

Mladen Kezunovic
Texas A&M University

<http://www.ee.tamu.edu/~pscpc/index.html>

Uses of Operational and Non-Operational Data

Research Seminar
Abu Dhabi, UAE, March 8, 2007



Outline



- Introduction
- Background: Operational VS Non-operational Data
- New Concept: Transparent Data
- New Solutions: Different utility groups
- Examples: Demonstration Project
- Conclusions



Introduction



- Basic problem: how to utilize data “explosion” in power systems
- Data “explosion” is associated with introduction of substation IEDs
- Current status: “pipeline” of R&D, demonstration, deployment
- Funding parties: State of Texas (ETF), NSF (Pserc), DOE (CERTS, CTC), EPRI, utilities, ERCOT, vendors



Outline



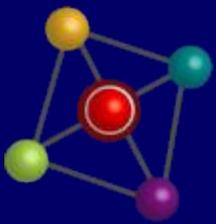
- Introduction
- **Background:** Operational VS Non-operational Data
- New Concept: Transparent Data
- New Solutions: Different utility groups
- Examples: Demonstration Project
- Conclusions



Background



- Traditional data separation: operational and non-operational
- New concept: make data transparent to the user
- Properties of new data: redundancy, robustness, more information
- Problems to be solved: data acquisition, data integration and information extraction, information presentation

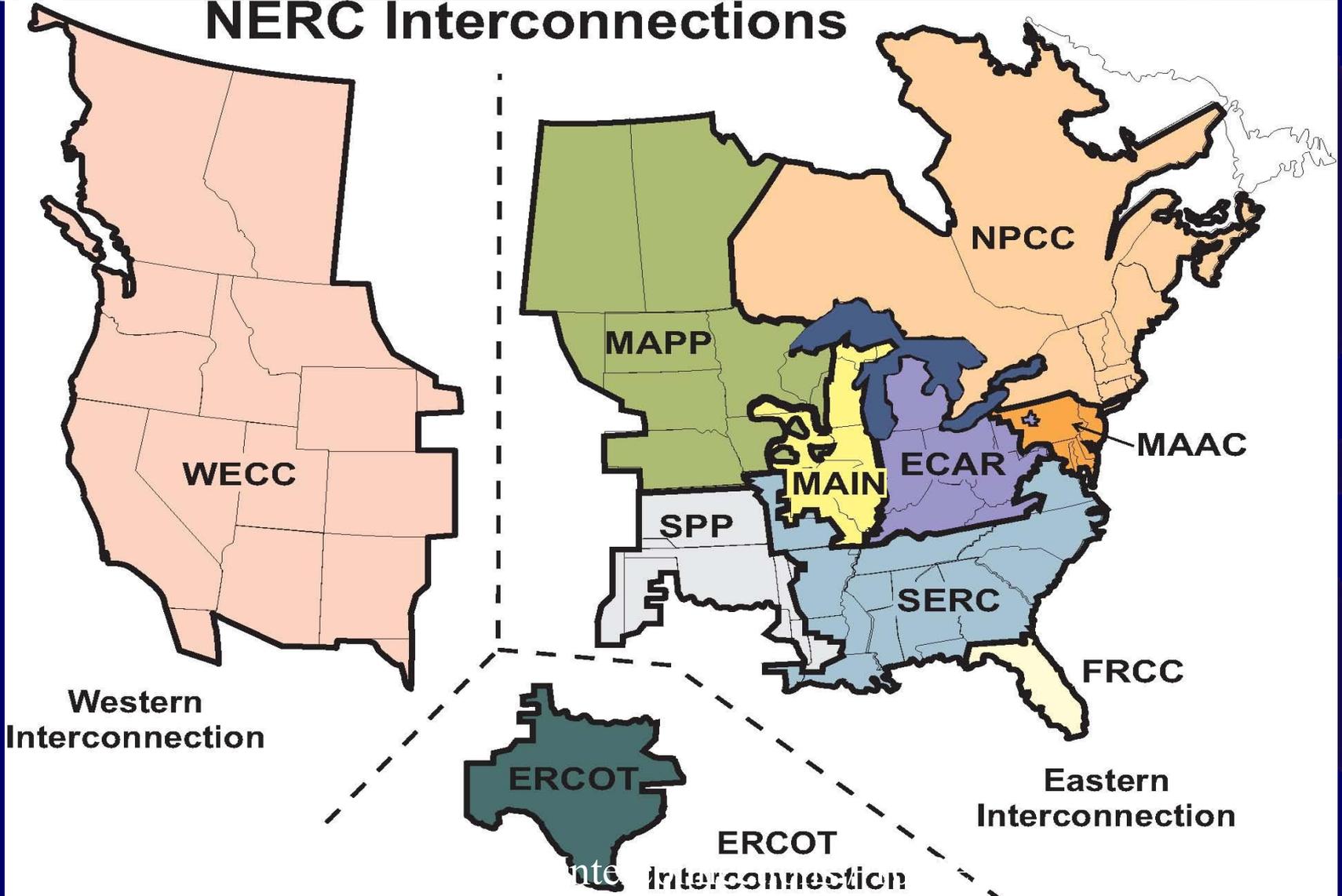


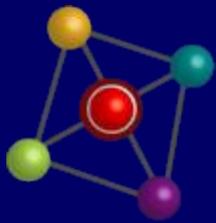
TxGEE

USA Interconnections



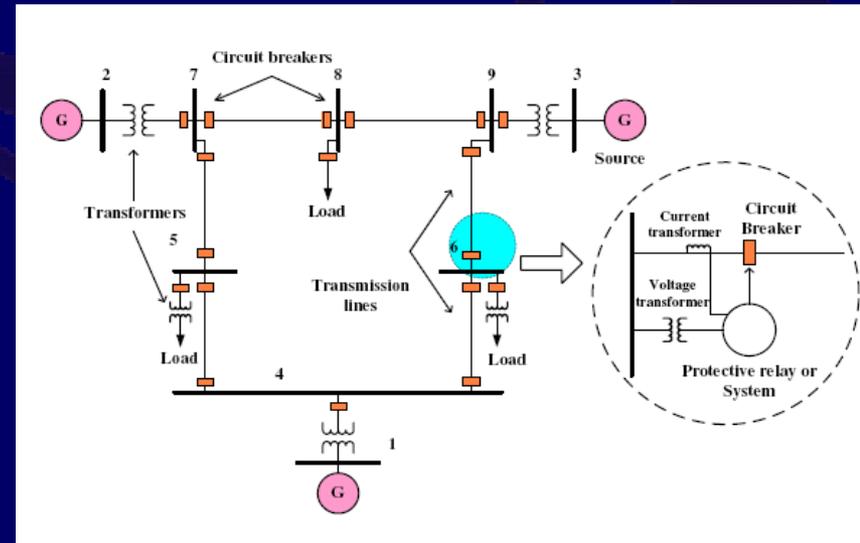
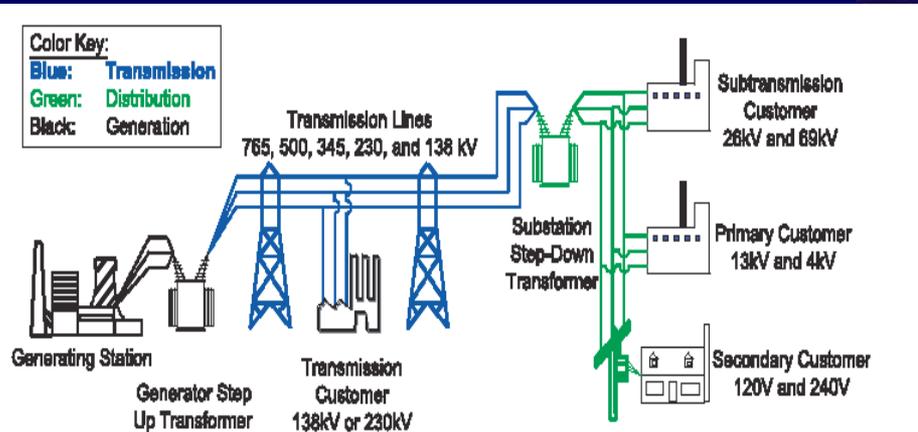
NERC Interconnections

