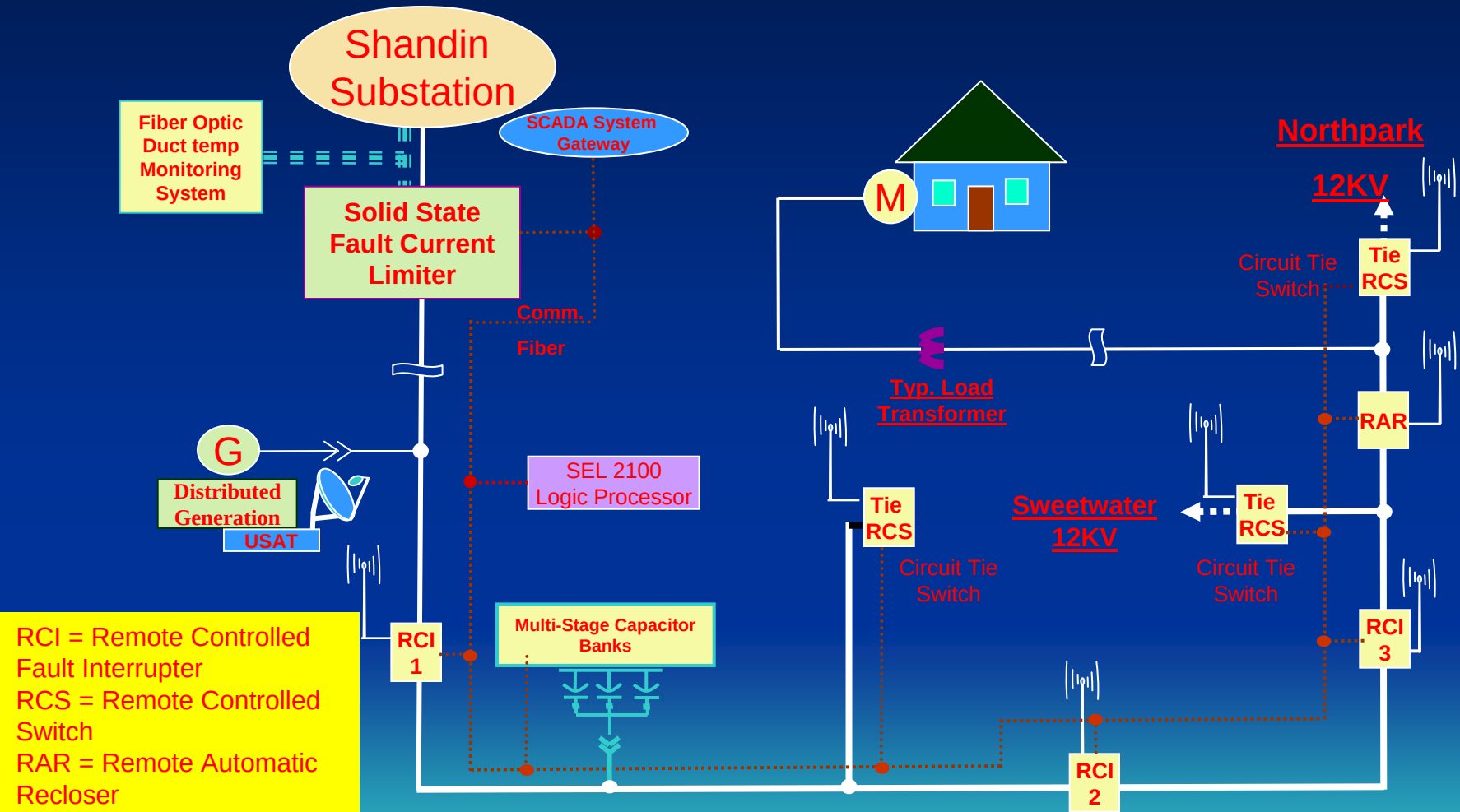
- Using numerous smart meters at strategic locations to better predict an outage size and location based on historical trends stored within these meters
- Developing hardware and software technologies that measure the performance of transformers and breakers for more efficient utilization of assets and predict failure
- Performing reliability statistical analysis about customer outages, using data that is fed into a reliability assessment application
- Testing a saturable core HT superconducting FCL

