



The Twenty-First Century Substation Design

**Mladen Kezunovic
Texas A&M University**

PSERC Webinar
February 15, 2010

Outline

- Background
- Introduction
- Sub. design options
- Retrofit solutions
- Standardization
- Conclusion
- Publications

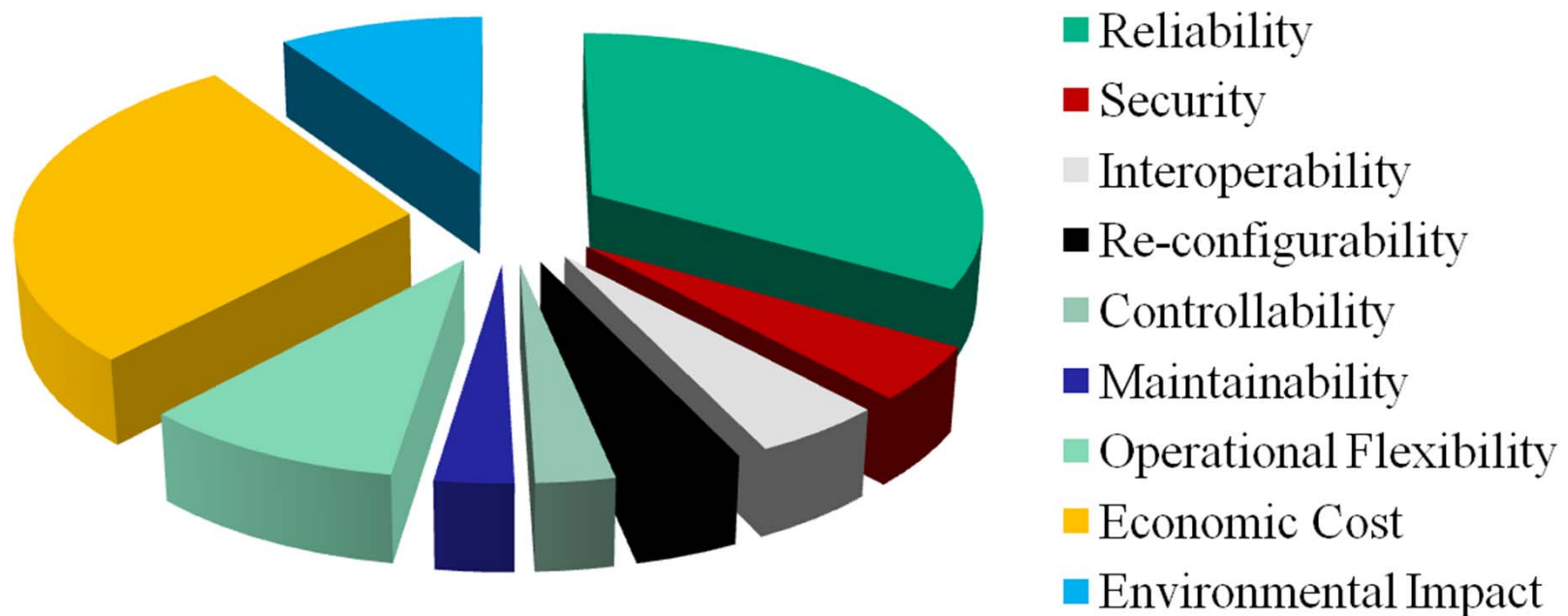


Background



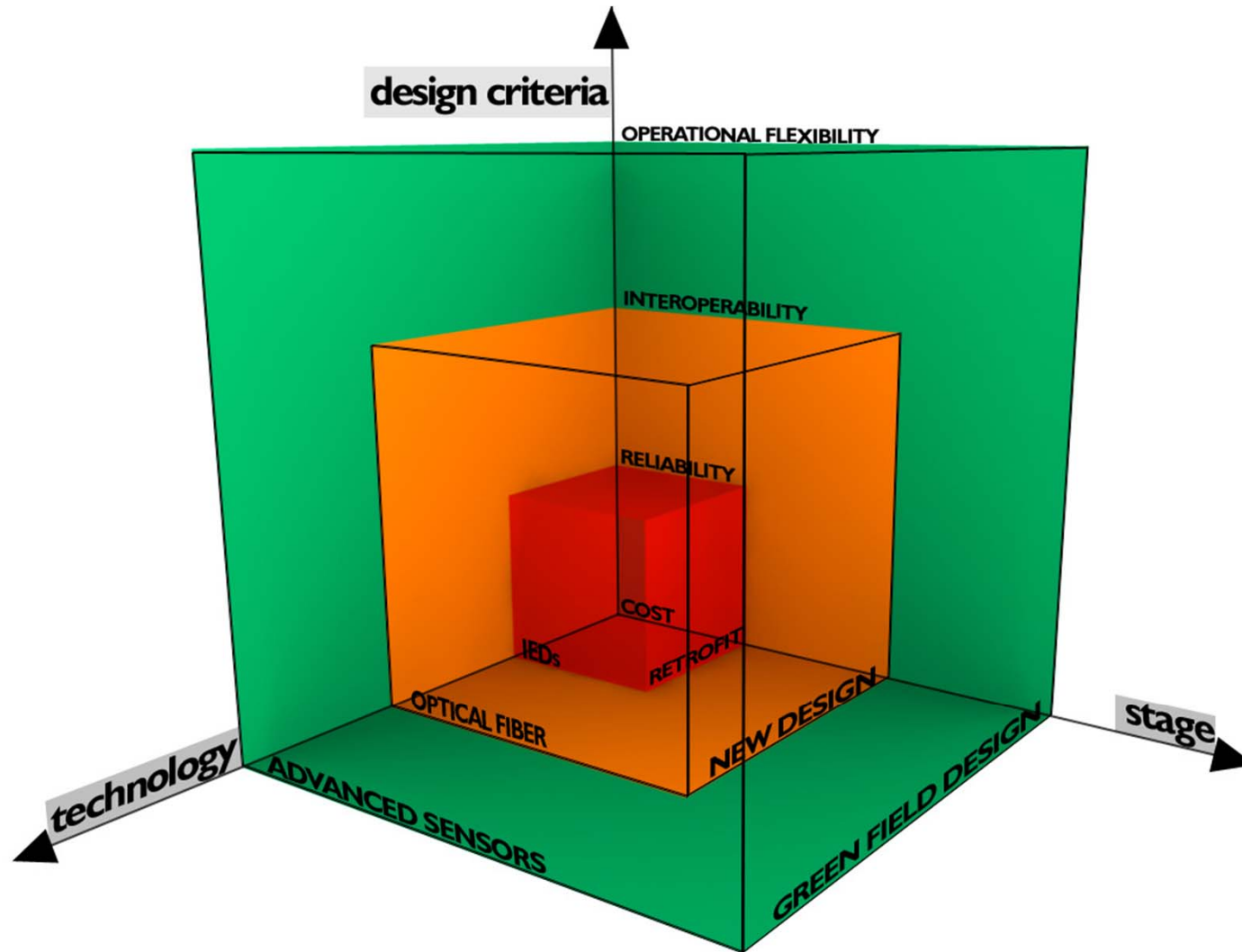
- This presentation is a summary of a Pserc report 10-15, September 2010
- The report talks about primary (ASU) and secondary equipment (A&M)
- The report may be downloaded from:
http://www.pserc.wisc.edu/research/public_reports/td.aspx
- Several papers where details are available:
<http://epipc01.tamu.edu/resume/kezresume.htm#Publications>

Substation design criteria



Source: D. Atanackovic, D.T. McGillis, F.D. Galiana, "The application of multi-criteria analysis to substation design", *IEEE Trans. Power Systems*, vol. 13, issue 3, pp: 1172-1178, 1998

Design Optimization



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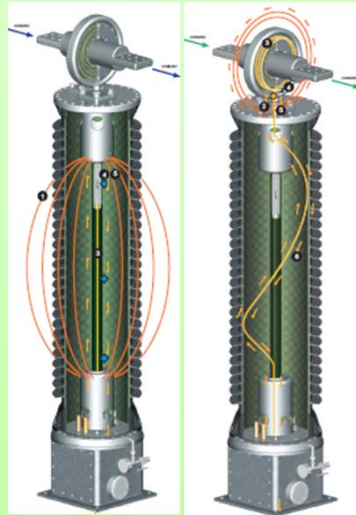
Introduction

- Sensors
- Communication technology
- Intelligent Electronic Devices (IEDs)
- Data Processing technologies

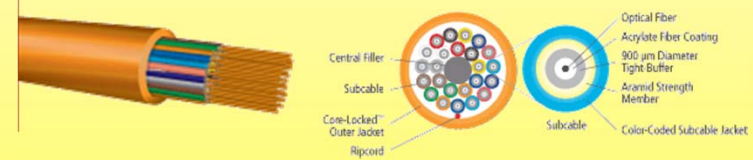
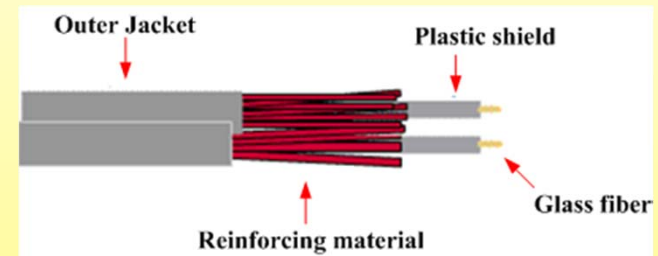
Current technology