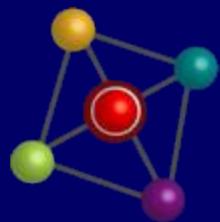




TxCEE

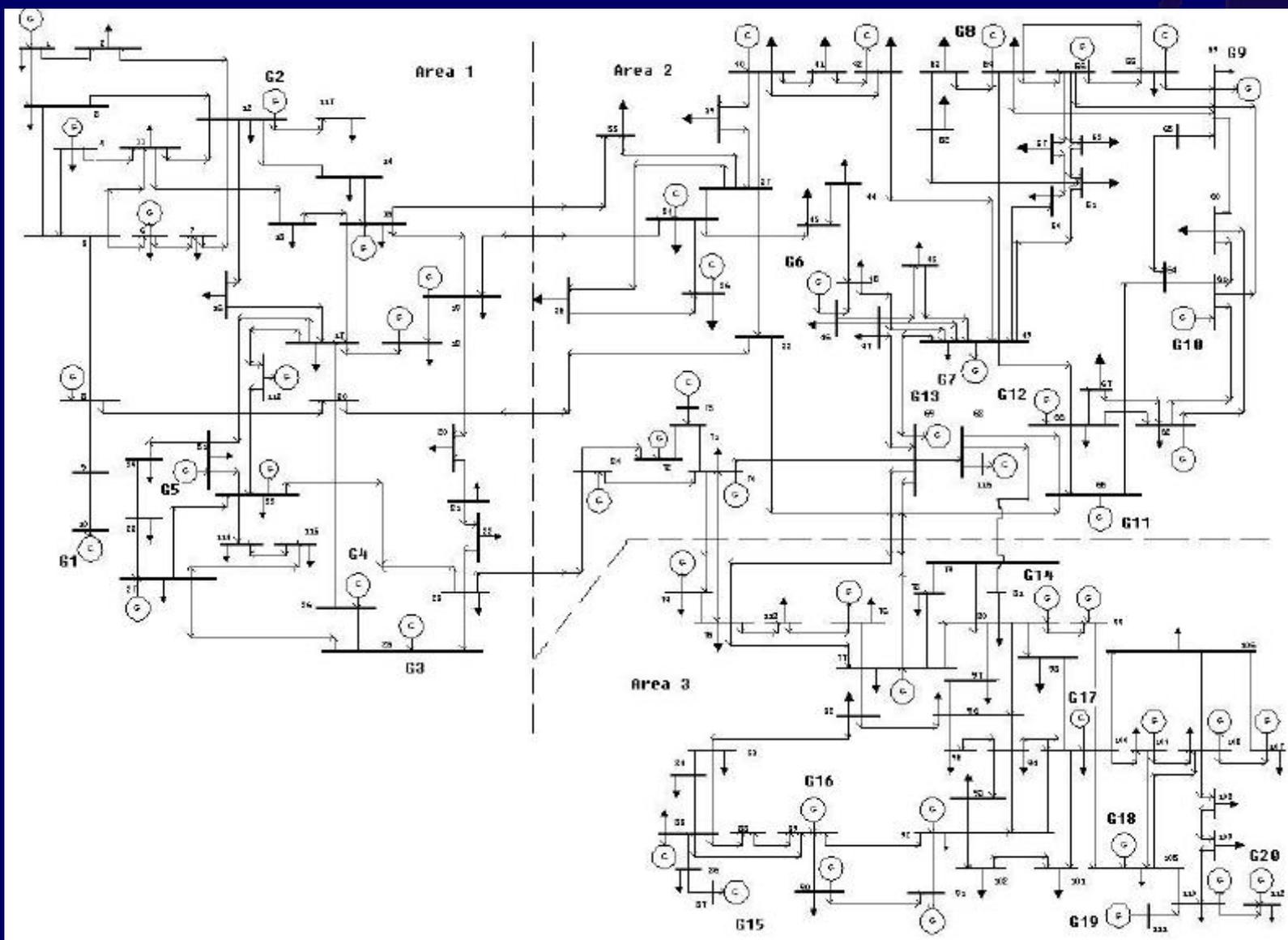
Power System Layout

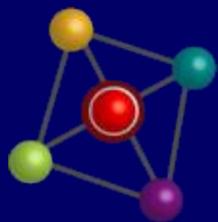




TxCEE

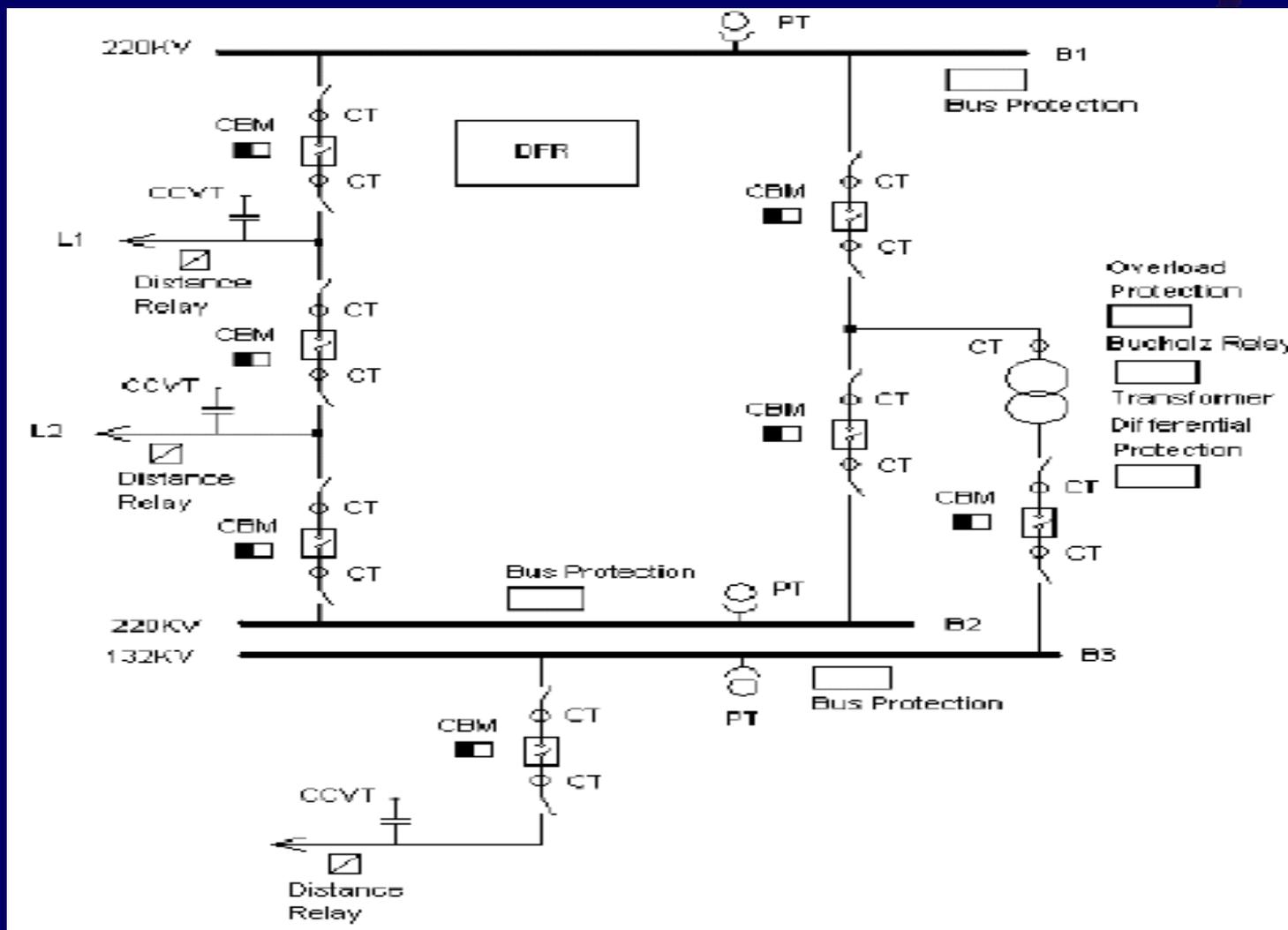
118-bus system

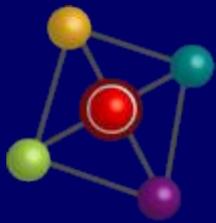




TxCEE

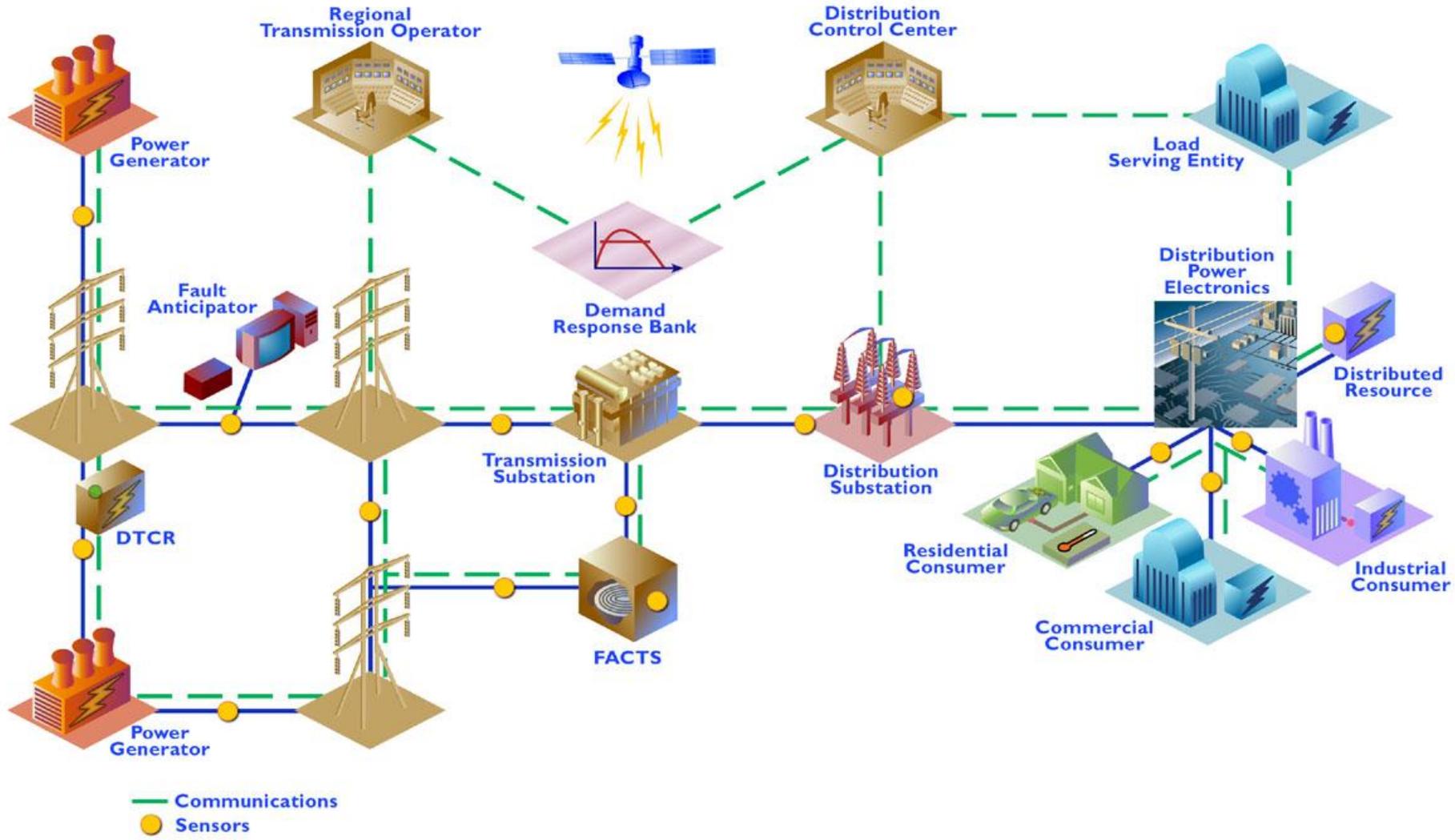
Substation Layout





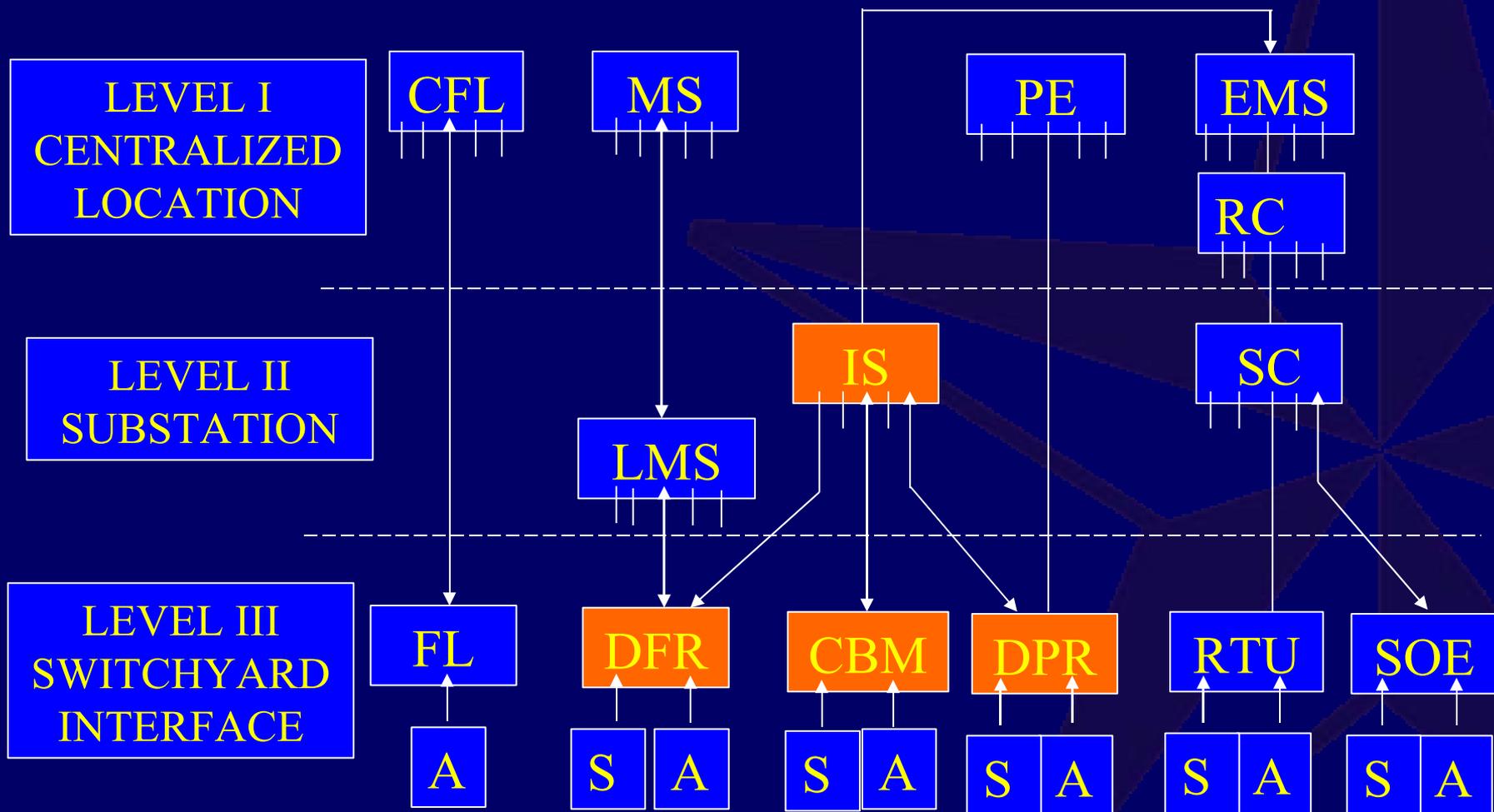
TxCEE

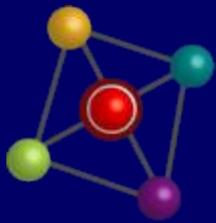
IT layout





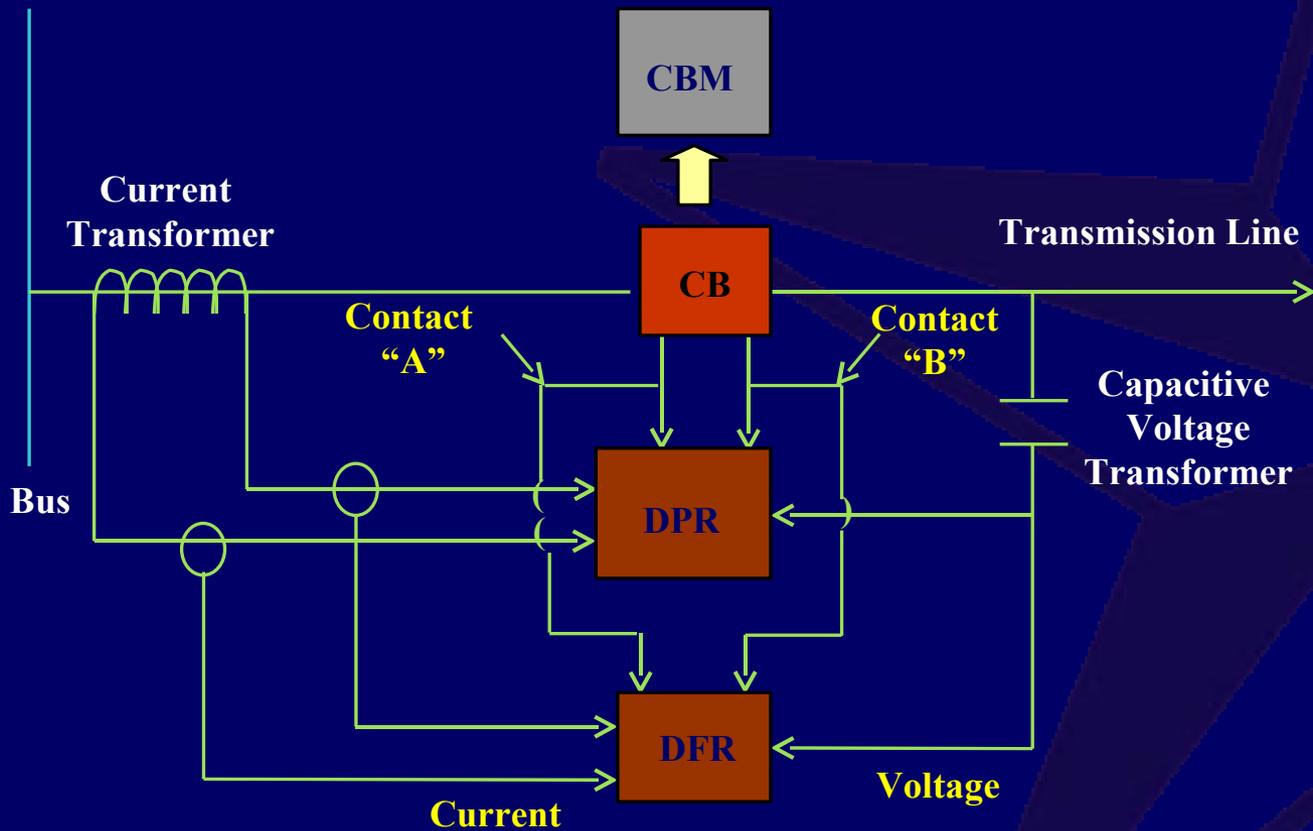
Integration of operational and non-operational data





TxCEE

Benefits

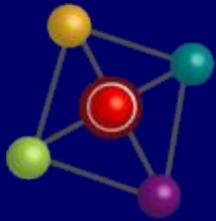




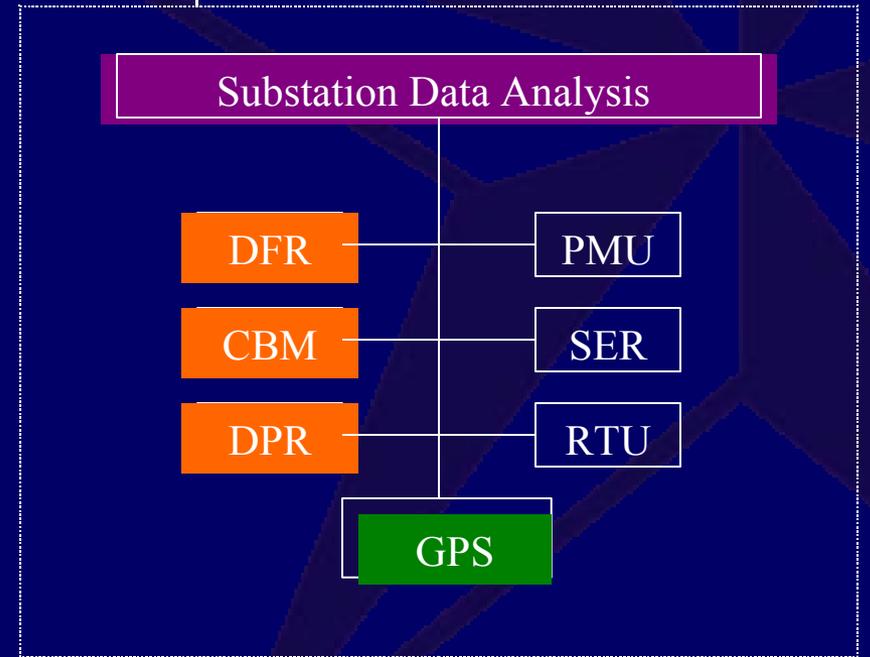
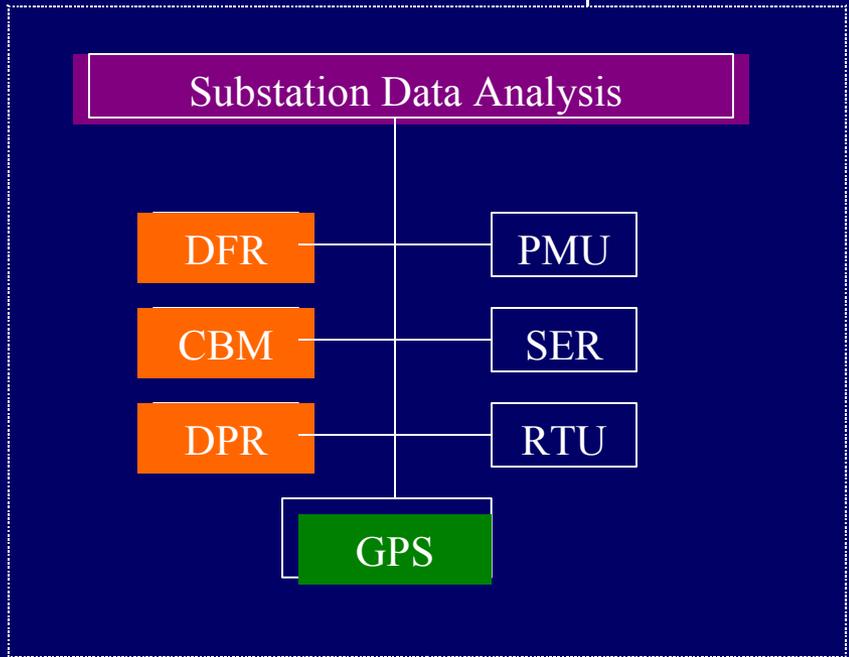
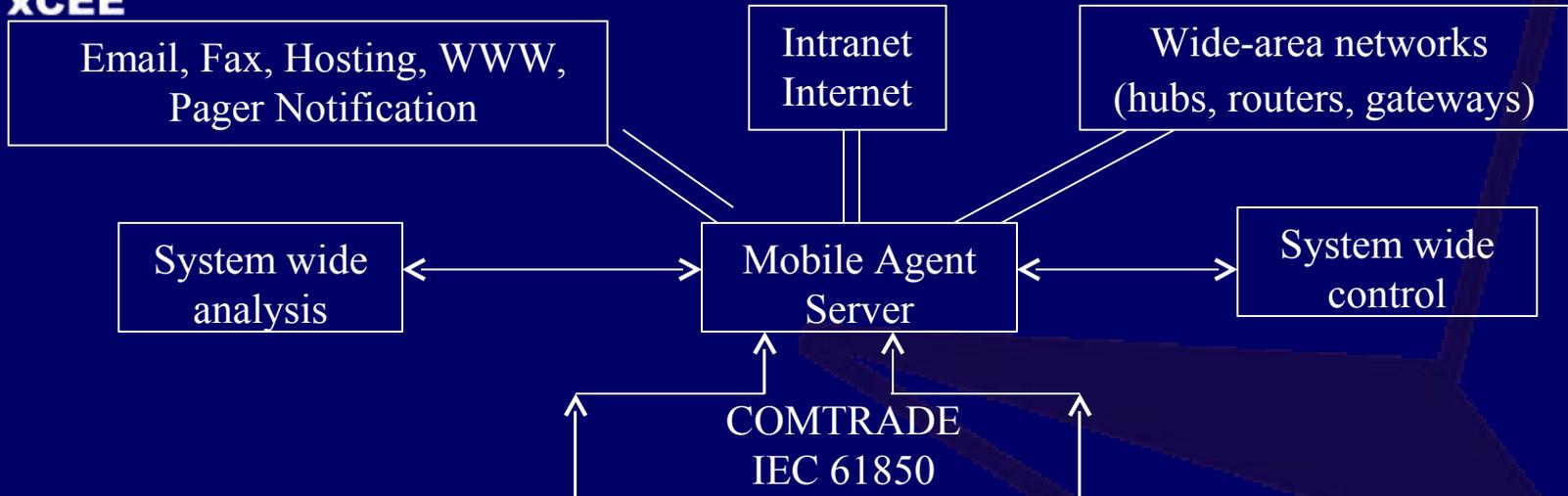
Outline



- Introduction
- Background: Operational VS Non-operational Data
- **New Concept:** Transparent Data
- New Solutions: Different utility groups
- Examples: Demonstration Project
- Conclusions