Circuit of the Future (CoF)

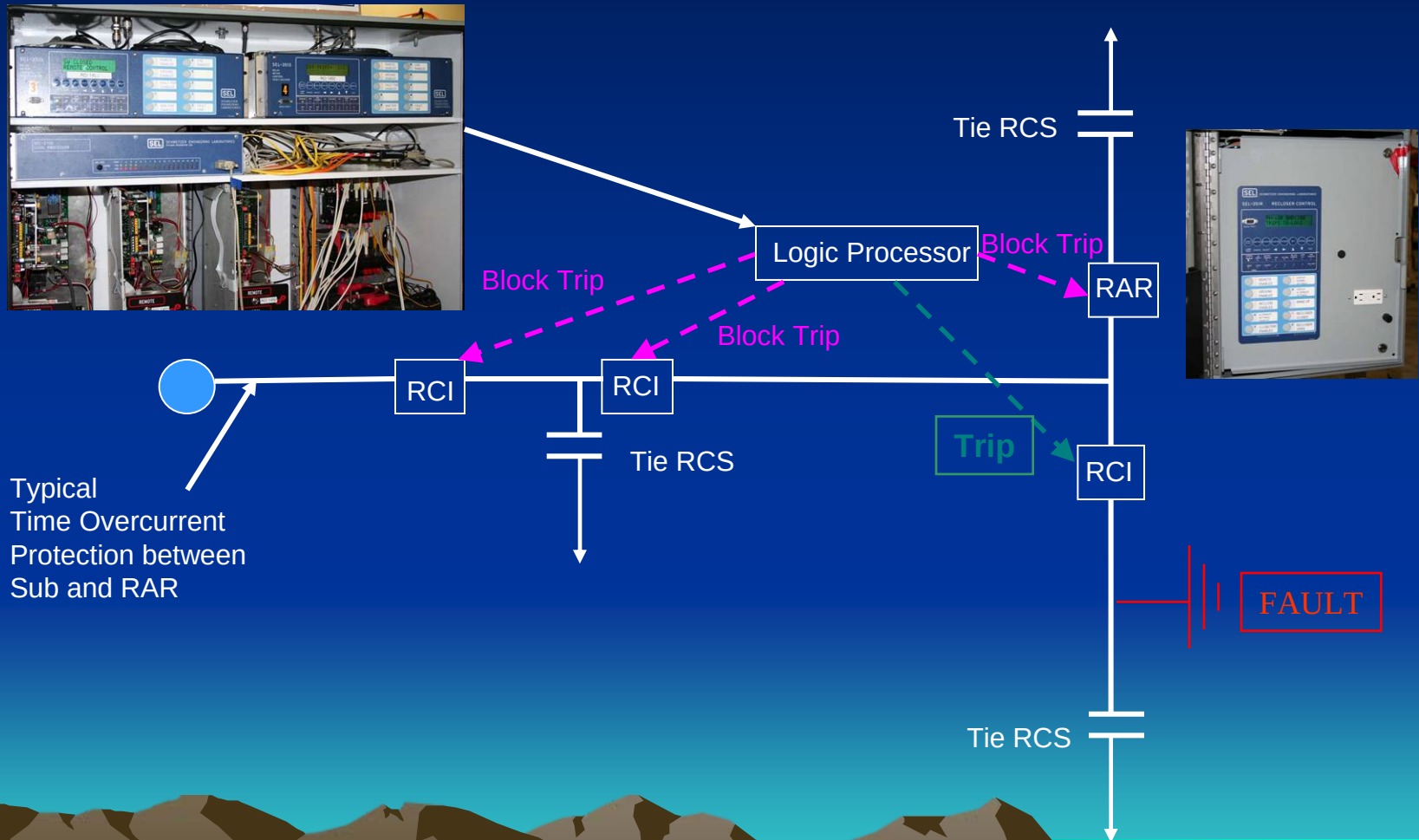
- New circuit
- Approximately 23,000 amps fault duty
- Serves approximately 2,000 customers
- Overhead / underground facilities
- New hardware and protection schemes
- High speed communications with fiber