Sensors



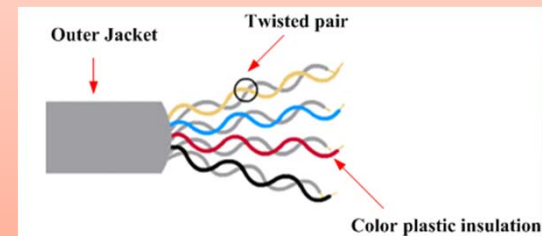
Wiring



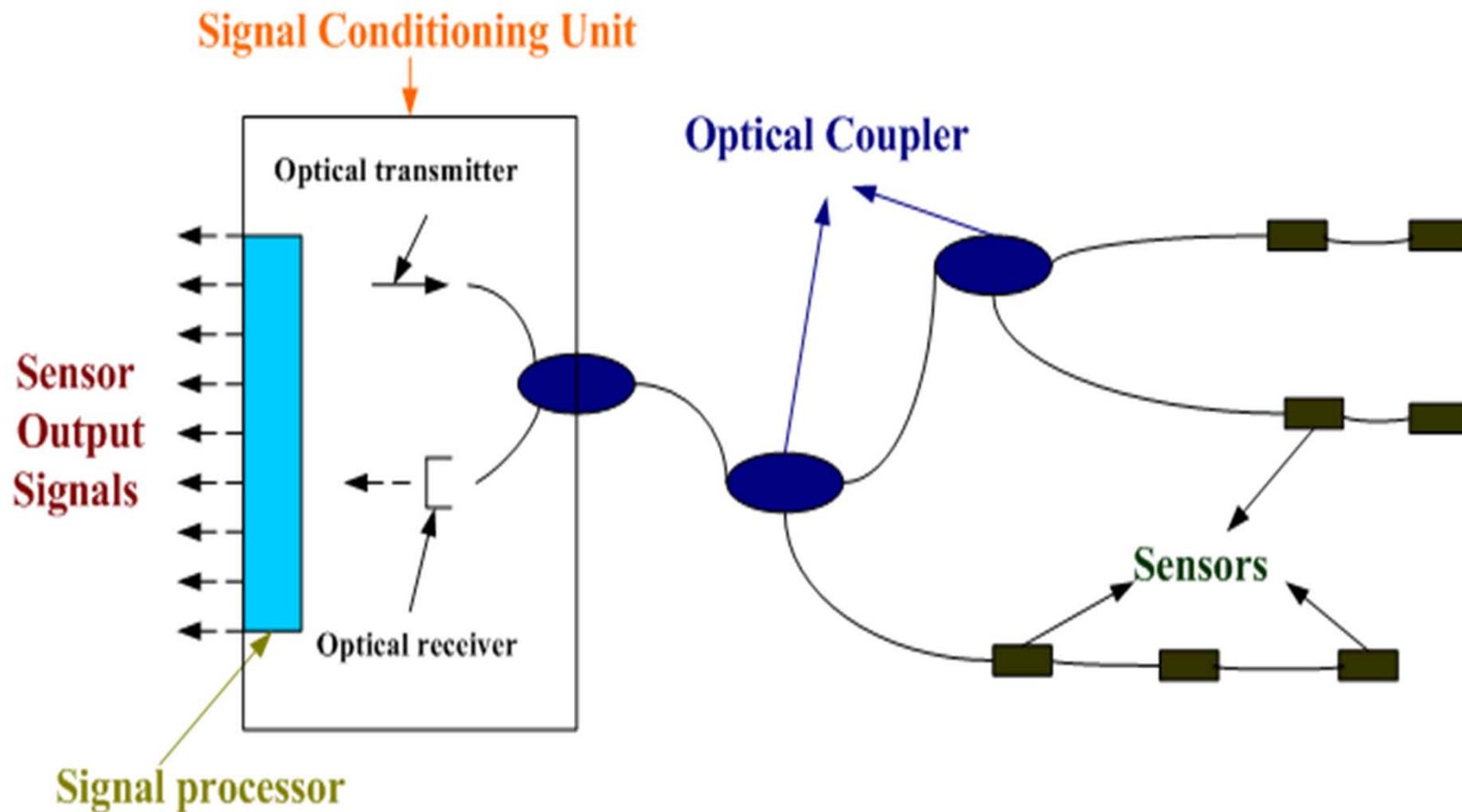
Multifunction IEDs



Communication media, network device

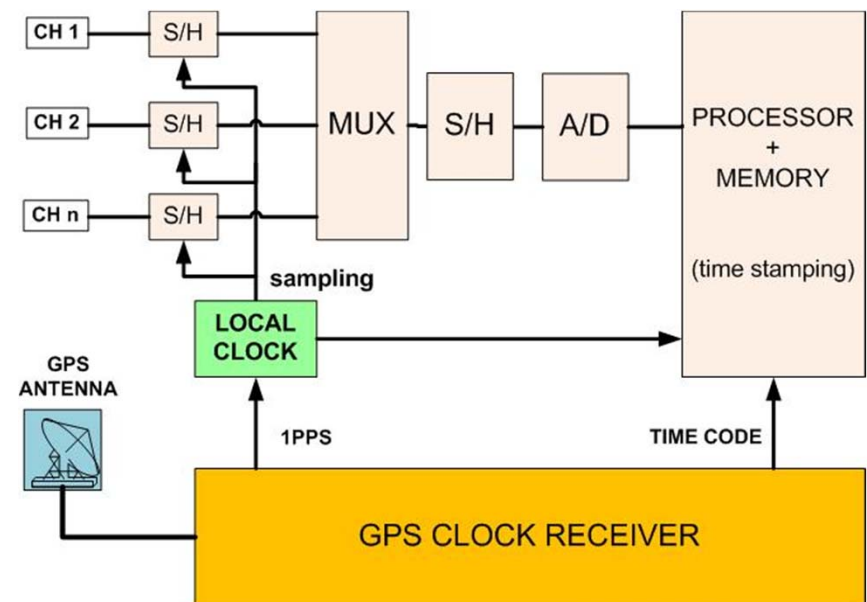
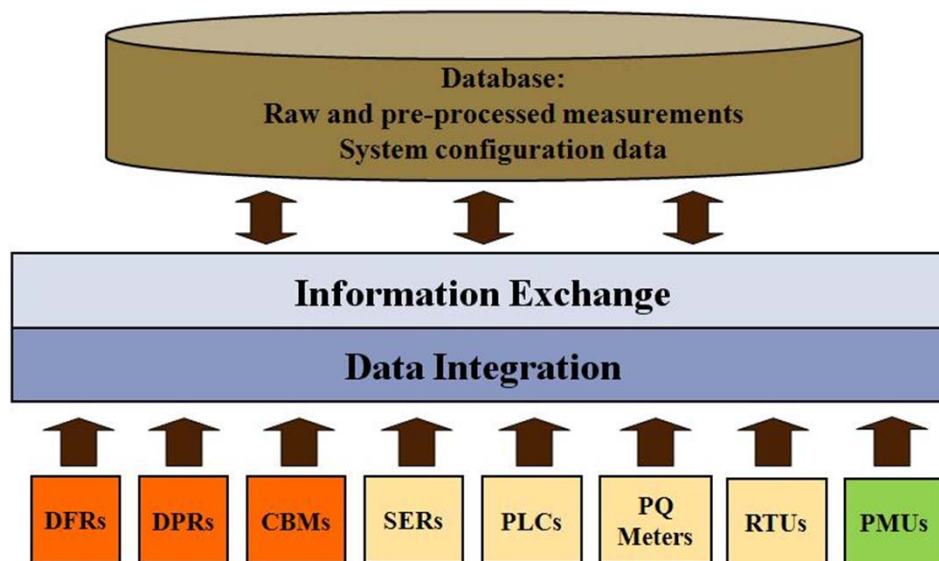


Future technology



Multiplexing: Fiber Fabry-Perot Interferometers (FFPIs) sensors

Linking data and technology

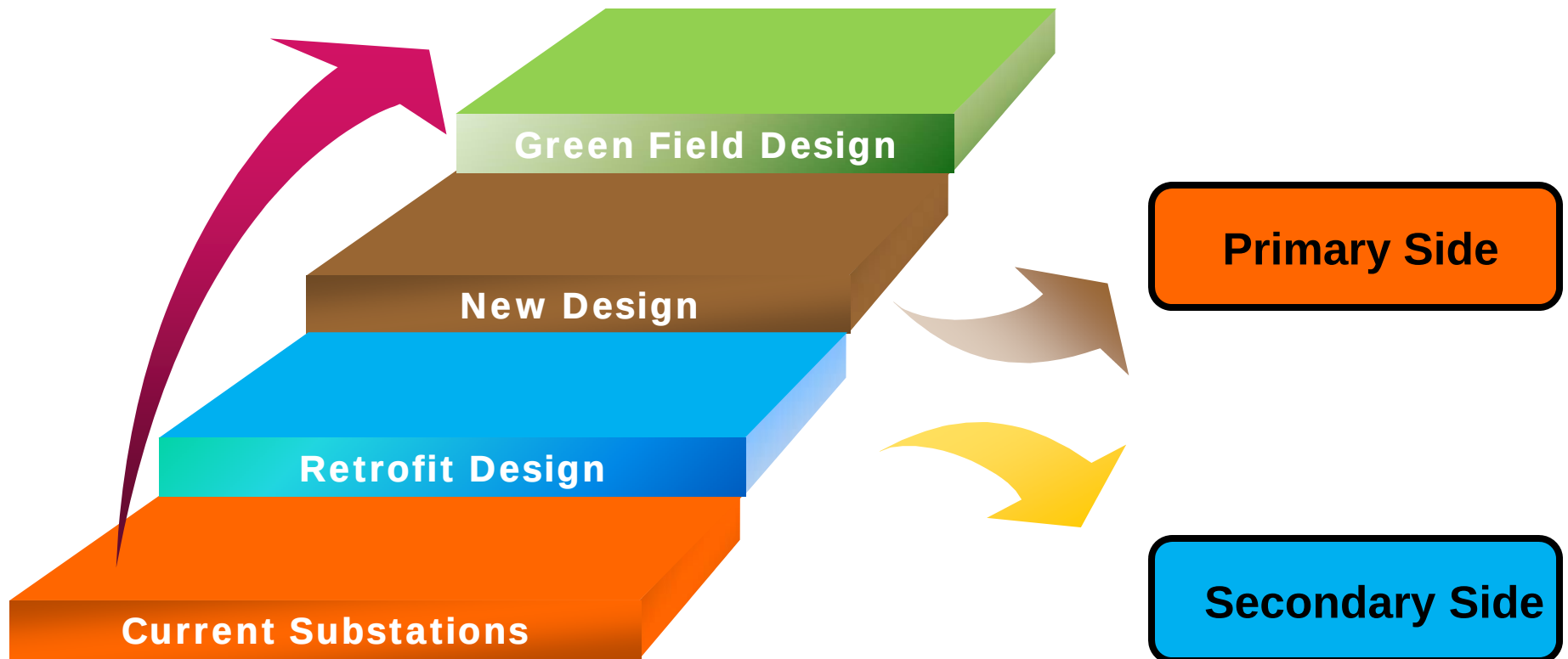


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Substation Design Options

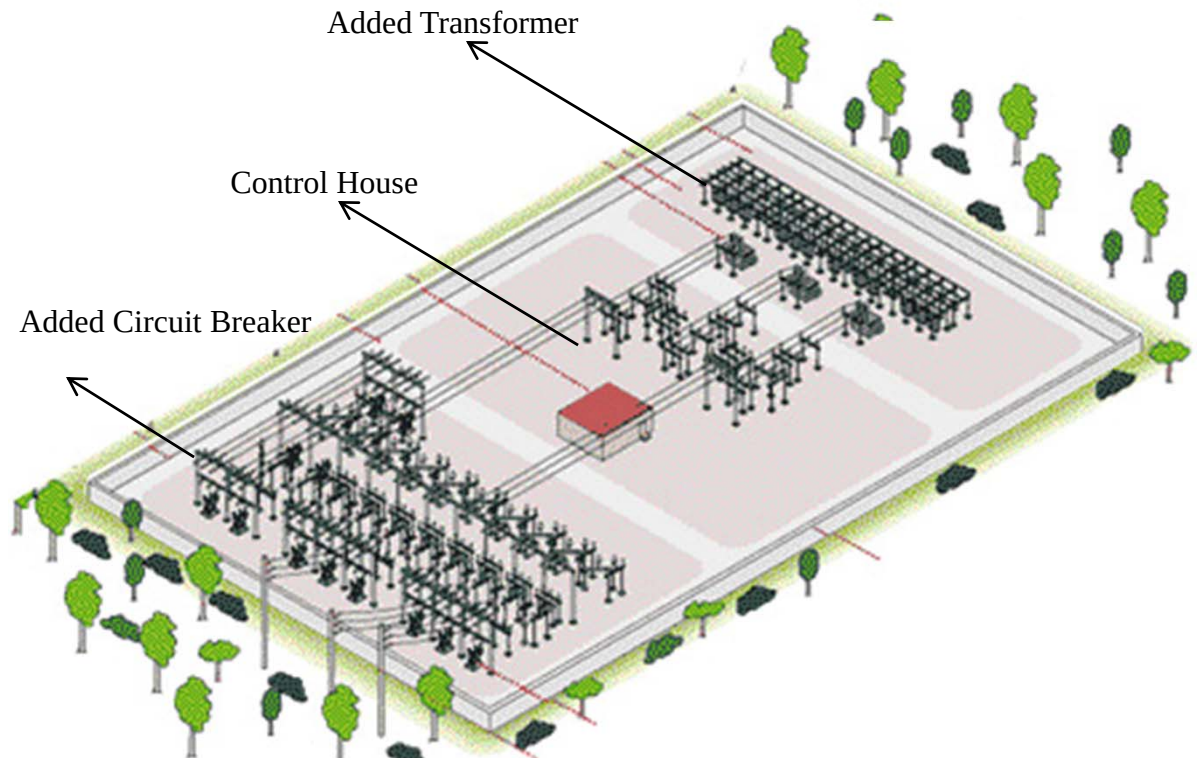


Existing substations

✓ Replacing the existing equipment by new technologies due to:

- Design criteria
- Replacement schedule (maintenance strategy)
- Asset management
- Maintenance cost

✓ Expanding the existing substation due to operating conditions and using new technologies



