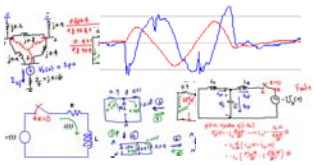
Source: www.mwftr.com

Charles Kim, "Lecture Notes on Fault Detection and Location in Distribution Systems," 2010.

FAULT DETECTION AND LOCATION IN DISTRIBUTION SYSTEMS

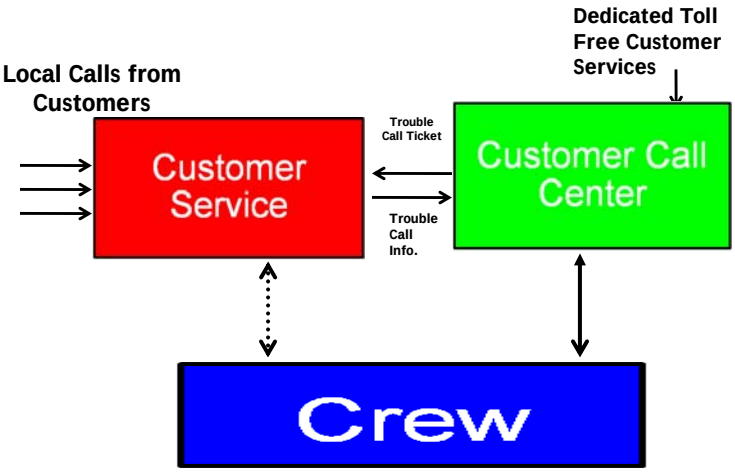
6. Fault Location Using Utility Smart Grid Infrastructure



Charles Kim

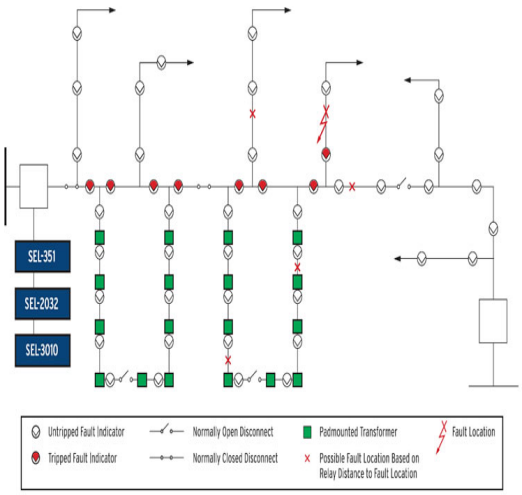
June 2010

Outage Management: Current Status

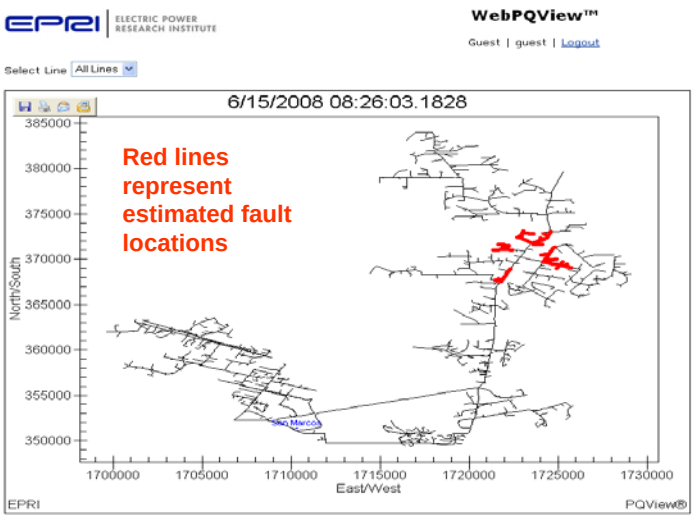


Efforts for Improvement (Off-line)

- Fault Indicators
- SCADA
- Substation-based Feeder Monitoring System (PQView)
- Fault Location Algorithms



PQView: Picture of San Marcos West Bus w/ estimated fault locations



DSOR: June 15, 2008

DISTRIBUTION SYSTEM OPERATIONS REPORT

FROM 12:01 AM TO 12:00 MIDNIGHT OF SUNDAY, JUNE 15, 2008

Type	Outage ID	Cir	Substation	District	Start Date Time	Restr. Date Time	Duration	#Cus
BRAN	080615E5005	599	SAN MARCOS	NE	06/15/2008 0836	06/15/2008 1155	3 hr 19 min	115

