Improving Network Reliability with Reclosers

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Reclosers are a fault interrupting devices that open and close into a faulted line in an attempt to restore power. Since the majority of faults are temporary, the use of reclosers can significantly improved the reliability of distribution networks. Most modern reclosers are controlled with electronic relays which give a great deal of flexibility in protection, restoration, and communication. The presentation session will cover

1. Recloser basics
2. The benefits of reclosing / reclosers
3. The application of reclosers
4. Automating multiple reclosers
The Need for Protection
Recloser

In **electric power distribution**, a **recloser**, or **autorecloser**, is a **circuit breaker** equipped with a mechanism that can automatically close the breaker after it has been opened due to a **fault**.[1][2] Reclosers are used on overhead distribution systems to detect and interrupt momentary faults. Since many short-circuits on overhead lines clear themselves, a recloser improves service continuity by automatically restoring power to the line after a momentary fault.

- Wikipedia
Basic Components of a Recloser

- Interrupter
- Current Sensor
- Actuator
- Relay / Control
Interrupter Module Details

Features
- Vacuum bottle for interruption
- Solid dielectric insulation
- Integrated CT
- Integrated Voltage Sensors
- Magnetic actuator
Operation Options

Single Phase Operation

Three Phase Operation

Single Phase
Module Configuration Options

**L – Modules**
- Live Front Transformer Load Break Switch
- T-Body connections

**C – Modules**
- Dead Front Vault Application
- Front Access Dead Front Pad Mounted Switchgear

**Z – Modules**
- Dead Front Subsurface Application
- Front Access Dead Front Pad Mounted Switchgear
Mounting Options
Major Manufacturers

Cooper

G&W

Noja

ABB

Nulec

G&W
Relay / Controls

- Brains vs. Brawn
  - Takes input from CT’s (and voltage sensors) and makes decision to trip or not

- Electronic controls - Flexibility
  - Advanced protection (directionality, under voltage…)
  - Logic for more advanced applications
  - Communication
Protection

- Different protection settings on different reclose
- Software settable
- Data recording
Recent Innovations

6 Integral Voltage Sensing
- Reduce clutter
- Reduce weight

True Mechanical Block
- Additional safety

Pulseclosing
- Electronic pulse instead of reclose
- Theory - reduce system stress
- Only 1 manufacturer

Figure 2. PulseClosing Technology drastically reduces overcurrent stress on the system, as shown here for a permanent phase-wire to grounded-neutral fault.
Communication Hardwired

- Most reliable media
- Cost / distance
- Types
  - Copper over short distances
  - Multimode fiber from 0-4km
  - Single mode fiber from 0-30km or more
Communication Wireless

- Economical over long distances
- Wireless channel not as reliable
- Types:
  - Cell radio
  - Licensed / unlicensed band radio
  - Mesh radio
  - Ethernet
Site Ready - Significant Benefits

- 20% Installation
- 13% Maintenance
- 5% Disposal
- 4% Acquisition Costs
- 20% Freight
- 38% Product Distribution

G&W
What is reclosing and why do you do it?

Table 1. Example of Reclose Success Rate in a High Lightning Area

<table>
<thead>
<tr>
<th>Reclosure</th>
<th>Success Rate</th>
<th>Cumulative Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; shot (immediate)</td>
<td>83.25%</td>
<td>83.25%</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; shot (15 to 45 sec)</td>
<td>10.05%</td>
<td>93.30%</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; shot (120 sec)</td>
<td>1.42%</td>
<td>94.72%</td>
</tr>
<tr>
<td>Locked out</td>
<td>5.28%</td>
<td></td>
</tr>
</tbody>
</table>

Source: Electric Power distribution Handbook, pages 430-431

- Up to 95% of faults can be cleared during a 3-shot reclose cycle
- Improvement in metrics
  - SAIDI
  - SAIFI
  - MAIFI
Reference Metric Definitions

SAIDI – System Average Interruption Duration Index
\[
SAIDI = \frac{\text{sum of all customer interruption durations}}{\text{total number of customers served}}
\]

SAIFI – System Average Interruption Frequency Index
\[
SAIFI = \frac{\text{total number of customer interruptions}}{\text{total number of customers served}}
\]

MAIFI – Momentary Average Interruption Frequency Index
\[
MAIFI = \frac{\text{total number of customer interruptions less than the defined time}}{\text{total number of customers served}}
\]
Recloser vs. Switches

- Cost
- Actuation
- Fault clearing and coordination
- Reclosing into fault
Recloser vs. Breaker

- Cost
- Self contained system
- Indoor vs. outdoor
- Physical size
- Maintenance
- Frequency of operations
- Ratings
Line Segmenting Evolution

- Manual Switch
- Automated Sectionalizers
- Automated Switch
- Recloser

Functionality vs. Reliability Return on Investment
Typical Radial Circuit

- Fuses on customer feeders
- Reduce permanent faults by 95%
- Disadvantage – all customer are out on permanent fault line fault
Basic Application Schemes

Fuse Saving

**Description** - Recloser is set to fast operate curve for one or two attempts, saving the fuse if possible, and then operate on its slow operate curve on its last try to energize the line. Permanent fault downstream of fuse - the fuse will blow before the recloser trips for the final time, allowing power to be restored to the line not affected by the fault.