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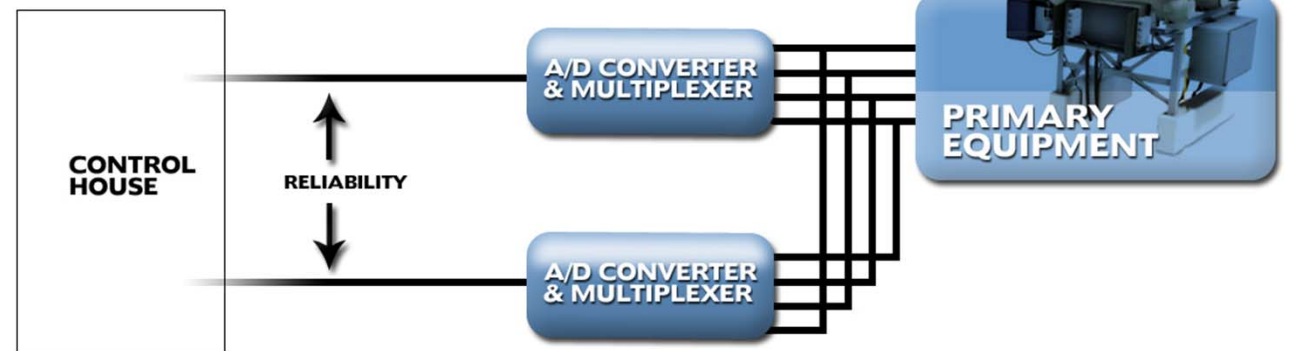
Retrofit: fiber optic cables

Advantages:

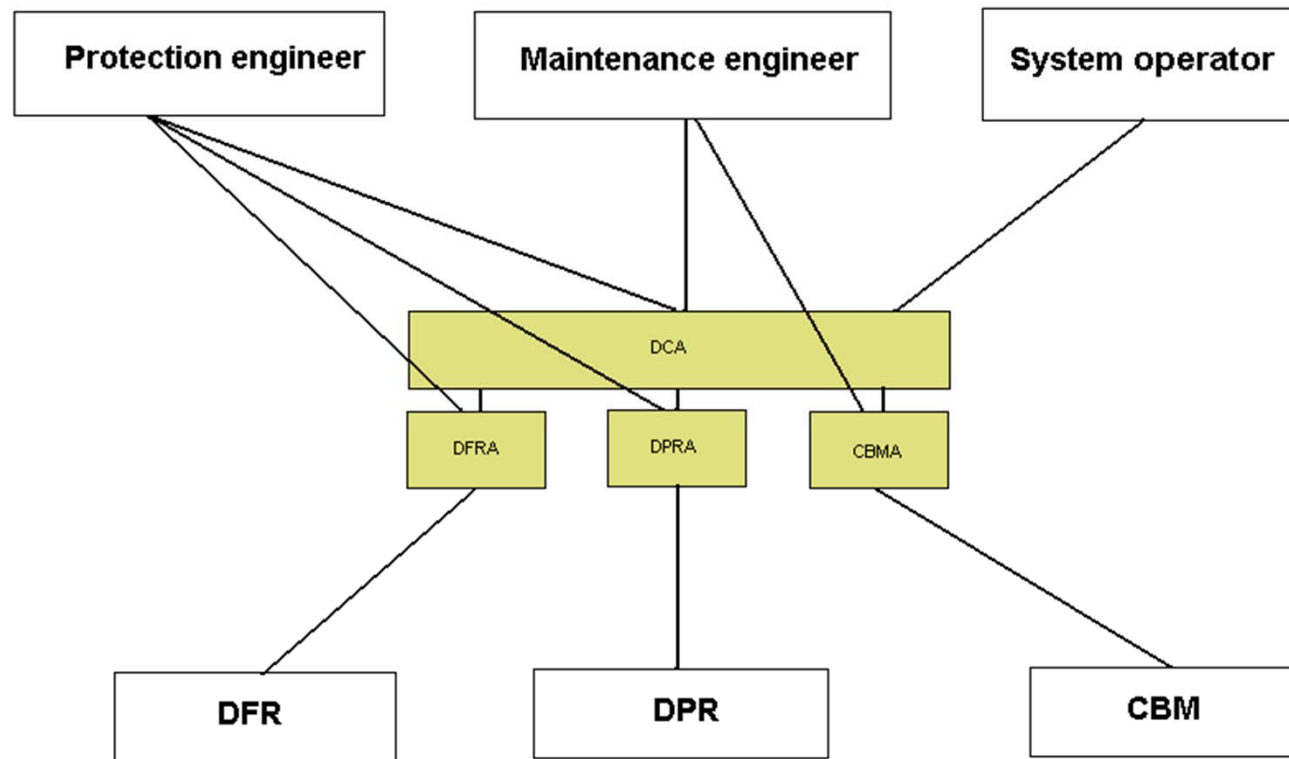
- Greater resistance to electromagnetic
- Lower cost (due to Multiplexing)
 - High reliability
 - Higher performance
 - Lower weight
 - Higher speed
- Longer distance of transmitting information

Disadvantages:

- ❖ Difficult installation, expert human resource is required
- ❖ Sensitive to twists



Retrofit: Data uses



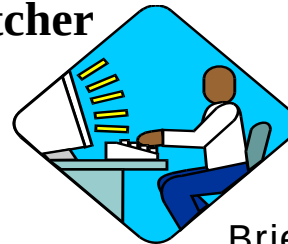
Retrofit: Data Uses

Engineer



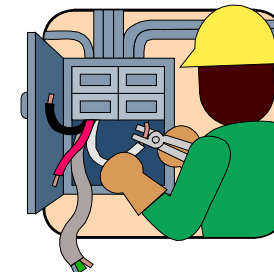
Comprehensive
Report

Dispatcher

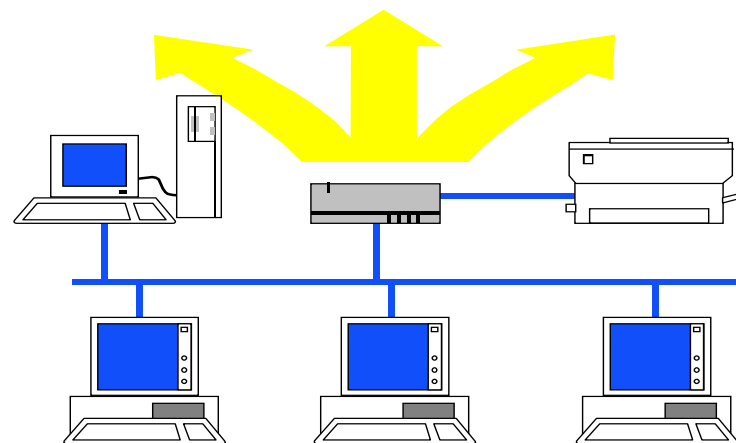


Brief Report

Technician



Summary
Report



Electronic and paper reports can be customized according to the need of a particular category of users and disseminated via fax, e-mail, website, pager, etc.

New design

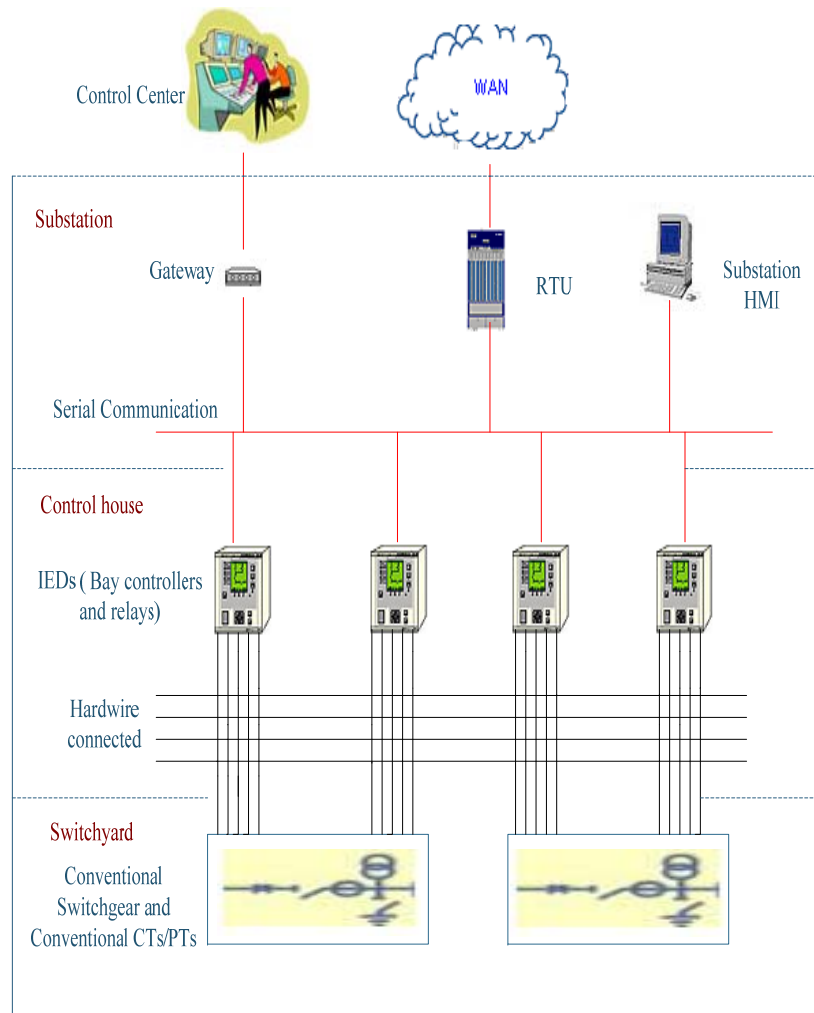
Design Approach

- Synchronized sampling technology and multifunction IEDs represent major elements of the new design;
- The proposed design use advanced concept for data and information processing;

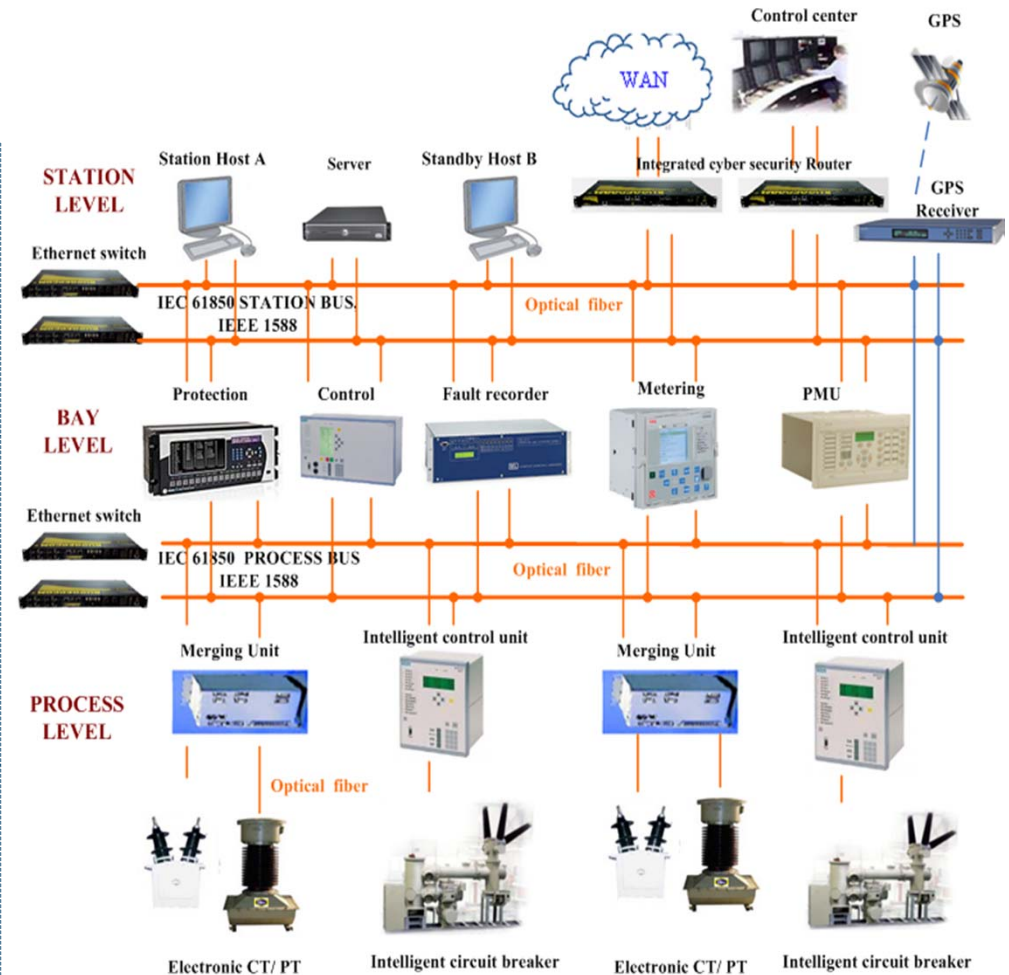
Benefits

- New design merges the new technology and design criteria;
- Automated integration of IED data allows more comprehensive view of the fault events and related consequences;
- The new design will benefits multiple utility groups: protection, maintenance , asset management and operations;