Response Times (ETS) 0 hr 42 (FV) N/A (Crew Callout Initiated) 0 hr 4 min (CrewFilled) 0 hr 39 min (Crew Assembled) 3 hr 26 min

Cause EQUIPMENT, CABLE UG, DAMAGED

Area affected DEER SPRINGS RD AND TWIN OAKS RD N/O OLIVE, S/O CAMINO MAYOR

Individual Outage Development

OUTAGE_ID	080615E5005	*Time ETS called*	0853	*Time FV requested*	0853
OUTAGE_TYPE	BRAN	*Time ETS on scene*	0935	*Time FV on scene*	N/A
CIRCUIT ID	599	*Time crew requested*	0853	*First manual operation*	1018
Substation	SAN MARCOS	*Time crew Callout started*	0857	*First SCADA operation*	N/A
Time occurred	0836	*Time crew filled*	0936	*Damaged device*	UG CABLE
1st cus. restored	1032	*Time crew Assembled*	1302	*Damaged from structure*	H3673672806
Time restored	1155	*Cause Identified*	1210	*Damaged to structure*	P812236
		Time crew on scene	N/A		
Cause	EQUIPMENT, CABLE UG, DAMAGED				
Area affected	DEER SPRINGS RD AND TWIN OAKS RD N/O OLIVE, S/O CAMINO MAYOR				

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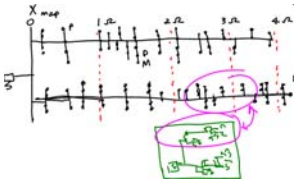
Problem

- Long and expensive Outage Response
  - Distribution fault location involves errors
  - Fault indicators have shown reliability problems
  - SCADA information is not being used properly
  - Maps show multiple fault locations or inaccurate position
  - Fault distances are difficult to interpret
  - Current OMS is not efficient

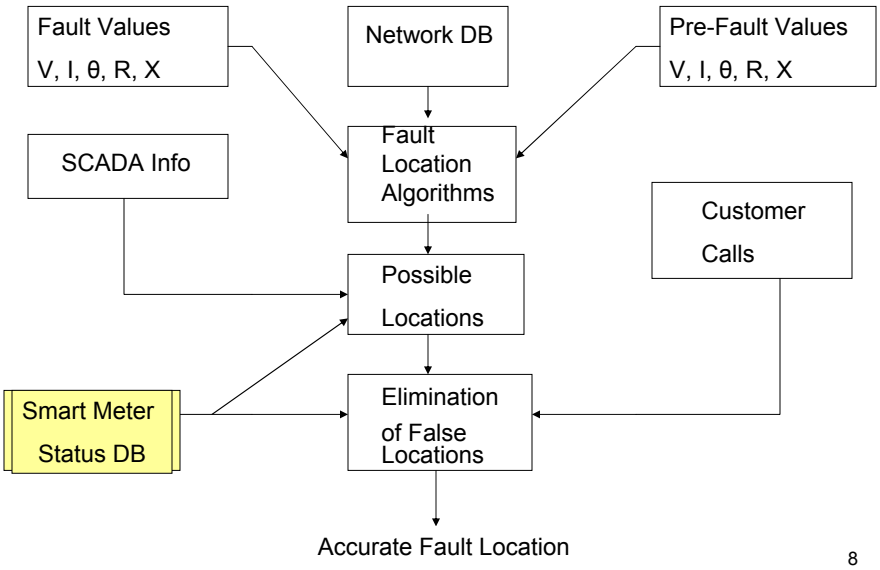


- Solution Needs
  - Accurate location of fault
  - Use of the existing fault location algorithms
  - Fault anticipation with detection of self-clearing insulation breakdown events
  - Use of Smart Grid infrastructure (IED, communication, smart meters) into advanced OMS

Available Means for Solution

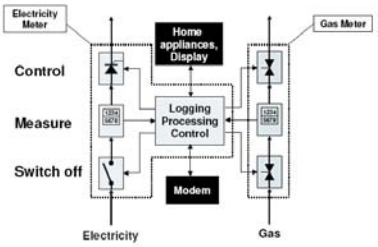
- PQView or Monitoring Systems at Substations
- Fault Location Methods are employed
- Fault Indicators are installed
- Data bases created with load data has been used for fault locating and other analysis
- OMS system has been replied upon customer calls and crew dispatch and communication
- SCADA incorporated
- GIS applied
- Smart Meters are deployed
- Smart Grid Demo Projects are undergoing.
- Vendors are swarming around the utility engineers for new technology, new method, and mew integrated system
- New hope of fast response to outage problem

Solution Approach



What is the Smart Meter?