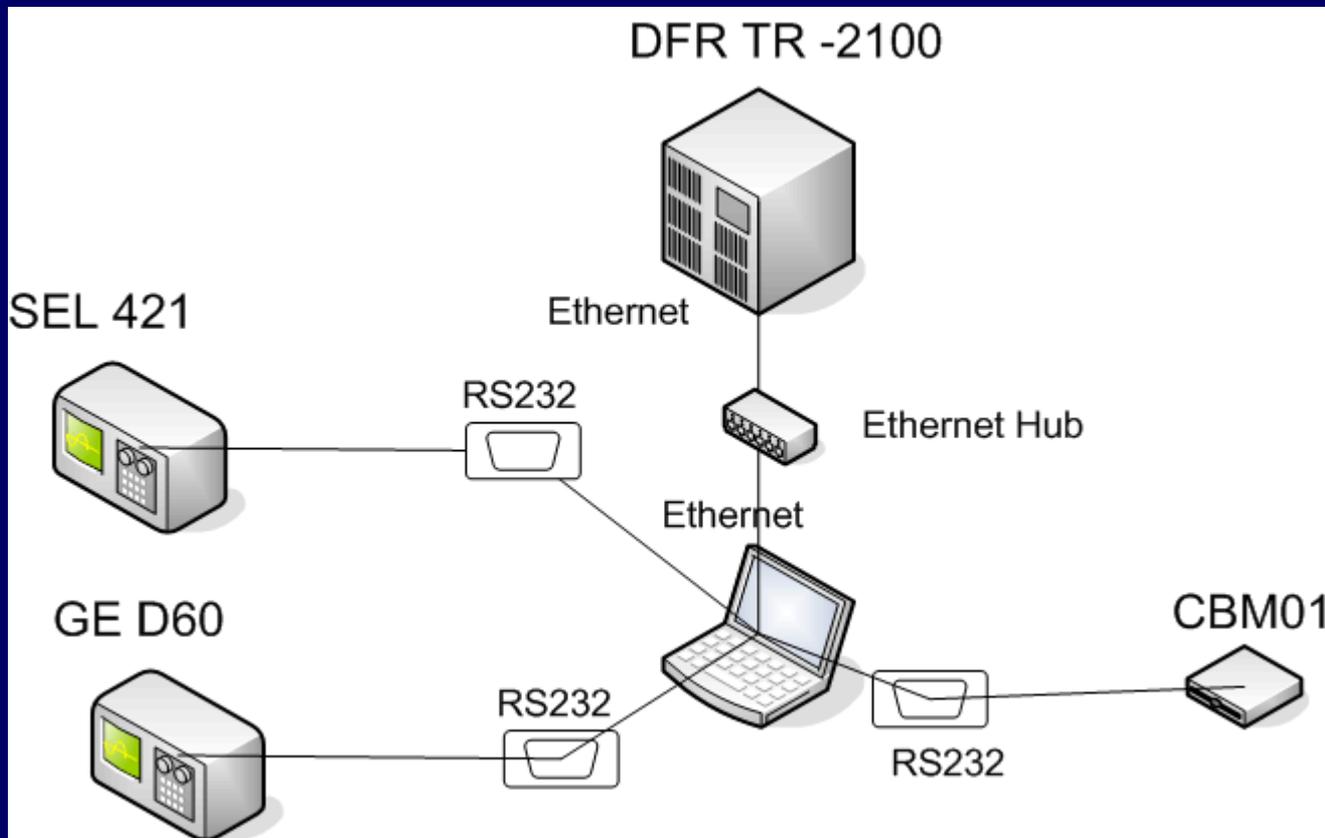


TxCEE

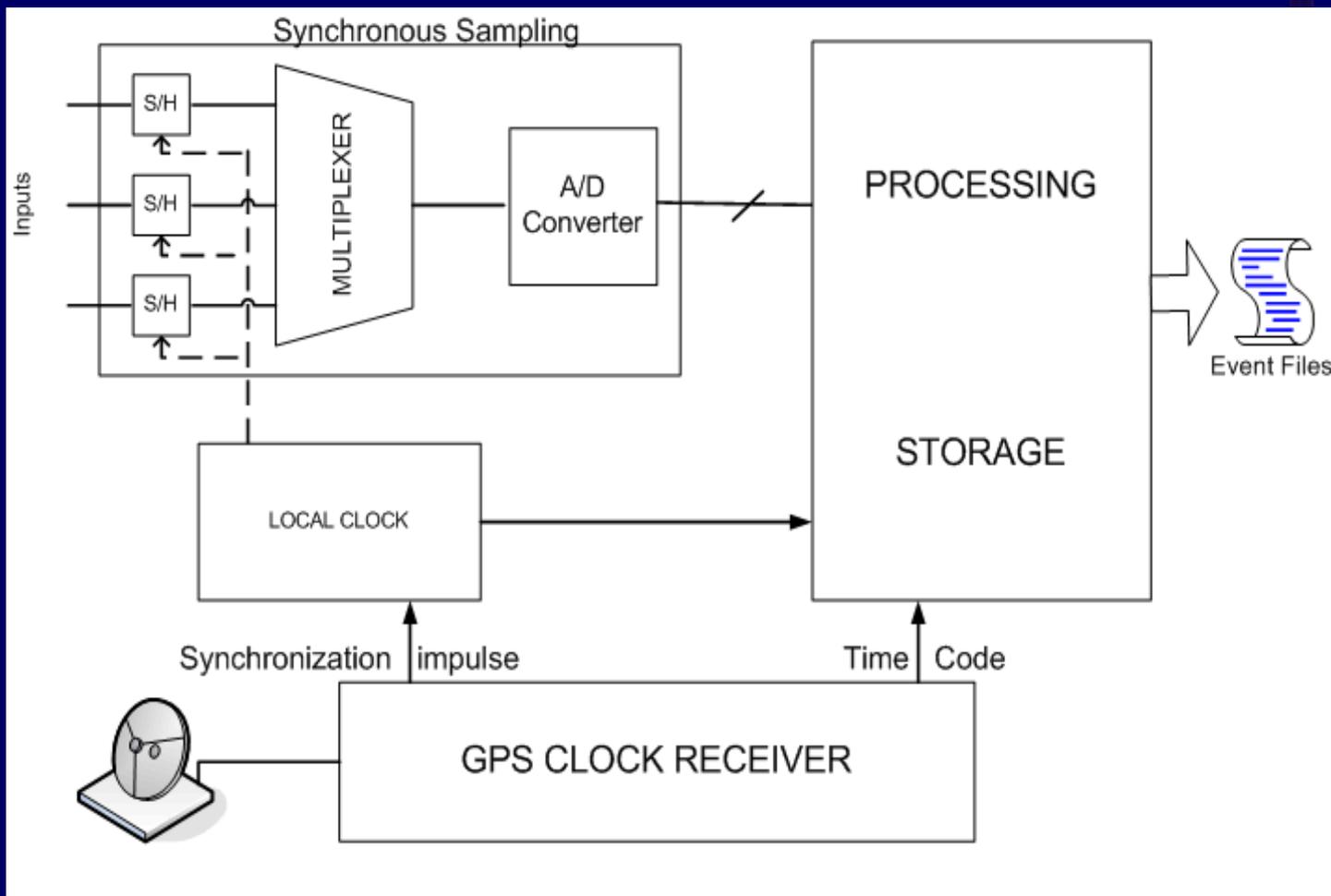




IED connections

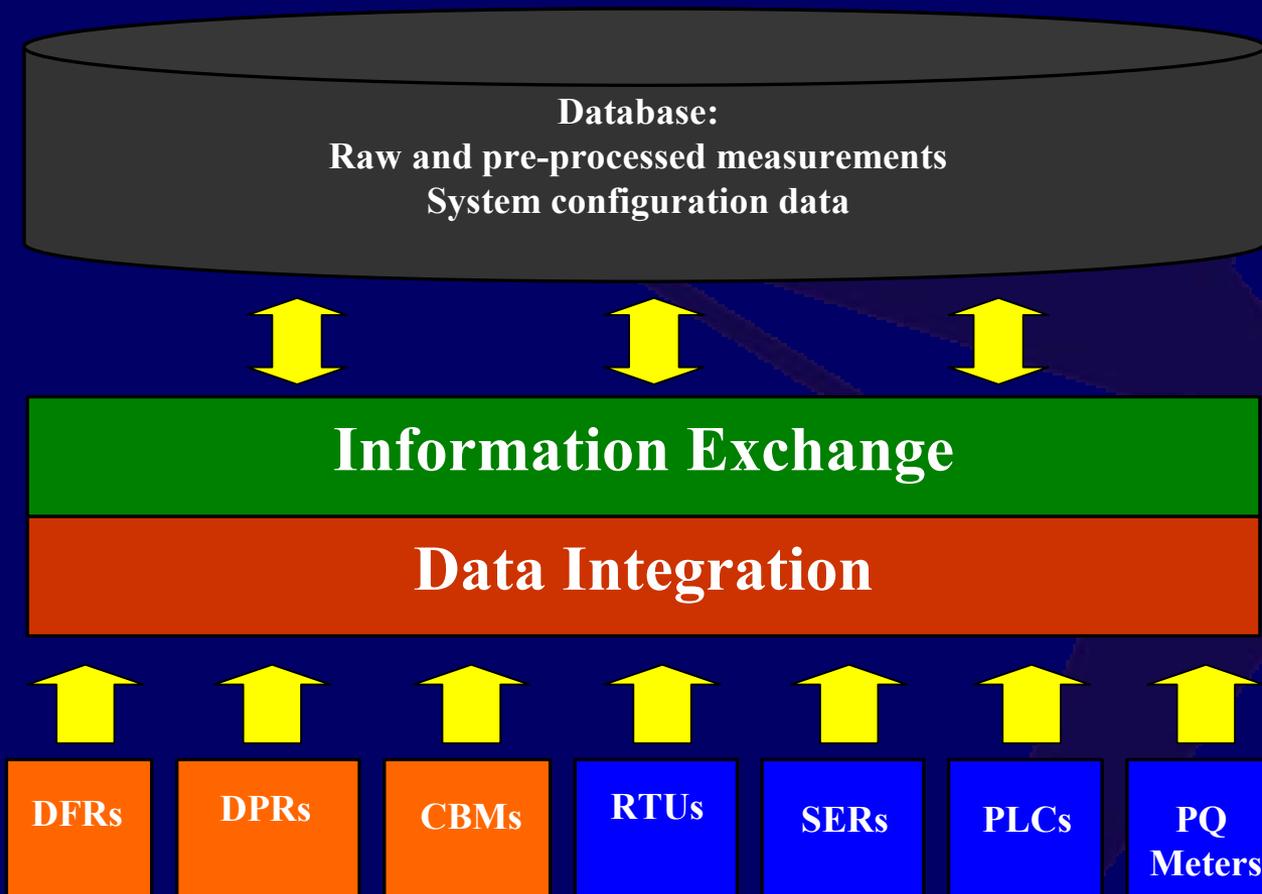


Synchronized Sampling





Data Integration

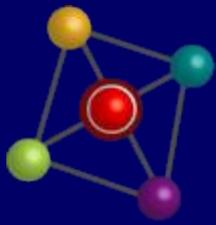




Outline



- Introduction
- Background: Operational VS Non-operational Data
- New Concept: Transparent Data
- **New Solutions:** Different utility groups
- Examples: Demonstration Project
- Conclusions



TxCEE

Multiple uses of data



Protection Group



Comprehensive Report

Operator

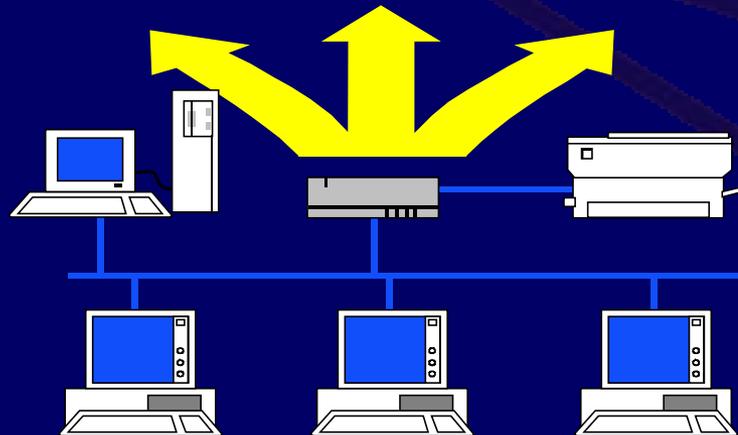


Brief Report

Maintenance



Summary Report





Outline

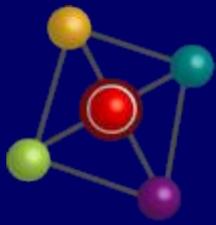


- Introduction
- Background: Operational VS Non-operational Data
- New Concept: Transparent Data
- New Solutions: Different utility groups
- **Examples:** Demonstration Project
- Conclusions



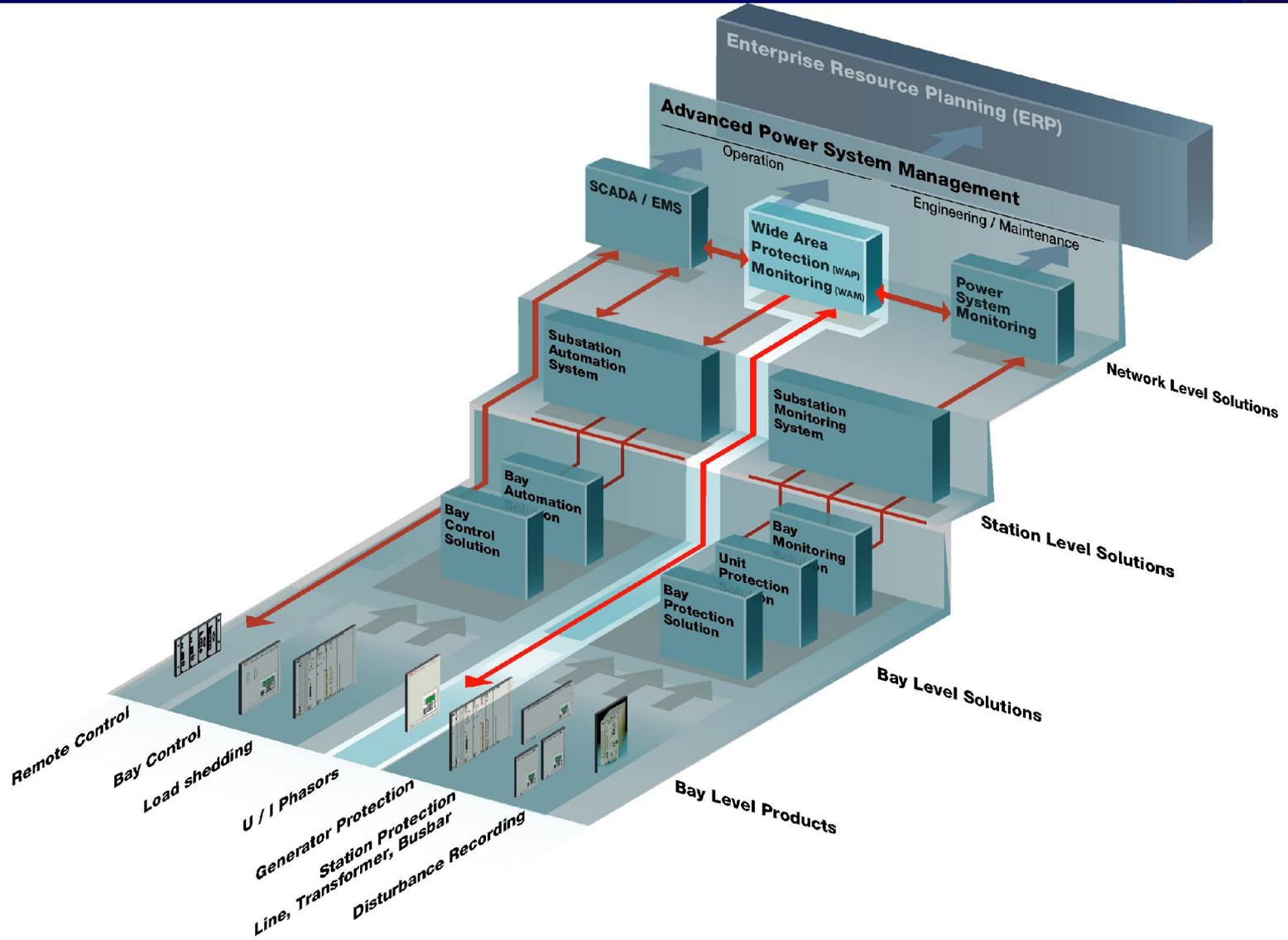
Demonstration Projects

- Data Acquisition and processing
 - All-digital protection system
 - Automated topology processing
 - Transient testing of substation systems
- Data Integration and Information Extraction
 - Automated substation processing
 - Enterprise-wide applications
- Information Presentation
 - Models
 - Physical images



TxCEE

Existing solutions

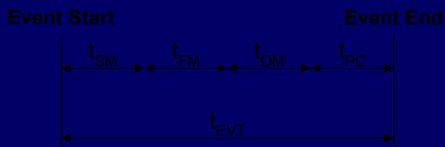
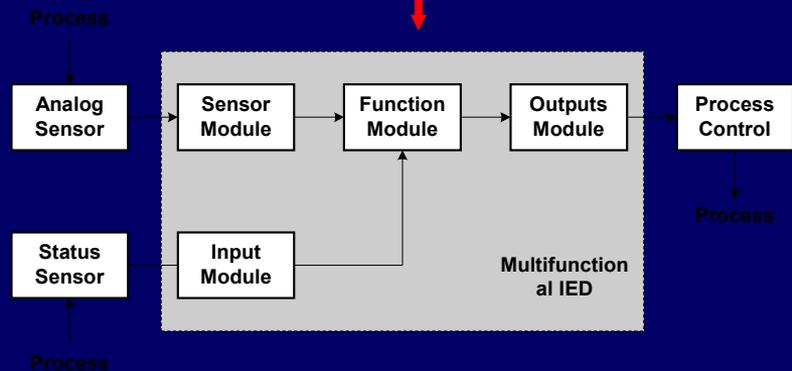
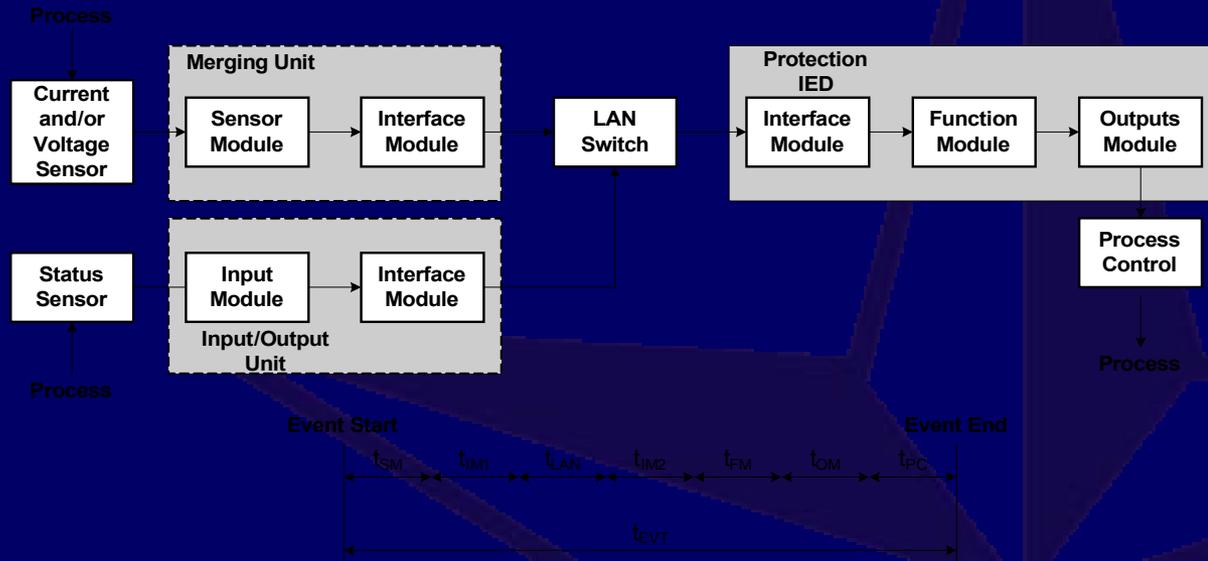




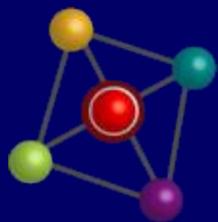
New Versus Existing solution



- Existing Solution: analog current and voltage signals are supplied to IED
- Field signals are brought into control house via standard copper wires

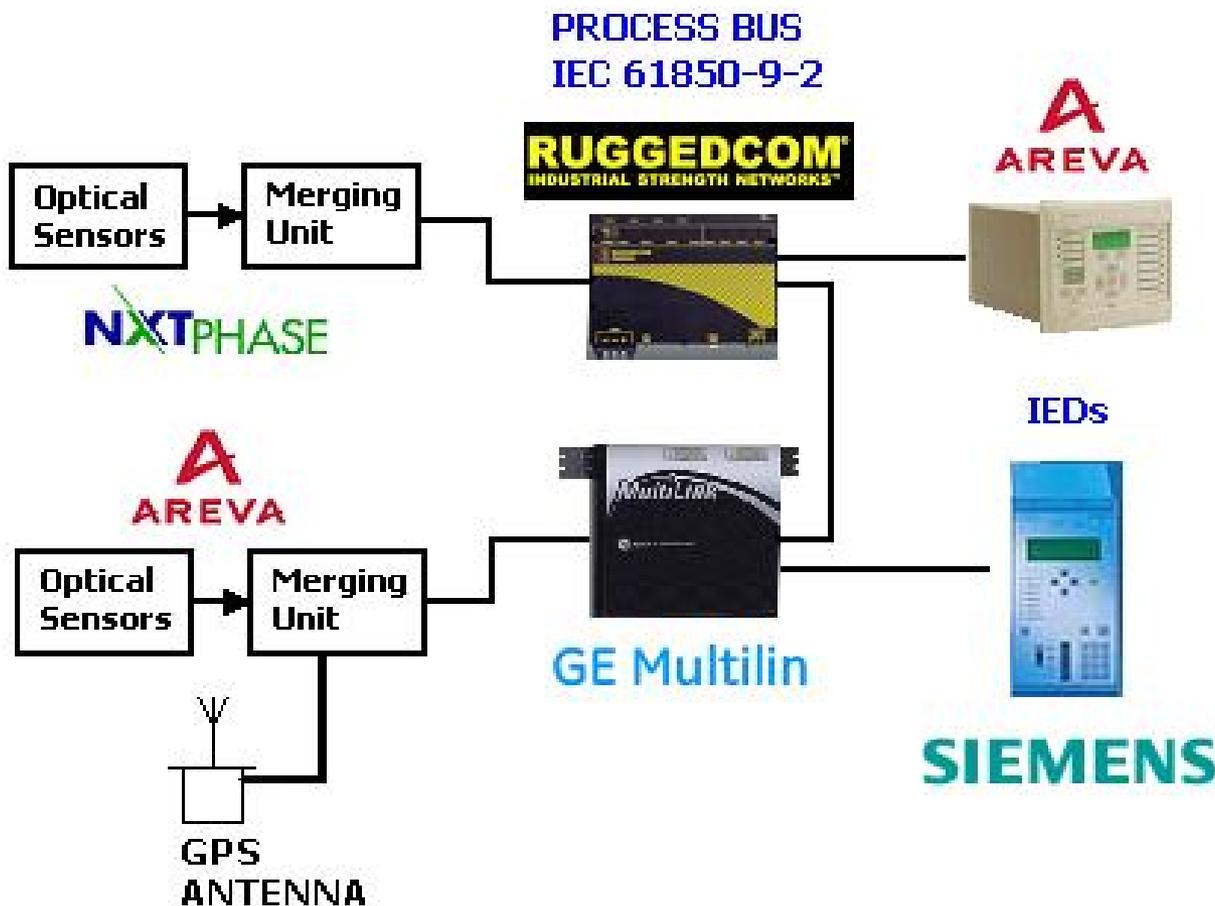


- New solution: digital current and voltage samples are supplied to IED via the substation LAN. It requires Interface Modules in MU and IED
- Field signals are brought in to control house via process bus