Circuit Features



Trip Blocking Scheme



Restoration after Fault

- In the future, computer system will analyze peak loading for previous week and suggest to operator the appropriate tie switch(es) to close to restore the unfaulted line section(s)
- RCI's have directional sensing, go solid if fed from reverse direction
- History data server stores load data from RAR's and RCI's

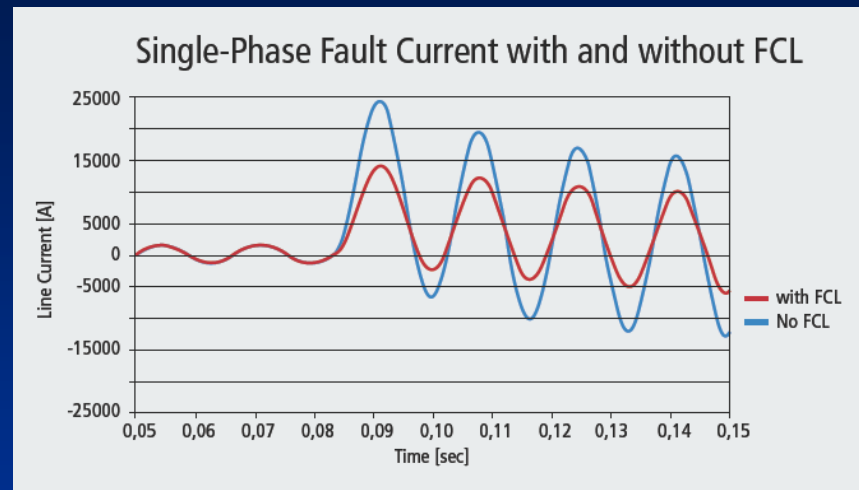
Circuit Fault Status

- Two faults on circuit (2007 and 2008)
 - Protection system operated correctly
 - Post-fault isolate function did not work the first time due to problem with voltage sensor location
 - Problem corrected Summer 2008 and the everything functioned as expected

Goal 2 - Protection with Fault Current Limiter (FCL)

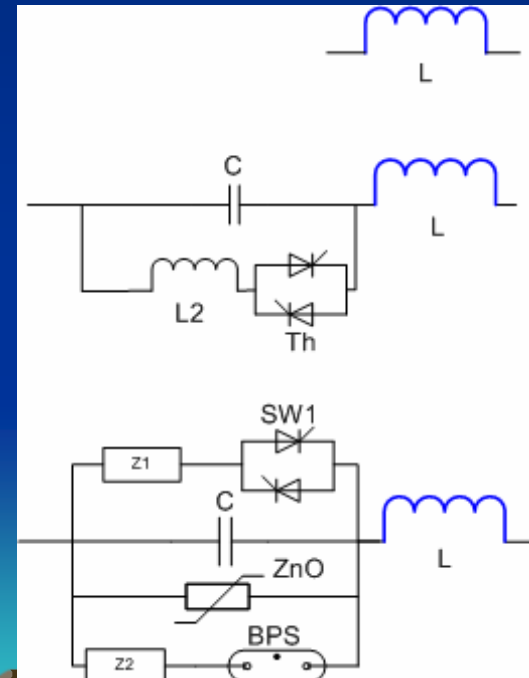
- **Install fault current limiter**
 - Bypass switch in substation
 - Superconducting FCL by Zenergy/SC Power installed a month ago
 - Potential for solid-state FCL (Silicon Power/ EPRI) installation by mid 2009
- **Investigate and model protection changes necessary**
 - Due to reduced fault current from 23-kA to about 18.5-kA
 - Due to distorted wave shapes
 - Obtain/construct FCL models
- **Implement protection changes subsequent to FCL installation**

Fault Current Limiter on CoF



FCL Modeling

- PSCAD model to analyze:
 - Protection Applications
 - Automation Applications
- Variable Device Model
 - Passive
 - Basic Circuit Elements
 - Superconducting
 - Solid State
 - Resonance Based
 - Switched Bypassing
 - Bridge Type
 - Hybrid