- The Smart Meter is a digital technology device that is capable of taking remote reads
  - Two-way communication between electric meters and utility back office
  - – Remote disconnect/connect integrated within the meter
  - – Interval storage of meter reads – residential hourly, commercial & industrial (C&I) every 15 minutes
  - – Tamper / theft detection



Schematic overview of a typical smart meter configuration

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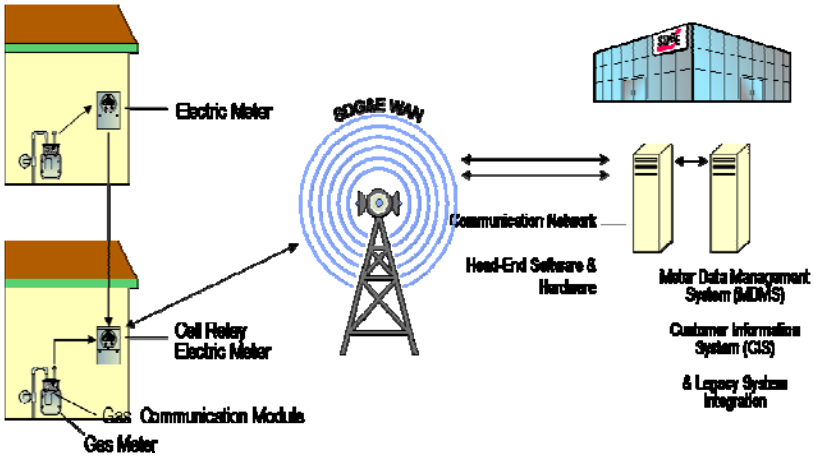
How Does Smart Meter Work?



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Smart Meter and DR

- Smart Meter technology will help drive demand response and dynamic pricing.

Smart Meter

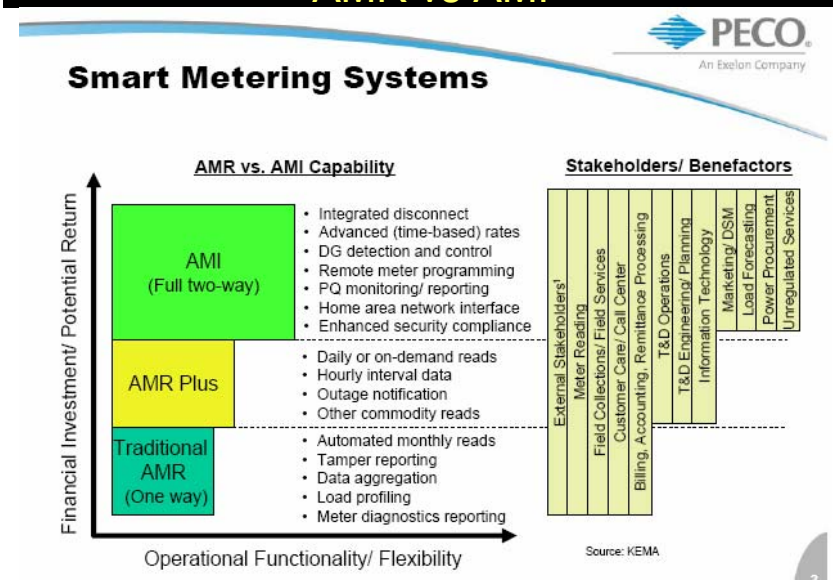
- Demand response refers to the reduction of customer energy usage at times of peak usage in order to help address system reliability.

Demand Response

- Retail prices for energy consumed that offer different prices during different time periods.

Dynamic Pricing

AMR vs AMI

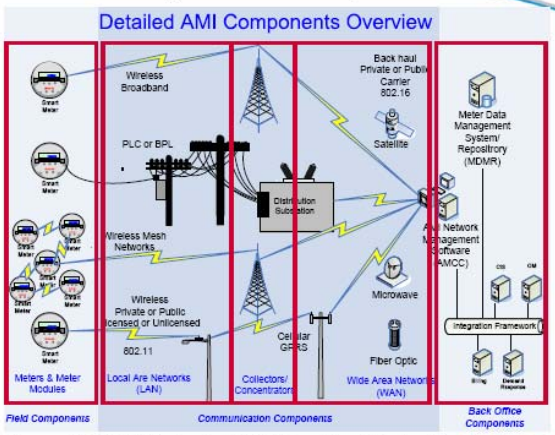


- Source: G. Pritchard and J. Buxton, "AMI 101" May 13, 2009

Smart Meter System Components

PECO
An Exelon Company

Smart Meter System Components



Smart Meters AMI LAN Network WAN Backhaul Network System Controller/ Data Processor