Hardware implementation

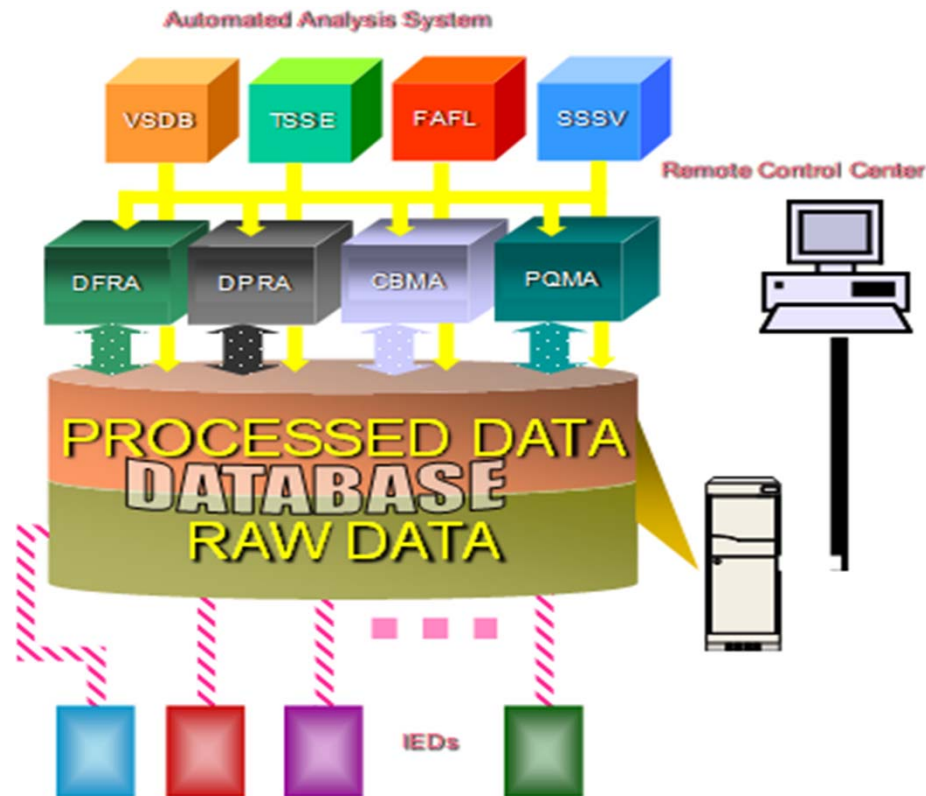


Legacy substation diagram



Proposed substation diagram

Software Implementation



FAFL: Fault Analysis including Fault Location;
 ISDB: Identification in Substation Data Base;
 VSDB: Verification in Substation Data Base;
 TSSE: Two-Stage State Estimation;
 SSSV: Substation Switching Sequences Verification.

Green field design



Features

- More compact and integrated functions
- High-speed communication and reliable fault analysis and automation control
- Link the electricity market operation with real-time monitoring of the physical grid

Benefits

Ideally, the new design will provide the following information:

- Cause-effect relationship of the fault
 - Anomalous changes in the LMPs;
 - Trigger alarms based on volumes;
- Identification of predicated limitations of available transmission capability (ATC) that is problematic;
 - Identification of energy needs as a consequence of planned events;
- Predicated high reactive power demands.



The diagram illustrates a Smart Grid architecture with the following components and connections:

- Power Generators:** Two red power plant icons on the left.
- Regional Transmission Operator (RTO):** A control center icon at the top left.
- Distribution Control Center (DCC):** A control center icon at the top right.
- Transmission Substation:** A large substation icon in the center.
- Distribution Substation:** A smaller substation icon to the right of the transmission substation.
- Load Serving Entity (LSE):** A building icon at the top right, connected to the DCC.
- Distributed Resource:** A small power source icon on the right.
- Residential Consumer:** A house icon at the bottom right.
- Commercial Consumer:** A building icon at the bottom right.
- Industrial Consumer:** A factory icon at the bottom right.

Legend:

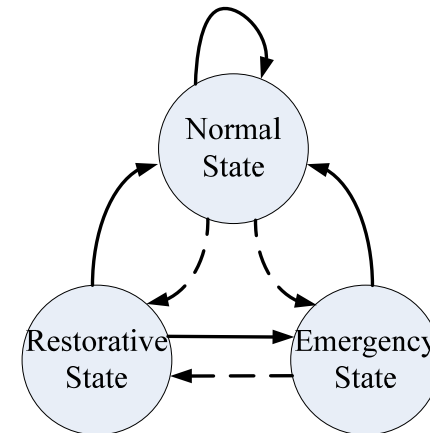
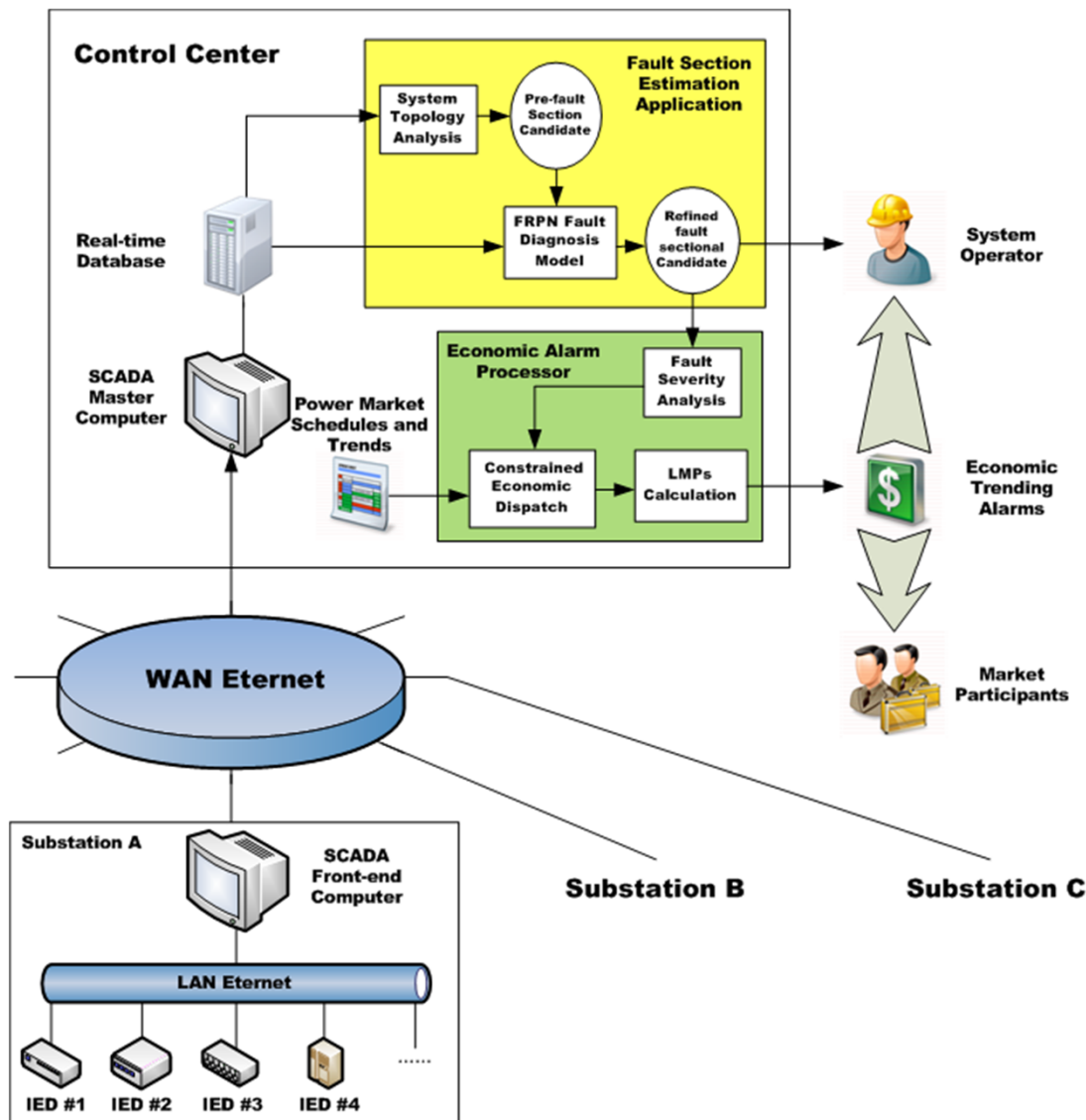
- Communications (Green dashed line)
- Power (Blue solid line)
- Sensors (Yellow circles)

Flow:

- Power Flow (Blue solid lines):** From Power Generators through the Transmission Substation to the Distribution Substation, and then to various consumers (Residential, Commercial, Industrial) and the Distributed Resource.
- Information Flow (Green dashed lines):** Between the RTO, DCC, and various substations/consumers. The DCC also manages the Load Serving Entity.
- Sensors (Yellow circles):** Located at key points along the power lines to monitor the grid.

Source: Dejan J. Sobajic and John H. Douglas, "Market Watch: an advanced framework for real-time market operations and monitoring", IEEE power & energy magazine, pp: 45-49, March/April, 2004

Intelligent Economic Alarm Processor



Type	Configuration	Market Parameters
Normal	All MPs Complete	Within limits
Emergency	All MPs Complete	Parameters violate the limits
Restorative	Structure incomplete	Within limits