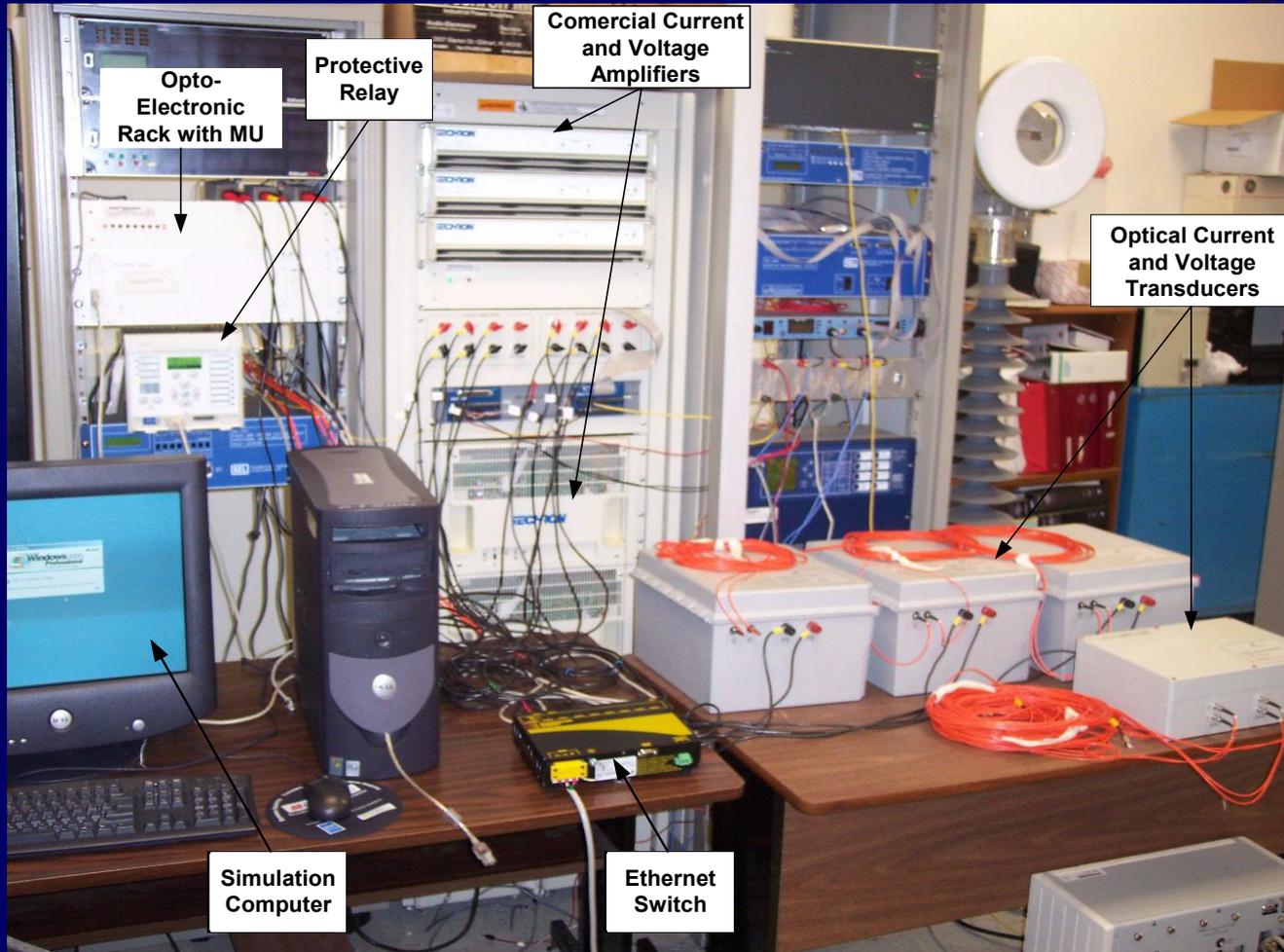


TxCEE

All-digital system



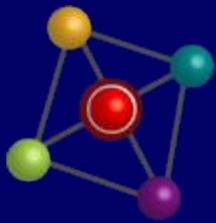
Modeling, simulation and lab tests





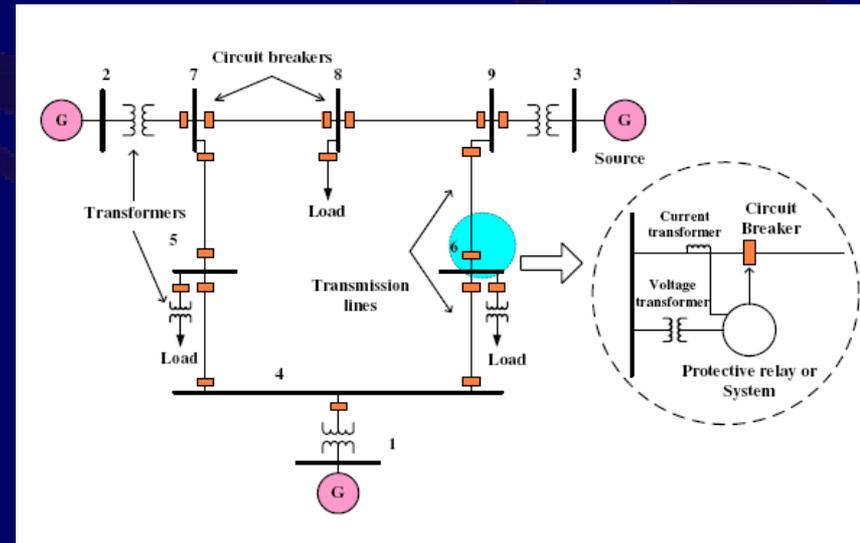
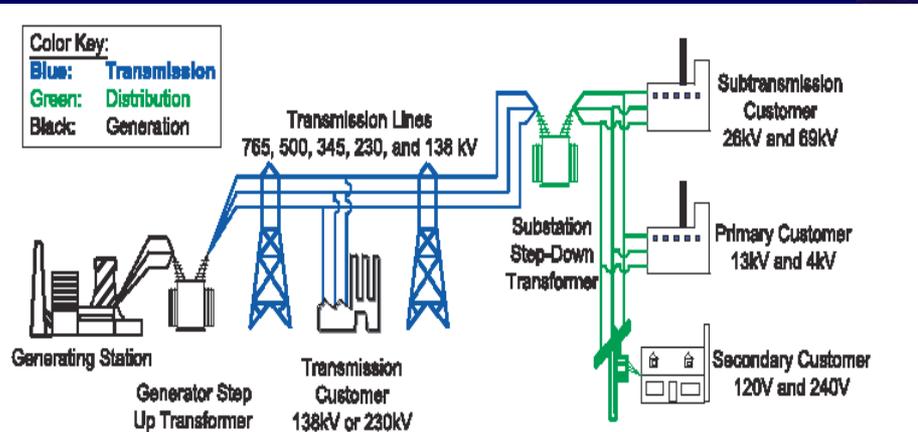
Demonstration Projects

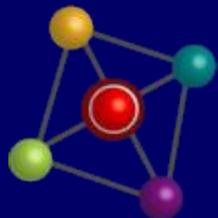
- Data Acquisition and processing
 - All-digital protection system
 - **Automated topology processing**
 - Transient testing of substation systems
- Data Integration and Information Extraction
 - Automated substation processing
 - Enterprise-wide applications
- Information Presentation
 - Models
 - Physical images



TxCEE

Power System Layout

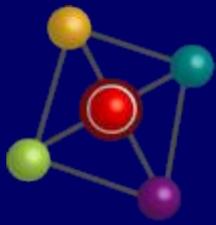




TxCEE

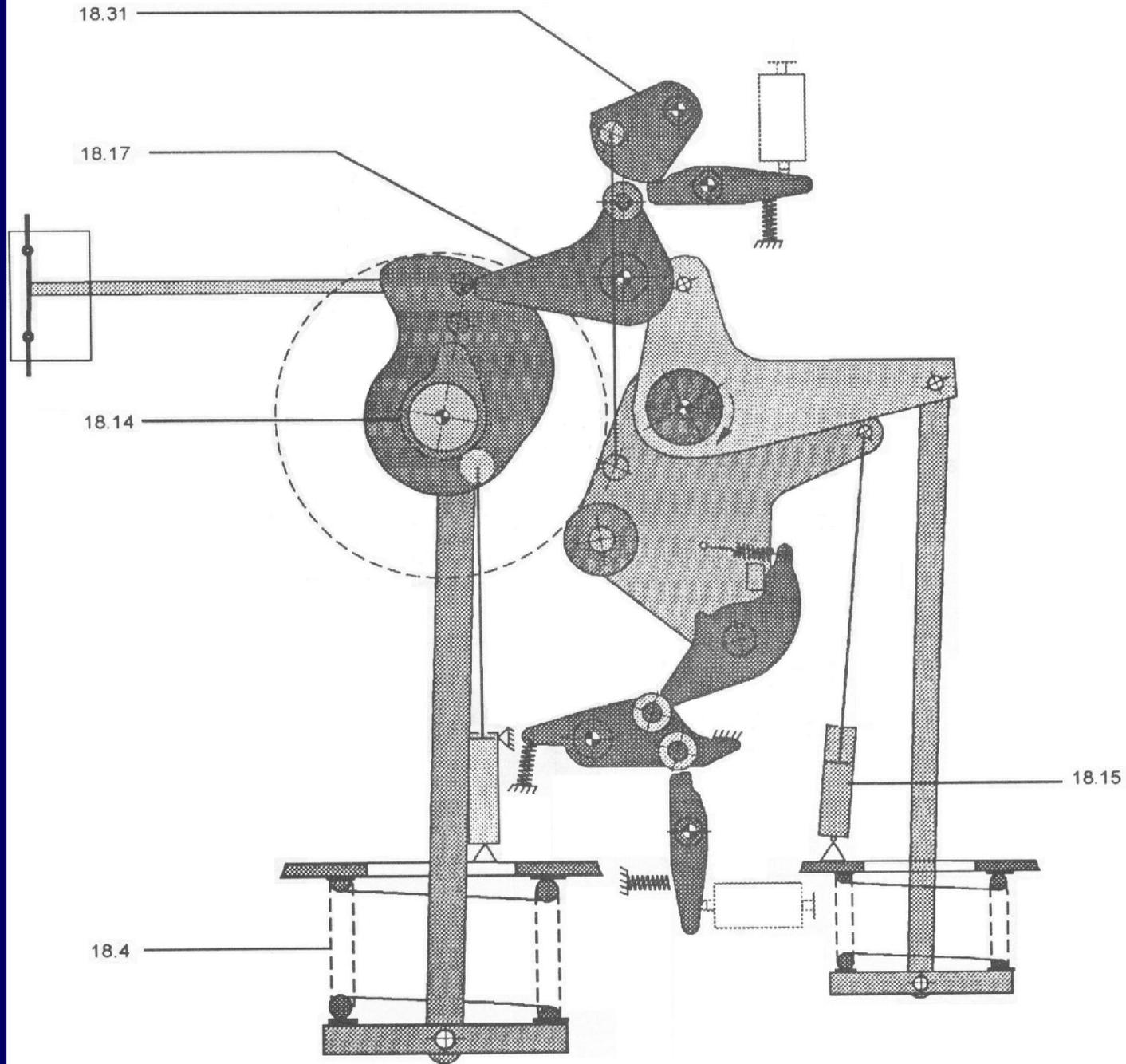
Circuit Breaker

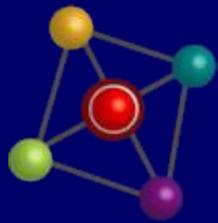




TxCEE

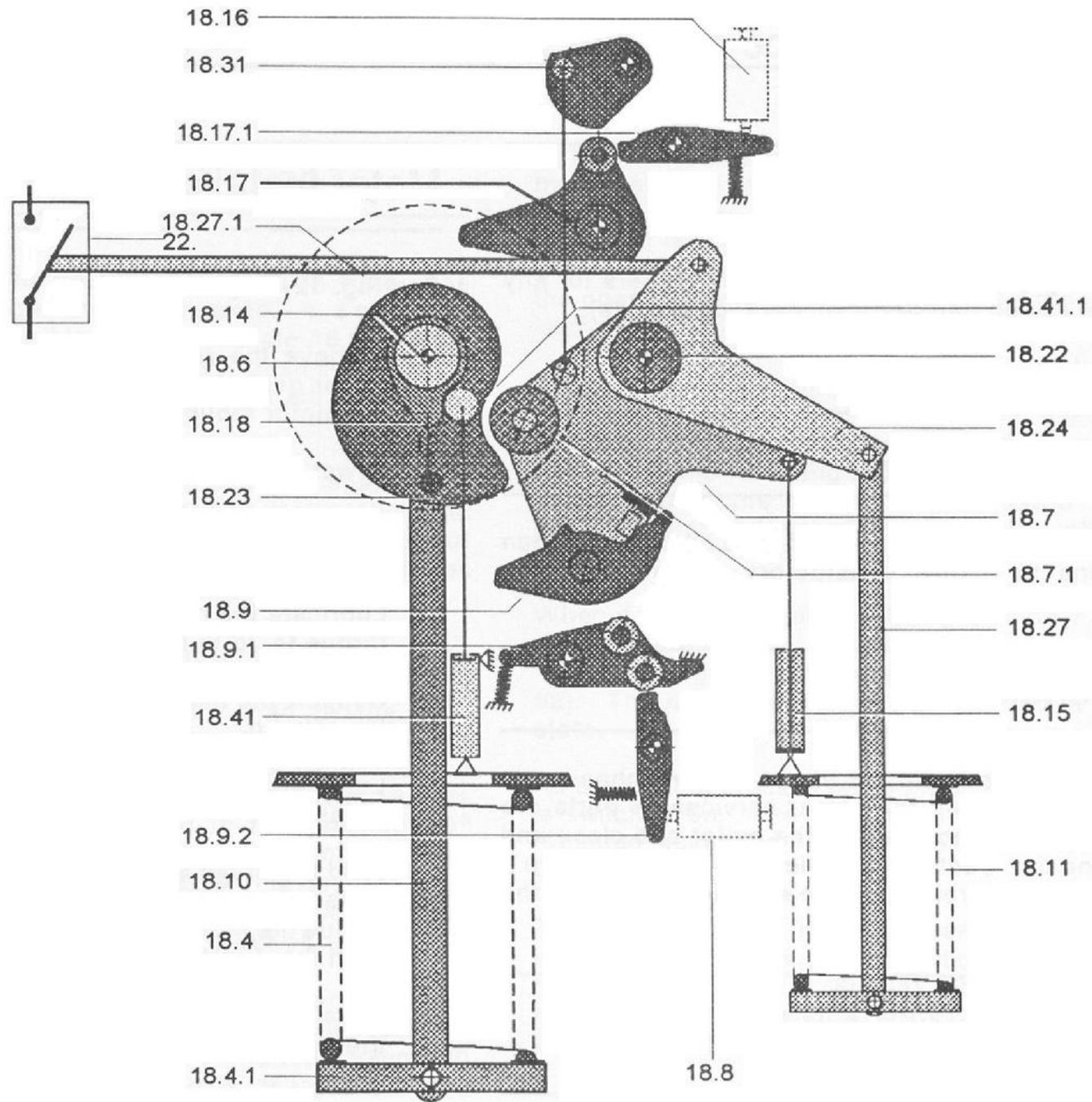
*Mechanical Structure
(Closed State)*

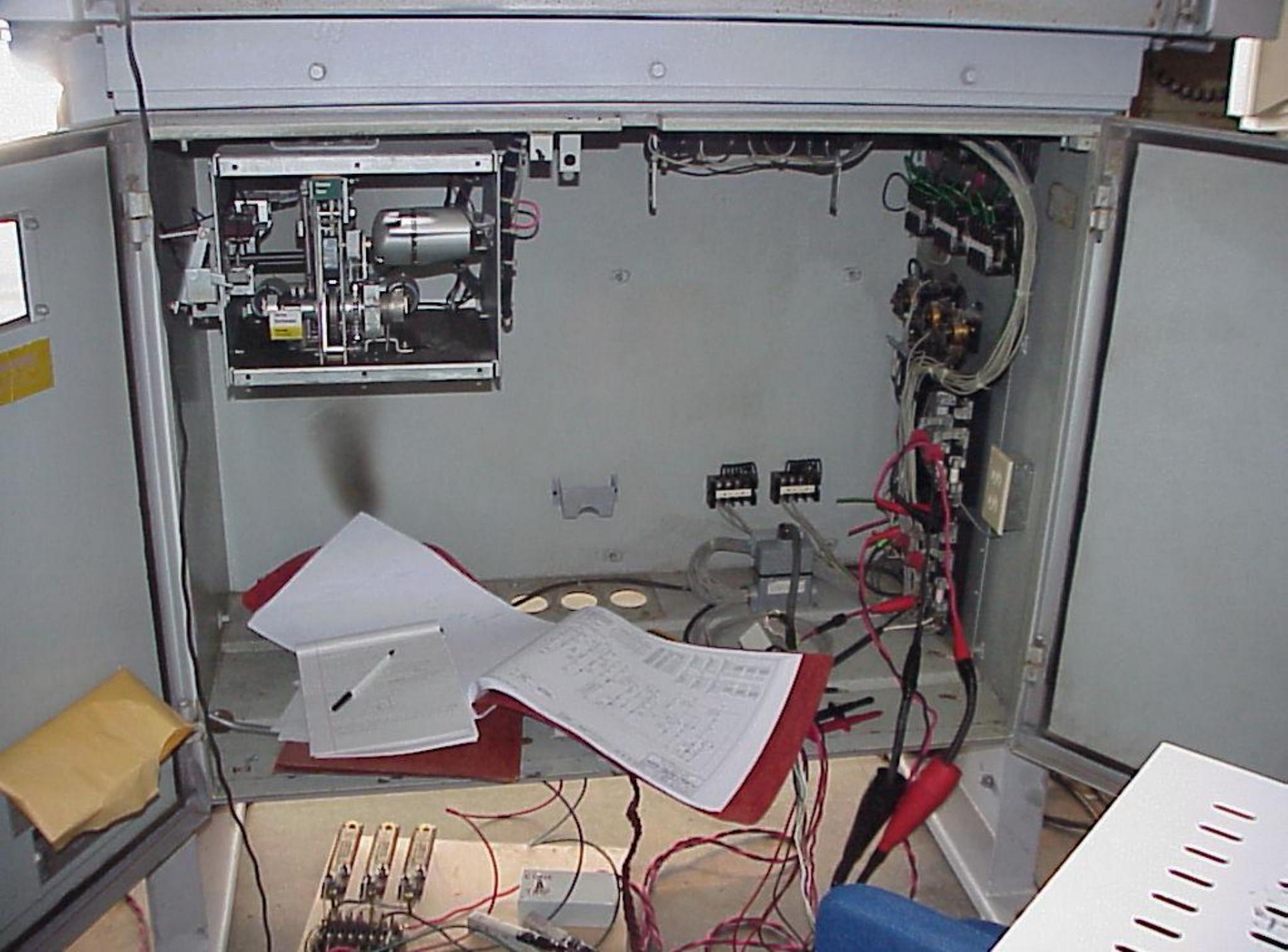




TxCEE

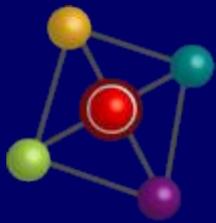
Mechanical Structure (Open State)





Performance Characteristics

| SIGNAL TYPE | WAVEFORMS | |
|------------------------------|--|---|
| | Circuit Breaker OPEN Operation | Circuit Breaker CLOSE Operation |
| Trip and Close Initiates |  |  |
| A and B Contacts |  |  |
| Trip and Close Coil Currents |  |  |
| X and Y Coils | None |  |
| Phase Currents |  |  |
| DC Voltages |  |  |

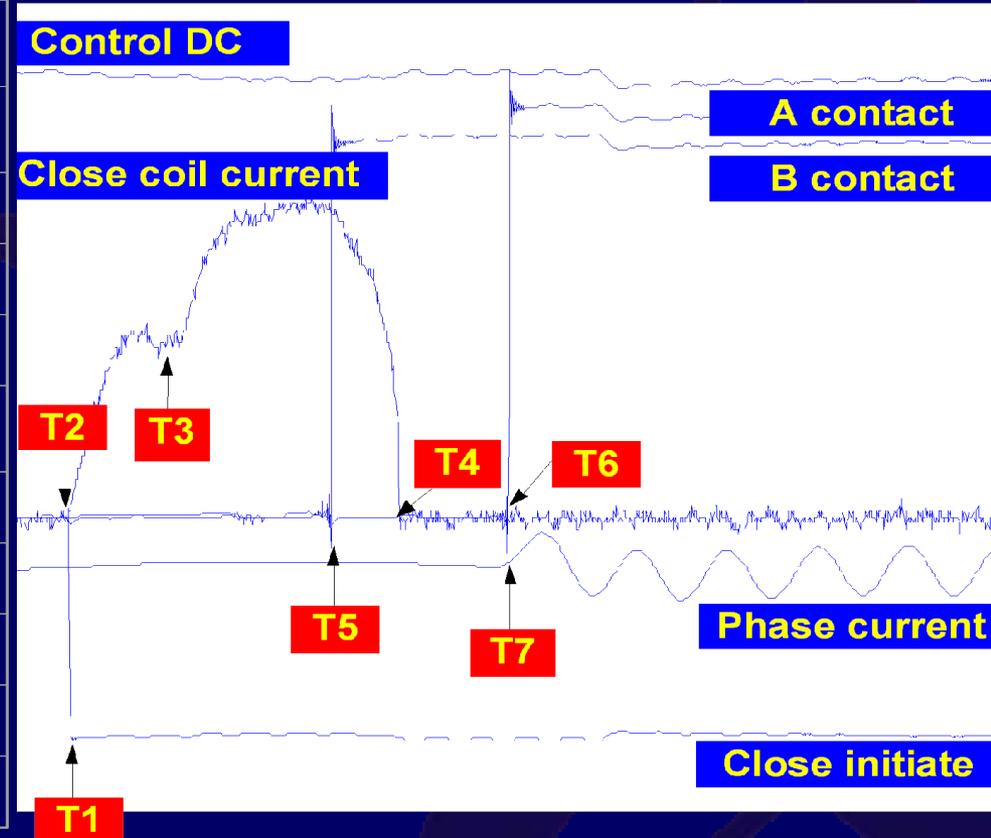


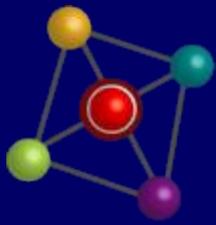
TxCEE

Time Parameters



| Event # | Event Description | Time |
|---------|--------------------------------------|------|
| 1 | Trip or close operation is initiated | T1 |
| 2 | Coil current picks up | T2 |
| 3 | Coil current dips after saturation | T3 |
| 4 | Coil current begins to drop | T4 |
| 5 | B contact breaks or makes | T5 |
| 6 | A contact breaks or makes | T6 |
| 7 | Phase currents breaks or makes | T7 |
| 8 | X coil current picks up | T8 |
| 9 | X coil current drops out | T9 |
| 10 | Y coil current picks up | T10 |