Smart Meter Requirement

PECO
An Exelon Company

Smart Meter Functional Requirements

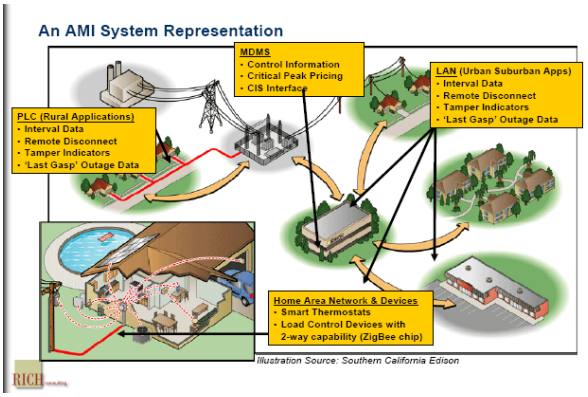
- Bidirectional data communications capability
- Remote disconnection and reconnection
- Ability to provide 15-minute or shorter interval data to customers, EGSs, third-parties and the regional transmission organization ("RTO") on a daily basis, consistent with the data availability, transfer and security standards adopted by the RTO
- A minimum of hourly reads delivered at least once per day
- On-board meter storage of meter data that complies with nationally recognized non-proprietary standards such as ANSI C12.19 and C12.22 tables
- Open standards and protocols that comply with nationally recognized non-proprietary standards, such as IEEE 802.15.4
- Ability to upgrade these minimum capabilities as technology advances and becomes economically feasible
- Ability to monitor voltage at each meter and report data in a manner that allows EDC to react to the information
- Remote programming capability
- Communicate outages and restorations
- Ability to support net metering of customer-generators
- Support automatic load control by EDC, customer and third-parties, with customer consent
- Support time-of-use and real-time pricing programs
- Provide customer direct access to consumption and pricing information

AMI Can Do a Lot!

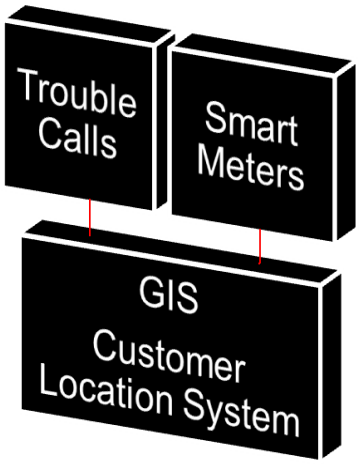
- **Billing and Member Service**
  - Remote Disconnect, Service Limiting
  - Theft and Meter Tampering
  - Rates and Financial Planning
  - Demand Limiting
  - **Outage Detection and Restoration**
  - Prepay
- **Engineering and Operations**
  - Distribution Transformer Loading Assessment
  - System Planning and Work Plan Evaluation
  - Voltage Monitoring and Evaluation
  - Blink Count Evaluation
- **Energy Management and Demand Response**
  - Time of Use (TOU)
  - Critical Peak Pricing (CPP)
  - Peak Loss Evaluation
  - Meter Accuracy Improvement
- **Fault Detection/Location ?? → Outage Management Tool**
  - **"Ping" the meters**

AMI Benefit in Fault Location and Restoration

- Outage Notification ("Last Gasp") Message from a meter when it loses power over the same network (LAN) sending metering data to a gateway or meter data collector.
- "Pinging" of AMI from OMS
  - Identification of Energized/De-energized Meters
  - Verification of restoration after outage