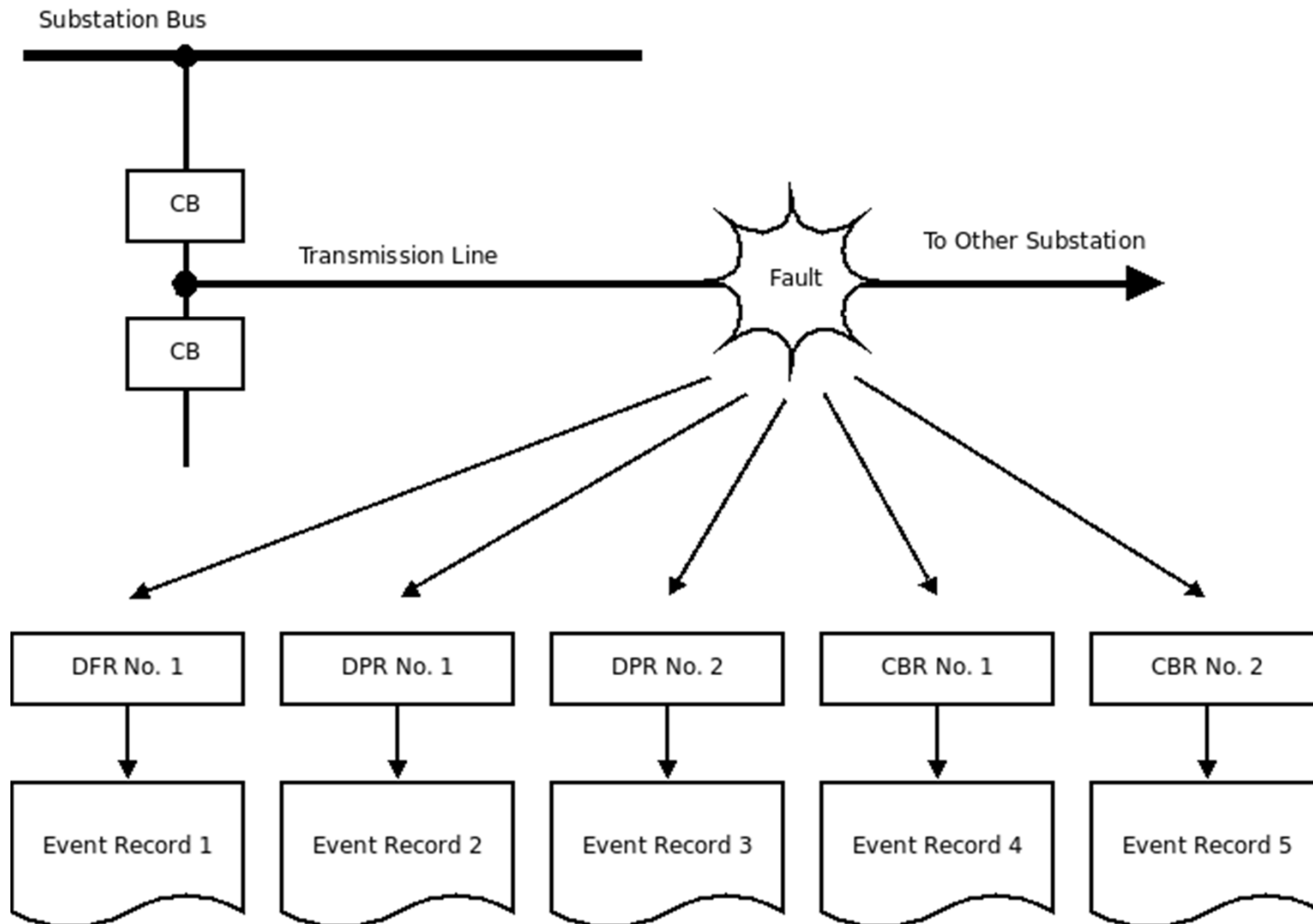
*MPs (Market Participants) include generator companies, transmission owners, load serving entities and other nonasset owners such as energy traders.

Outline

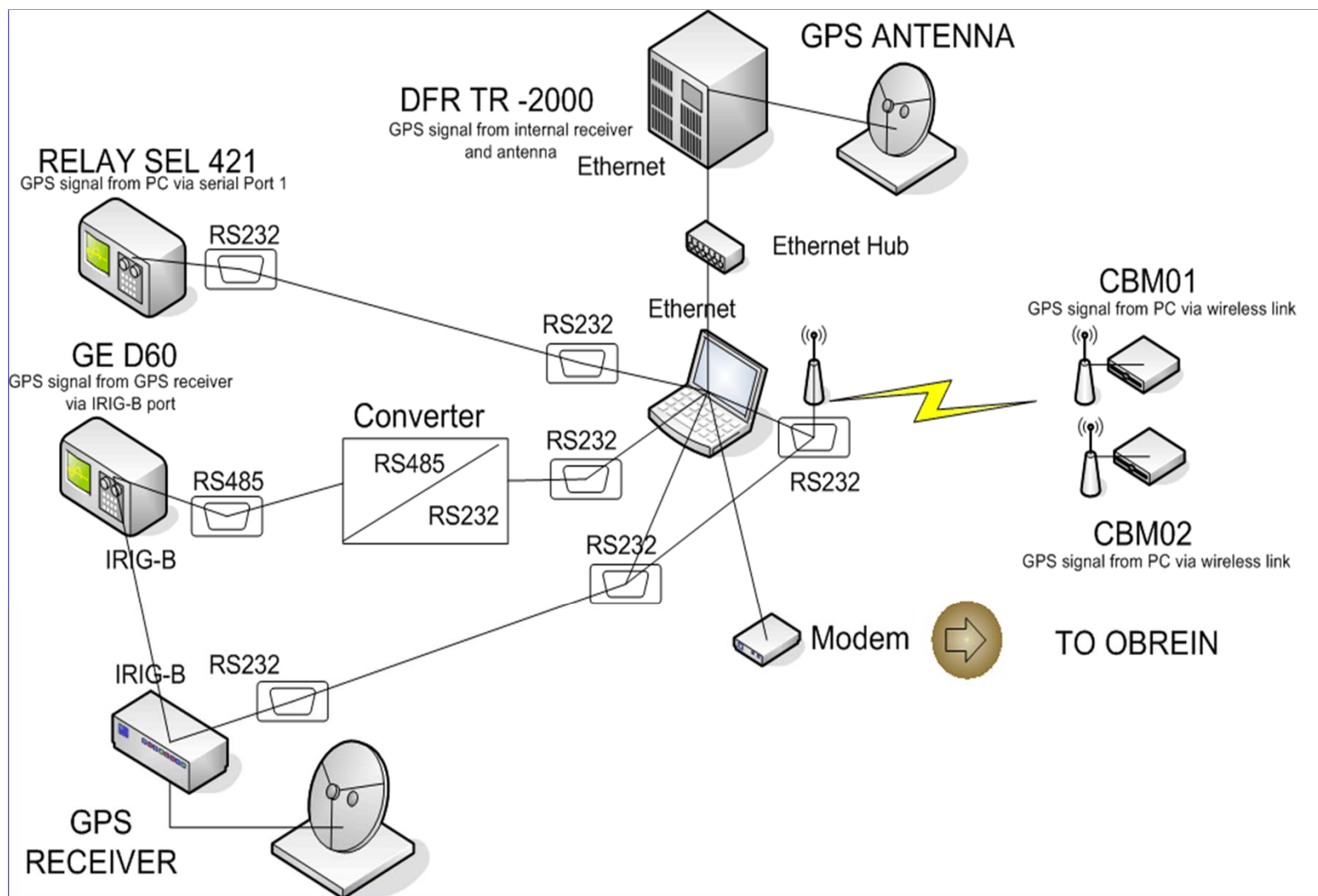
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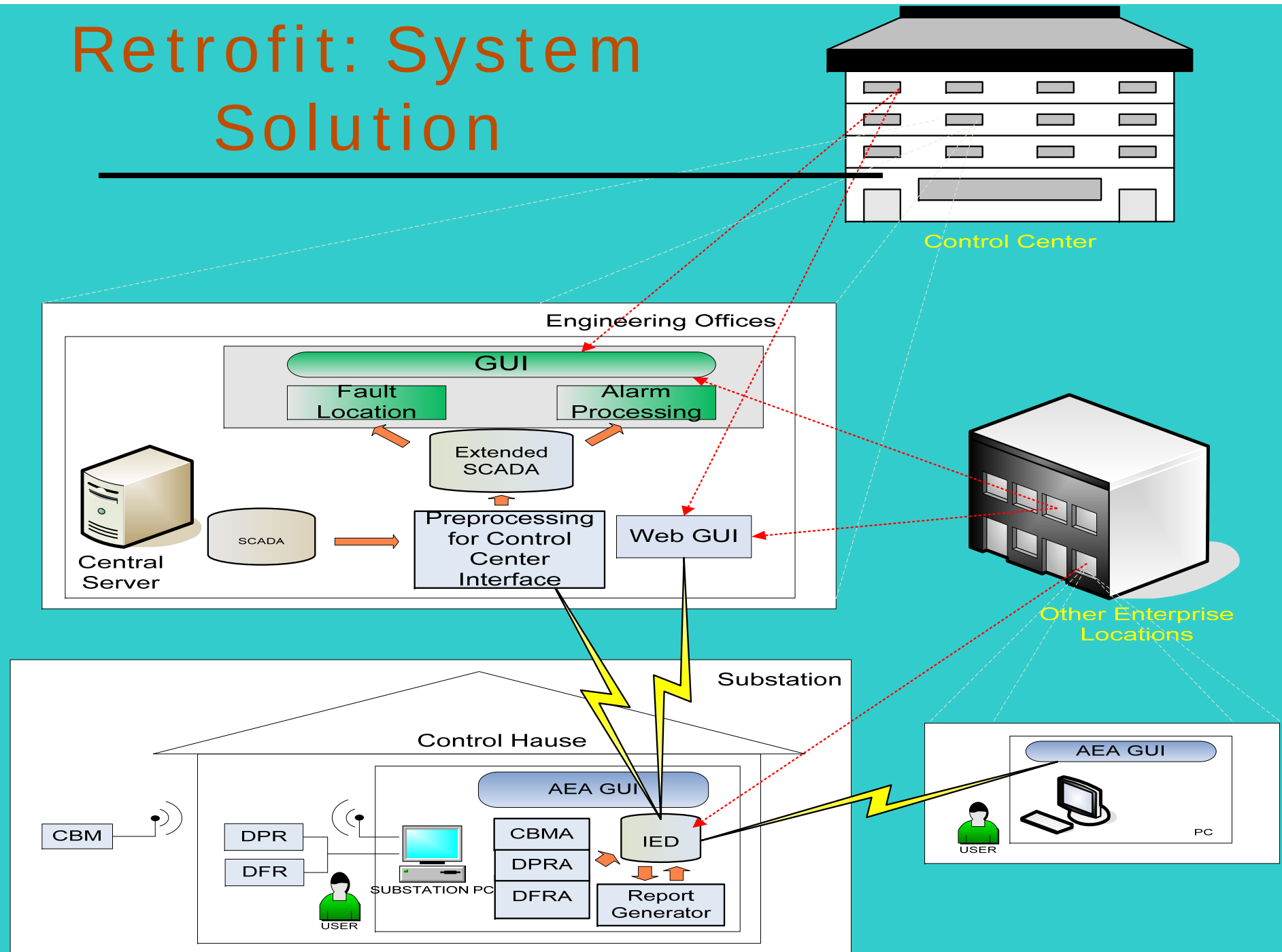
Multiple IED Records/Single Fault



Retrofit: Time Synchronization

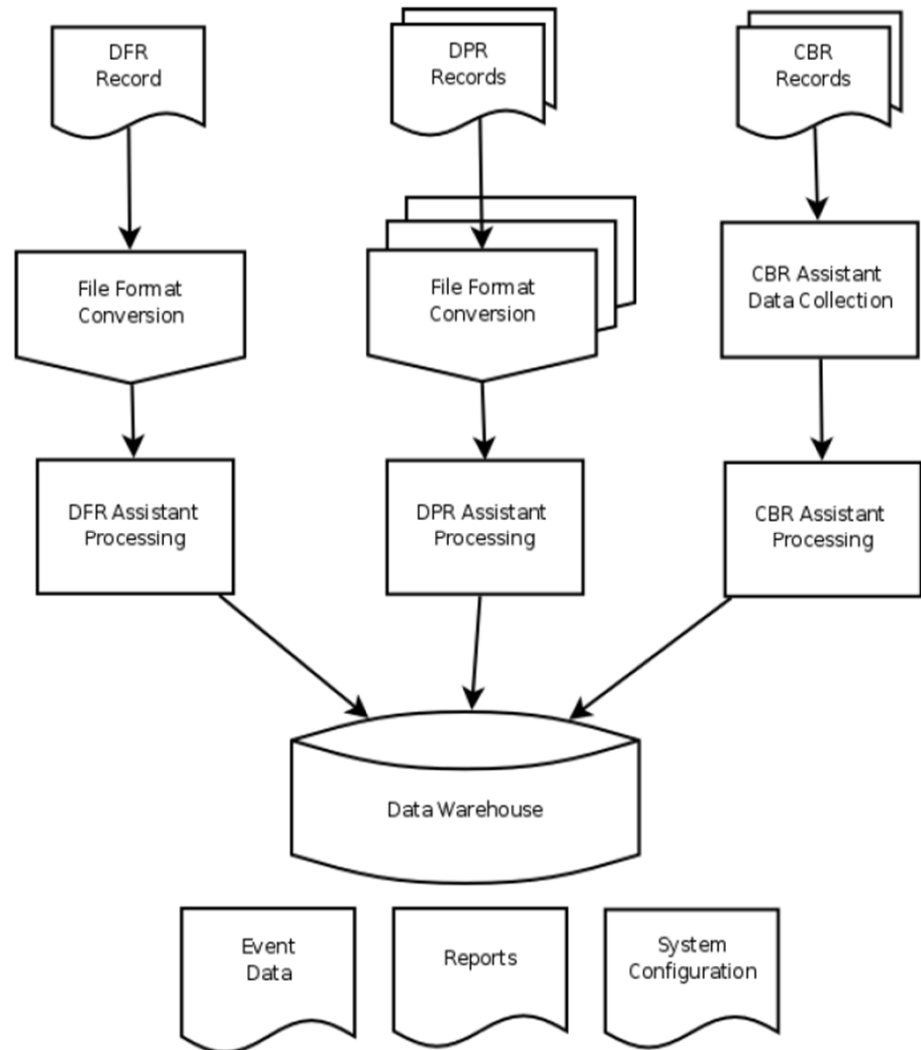


Retrofit: System Solution



Substation Assistant™

- Data Integration: DFR, DPR, CBR
- Automated Fault Analysis
- Data Warehouse
- Viewing Data and Reports



Web Interface (DFR, DPR, CBR)



Substation Assistant™ Data Management 3.0: System Events - Opera

File Edit View Bookmarks Widgets Tools Help

Substation Assistant™ ... X

http://192.168.0.98/DFRAWA/eventstable.jsp?event=26437

Google

Substation Assistant™ Data Management System Events

User Info
Welcome **admin**, today is: Mon Nov 16 08:19:01 CST 2009. If you are not admin please [click here](#).

