21st Century Intelligent Grid Solution: Use of Synchronized Sampling

The Intelligent Utility
April 18, 2007
Outline

- Participants
- Fundamental Improvements
- Project Tasks
- Applications
- Field demonstration
- Deliverables
- Commercialization
Participants

- Texas A&M University:
  - Kezunovic
  - Singh
  - Huang
- UT Austin:
  - Grady
  - Santoso
- UT Arlington:
  - Lee
Outline

- Participants
- Fundamental Improvements
- Project Tasks
- Applications
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Background

Synchronized sampling
Data integration
Information extraction
Existing Infrastructure

LEVEL I CENTRALIZED LOCATION
- CFL
- MS
- PE
- EMS
- RC

LEVEL II SUBSTATION
- IS
- LMS
- SC

LEVEL III SWITCHYARD INTERFACE
- FL
- DFR
- IED
- DPR
- RTU
- SOE

- A
- S
- A
- S
- A
- S
- A
Scanning vs synchronous sampling
Existing Products
Synchronized Sampling and Time Stamping

- GPS CLOCK RECEIVER
- LOCAL CLOCK
- MUX
- A/D
- PROCESSOR + MEMORY
- GPS ANTENNA
- S/H (Sampling)
- S/H (Channel 1)
- S/H (Channel 2)
- S/H (Channel n)
- 1PPS (GPS 1 PPS Time Code)
- TIME CODE
IED GPS Synchronization

TAMU IED LAB SETUP

- RELAY SEL 421
  - GPS signal from PC via serial Port 1
  - RS232 connection

- GE D60
  - GPS signal from GPS receiver via IRIG-B port
  - RS485 and RS232 connections

- Converter
  - RS485 and RS232 connections

- GPS RECEIVER
  - IRIG-B connection

- DFR TR -2000
  - GPS signal from internal receiver and antenna
  - Ethernet connection

- GPS ANTENNA
  - Ethernet Hub connection

- CBM01
  - GPS signal from PC via wireless link

- CBM02
  - GPS signal from PC via wireless link
Future Infrastructure

- Email, Fax, Hosting, WWW, Pager Notification
- Intranet Internet
- Wide-area networks (hubs, routers, gateways)
- System wide control
- Mobile Agent Server
- COMTRADE IEC 61850
- Substation Analysis and Control
  - DFR
  - SER
  - DPR
  - PMU
  - CBM
  - RTU
  - GPS
- Substation Analysis and Control
  - DFR
  - SER
  - DPR
  - PMU
  - CBM
  - RTU
  - GPS
Background

Synchronized sampling

Data integration

Information extraction
The Main Idea

Transmission Line

Current Transformer

Bus

Contact “A”

Contact “B”

Capacitive Voltage Transformer

Current

Voltage

CBM

CB

DPR

DFR
Selected IEDs

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Data Integration Concept

Database:
Raw and pre-processed measurements
System configuration data

Information Exchange

Data Integration

DFRs  DPRs  CBMs  RTUs  SERs  PLCs  PQ Meters
Background

Synchronized sampling
Data integration
Information extraction
Automated Analysis

Email, Fax, Hosting, WWW, Pager Notification

Intranet Internet

Wide-area networks (hubs, routers, gateways)

System wide analysis

Mobile Agent Server

System wide control

COMTRADE IEC 61850

Substation Analysis and Control

DFR
CBM
DPR

PMU
SER
RTU

GPS

Substation Analysis and Control

DFR
CBM
DPR

PMU
SER
RTU

GPS
Reports can be customized according to the need of a particular category of users and disseminated via fax, e-mail, website, pager, etc.
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Project Tasks

Task #1. Development and demonstration of new field GPS-enabled equipment
Task #2. Deployment of software for new applications
Task #3. Exploration of new services and study of economic benefits
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Applications

Substation-wide: a) Intra-station (local)
   b) inter-station (adjacent)
   EMS-wide
   Utility-Wide
   ERCOT-wide
Intra-station Applications

- Relay operation
- Fault location
- CB operation
- Switching
Inter-station Applications

GPS Satellite

Sending end

\( i_s(k) \) → Fault Location → \( i_F(k) \) → \( i_r(k) \)

Receiving end

\( v_s(k) \) \( v_r(k) \)

\( d_s \)

\( d_r \)

Short line Model

Lone line Model

\( R \) \( L \)

\( C \)
Measurements from Adjacent Substations

- **Short Line Model**
  \[
  i_d(k) = i_S(k) + i_R(k)
  \]

