Application of Risk Analysis and Optimization to an Integrated Reliability Improvement Program

Charlie Williams, P. E., C.P.Q.
Power System Services
S&C Electric Company

Reliability Program Objectives

- Achieve a stated level of reliability improvement at minimum cost
- Given a stated level of funding achieve the maximum level of reliability improvement
- Defined as constraints, requirements and objectives
The “Issues”

• No methodology other than “gut feel” to determine how to allocate resources to reliability improvement programs
• How do we assure management we are making the most cost effective allocation of resources to achieve the required reliability improvements?
• An integrated approach is needed that evaluates all possible initiatives or programs for reliability improvement

The “Risks”

• Effectiveness of different programs varies
  – Nothing is 100%
  – Wildlife protection, lightning protection and other initiatives have varying degrees of effectiveness
• Unit Costs vary with the targeted devices
  – One branch line is 2 spans long
  – Another may be 2 miles long
• Repeatability – The “80-20 Rule”
  – 80% of outages are random and do not repeat in the next year
  – 20% are chronic repeaters
Integrated Reliability Improvement Program

- Requires an integrated approach which:
  - Recognizes all options for improvement
  - Estimates improvement for each option
  - Evaluates costs of each option
  - Optimizes the mix of improvement options
  - Evaluates risk and variability of each option

Program Guidelines

- Requirement = Item must be achieved
  - Given amount of reliability improvement
- Constraint = Limitation of budget or other resources
- Objective = Maximum improvement or Minimum Cost
Reliability Improvement Initiatives
2 Types
Fault Prevention
Fault Mitigation

- Wildlife Protection
- Lightning Protection
- Infrared Inspection
- Tree Trimming
- Additional Sectionalizing
- Faulted Circuit Indicators (FCI's)
- Automation
- Others (Fuse Coordination, ...)

Fault Mitigation by Design

Feeder Reliability

- Loop RCL
- Loop SCADA RCL
- Loop AUTO TI:0
- SG/DA LOOP:080

System Cost

- 2 Segments
- 6 Segments
Outage Database is Mandatory
Data Mining is Key

- For each initiative identify and quantify the reliability improvement expected
  - Extract information from outage database
  - Identify specific devices, line sections or feeders which have causes related to the initiative
  - quantify the CMI for the location
  - sort all locations/devices in Pareto fashion

Reliability Improvement Estimates

- Historical performance is base case
- Improvement will not exceed historical base case
- Use CMI and multiplicity as measures of future performance
- Evaluate effectiveness of improvement options
Effectiveness Definition

- Effectiveness = Post Improvement probability a device will not have another outage from the same cause
- IE: If only 20% of the devices treated for wildlife protection have wildlife caused outages in the next year then the wildlife protection program is 80% effective

Probable Reliability Improvement

Improvement is a function of:

- Historical Annual CMI of the Device
- Repeatability of the fault
- Effectiveness of the repairs
- # Devices Repaired

Net Effect of repeatability and effectiveness is to reduce the reliability improvement estimate
Estimating Effectiveness

- Defined as probability distribution based on historical performance
- Nothing is "100%"

Effectiveness Probability Distributions
Cost Estimates for Options

- Branch Lines vary in length
- Costs will vary with length and other factors
- Define variability as a Median cost with a probability distribution
- Cost Estimate = unit cost X probability X Units Repaired

Cost Probability Distribution

![Cost Probability Distribution Chart]
Historical Device CMI

Risk Analysis

- Uses a statistical simulation (Monte Carlo or Latin Hypercube)
- Evaluates the equations for
  - Reliability Improvement
  - COST
- Allows quantification of the variability of the outcomes
Reliability Improvement Risk Analysis Results

Cost Estimate Risk Analysis Results
Optimization

- How much of each option to optimize the objective?
- Determined by # Devices Repaired and Cost expended on each Option
- How much to invest in lightning Protection vs. Infrared

Optimize # Units of each Option for Cost and Reliability Improvement
Optimization

- No direct Solution available
- Solved by Monte Carlo or Latin Hypercube Simulation
- Determines optimum # Units for each Option to achieve Objectives, meet Requirements and conform to Constraints
Targeting Reliability Initiatives