Events Search Users Report Viewer System Builder About Logout

Event Chart

Get or Delete Event Data

Waveforms

USER COMMENTS

No comment has been added for this event.

System Events Help

Click on event time stamp to select an

Filter Results

Client: First Energy IED: ALL Circuit: ALL Outcome: ALL

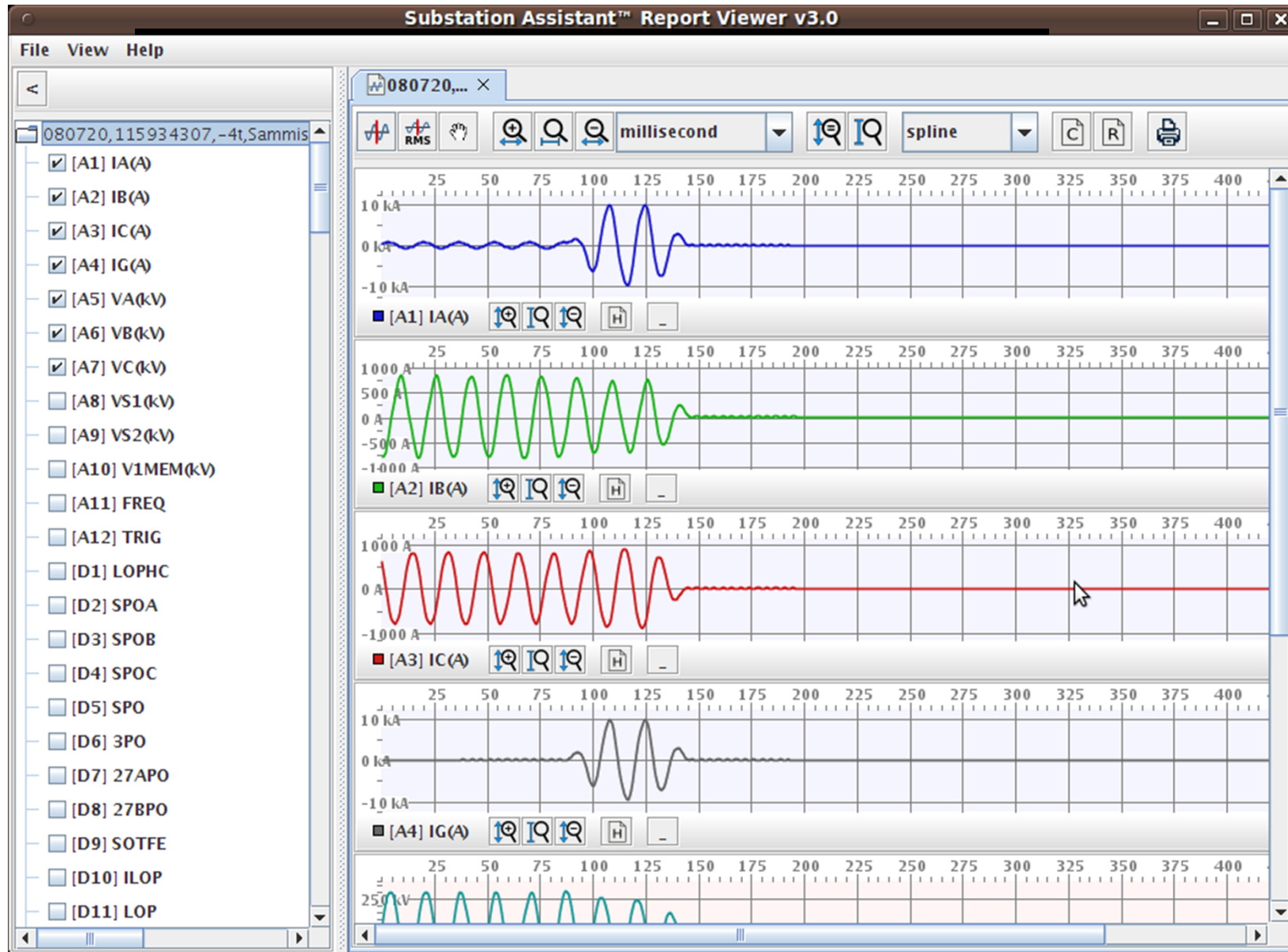
Event Table

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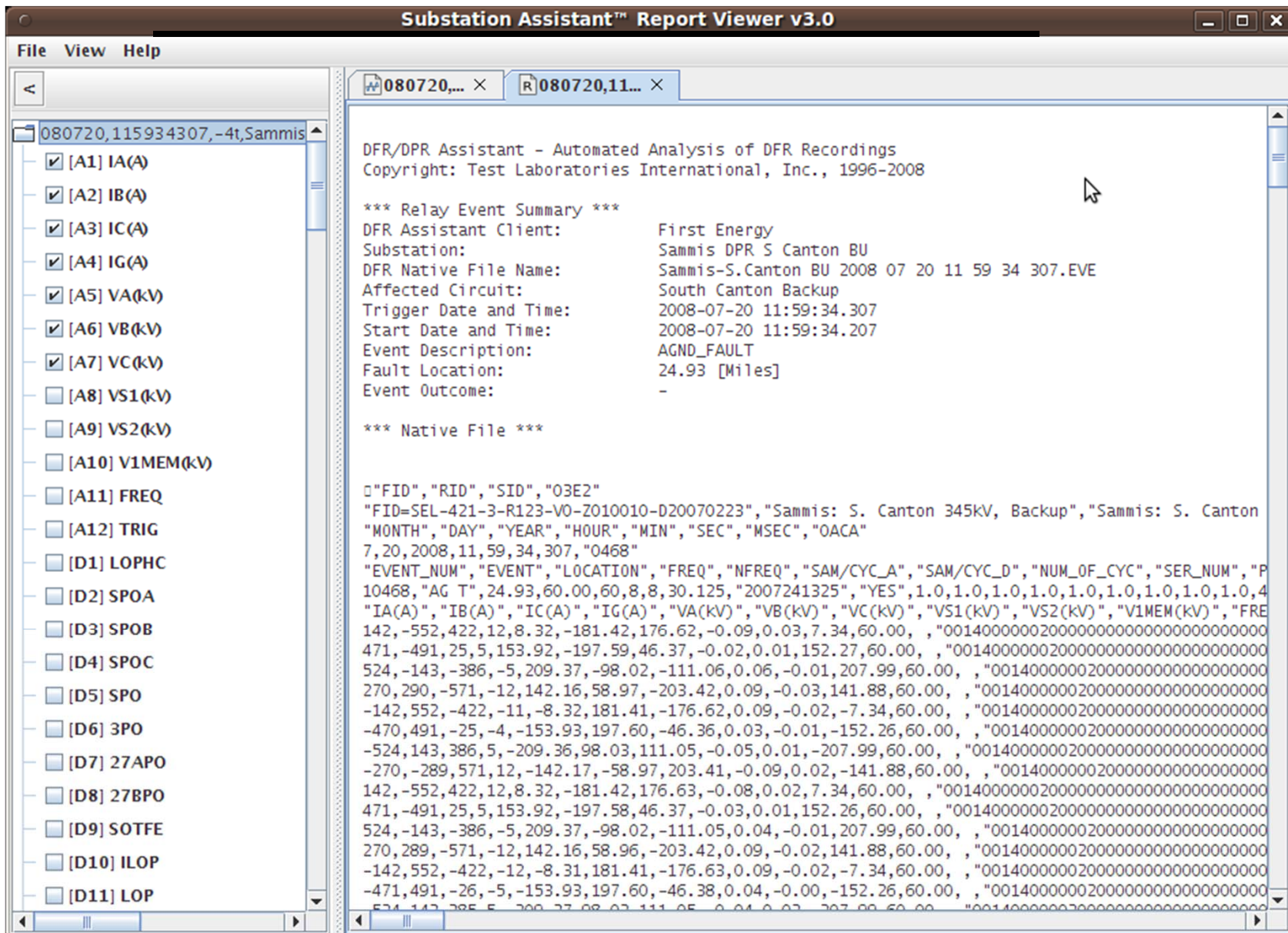
Processed Date/Time	Event Date/Time	Substation Branch	Event Type Outcome	Location 1-End/2-End	Get Data
2009-07-29 10:11:52.989 EDT	2008-07-22 05:50:51.685 EDT	Sammis Highland	UNCLASSIFIED EV_NO_CLR	NA	
2009-07-29 10:16:52.927 EDT	2008-07-21 18:26:57.795 EDT	Sammis Wylie Ridge	GND_FAULT EV_CLR_SELF_REMOTE	NA	
2009-07-29 10:15:24.235 EDT	2008-07-20 11:59:34.343 EDT	Sammis DPR Highland Pri Highland Primary	AGND_FAULT -	-414.7 NA	
2009-07-29 10:14:56.250 EDT	2008-07-20 11:59:34.305 EDT	Highland DPR Sammis Pri Sammis Primary	AGND_FAULT -	498.5 NA	
2009-07-29 10:13:30.537 EDT	2008-07-20 11:59:34.302 EDT	Sammis DPR S Canton Pri South Canton Primary	AGND_FAULT -	24.85 NA	
2009-07-29 10:12:58.094 EDT	2008-07-20 11:59:34.307 EDT	Sammis DPR S Canton BU South Canton Backup	AGND_FAULT -	24.93 NA	
2009-07-29 10:11:45.090 EDT	2008-07-20 11:59:34.295 EDT	Highland Sammis	NOT_FAULT EV_NO_CLR	NA	
2009-07-29 10:21:20.927 EDT	2008-07-20 11:59:34.207 EDT	Sammis South Canton	AGND_FAULT EV_CLR_LOCAL	23.7 NA	
2009-07-29 10:09:00.357 EDT	2008-07-16 19:08:44.137 EDT	Sammis Highland	CGND_FAULT EV_CLR_SELF_REMOTE	72 NA	
2009-07-29 10:17:11.974 EDT	2008-07-16 19:08:44.157 EDT	Highland Hanna	NOT_FAULT EV_NO_CLR	NA	
2009-07-29 10:14:34.936 EDT	2008-07-16 19:08:44.217 EDT	Highland DPR Sammis Pri Sammis Primary	BGND_FAULT -	-334.8 NA	
2009-07-29 10:15:10.233 EDT	2008-07-09 11:27:52.280 EDT	Highland DPR Sammis Pri Sammis Primary	ER -	NA	