- **Long Line Model**
  \[
  i_{d1}(k) = i_S(k - P) \left[ 1 - \frac{Rd}{2Z_c} \right] + i_R(k) \left[ 1 + \frac{Rd}{2Z_c} \right] + \frac{v_S(k - P)}{Z_c} - \frac{v_R(k)}{Z_c}
  \]

  When no internal fault, those features equal to zero
  When there is an internal fault, those features are related to fault current
Applications

Substation-wide: a) Intra-station (local)
   b) inter-station (adjacent)

EMS-wide
Utility-Wide
ERCOT-wide
EMS-wide Applications

- Alarm processor
- Topology processor
- State estimator
- Automated analysis of faults
- Fault locator

Hybrid control room in Beznau plant in Switzerland

Courtesy Nordostschweizerische Kraftwerke AG
EMS-wide Applications

Applications

Fault Analysis
  - Sequence of events
  - Fault location

State estimation
  - Topology processor
  - Two-stage estimator
Applications

Substation-wide: a) Intra-station (local)
b) inter-station (adjacent)

EMS-wide
Utility-Wide
ERCOT-wide
Utility-Wide Applications

Engineer
Comprehensive Report

Dispatcher
Brief Report

Technician
Summary Report
Utility-wide Applications

LEVEL I
CENTRALIZED LOCATION

LEVEL II
SUBSTATION

LEVEL III
SWITCHYARD INTERFACE

FL
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ERCOT

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Examples of New Functions
Applications

Substation-wide: a) Intra-station (local)  
b) inter-station (adjacent)  
EMS-wide  
Utility-Wide  
ERCOT-wide
ERCOT-Wide Applications

- Multi-utility state estimator
- Voltage stability
- Model improvements
- Intelligent Alarm Processor
ERCOT-wide Applications

System protection center

Transmission network

Local protection

Local protection

Local protection

Local protection
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Field Demonstration

Field deployment
GPS synchronization
System architecture
IED GPS Synchronization

TAMU IED LAB SETUP

RELAY SEL 421
GPS signal from PC via serial Port 1

GE D60
GPS signal from GPS receiver via IRIG-B port

IRIG-B

GPS RECEIVER

IRIG-B

DFR TR-2000
GPS signal from internal receiver and antenna

Ethernet

Ethernet Hub

GPS ANTENNA

Converter

RS485
RS232

RS232

RS232

RS232

CBM01
GPS signal from PC via wireless link

CBM02
GPS signal from PC via wireless link
System Architecture

**SUBSTATION**
- CBM
- DPR
- DFR
- AEA Client
- Substation DB
  - SUBSTATION PC

**CONTROL HOUSE**

**CENTRAL OFFICE**
- Server DB
- Web Server
- AEA Server
- Web Application
  - SERVER PC

**REMOTE USER**
- Remote Desktop
  - Web browser
  - Remote Desktop
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<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Enhances the utility functions</th>
<th>Provides Short Term ROI</th>
<th>Leads to Texas products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software for fault location, alarm processing and topology monitor</td>
<td>Protection, Operations, Maintenance</td>
<td>Fully utilized existing IEDs, reduced reaction and restoration time, improved maintenance</td>
<td>Several potential vendors in Texas</td>
</tr>
<tr>
<td>Circuit breaker monitor</td>
<td>Maintenance, Operations</td>
<td>Reduced maintenance cost and time, improved operating capability</td>
<td>Vendor in College Station, Texas</td>
</tr>
<tr>
<td>ERCOT applications</td>
<td>Operations, Planning</td>
<td>Improved reliability and planning, enhanced system transactions</td>
<td>Several potential vendors in Texas</td>
</tr>
<tr>
<td>New Test set and calibration lab</td>
<td>Equipment purchase and field maintenance</td>
<td>Assured performance of purchased IEDs and more reliable operation</td>
<td>Vendor in College Station, Texas</td>
</tr>
</tbody>
</table>
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Cost-Benefits

- Leverages R&D cost through matching funds
- Complements on-going R&D efforts
- Reduces down-time in the Texas grid
- Increases productivity of utility staff
- Utilizes existing GPS-enabled IEDs
- Creates new jobs for products and services
- Keeps Texas-educated talent in the state
- Demonstrates how CCET partnership works
CCET Partnership

EPRI: Substation Automation

DOE CERTS: Topology

DOE CTC: Visualization

Utilities: Field demo

Vendors: Products

NSF/PSerc: Algorithms
Questions?