Distribution Automation - An Overview

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A Little History

- **Late 1970’s**
  - SCADA: big computers, slow & unreliable communication
  - Sectionalizers, reclosers, some loop scheme, auto-transfer

- **Mid 1980’s**
  - SCADA: computers getting faster, radio communication advances

- **Early 1990’s**
  - SCADA - faster and faster - more memory - more applications become available
  - Still no true automation

- **Mid 1990’s**
  - SCADA - starting to see the next generation replacing the old
  - True automation debut’s on the scene
A Little History

- **Late 1990’s**
  - SCADA - starting to see the next generation replacing the old
  - Distribution automation debut’s on the scene - based on SCADA control

- **2000’s**
  - SCADA applications grow significantly due to significant computer power growth
  - Communication makes quantum leaps
  - Distributed intelligence based DA arrives

- **Future**
  - Systems become fully integrated - automatic optimization; integration from generation to refrigerator
Distribution

- Gets the “watts” to the customer
- Biggest impact on customer’s perception of Quality of Supply
- Small part of customer’s bill
  - Cost cutting has little overall effect on the customer’s bill
Drivers

- Market Trends
- Utility Incentives
  - Rates
  - Customer Satisfaction
  - New Business Development
Measurements

- **SAIDI** – System Average Interruption Duration Index
- **SAIFI** – System Average Interruption Frequency Index
- **CAIDI** – Customer Average Interruption Duration Index
- **MAIFI** – Momentary Average Interruption Frequency Index

*If you don’t measure it... you won’t improve it*

– Anonymous Management Truth
Reliability Improvement Strategies

- Worst Circuit improvement
- Repeat outage improvement
- System improvement
- Condition improvement
How?

- Tactical vs. Strategic approaches
- System Maintenance / rebuilding / upgrading
  - Tree Trimming; Surge Arresters; Line upgrades; shield wire;
- Distribution Automation
Distribution Automation

- Distribution Automation is routinely found to be the lowest cost per SAIDI minute improvement.
  - DA is also the fastest path to reliability improvement
# Advanced Distribution Circuit Reliability Techniques

<table>
<thead>
<tr>
<th>SCADA</th>
<th>Source Transfer</th>
<th>Distributed Intelligence</th>
<th>HRDS Open-Loop</th>
<th>HRDS Closed-Loop</th>
<th>Power Electronic Switching</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-60 min</td>
<td>2-5 sec</td>
<td>10-60 sec</td>
<td>3 sec</td>
<td>No-Outage</td>
<td>No-Outage</td>
</tr>
<tr>
<td><strong>Extended Outage</strong></td>
<td><strong>Spot Solution</strong></td>
<td><strong>Tactical / Strategic</strong></td>
<td><strong>Tactical Solution</strong> Only Customers Beyond Fault Impacted</td>
<td><strong>Tactical Solution No-Outage</strong></td>
<td><strong>Tactical Power Quality</strong></td>
</tr>
<tr>
<td>Impacts SAIDI, SAIFI, CAIDI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Dispatcher decision making required</strong></td>
<td><strong>Autonomous Typically applied for one customer</strong></td>
<td><strong>Autonomous - Distributed Intelligence Scalable / Asset Management</strong></td>
<td><strong>Unlimited Units - Universal Application</strong></td>
<td><strong>Unlimited Units - Special Application Primary Network</strong></td>
<td><strong>UPS - 30 sec Ride-through</strong></td>
</tr>
</tbody>
</table>
Example
A Cooperative Case Study

- Large Retailer
- Not happy with reliability
- System constraints prevent “traditional” approaches
- Advanced Feeder Automation used to solve problem
For reference information, refer to following slides

Or

Call Doug Staszesky
773-338-1000 ext 2560
REFERENCE MATERIAL

The information beyond this slide is for your reference and will not be reviewed during the session.
Value of Reliability
On average, every day perhaps half a million Americans lose power for over two hours – costing the American economy $100 billion a year equipment upgrades, real-time monitoring, and on-site generation. (EPRI)

Average cost of a one-hour outage at nearly $300,000. (Midyear National Business Customer Assessment conducted by RKS Research & Consulting)
Value

- New Zealand Utility - $30,000 to $100,000 per SAIDI minute
  - Based on combined utility cost and value to customer
  - Based on nature of circuit/area and type of customer on circuits
US Utilities

- US Utilities - $1.5MM per SAIDI minute improvement
  - Absolute value for comparison of techniques
  - Based on cost to achieve one minute of improvement
- Utility 1 - $1.5MM per minute - mandate from PUC to reduce SAIDI or $6MM penalty
- Utility 2 - $1.20 per customer (approx 1.2MM cust)
- Utility 3 - Started at $200k/minute - escalated to $1.5MM per minute as low hanging fruit picked
- Utility 3 - spent $30MM to reduce SAIDI by 10 minutes
What To Do?