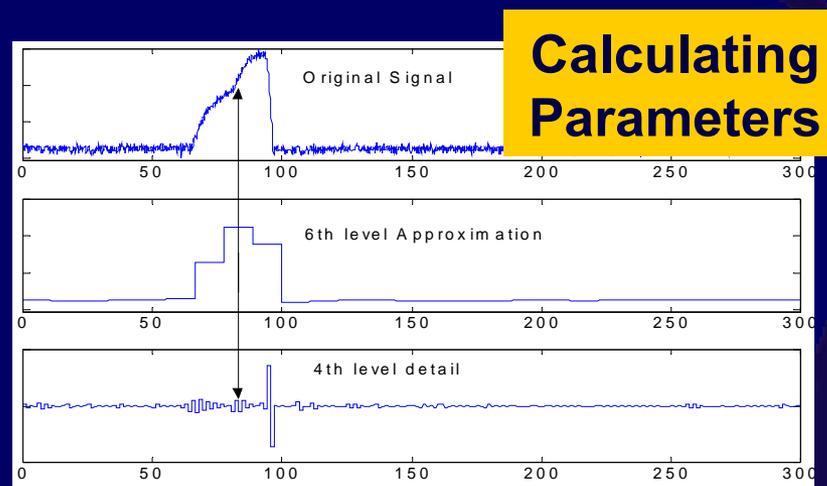
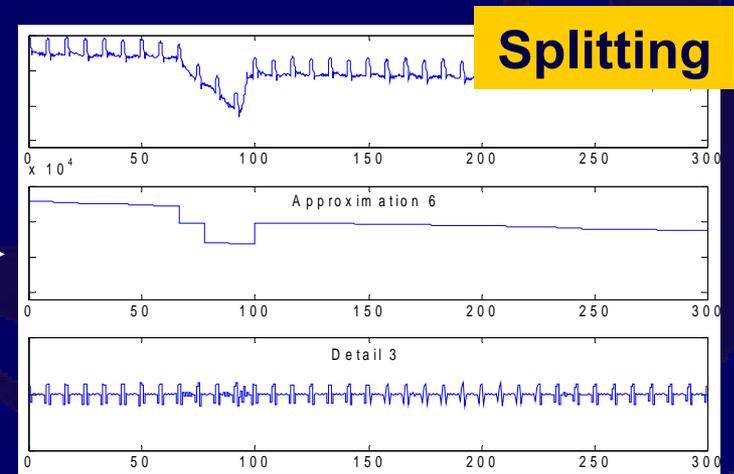
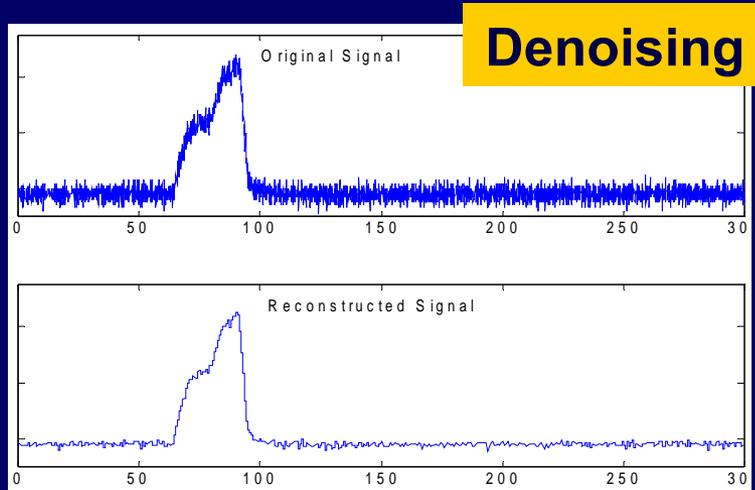




TxCEE



Feature Extraction

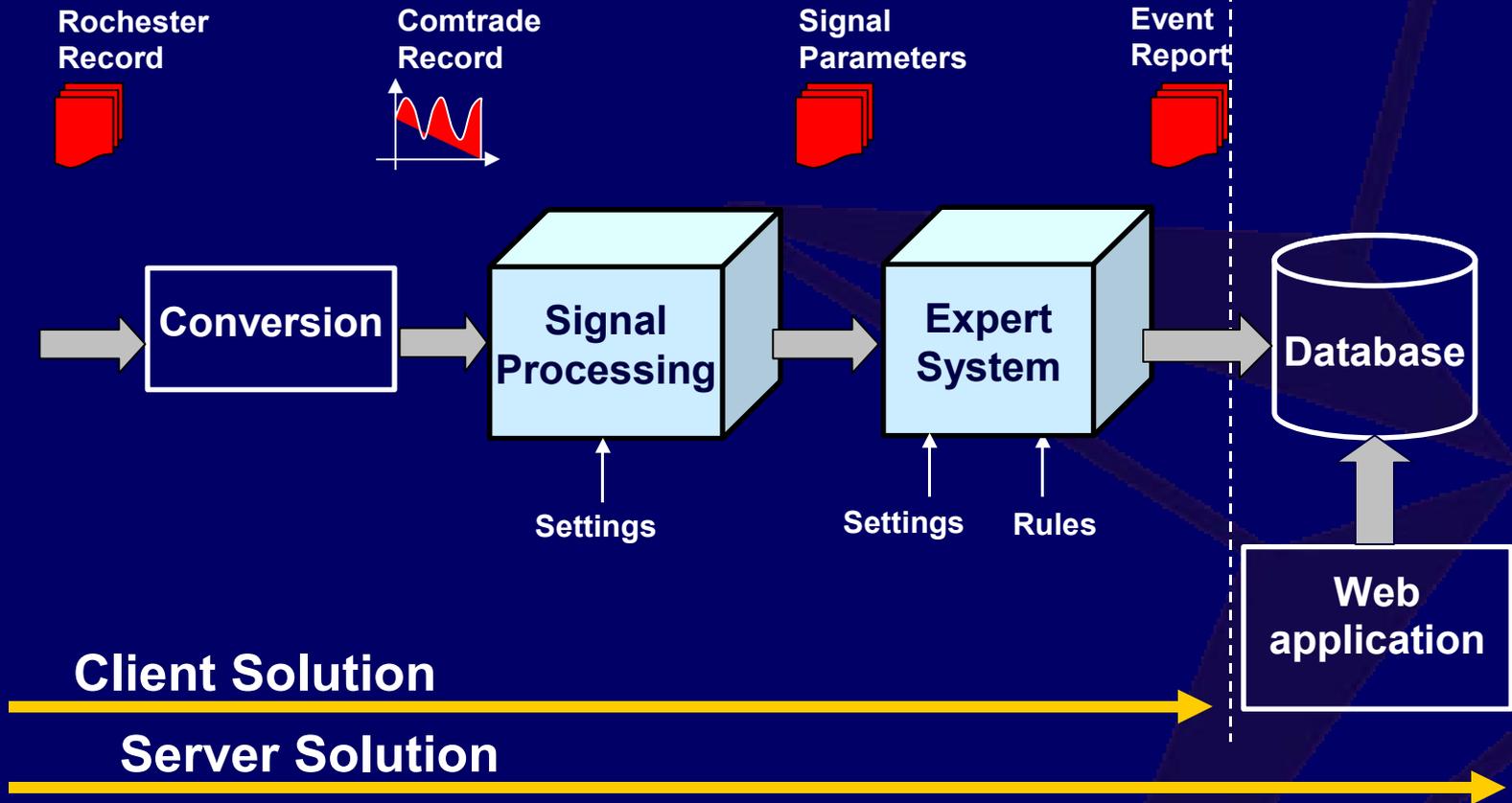


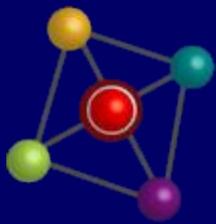


TxCEE



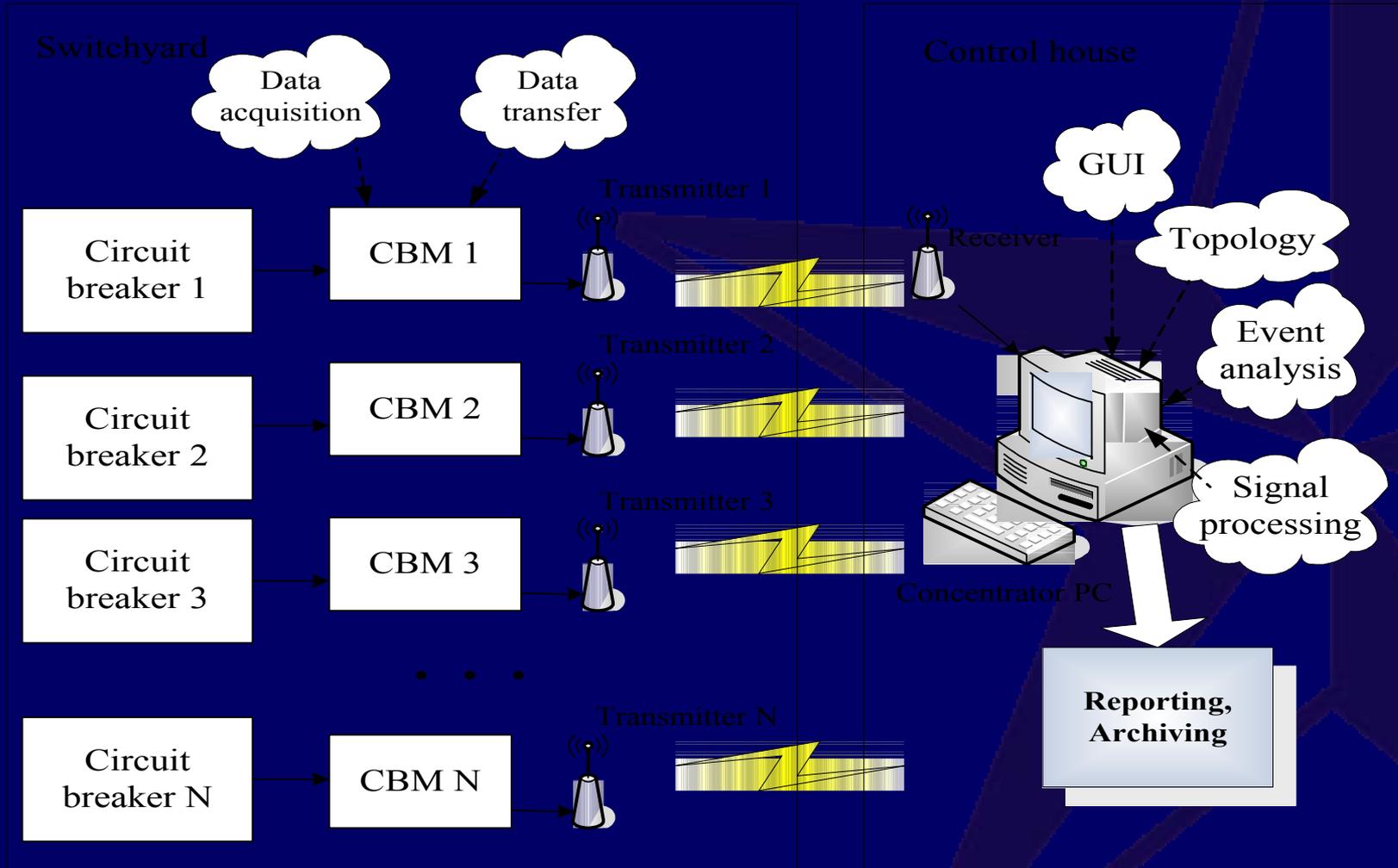
Functional Description

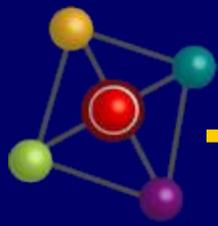




TxCEE

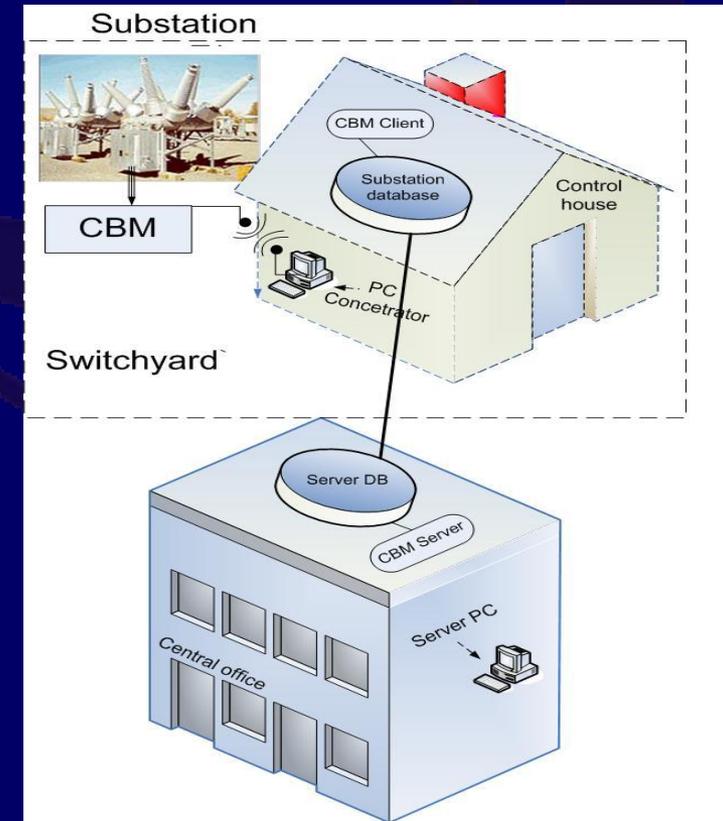
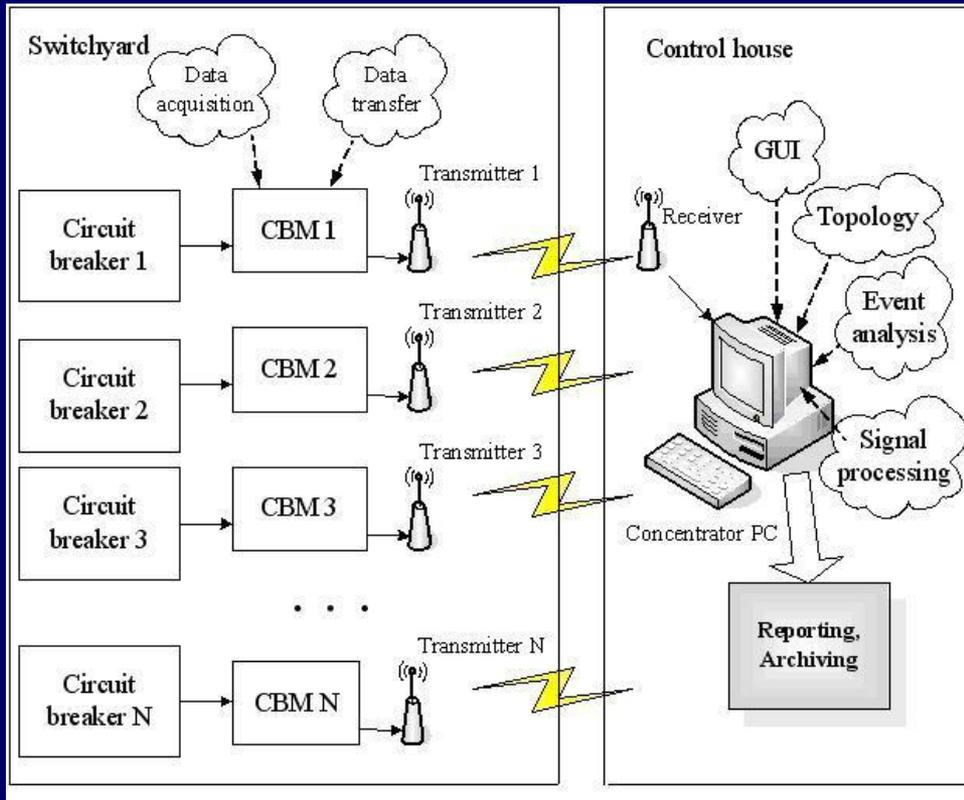
Topology processing





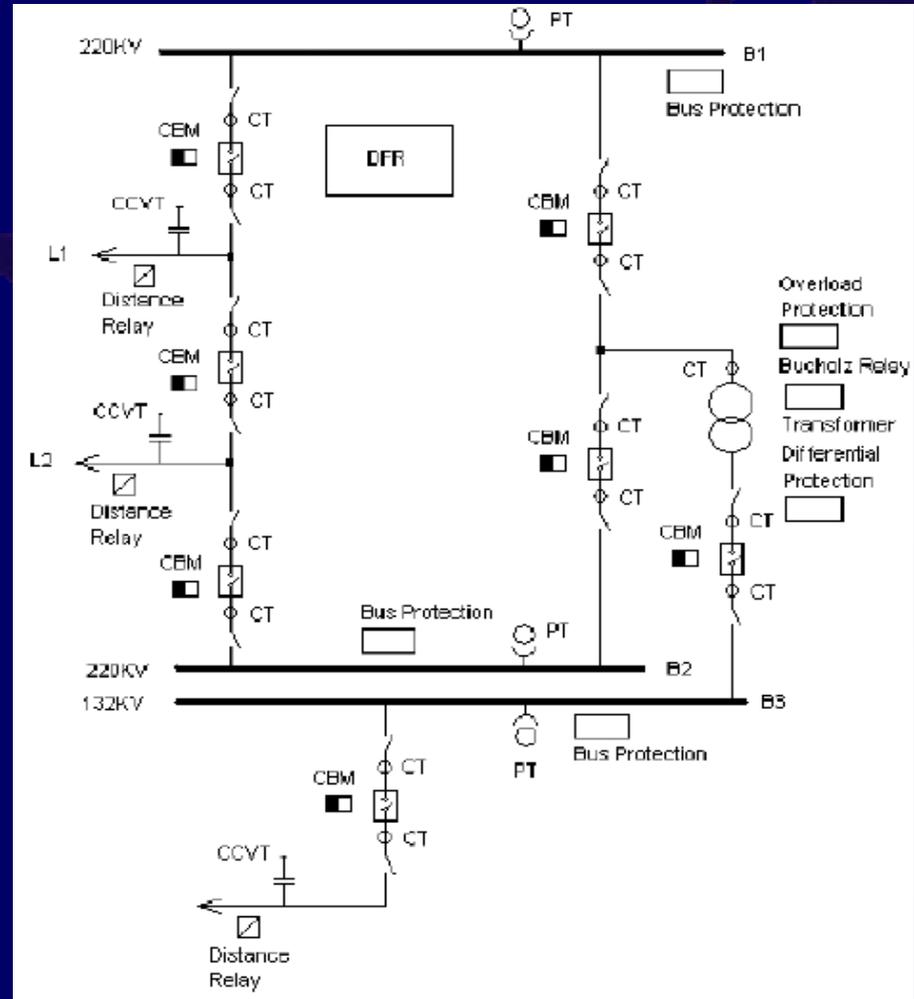
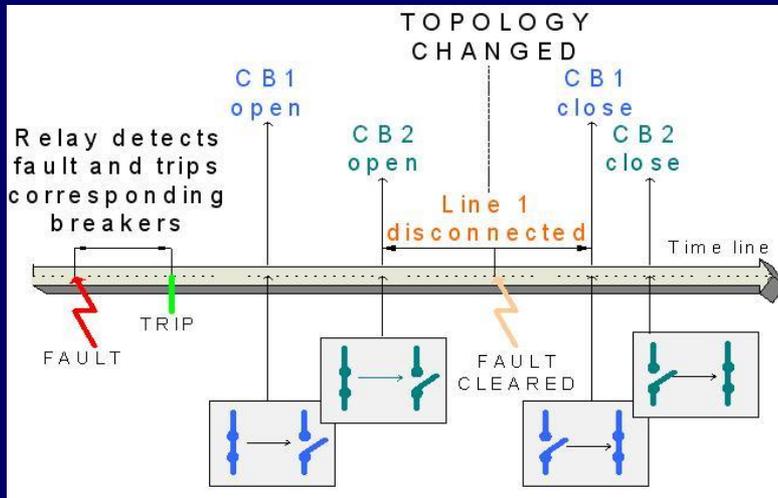
TxCEE