FCL Modeling Data Needs

- **Limiting capability**
 - Current limiting
 - Voltage drop
- **Time constants**
 - Insertion time
 - Recovery time
- **Waveform changes**
 - General noise
 - Harmonics

Goal 3 - Advanced Protection Schemes

- Evaluating schemes and select most promising ones for modeling
- Select schemes and equipment for field test on the CoF
- “Short list”
 - Adaptive protection settings (A4, overcurrent)
 - Additional information from existing relays
 - Fault location by triangulation
 - Model (PSCAD) next generation schemes (loop, DG, PHEV sites, alternate communication technologies)

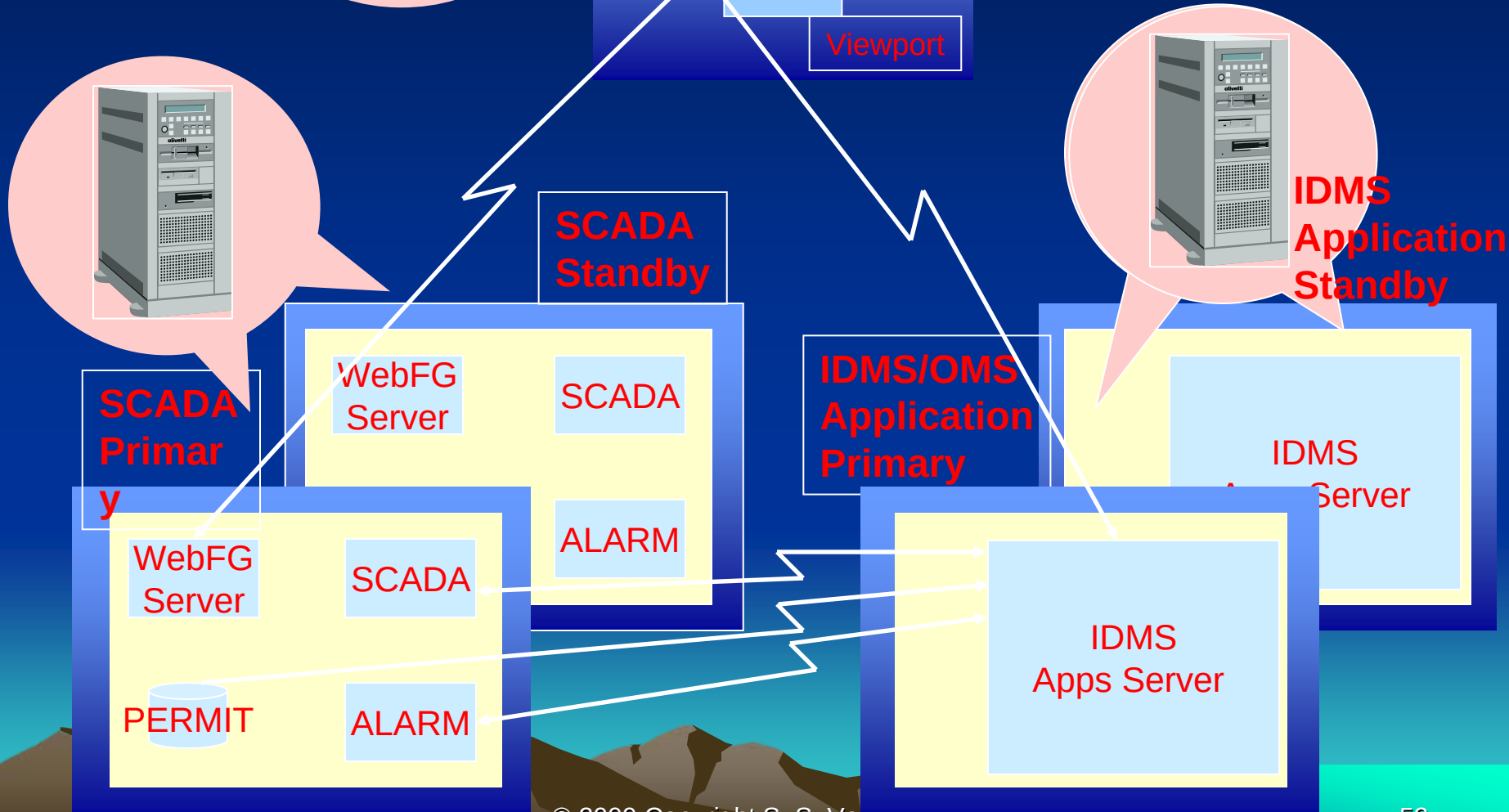
Modern Distribution Control Center



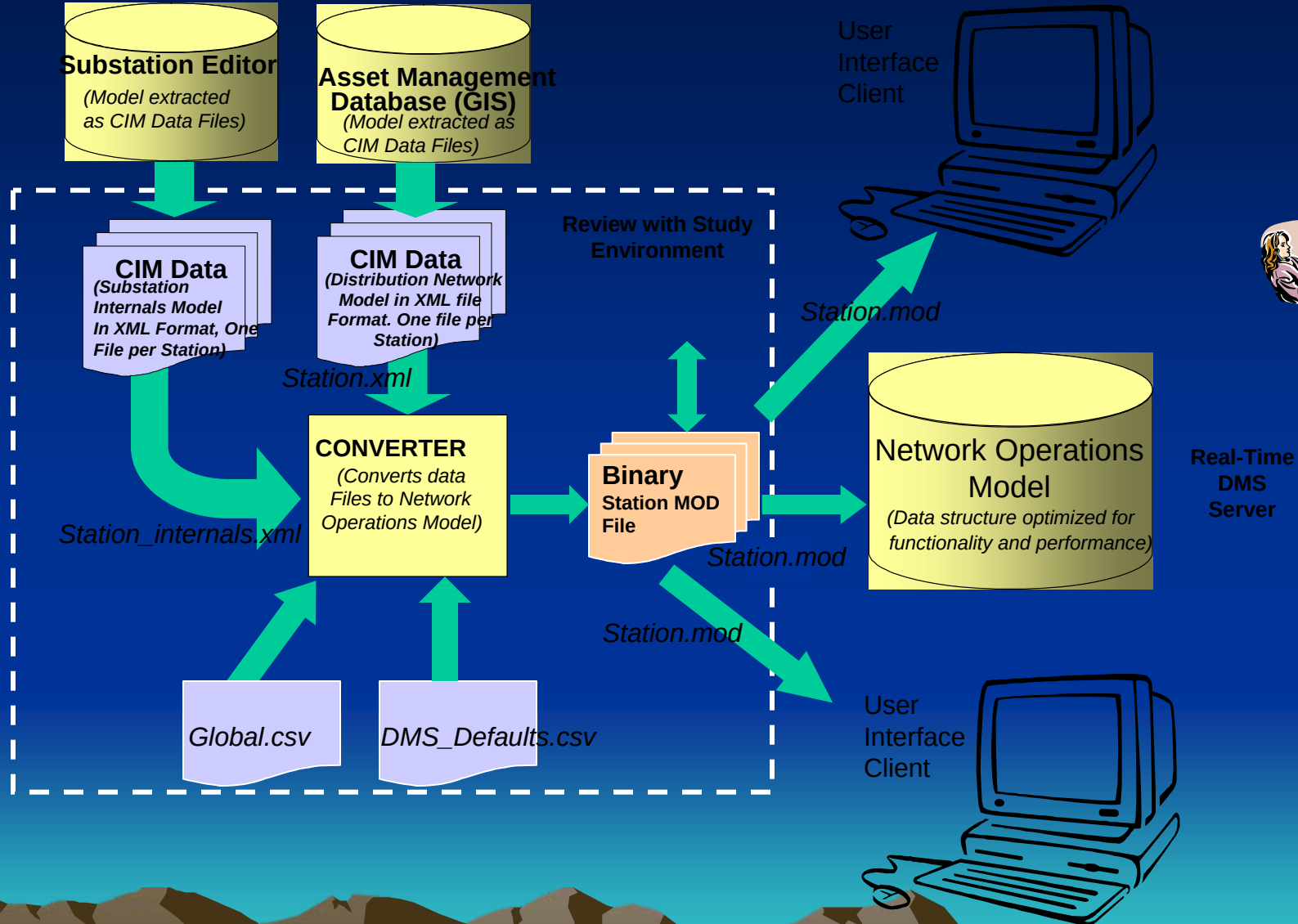
Source: Alabama Power Company

IDMS Architecture

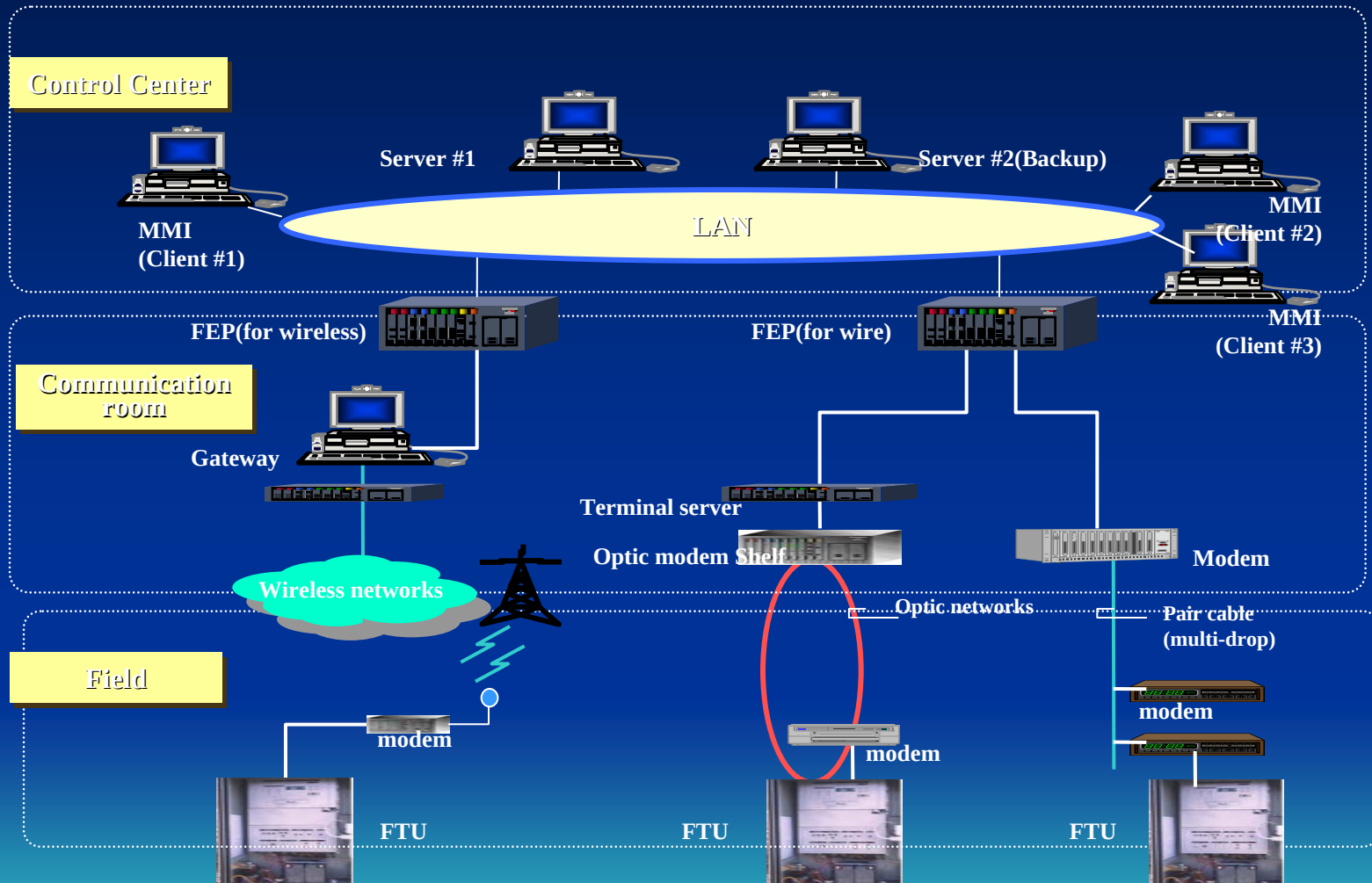
Client PCs running e-terrabrowser



Data Management Overview



Communication System Architecture



Role of New Technologies in IDMS and ADA

- New technologies are essential to enhance ADA