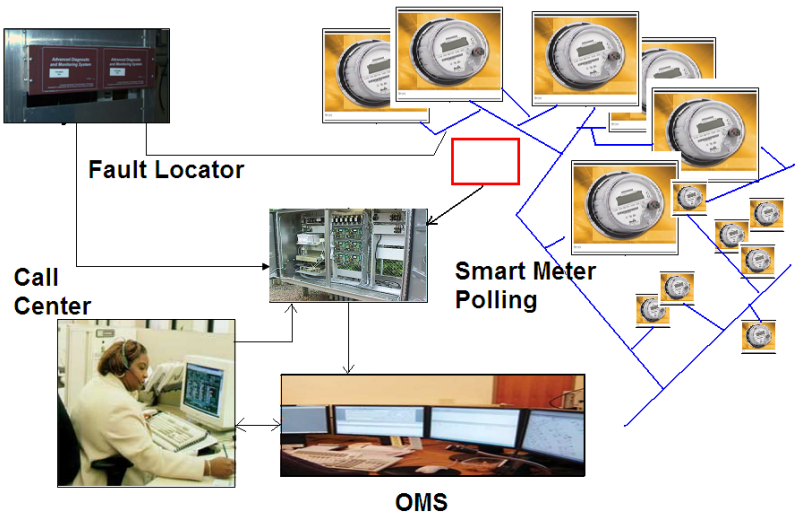


Alternative Solution – AMI Alone



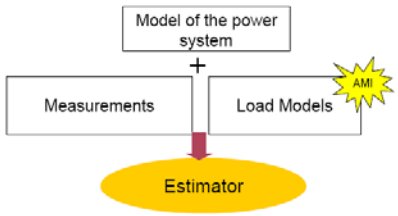
- No Fault Location Algorithm
- Only AMI (Smart Meters and Trouble Calls)
- Relies solely on an efficient trouble call management system and an easily accessible AMI &Smart Meter data base, and GIS for fast crew dispatch.
- Drawbacks:
  - Does not give diagnostic insight into the distribution power systems
  - Self-clearing faults are not detected

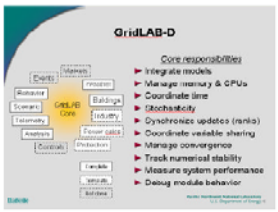
Better Solution Approach

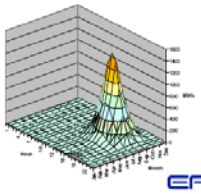


EPRI Vision

New simulation approaches for automation and DR integration (planning and real time applications)







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EPRI ELECTRIC POWER RESEARCH INSTITUTE

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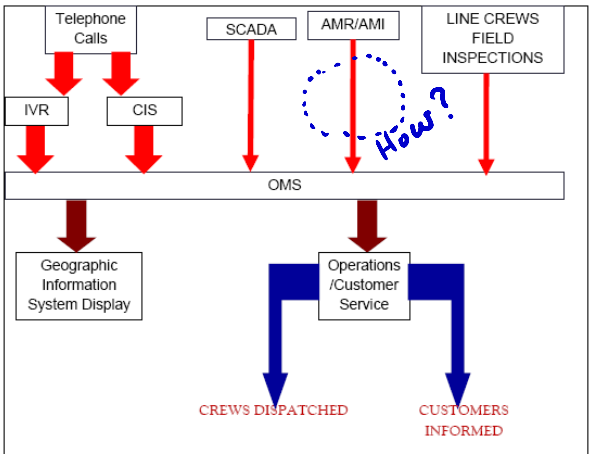
AMI and OMS

IVR: Interactive Voice Response for Crew Call-Out
CIS: Customer Information Systems



- **Source: "Outage Management Systems (OMS)"** , NEI Electric Power Engineering, 2008

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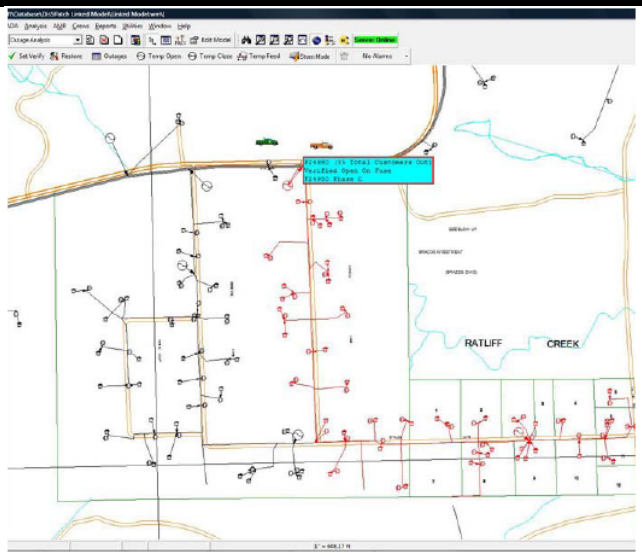
OMS Screen Example



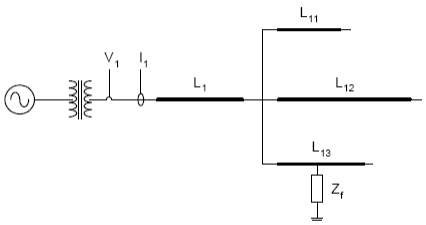
Typical OMS screen showing customer outages.