- Not Just "WORST Performing Feeders"
- Target by interrupting device
  - Includes RCL, FUS and STA devices
- Address Repeat Outages
  - Multiples on a device
  - Multiples to customers
  - Future Repeatability

Targeting Improvements & Repairs

- Must Understand how faults REALLY work!
- Induced Lightning Flashovers vs. Direct
  - Issues are:
    • Low BIL/CFO
    • Open points
    • ArresterSpacing
    • Failed arresters
    • Grounding on Static Wire Line Designs
- Tree faults require sustained wire to wire contact
  - Lateral limb contact doesn’t cause faults
- Animal Contact Points ABOVE the transformer fuse
Targeting Reliability Initiatives

- Requires “Data Mining” of outage database
- Looks at specific outaged devices (Fuse, Rcl, Fdr, etc) based on causes
- Considers repeatability of outages
- Majority of outages have low repeatability (10% - 25%)

<table>
<thead>
<tr>
<th>Outage History</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Pattern has 80% probability of Repeat outage in 2006

Outage Causes

Storm/Wind & Unknown account for 36% of all Outages
Unknown or STORM Caused Outages?

- Storm or Unknown are not REAL causes
- They are the result of not finding an identifiable cause
- Many are the result of failures of Fuse Save schemes
The "Unknown" Problem

- Unknown caused outages cannot be targeted by a specific program
- Use a Maximum Likelihood Analysis to convert unknowns to a probable cause
- Assumption:
  - Requires cause pattern analysis
Outage Cause Analysis

- Unknown or Storm caused outages are difficult to target fixes
- Apply Maximum Likelihood Analysis
  - Causes of unknowns are similar to knowns
  - Actual cause was not found or reported

Maximum Likelihood Analysis

- Uses key characteristics of known causes to develop probable cause tables for unknown cause outages
- Allows determination of probable cause for all unknown or storm/wind outages
Maximum Likelihood Analysis

- Assumes unknown outages are similar in cause to known outages
- Uses characteristics of known cause outages to estimate causes of unknown outages
- 4 key characteristics used
  - Month
  - Hour
  - Device Type (FUS, RCL, etc)
  - Weather

Outage Pattern Analysis

- 3 distinct patterns exist
  - 1. Summer Peakers - Lightning, Trees
  - 2. Constant Level - Composite (Car hit pole, defective equipment, others)
  - 3. Spring and Fall Peakers - Animal & Bird
Base Load "Constant" Outages

Summer Peaking Outages
Direct Strike

Animal & Bird Outages

Animal & Bird Outages

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000</td>
<td>2000</td>
<td>3000</td>
<td>4000</td>
<td>5000</td>
<td>6000</td>
<td>7000</td>
<td>8000</td>
<td>9000</td>
<td>10000</td>
<td>11000</td>
<td>12000</td>
</tr>
</tbody>
</table>
Maximum Likelihood Analysis Results
How Faults Happen

- Knowing and understanding how faults happen is essential to targeting reliability improvements
- Field personnel (engineers & line personnel) must be trained in how faults work
- This can make or break fault prevention initiatives
Permanent Animal Fault

"Effective"
Tree Trimming
Training is a Must

- Engineers and Line Personnel MUST understand HOW FAULTS WORK to effectively implement programs
- Beware of common perceptions about this!
- System wide training is required
- Videos and Photos are helpful

Improved Targeting of Programs

- Use Probable Cause for:
  - "Unknown"
  - "Storm" or Weather
  - Other Undefined Cause Outages
- Optimize the funds spent on all programs as an integrated effort
- Achieve the most cost effective mix of programs
Results

- Reliability Program Cost effectiveness was doubled when compared to initial “gut feel” approach.
- Management presented with probability estimates of costs and benefits of an integrated program.
- This approach results in an integrated reliability improvement program that optimizes the cost effectiveness of the improvements by allocating appropriate $ to each initiative.
- This technique was applied to a 3 year reliability improvement program that drove SAIDI from 123 to 78 for a major electric utility.