- The design of IDMS, as second generation DMS, need to keep the advances in new technologies in mind
- New technologies facilitate IDMS to integrate OMS, DMS and SCADA functions into one seamless function

Examples of New Technologies for IDMS and ADA

- Smart meters will enhance fault location identification function
- Remote controlled switches and protective devices will allow Integration of Fault Isolation and System Restoration into one function
- Microgrid (DG) integration with utility system will yield higher reliability.

Smart Distribution Operations of the Near Future

Advanced IDMS Applications

- Automatic fault detection and location AFISR (Automatic Fault Isolation and Service Restoration)
- Optimal Volt/Var Loss Management
- Fast on-line power flow Analysis

Smart Distribution Operations of the Near Future

Advanced IDMS Applications

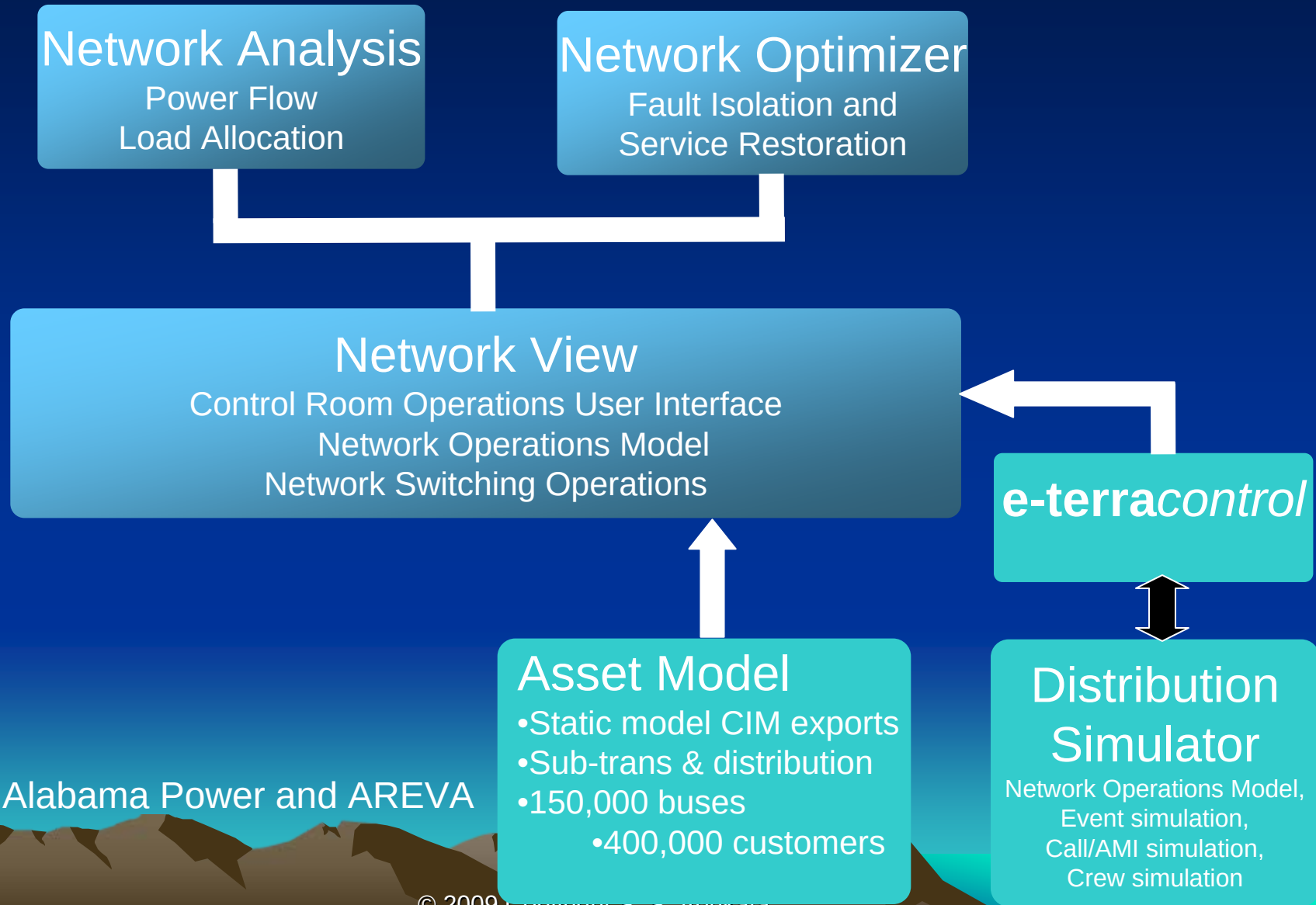
- Fast short circuit / coordination analysis
- Automatic contingency analysis
- Advanced outage analysis / prediction
- Automatic vehicle location system (crew management)