- Feeder Automation?
- Substation Automation?
- Stand-Alone?
- Central Intelligence?
- Distributed Intelligence?
- Automated?
- Manual? (Path to full automation?)
Pieces of the DA puzzle

- DA Master Station
- Distributed Intelligence
- Protocols
- Communication networks
- Voltage Control
- VAR management
- Switching
- Feeder automation
- AMR
DA Elements

- Protocol
- Communications
- Training
- Maintenance / Updating
Strategic Approaches

- Large geographic area
- Overall project investment is extensive
- Project may have several goals
- Project utilizes a combination of traditional and “outside the box” approaches
- Serves a large number of customers of all types
Tactical Approaches

- Limited to small geographic area
- Investment is limited
- Goals are narrowly defined
- Specific technological solutions
- Serves a limited number of critical and/or high-value customers
Tactical DA Applications

- **Airport Automation**
  - Oncor, Xcel (Denver), Carroll Electric; Adams Co-op
  - Critical application; Security Concerns; Passenger Safety

- **Xcel (Minneapolis)**
  - Capital Deferral
  - Reliability Improvement
Tactical DA Applications

- Mississippi Power Co.
  - Casino reliability
  - Reduced losses

- Empire District at Branson, Missouri
  - SCADA solves a problem in high traffic area
  - Customer satisfaction

- Lakeland, Florida
  - Full distribution automation, tactical application
  - Foil the competition
Tactical DA Applications

- Reedy Creek Improvement District
  - Reliability improvement at Disney World
  - Keep the customers happy

- Delmarva / Connectiv
  - Direct monetary savings
  - Better system utilization
  - Customer driven

- Blue Ridge Electric Cooperative
  - Reliability improvement for large retailer
  - Advanced use of distributed intelligence to maximize asset use
Strategic DA Applications

- Public Service Electric & Gas of New Jersey
  - SCADA since 1975 for reliability enhancement

- City of Naperville
  - IntelliTEAM for reliability improvement; started small – grew to strategic implementation

- ComEd
  - IntelliTEAM & IntelliTEAM II — distributed intelligence
  - Response to 1999 heat wave reliability problems
  - Regulatory pressure

- FP&L
  - IntelliTEAM II to meet regulatory challenges
High-Reliability Distribution System

- High-speed fault clearing
- Open or closed loop application
- “No outage” operation in closed loop mode
- Up and running
  - International Drive – Orlando
  - UCSB – California
  - Danvers – Virginia
  - Greater Toronto Airport
Power System One-Line

Substation A

Substation B

3 miles
UG Primary Network (closed loop)

Normal Condition

Each loop can have any number of switches

T = 0 sec
UG Primary Network (closed loop) Fault Condition

T < .10 sec
UG Primary Network (closed loop) Fault Cleared

T = .10 sec
Another HRDS Project

- University
  - West Coast
  - East Coast
- Implementing HRDS system to:
  - Support biosciences research
  - Improve reliability of existing system for “normal” campus load
- Value
  - Attract research (read this $$$$)
Advanced Feeder Automation
IntelliTEAM II

- Automatic fault isolation and load restoration
- Distributed intelligence - utilizing “agents”
- Scalable, building block approach
- Supports complex systems of virtually any size
- Does not require SCADA - but supports integration with SCADA systems
- Utilizes peer-to-peer mesh communication network
- Solve very specific reliability problems with tuned automation schemes
- Maximize the use of existing assets
- Fastest and least expensive way to improve reliability
Scalable, Building Block Approach

- From one switch – to eight source line segments
- Build to meet any desired circuit / system configuration

Defined as
automated switch

Simplest
segment

Up to (8)
switches
A “Simple” IT-II System
Key Examples

- Blue Ridge Electric Cooperative – North Carolina
- Enmax – Canada
- FPL – Florida
- Progress Energy – Florida
Advanced Feeder Automation

Enmax – Western Canada
Enmax - Advanced Feeder Automation

Goals:
- Significantly reduce SAIDI
- Improve customer service
- Minimal cost impact to customers

Expected Benefits:
- Reduced costs from fewer service complaints/investigations
- Stepping stone to bring system to 21st century technology
Enmax - Advanced Feeder Automation

- Targets
  - A multiple-year, Feeder Automation (FA) project is now underway
  - Phase I (to complete in Nov, 03) involves 7 subs, 19 feeders and 46 switches (32 overhead & 14 underground)
  - Completion will include over 200 switching points and automate over 80 feeders
  - The primary requirement is automatic circuit reconfiguration in less than 60 seconds
Enmax - Advanced Feeder Automation

- Key Project Requirements:
  - Reconfiguration in under 1 minute on fault or loss of voltage
  - Minimum availability for each FA feeder over 99.9%
  - Detect Under-Voltage & Under-Frequency Load Shedding & disable auto-reconfiguration
  - Station breakers must also participate in reconfiguration, despite most having electro-mechanical relays and 1-shot to Lockout
  - Project to include a Communication Management System (CMS) to enable operators to monitor, interrogate & control the operation of all components in the FA System
**Enmax - Advanced Feeder Automation**