AMI Functions in OMS

- Outage Notification
  - AMI detects the outages and transmits outage messages to AMI network.
  - AMI network sends its outage data to the OMS.
- Outage Verification
  - OMS orders AMI to periodically “ping” all the meters.
- System Restoration
  - AMI reports restored meters to the OMS.
- Restoration Verification
  - AMI status
  - AMI detects sustained voltage and transmits message to OMS.

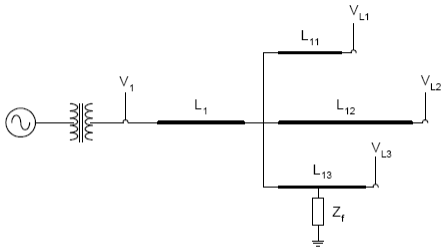
AMI-Supported Fault Location

Traditional Fault Location



Impedance to the fault from Substation measured data

AMI supported Fault Location



Voltage (@ substation) and Voltage Sags (from AMI) -- Voltage Profile based Location

- Source: El-Fouly and Abbey, "On the Compatibility of Fault Location Approaches and Distributed Generation", 2009 CIGRE/PES Symposium on Wide Scale Renewable Resources in Power Delivery System, Calgary, July 2009.

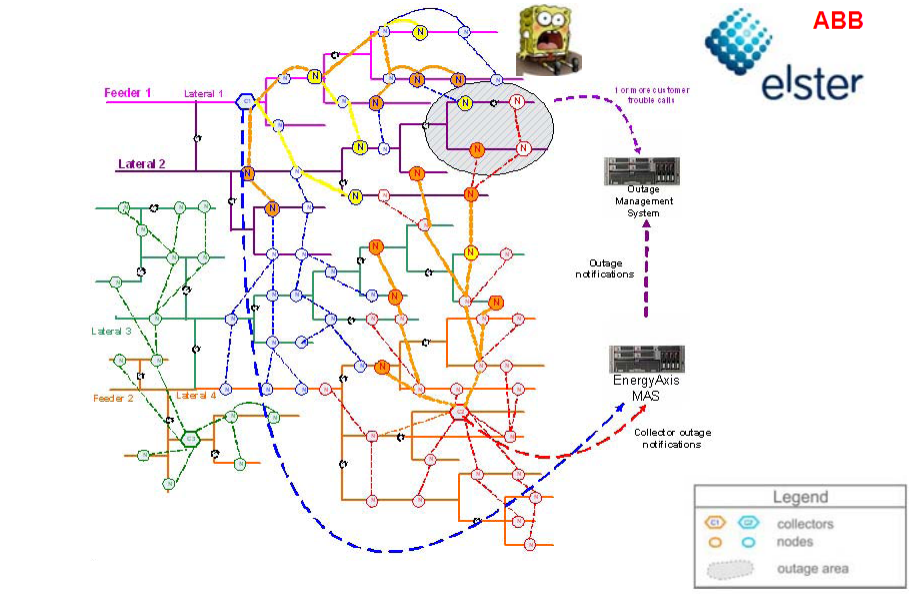
AMI Solution for Outage Management – White Paper

- RF-based AMI solution uses a combination of capabilities that when integrated with an OMS system provides a more complete outage solution for the utility.
- AMI solution include the following:
  - Endpoint outage notifications (last gasp capability)
  - Configurable electric metering endpoints that can differentiate between momentary and sustained events
  - Endpoint meter power status check or verification
  - Positive restoration notifications
  - Outage/exception logging and reporting by endpoint devices and/or collectors