Smart Distribution Operations of the Near Future

Advanced IDMS Applications

- Dynamic loading of power equipment (include harmonics)
- Distribution Operator Training Simulator (DOTS)

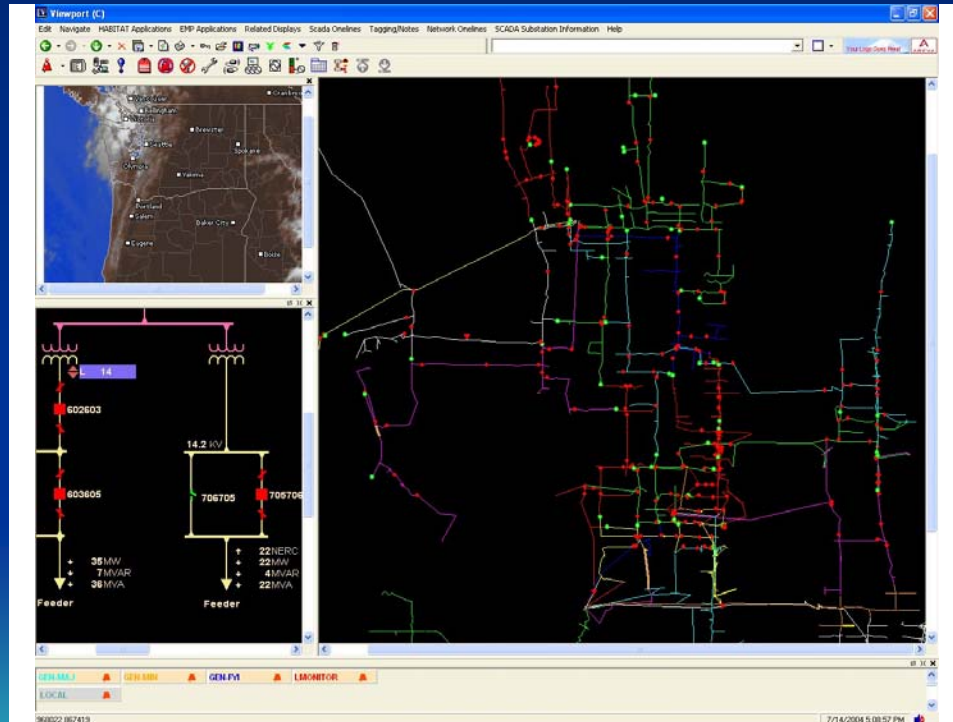
Distribution Operators Training Simulator



Source: Alabama Power and AREVA

Smart Distribution Operations of the Near Future

Conceptual IDMS Operator Console



Summary and Conclusion

- In this presentation, the past, present and future of energy systems is presented
- The vision, concept for “Smart Distribution Grid” is introduced.
- The path for reaching Smart Distribution Grid is identified.
- In this process, identified research challenges and opportunities for the next twenty years.
- What an exciting time to be in the power and energy field!