Topology Monitoring





Software – Sequence Analysis





Demonstration Projects

- Data Acquisition and processing
 - All-digital protection system
 - Automated topology processing
 - **Transient testing of substation systems**
- Data Integration and Information Extraction
 - Automated substation processing
 - Enterprise-wide applications
- Information Presentation
 - Models
 - Physical images



New methods for relay testing



Test Sets



- Portable/Field
- Lab

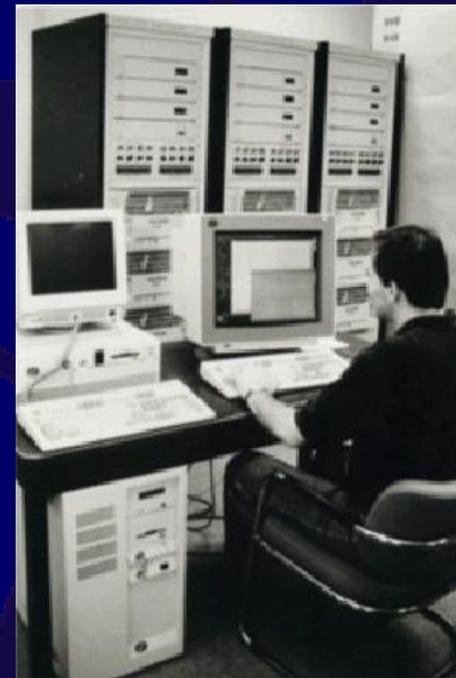
Open-Loop Solutions



New

- Lab
- Portable/Field
- **Permanent**/Field

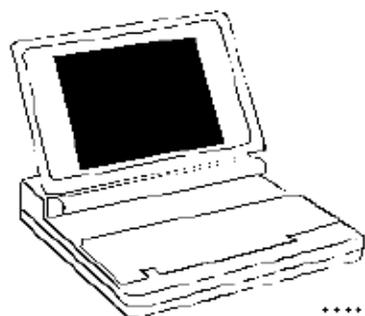
Real-Time Solutions



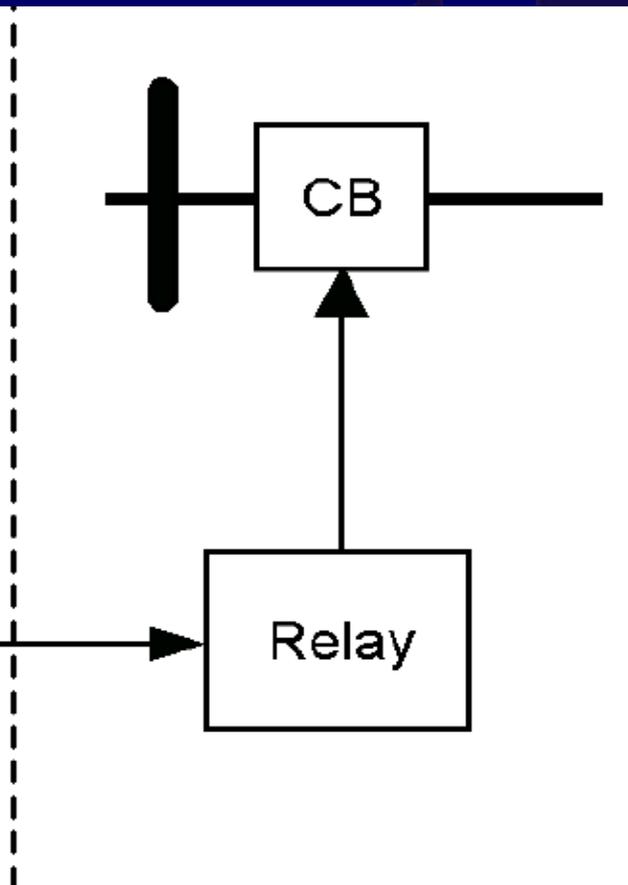
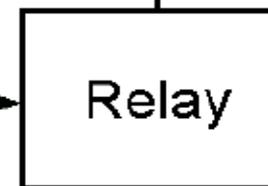
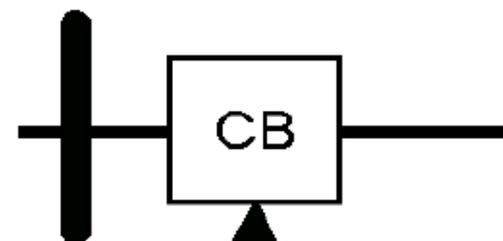
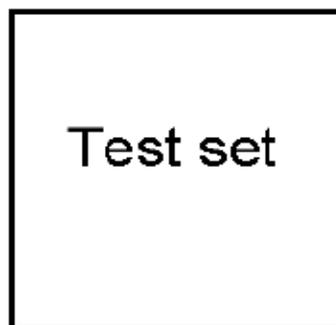
- Lab only

Field Portable Setup

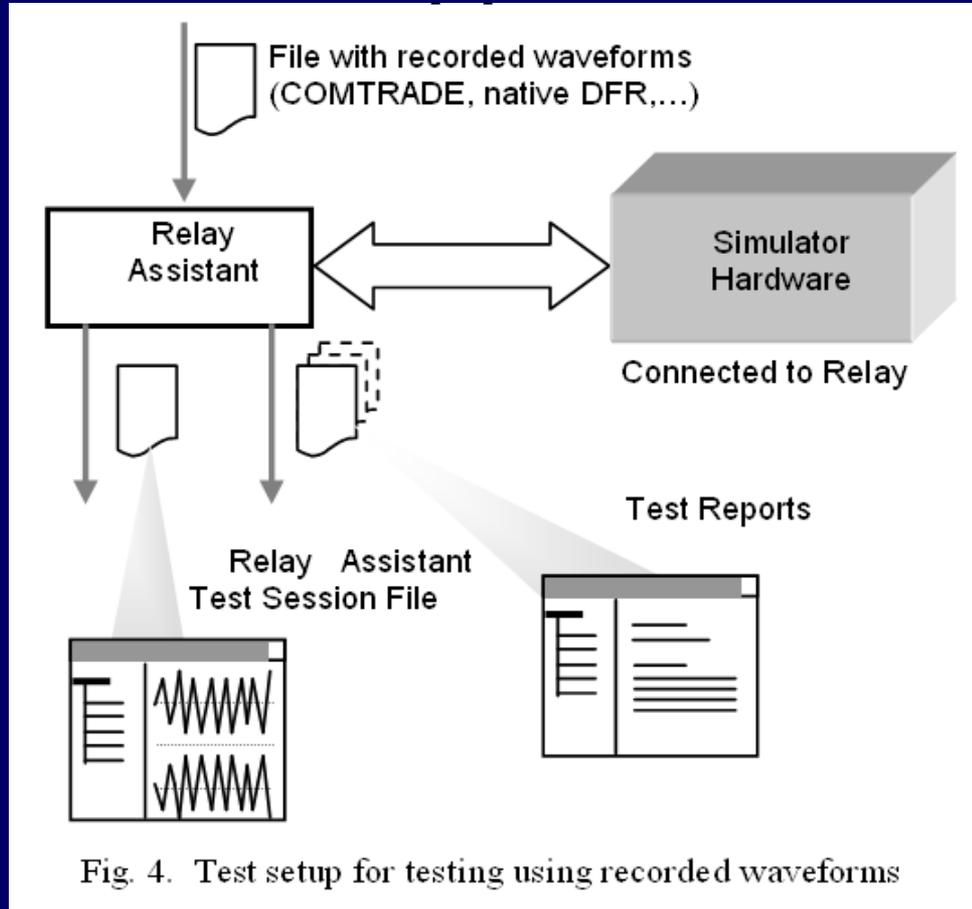
- Phasor Testing
- Fault playback



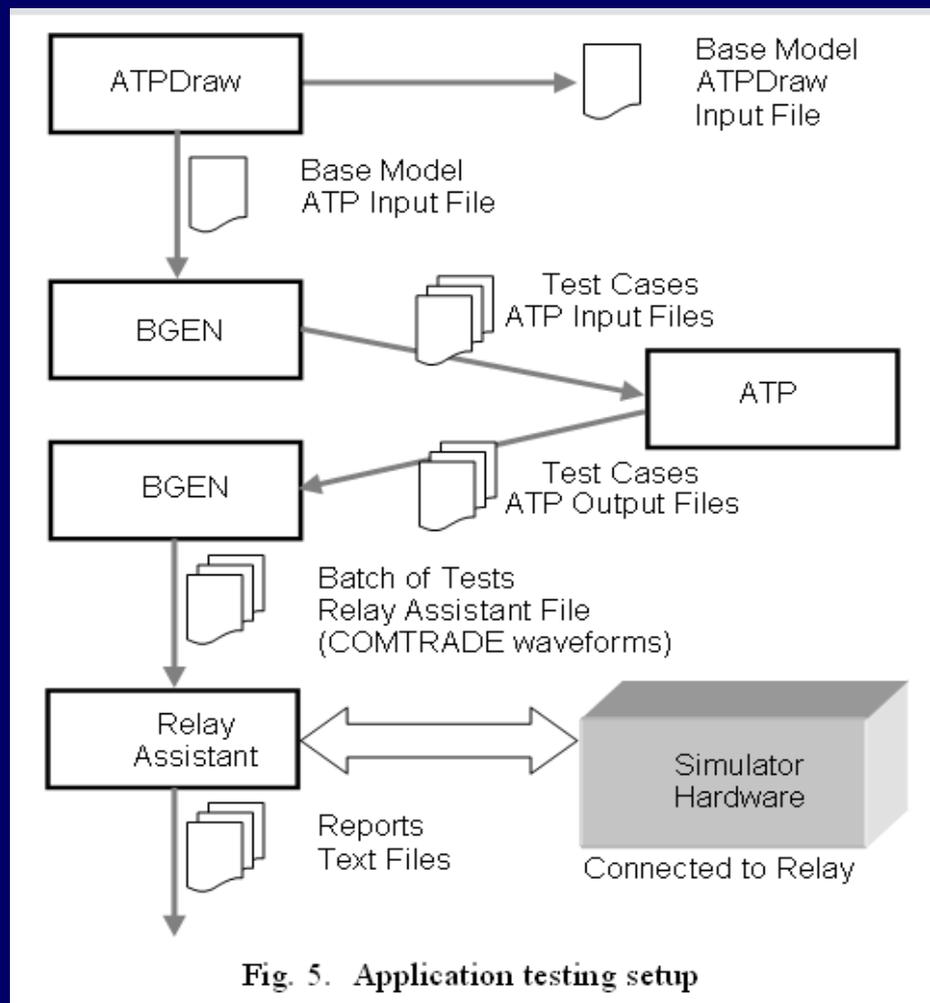
Laptop



Two Approaches: Field Recorded Transients



Two Approaches: Simulated Transients

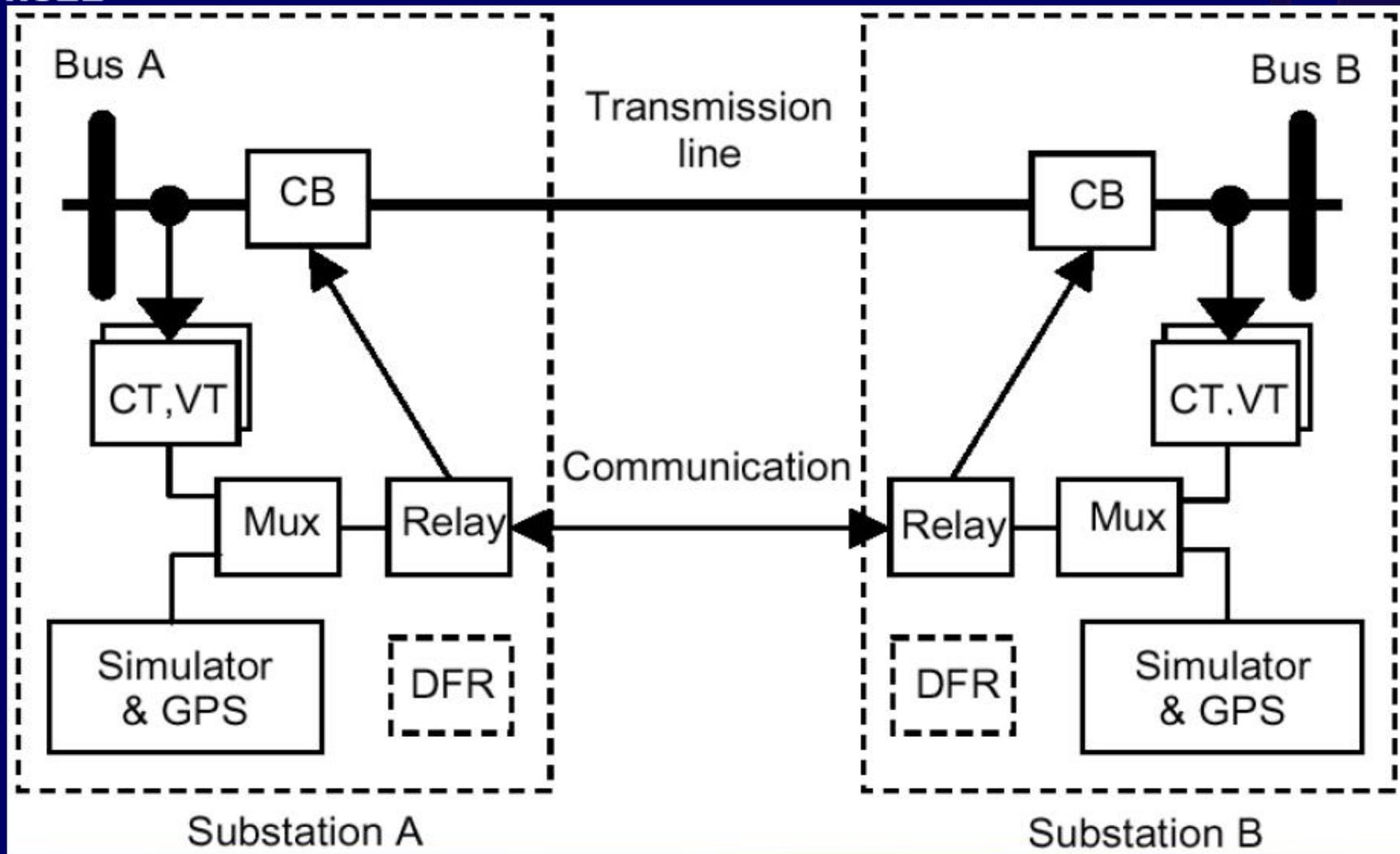




TxCEE



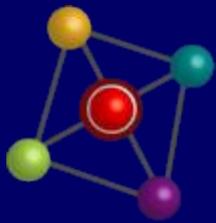
Field Permanent Setup





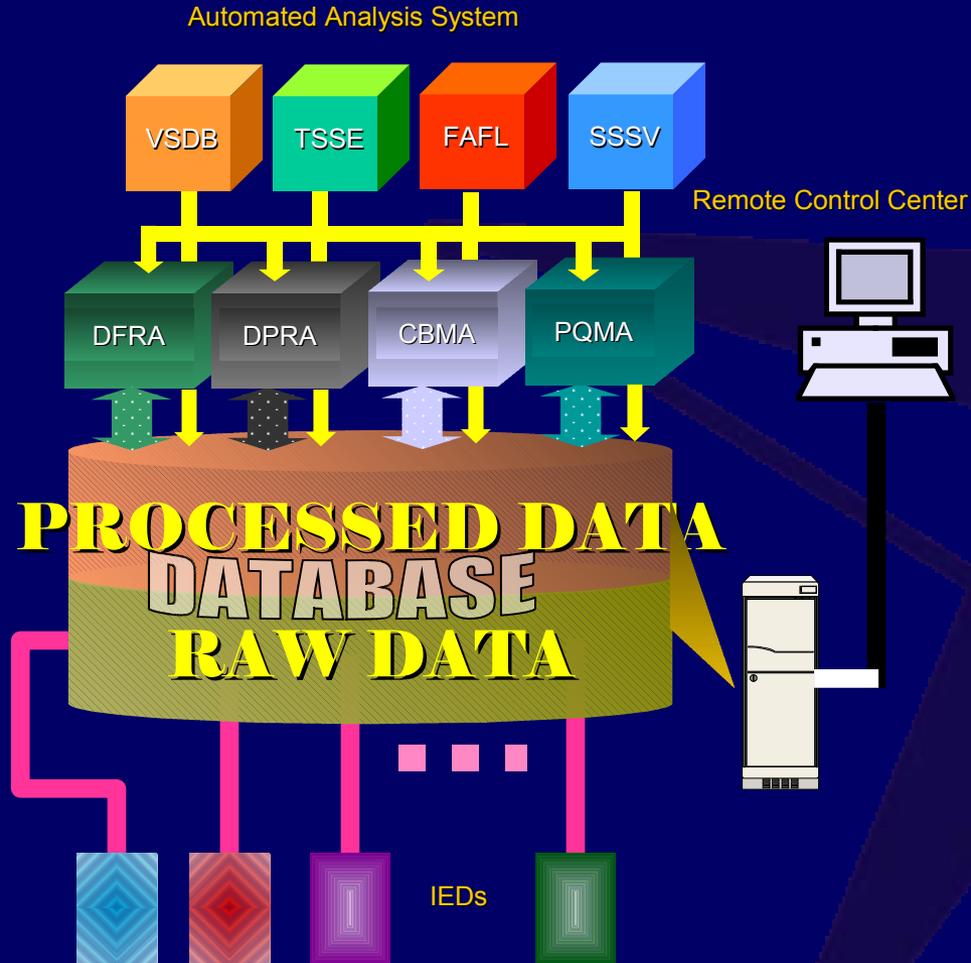
Demonstration Projects

- Data Acquisition and processing
 - All-digital protection system
 - Automated topology processing
 - Transient testing of substation systems
- Data Integration and Information Extraction
 - **Automated substation processing**
 - Enterprise-wide applications
- Information Presentation
 - Models
 - Physical images