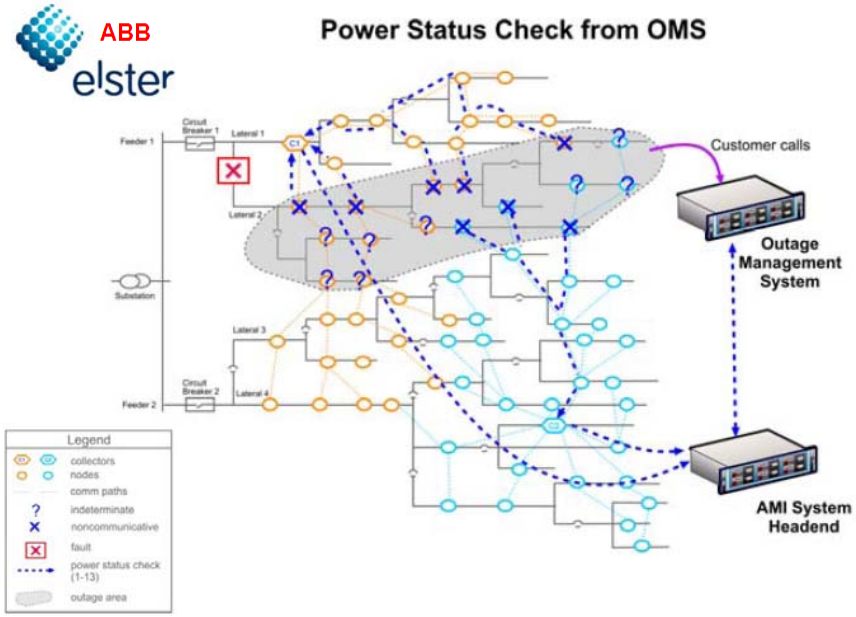
•Source: "Mesh networks and outage management," by Raymond Kelley and Ron D. Pate. www.elster.com. http://www.elster.com/en/downloads/Mesh_networks_and_out ement.pdf

elster

Outage Message Flow



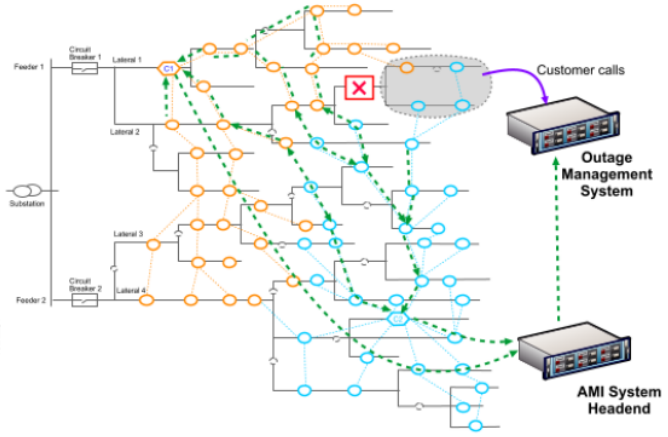
Meter Polling and Status Check

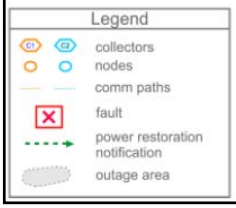


Power Restoration Notification

ABB elster

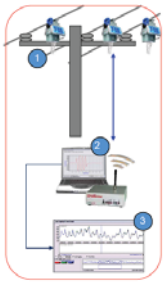
Power Restoration Notification (positively acknowledged)

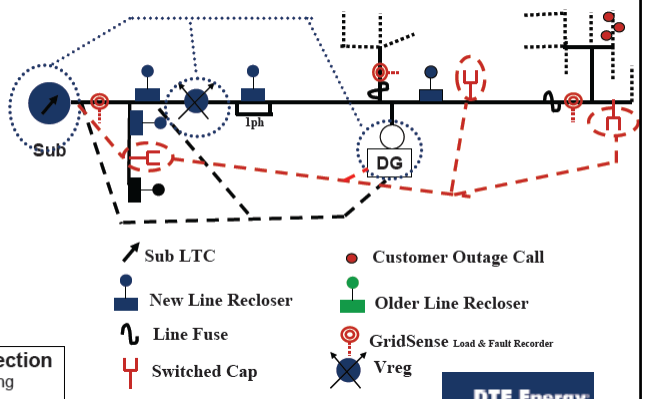




DTE's Approach with Grid Sensor (not Smart Meter)

- Close to wireless fault indicator





LineTracker Sensing & Detection
Automatic Adaptive Event Recording
- Fault Current
- Protection Operation
- Outages & Restorations

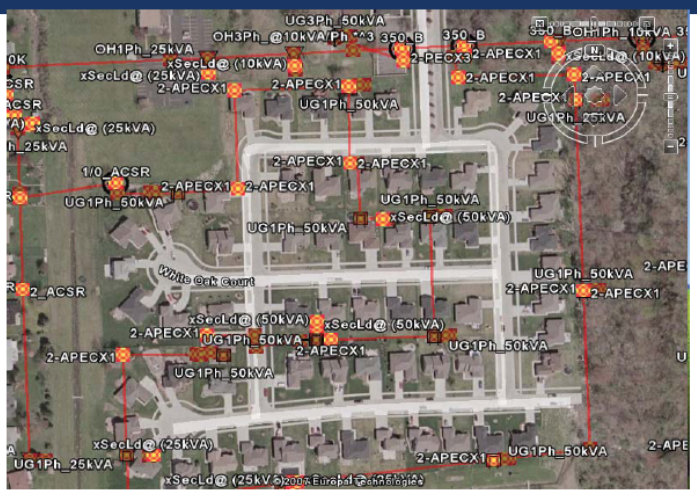
Load Profiling from 1 – 60 minute averages