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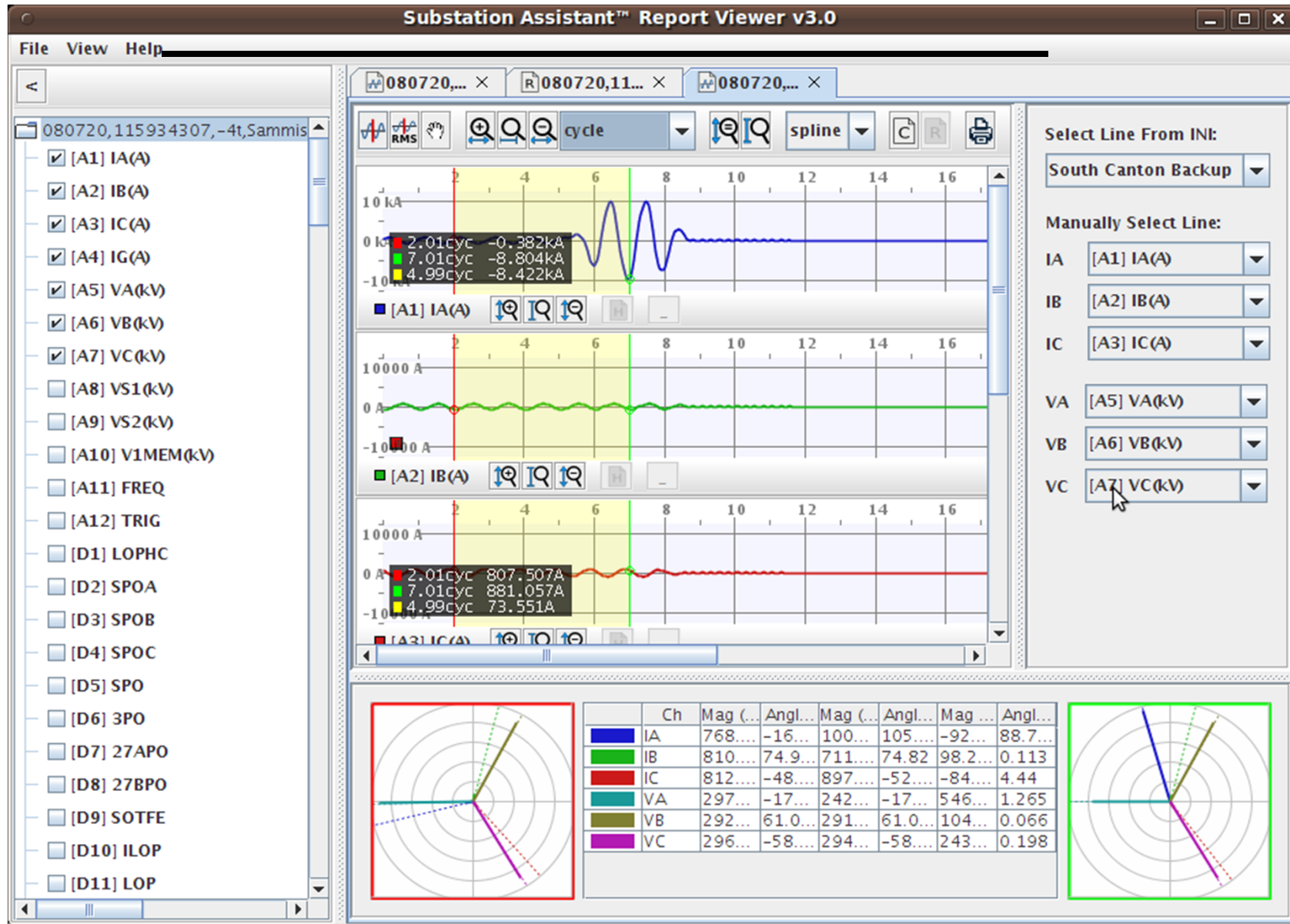
Report Viewer (via Web Start)



View Report (DPR example)



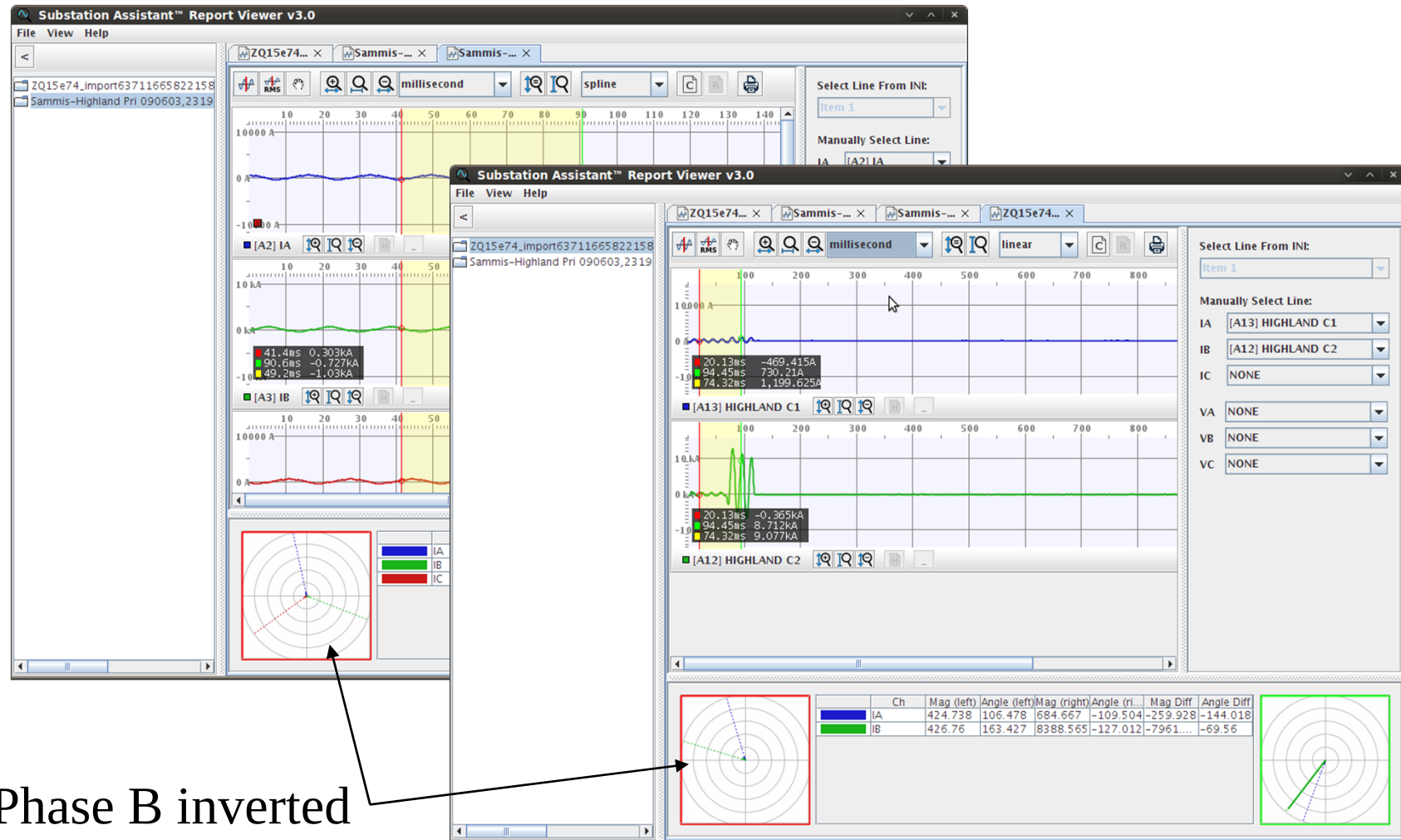
View Phasors



Troubleshooting (DFR Wiring)



Outcome: Maintenance Order (Fix DFR Wiring)