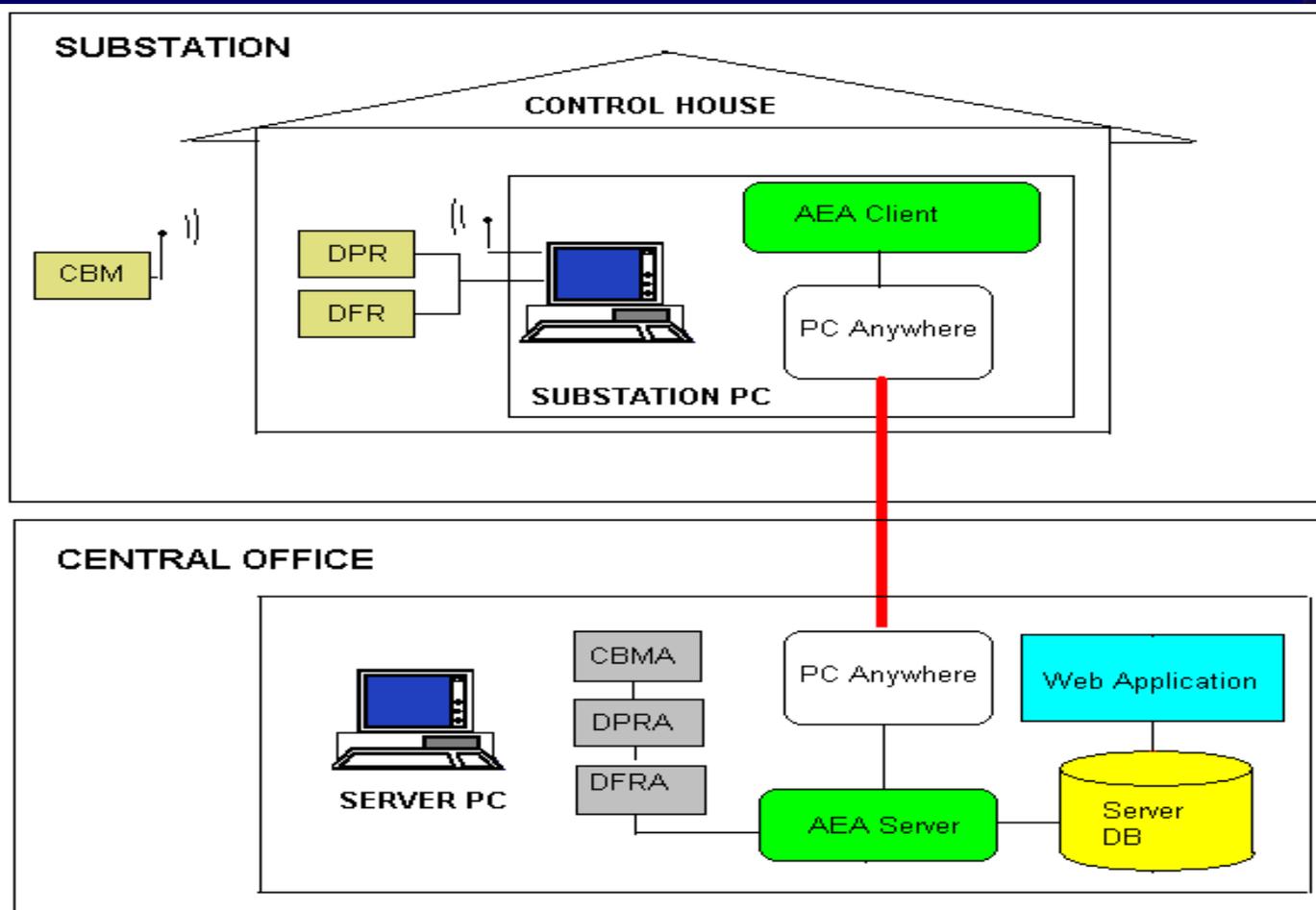


TxCEE

Use of substation data



System Architecture



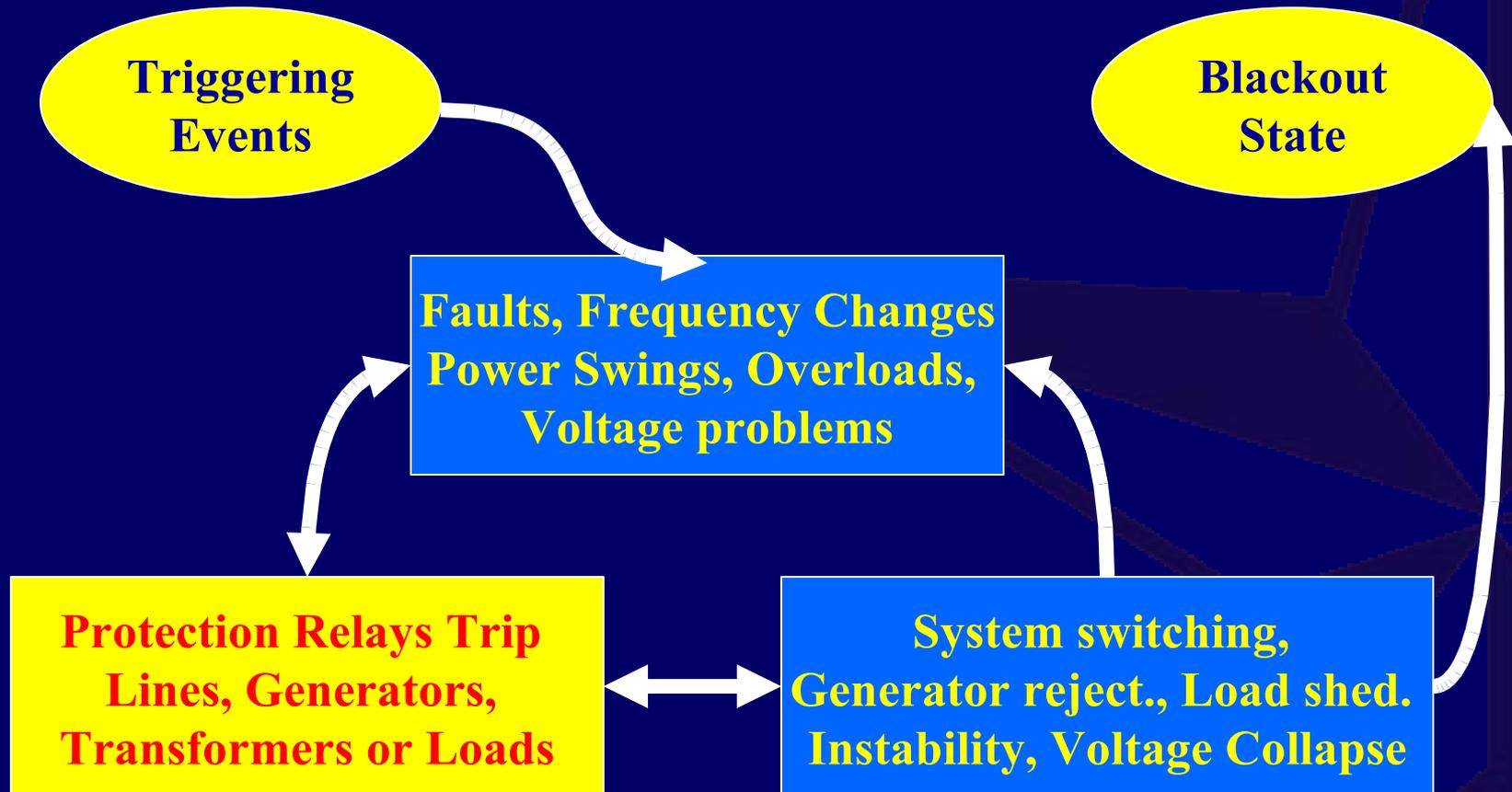


Demonstration Projects

- Data Acquisition and processing
 - All-digital protection system
 - Automated topology processing
 - Transient testing of substation systems
- Data Integration and Information Extraction
 - Automated substation processing
 - **Enterprise-wide applications**
- Information Presentation
 - Models
 - Physical images