**Positive** - prevents longer outages due to a blown fuse caused by a temporary fault. Lower fuse costs.

**Negative** - may cause more temporary outages to more customers since everyone on the feeder is disconnected instead of just allowing the customers downstream of the fuse to be interrupted.
Basic Application Schemes

Fuse Blowing

**Description** - Recloser will always use slow operating curve. If a fault occurs downstream of a fuse, the fuse will always blow before the recloser opens. Occurs for both temporary and permanent faults.

**Positive** - only those few customers downstream of the fuse are affected, and most of the customers on the feeder never see their power interrupted.

**Negative** - fuse needs to be replaced for all faults, even temporary ones, and the customers being fed through this fuse will be without power until the linemen can drive out to replace the fuse. If the fault was temporary all customers, including those downstream of the fuse, might have been restored after a brief interruption when the recloser opened, if a fuse saving scheme had been used instead of a fuse blowing scheme. Figure E-5 shows typical coordination curves that might be used for fuse saving.
Additional Reclosers

- Reduce outages by $\frac{1}{2}$
- Additional reclosers will improve reliability
- Diminishing returns
Additional Recloser Placement

- Areas with more frequent outages
- Key customers

Substation
Single Phase Reclosers

- Replacement for fuses
- Long single phase lines
Next Step – Looped Circuits

- Second source
- Faults can be isolated during repair
- Automation
Automation

- Switching Devices
- Communication
- Intelligent Controls
- Sensing

Program

Logic
Reliability Costs

- Cost of crew response
- Cost of lost energy sales
- Loss of Production costs for commercial and industrial customers
- Market retention costs for existing and new customers
- Reliability-based penalties
  - Performance Based Ratemaking (PBR) on SAIDI, SAIFI, and/or MAIFI
  - Rate case decisions
  - Lawsuits
- Advertising dollars needed to restore public image
# Customer Outage Cost

## Average Cost

<table>
<thead>
<tr>
<th></th>
<th>Large C&amp;I (&gt; 1MW)</th>
<th>Small C&amp;I (&lt;1 MW)</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage sag</td>
<td>$15,601</td>
<td>$203</td>
<td>$</td>
</tr>
<tr>
<td>1-2 seconds</td>
<td>$23,097</td>
<td>$1,230</td>
<td>$5.84</td>
</tr>
<tr>
<td>1 minute</td>
<td>$12,944</td>
<td>$543</td>
<td>$</td>
</tr>
<tr>
<td>15 minutes</td>
<td>$18,245</td>
<td>$831</td>
<td>$</td>
</tr>
<tr>
<td>30 minutes</td>
<td>$70,238</td>
<td>$2,367</td>
<td>$5.81</td>
</tr>
<tr>
<td>4 hour</td>
<td>$119,715</td>
<td>$4,220</td>
<td>$7.14</td>
</tr>
<tr>
<td>8 hours</td>
<td>$88,224</td>
<td>$7,361</td>
<td>$5.15</td>
</tr>
<tr>
<td>Average</td>
<td>$70,634</td>
<td>$2,735</td>
<td>$6.59</td>
</tr>
</tbody>
</table>

Sample Calculation 1

Based on outage cost only
Circuit – 7 reclosers
Manual switch - $5k each
Automated recloser system - $30k each
Total automated equipment premium – $175k \((30 – 5) \times 7\)

Customers on half of circuit – 4 large C&I, 4 small C&I, 3000 residential

<table>
<thead>
<tr>
<th>Outage</th>
<th>1-2 Seconds</th>
<th>1 Minute</th>
<th>30 Minutes</th>
<th>4 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>$51,377</td>
<td>$38,476</td>
<td>$102,946</td>
<td>$165,155</td>
</tr>
</tbody>
</table>

**Annual Return on Investment**

- 4 x (1-2 second outages) – 64%
- 1 x (4 hour outage) – 90%

**Payback Period**

- 4 x (1-2 second outages) – 1.6 years
- 1 x (4 hour outage) – 1.1 years
Sample Calculation 2

Based on outage cost only
Circuit – 7 reclosers
Manual switch - $5k each
Automated recloser system - $30k each
Total automated equipment premium – $175k ((30 –5) x 7)

Customers on half of circuit – 4 large C&I

<table>
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<th>1 Minute</th>
<th>30 Minutes</th>
<th>4 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>$92,388</td>
<td>$51,776</td>
<td>$280,952</td>
<td>$478,860</td>
</tr>
</tbody>
</table>

**Annual Return on Investment**
4 x (1-2 second outages) – 211%
1 x (4 hour outage) – 274%

**Payback Period**
4 x (1-2 second outages) – 0.5 years
1 x (4 hour outage) – 0.4 years
Distributed Transfer

Two or three separate reclosers communicating to each other to perform voltage loss transfer.

**Advantages**
- Cost
- Familiar hardware
- Spread out sources
Open Loop Scheme - Standard

- Non-communicating loop scheme
- Central control communication
- Peer to peer communication
Open Loop – High Speed

- Peer to peer communication
- Close before open

Substation 1

Substation 2
Closed Loop - Single Phase

- Additional restoration for residential loads

- Two parallel sources
- Peer to peer communication
- Communication assisted tripping
Flexible Network Scheme

Distributed Control

Local Controller

Advanced DMS Control

Operator

Automated switch or recloser

Data protocol

Peer to peer protocol
Take Aways

- Reclosers improve reliability
- Three options for reclosers
  - Three phase unit, three phase tripping
  - Three phase unit, single phase tripping
  - Single phase unit
- Apply near problem areas for most benefit
- Use automation to improve reliability further
Thank You