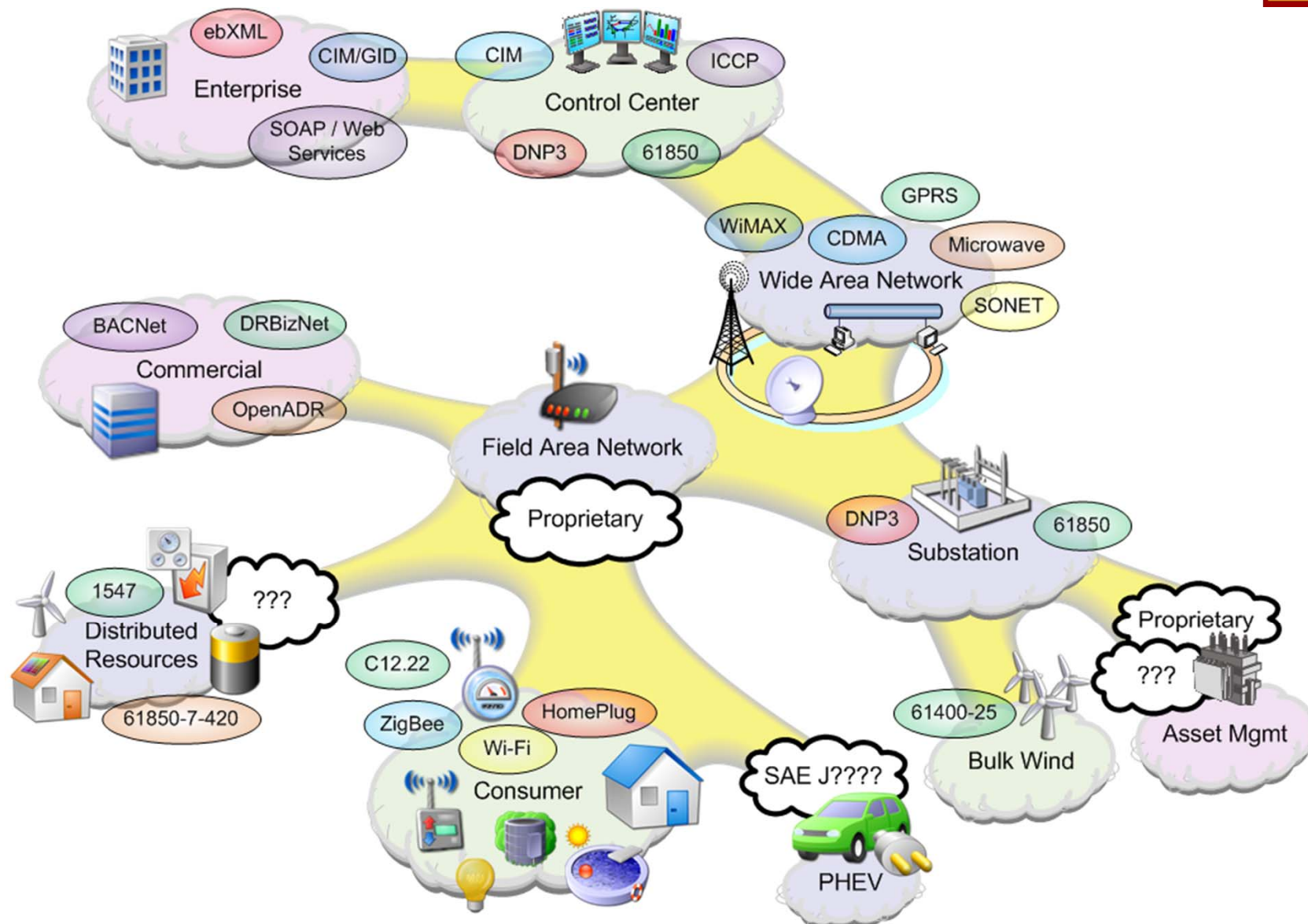
Phase B inverted

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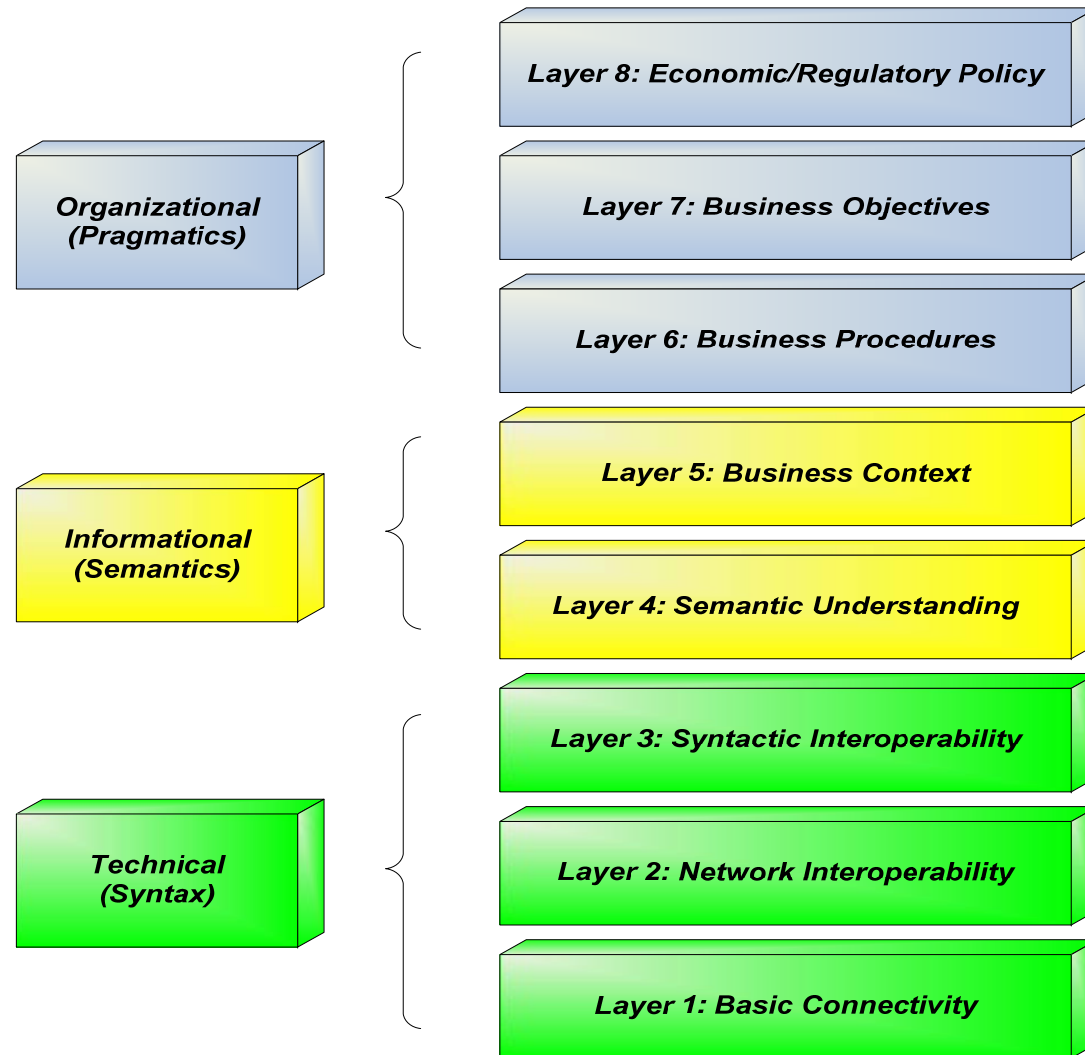


NIST SGIP

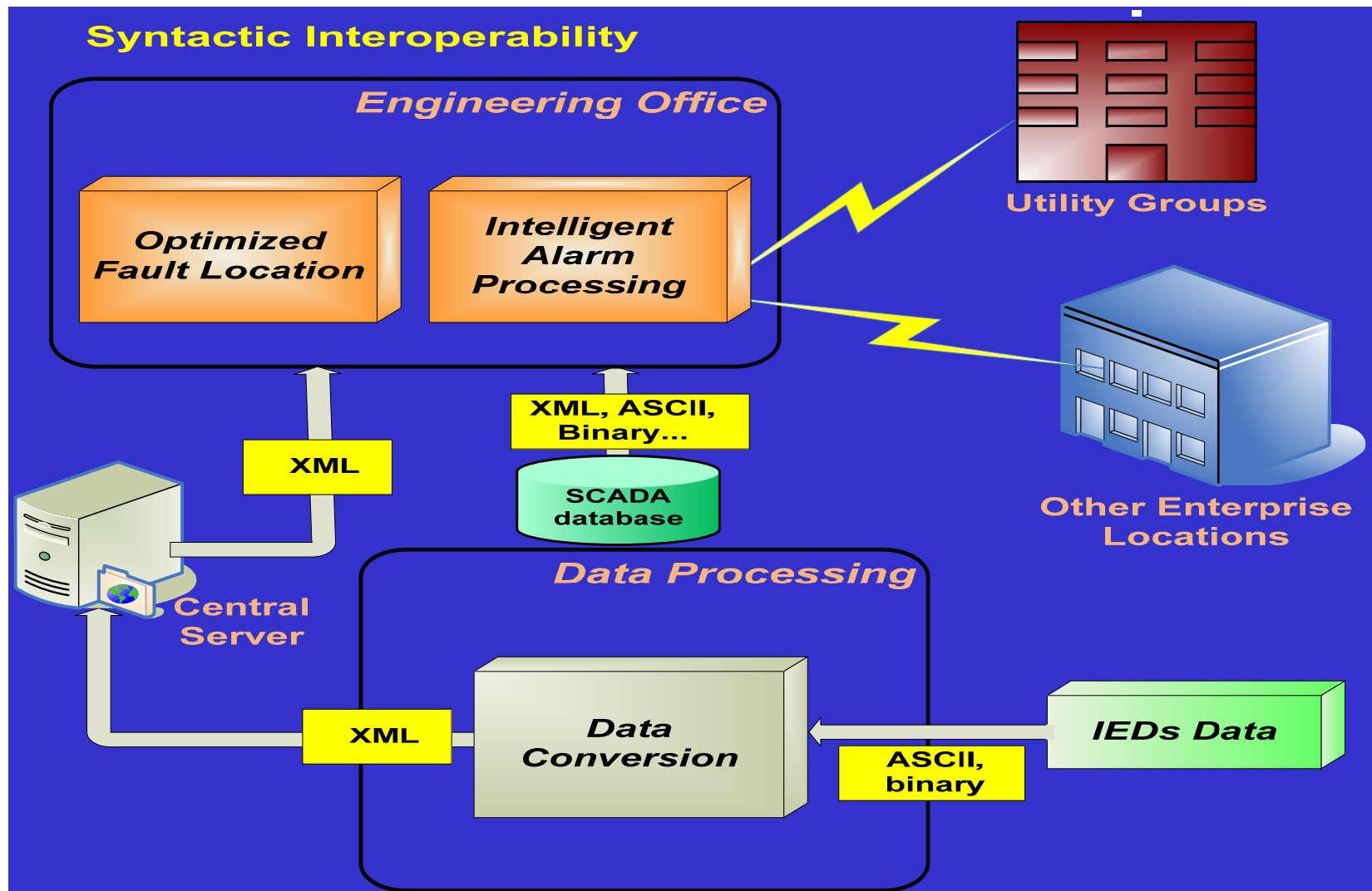


Courtesy of EnerNex

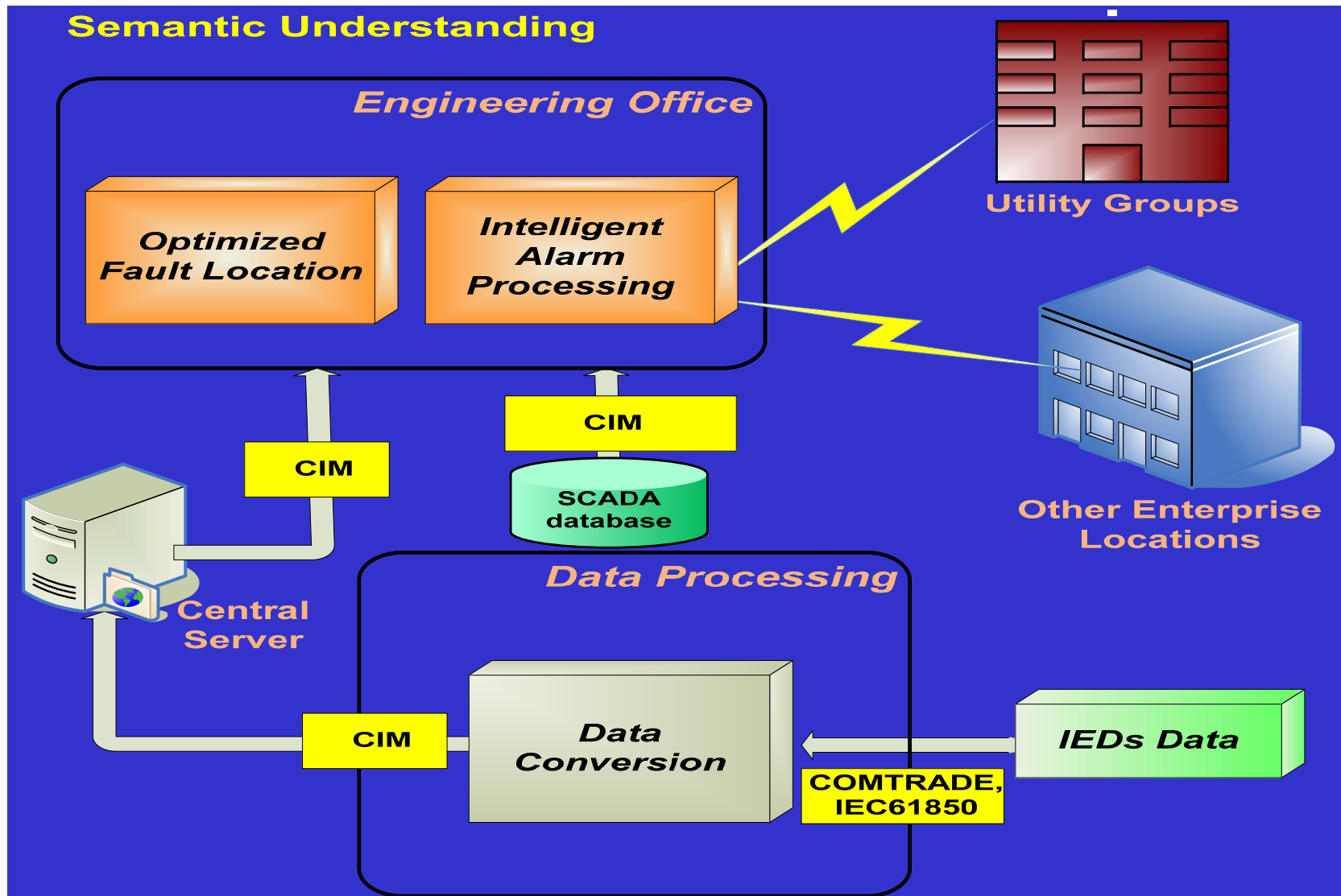
Interoperability



Preprocessing and database interfacing to the Control Center



IEC61970 (CIM)/IEC 61850 data model extensions



Conclusion

- Substation retrofit may benefit from hardware, software and middleware;
- New substation design should offer flexible layout and functional capability to serve many new applications;
- New substation designs should offer monitoring, control and protection features that will significantly enhance system resilience and market support

Publications

- Mladen Kezunovic, “Translational Knowledge: From Collecting Data to making Decisions in a Smart grid,” IEEE Proceedings (In print)
 - Mladen Kezunovic, “Smart Fault location for Smart Grids,” IEEE Transactions on Smart Grids (In print)
- Yufan Guan, Mladen Kezunovic, “System Monitoring and Market Risk Management using Intelligent Economic Alarm Processor ,” IEEE Intelligent Systems Magazine, (in print)
- Mladen Kezunovic, Vijay Vittal, Sakis Meliopoulos, Tim Mount, Smart Research for Large-scale Integrated Smart Grid Solutions,” IEEE Power and Energy Magazine (In print)
- Mladen Kezunovic, “Intelligent Design: Substation Data Integration for Enhanced Asset Management Opportunities,” IEEE Power and Energy Magazine, Vol. 8, No 6, November/December, 2010
- Mladen Kezunovic, Yufan Guan, Chenyan Guo, Mohsen Ghavami, “The 21st Century Substation Design: Vision of the Future”, IREP 2010, the Bulk Power System Dynamics and Control – VIII, August 1-6, 2010, Buzios, Rio de Janeiro, Brazil.