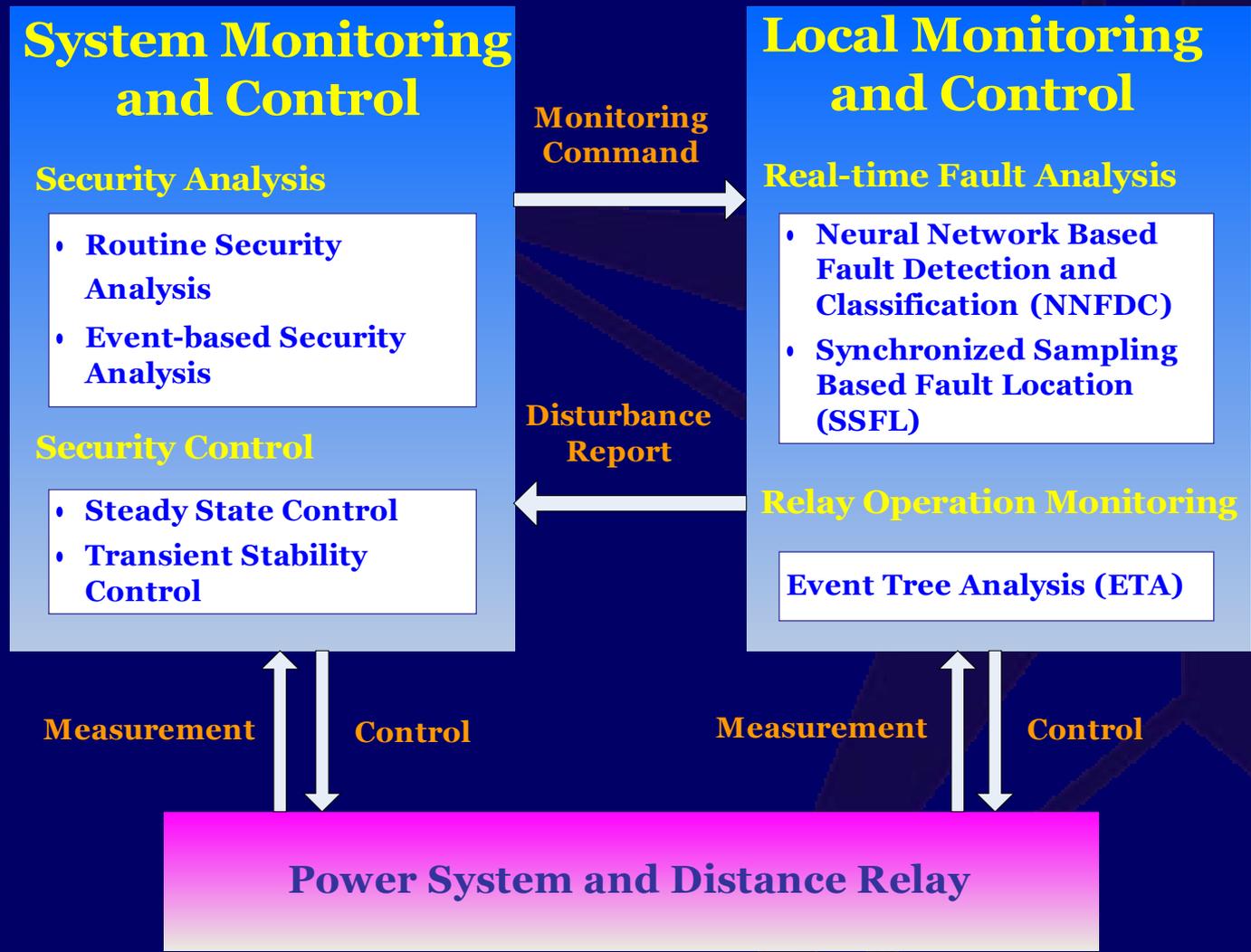
Typical Cascading Process



Relay operation is a major contributing factor



Overall scheme





Graphic Demonstration



System Level

Substation Level

**System Status
& Monitoring
command**

**Routine-based
Security Analysis**

**Local
Monitoring Tool**

Substation 1

**Candidate
control means**

**Selected
control means**

**Local
Monitoring Tool**

Substation 2

Expected

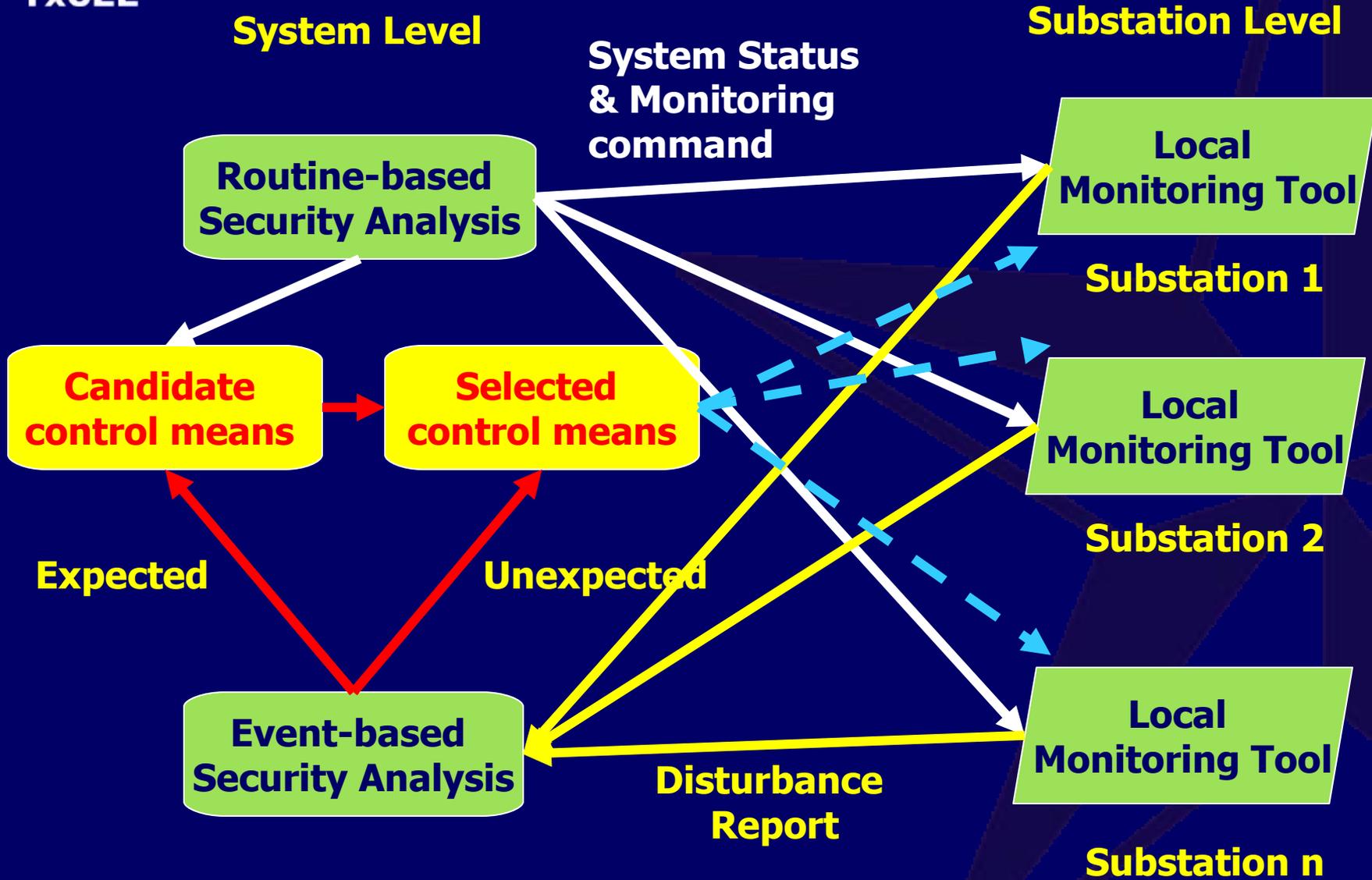
Unexpected

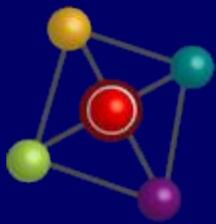
**Event-based
Security Analysis**

**Local
Monitoring Tool**

Substation n

**Disturbance
Report**

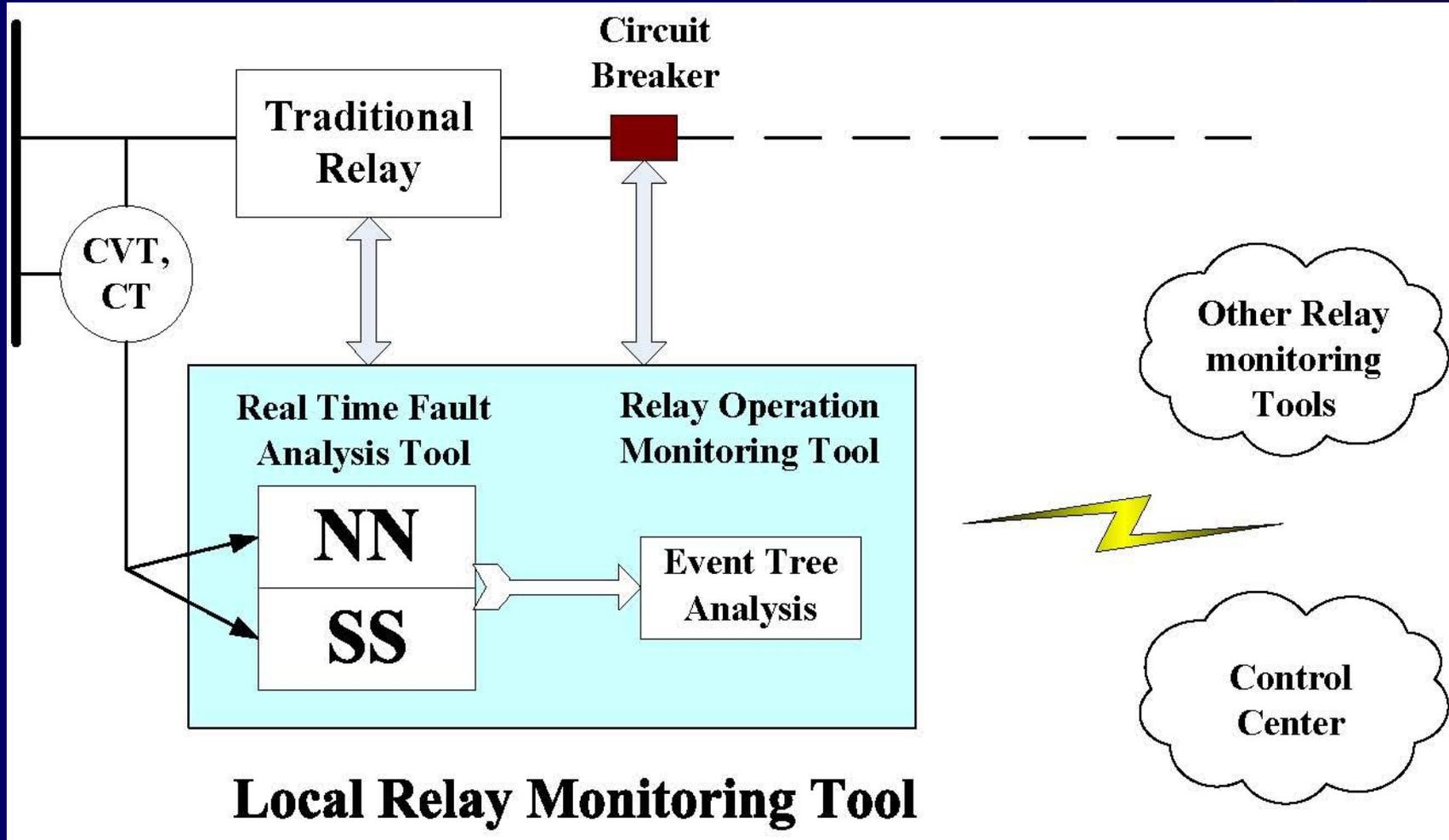




TxCEE

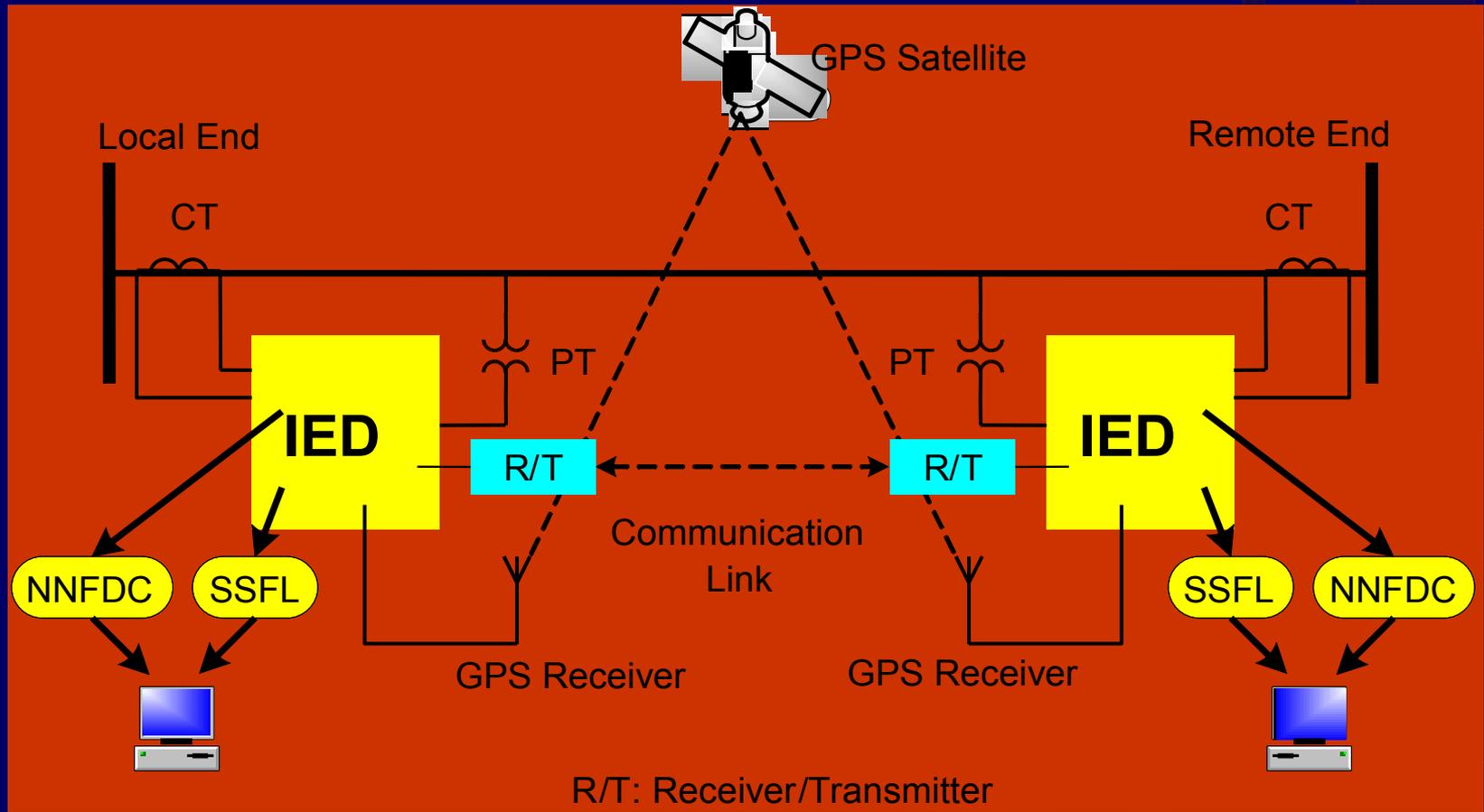


Local Monitoring Tools





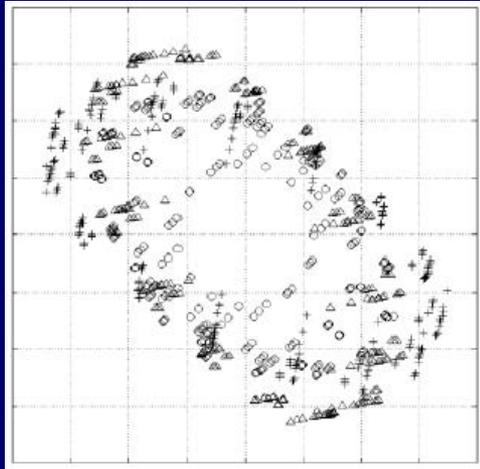
Synchronized sampling based fault location



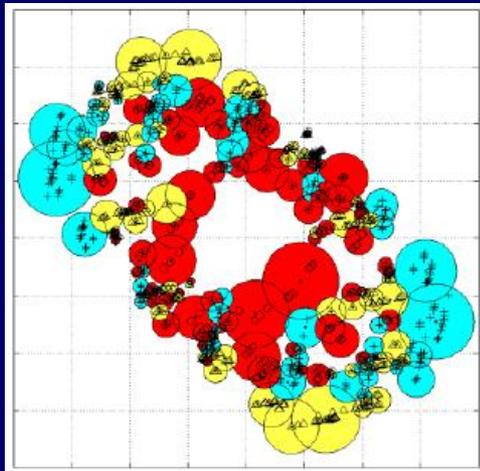


TxCEE

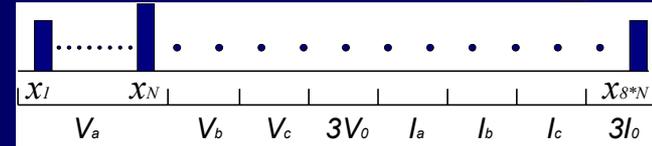
Neural Network Based Fault Diagnosis



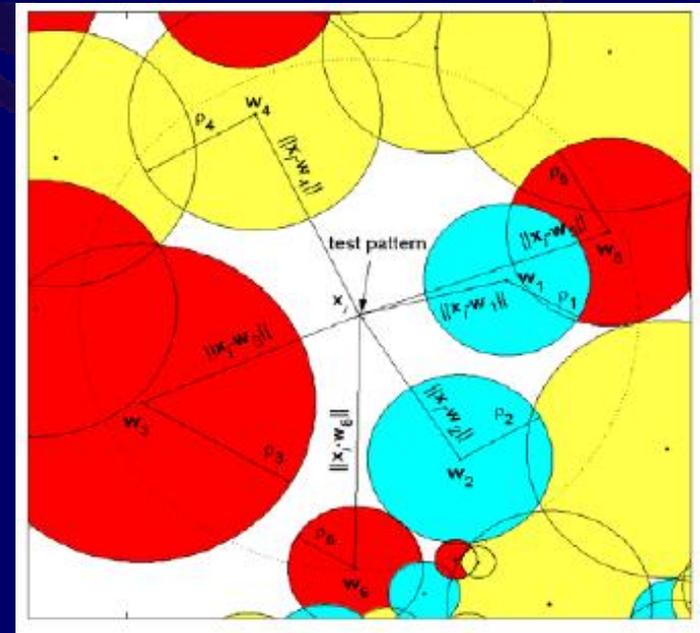
Pattern Space (2-D demo)



Training (Self-Organized Clustering Technique)

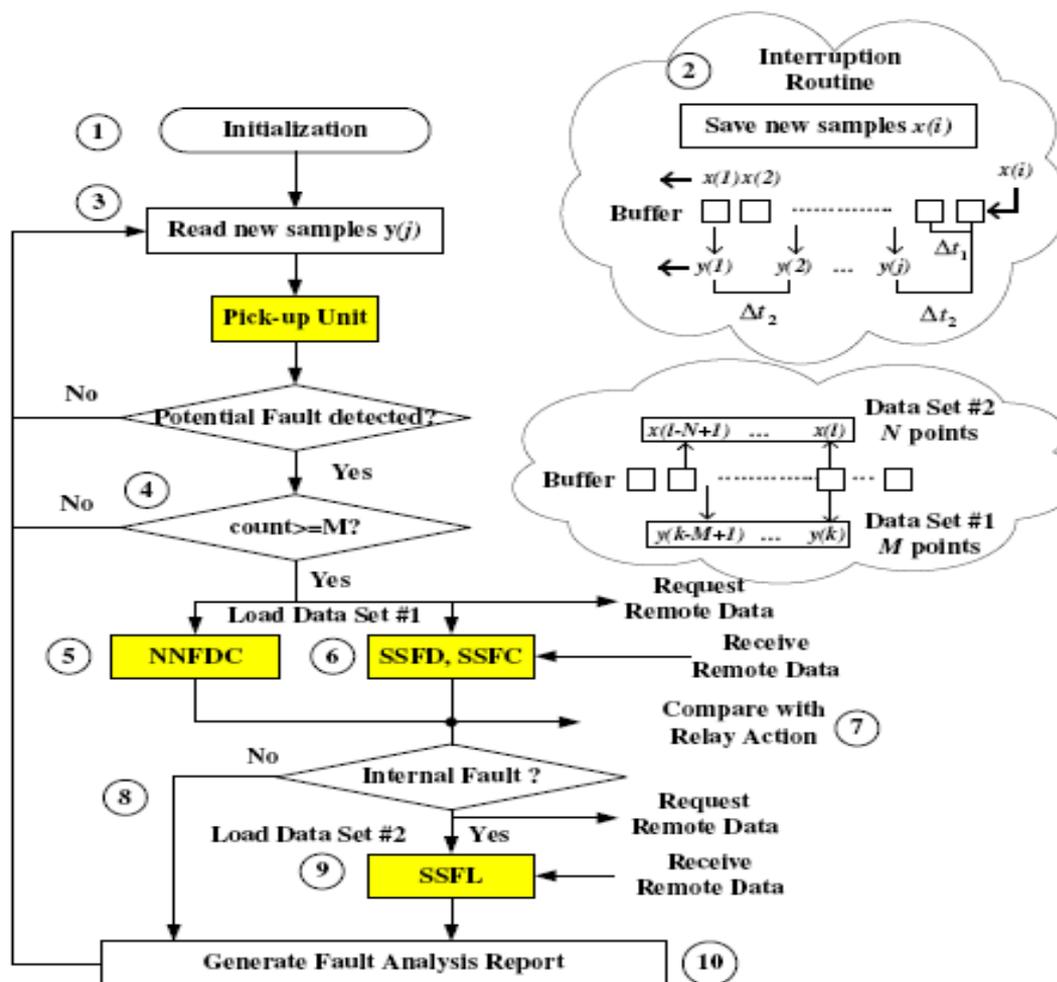


Input Pattern (using normalized raw samples)



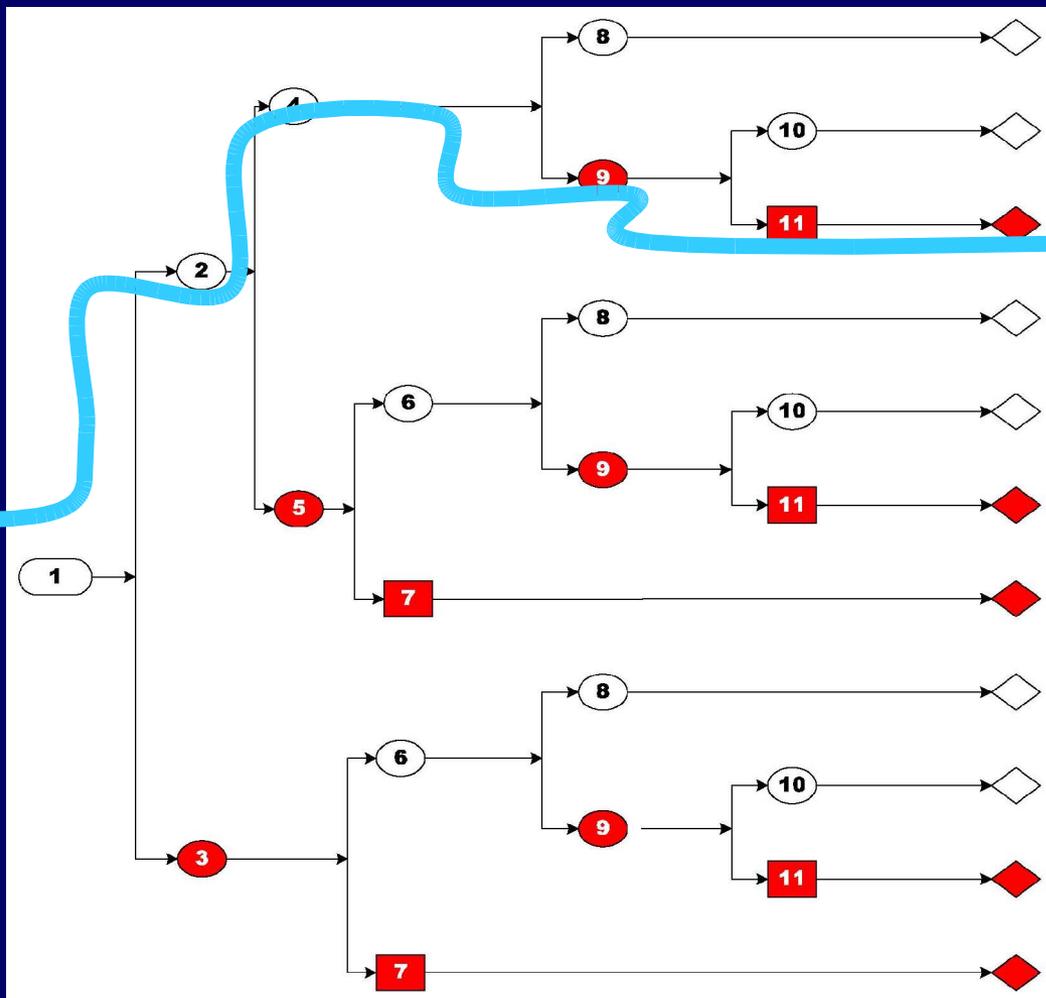
Testing (Fuzzy K-nearest neighbor classifier)

Real Time Fault Analysis Tool Based on Combination of the Two Algorithms





Event Tree Analysis for relay operation monitoring



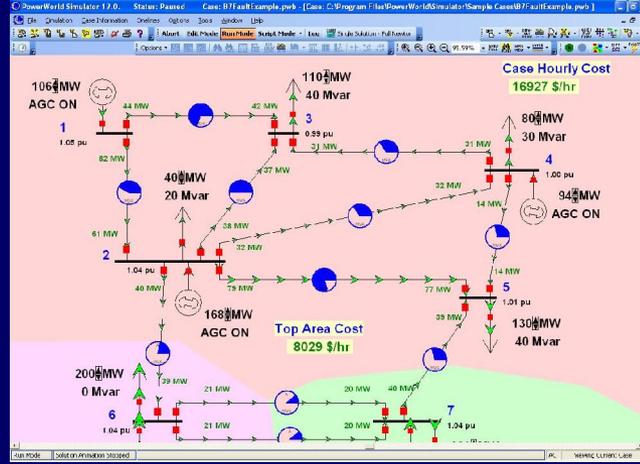
t

Real time Monitoring
Misoperation Alarms
(Red Nodes)



Demonstration Projects

- Data Acquisition and processing
 - All-digital protection system
 - Automated topology processing
 - Transient testing of substation systems
- Data Integration and Information Extraction
 - Automated substation processing
 - Enterprise-wide applications
- Information Presentation
 - Models
 - Physical images



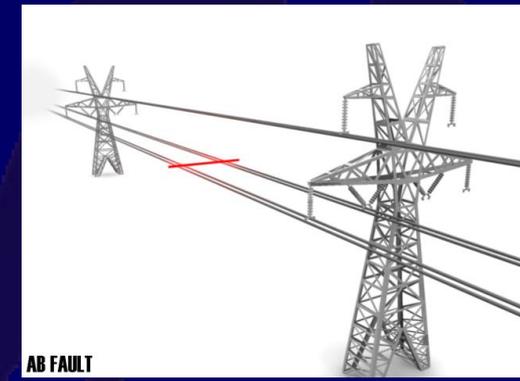
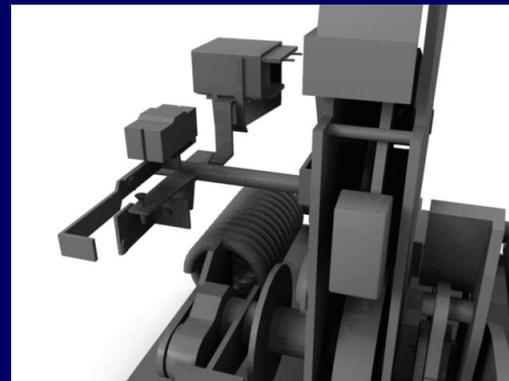
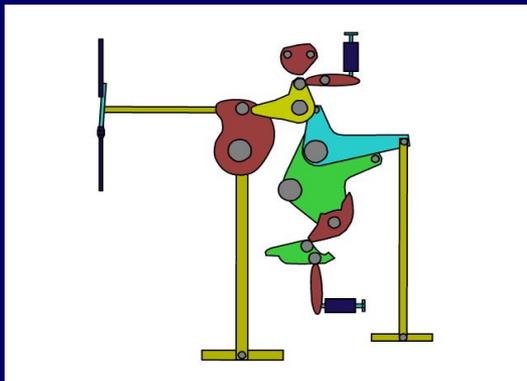
Power World
software
Topology

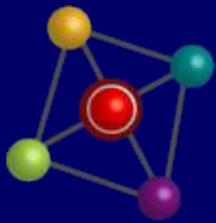


Fault Location



Equipment





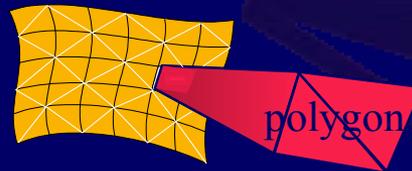
TxCEE

Visualization

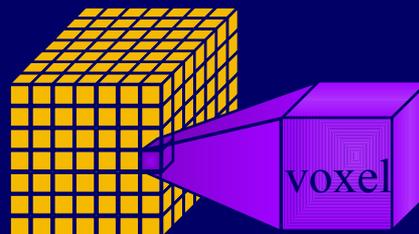


The representation, visualization, and manipulation of objects represented as sampled data in three or more dimensions.

3D Surface Graphics



3D Volume Graphics



Courtesy of University of Mannheim, Germany



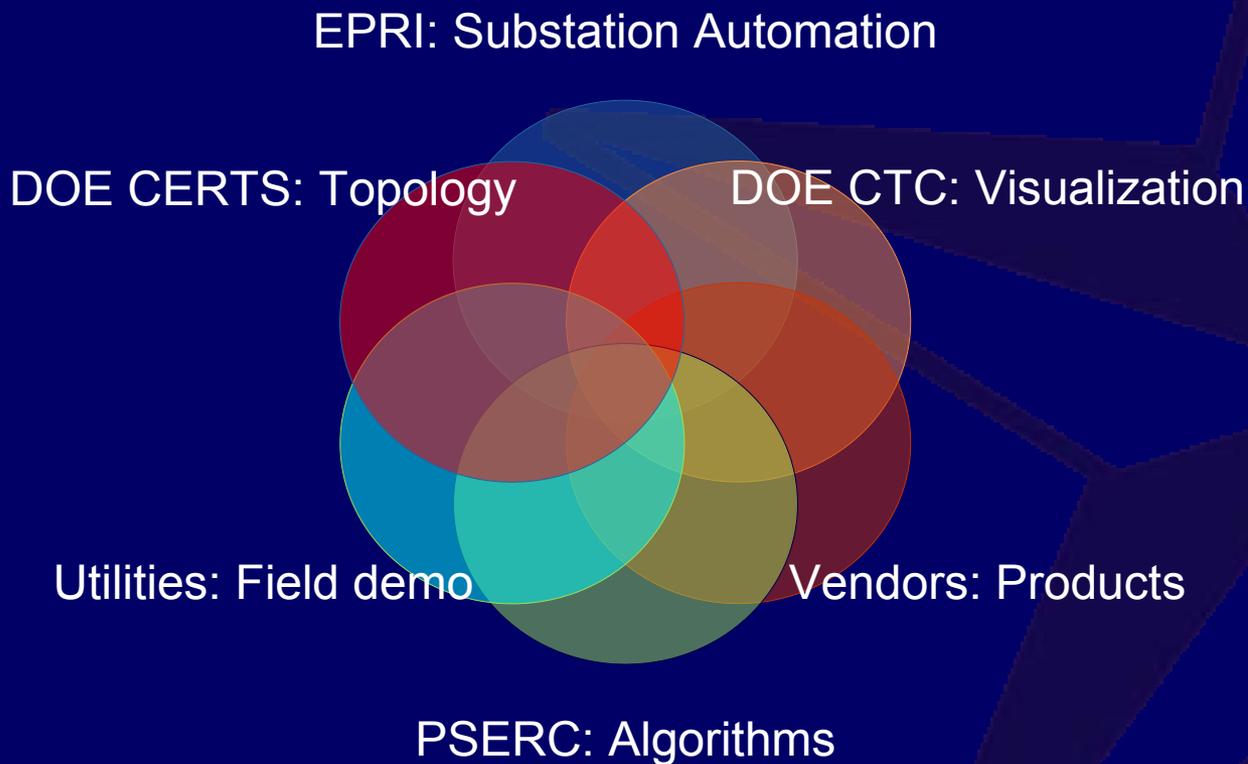
Outline



- Introduction
- Background: Operational VS Non-operational Data
- New Concept: Transparent Data
- New Solutions: Different utility groups
- Examples: Demonstration Project
- **Conclusions**



CCET Partnership





Questions?