- **Cost Analysis:** $0.11 per month per customer to provide reliability improvement
  - Total cost of capital
  - 20 year life (straight line depreciation)
  - 8.25% cost of capital (weighted average)
  - Total Average Annual Capital cost / Total # customers/12
    - = $0.34/cust/month
    - For average residential customer of 600kwh = $0.11 / month for automation program
An Installed System

Legend:
- Red: Substation Breaker
- Green: Automated Pad-mount Switch
- Orange: Automated Overhead Switch

Totals:
- 19 Feeders
- 14 Pad-mount Switches
- 32 Overhead Switches
Summary

- Many utilities find DA is important to their success.
- Justification of DA is unique to each system:
  - Business drivers
  - Cost drivers
  - Operational drivers
  - External drivers
- DA is not the only, but the fastest path to significant reliability improvement.
- Reliability improvement along with productivity and capital deferment can yield significant savings - and increase profits.
- IntelliTEAM II offers the easiest and fastest path to a working automation project.
Reliability Comparison
Manual Switching (local or SCADA)

Segment 1 Fault
50% of faults interrupt 100% of customers (0.5*1=0.5)

Segment 2 Fault
50% of faults interrupt 100% of customers (0.5*1=0.5)

Reliability Improvement
100(1 - 0.5 - 0.5) = 0%

Reliability improvement = 100(1-\sum(C_{FS1}+C_{FS2}+\ldots+C_{FS2}))
Segment 1 Fault
50% of faults interrupt 100% of customers \((0.5\times1=0.5)\)

Segment 2 Fault
50% of faults interrupt 100% of customers \((0.5\times0.5=0.25)\)

Reliability Improvement
\[100(1 - 0.5 - 0.25) = 25\%\]
Segment 1 Fault
50% of faults interrupt 100% of customers \((0.5 \times 0.5 = 0.25)\)

Segment 2 Fault
50% of faults interrupt 100% of customers \((0.5 \times 0.5 = 0.25)\)

Reliability Improvement
\[100(1 - 0.25 - 0.25) = 50\%\]
Making the Case
Gather Data

- **Cost Data ($)**
  - Budgetary quotes from suppliers
  - Past experience in installation
  - Past experience in operations & maintenance
  - “Hillbilly Windage Test”

- **Benefit data**
  - Objective benefits – direct, demonstrable
  - Subjective benefits – based on value structure, open to debate
Objective Benefits

- Deferment of capital spending - existing facilities
  - Increase feeder apparent capacity by real-time load balancing
    - Extend existing feeders
    - Avoid new feeder construction
    - Defer new substation construction
Objective Benefits

- Defer capital spending - existing facilities
  - Use condition-monitoring systems
    - Real-time derating of equipment to defer replacement
  - Reduce distribution system losses
    - “Loss reduction at the distribution system level provides capacity at less cost than obtaining capacity by the construction of generation or transmission facilities” -- 1982 World Bank Study
Objective Benefits

- **Reduce Operating Costs**
  - Reduce real power losses
  - Maintain desired power factor (penalty avoidance)
  - Implement condition-based maintenance
  - Incipient fault detection

- **Operating Cost Benefits (Personnel, overtime, travel, vehicle)**
  - Line patrol costs by fault location information
  - Crew time to identify and repair problems
  - Fault isolation
  - Voltage & Var control
Subjective Benefits

- Quality of service (SAIDI) (SAIFI) (CAIDI)
- Customer information and satisfaction
- Safety
  - Standard operator interfaces
  - System-wide operating practices
  - Standard protection schemes
  - Common switching & tagging procedures
Subjective Benefits

- Objective and Subjective parameters
  - Computerized displays of distribution system configuration
  - Use of remote controls to perform some switching work
  - Real-time load data for system planning
  - Automated feeder re-configuration for reduced outage time
  - Complete distribution system data for corporate use
Build the Case

- Collect cost data
- Collect hard dollar benefit data
- Collect soft dollar benefit data
- Build the benefit-cost model
  - Limited system benefit for automating just a little
  - Benefits increase rapidly as more and more automation is installed
  - Benefits level off as additional automation yields little additional benefit
Financial Analysis

- Determine first month or year in which annual benefits exceed annual costs
- Determine first month or year in which cumulative benefits exceed total cost
- Perform sensitivity analysis on impacts:
  - Inflation
  - Interest rates
  - Cost of capital
  - Different penetration percentages
  - Schedule changes
Financial Analysis

- Determine required benefit-cost ratio
  - Impact of hard and soft dollar benefits on desired ratio
    - All hard dollar benefits may only need 1 or 1.5 to 1 ratio
    - All soft dollar benefits may need 3 or 4 to 1 ratio

- Benefit is easy with performance based rates/rewards/penalties
Value Summary

- Keep the meters spinning
- Overtime reduction
- O&M Savings
- Deferred capital expenses
- Achieve Incentives / Avoid Penalties
- VAR Management
- Customer satisfaction
- Rate case
- Improved maintenance
- Area/business development
Average Customer’s Electric Bill

Based on analysis of FERC Form 1 data