DTE Energy

Fault Location

Google Earth Rendering of Outage Area using DEW V7 Google Interface

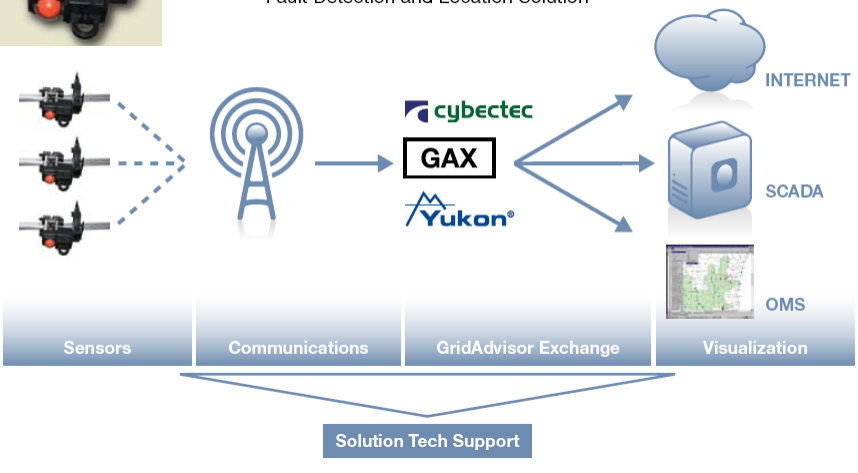
DTE Energy



Cooper Power with Smart Sensors

OutageAdvisor

Fault Detection and Location Solution



Issues

- No standard of using Smart Meters for distribution fault location --? Meter Data Management
- Smart meter generated data (1 million meters read every hour = 50TB)
- Is current communication system (stand alone or part of wider communication network) fast enough to link thousands of smart meters and to access DBs for urban area networks? → (max/optimal) Number of Endpoint meters reporting/Pinging outage to avoid data traffic jam and slow process??
- Handling Multiple simultaneous "last gasp" messages.
- Strategic selection of pinging meters?
- Power Loss or Communication Loss?
- Meter Malfunction and/or communication malfunction?
- Topology Dependence?
- Polling Method? Triggered Event Reporting from Meter?
- Theoretical limits in time and accuracy, etc?
- The effect on DG and DER in the Network?
- Hybrid Methodology?

Research Questions

- Modeling and Simulation of AMI Network
- Virtual AMI System
- AMI Test-bed for fault location purpose.
- Minimum Data Throughput for fault location purpose.
- Self-Diagnosis of AMI Network
- Large Data Handling
- Robust Algorithm for AMI enabled fault location
- Demonstration Project

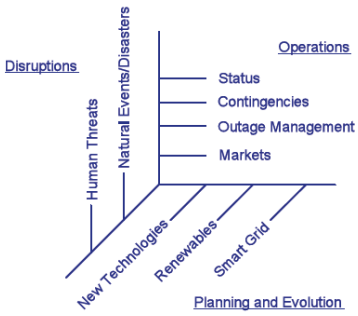
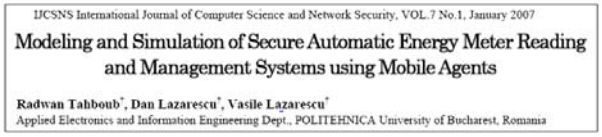


Figure 1. Three Axes of Power Grid Models

Source: "National Power Grid Simulation Capability: Needs and Issues," A report from the National Power Grid Simulator Workshop, Dec 9-12, 2008, Argonne, IL


IJCSNS International Journal of Computer Science and Network Security, VOL.7 No.1, January 2007

Modeling and Simulation of Secure Automatic Energy Meter Reading and Management Systems using Mobile Agents

Radwan Tahboub*, Dan Lazarescu*, Vasile Lazarescu*
Applied Electronics and Information Engineering Dept., POLITEHNICA University of Bucharest, Romania