Switch vs. Recloser

THE ULTIMATE GAS-FREE, OIL-FREE AND MAINTENANCE-FREE SOLUTION FOR AUTOMATION, PROTECTION AND SWITCHING APPLICATIONS

Recloser
Recloser in Switch Mode
Changing Utility Industry Provides New Opportunities

The growth of Distribution Automation (DA) is rapidly accelerating for distribution systems as a result of economical and technical changes in the electrical utility industry. A more competitive, deregulated utility industry has changed the purchasing process involving total life cycle costs, alliances, and methods to join with suppliers to grow revenue while simultaneously reducing costs. Significant contributions to this activity also include technology improvements, resulting in cost reductions for applying DA to the utility system. Microprocessor technology continues to eclipse itself in a matter of months, perhaps even weeks, increasing functionality at minimal cost. Applications in communications, transmission, substation, and distribution abound with expanded functionality and implementations crossing multiple segments, providing the user with customization throughout utility applications.

Industry change is prominent with deregulation. Utilities must examine their infrastructure and methodology while developing markets and new ideas in order to be successful in a competitive environment. Under continued examination are reliability, power quality, operation and training costs, maintenance costs, supplier relationships, customer requirements, and deferred generating costs.

Distribution system optimization, through the collection of real-time data to provide dynamic information and reconfiguration, is traditionally the fundamental application of DA. Recent technology has surpassed traditional DA functionality, quickly progressing to fault detection algorithms to isolate faults, reducing outage durations. Combined with load balancing and circuit switching, DA has advanced to a new level, integrating control functionality with communications.

Cooper Power Systems, a leader in distribution switchgear equipment, is committed to the future of the electric utility industry. An examination of the use of DA switches and DA reclosers provides an understanding of the benefits to utilities.

Functional Relationships

By definition, switches and reclosers have basic differences in their application on a distribution system. Switches are designed solely for executing load switching commands, while reclosers execute load switching commands and autonomously interrupt fault currents.

This autonomous operation can be extended to the entire distribution feeder, providing either a centralized or decentralized approach.

Centralized or Decentralized Automation

DA switches require a mandatory communication system to initiate the reconfiguration of the distribution system. DA reclosers perform independently of a communication system to reconfigure the distribution system.

Centralized Automation requires a mandatory communication system as the base for the distribution system, relying on substation equipment for protection requirements. The intelligence for operation of the components on the distribution system resides at a centralized processing location.

Decentralized Automation uses local intelligence to sectionalize the faulted area independent of communication systems. Supplemental communications may be used for restoration and analysis.

The application of reclosers throughout the distribution system independent of a communication system provides automatic fault isolation and improved reliability in both permanent and temporary fault detection. The purpose of communications in the decentralized automation approach is to provide required system metering and data collection on a real-time basis and to obtain system optimization during non-faulted situations. Communications may also be used to assist in the restoration of the configured system.

Decentralized automation must be explored to include the autonomous operation of the recloser, or multiple reclosers, and to include the use of a Loop Scheme (LS). The LS connects two or more distribution feeders together through decentralized intelligence methodology. The resulting benefits include the automatic isolation of the fault to a reduced area and fault protection in both the forward and reverse mode applications. The communication aspects are used for resetting the distribution reclosers to the normal state (manual reset is also available) when the appropriate fault analysis, troubleshooting, and repair have occurred. The communication system is not immediately required to reconfigure the distribution system to restore electrical service.
### Key Elements for Centralized and Decentralized Automation

<table>
<thead>
<tr>
<th>Centralized</th>
<th>Decentralized</th>
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<tr>
<td>• Substation breaker is required for fault interruption.</td>
<td>• Multiple reclosers used on the distribution circuit.</td>
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<td>• Entire distribution feeder requires a momentary outage.</td>
<td>• Only affected areas see momentary outage.</td>
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<td>• Sensitivity for phase and ground minimum trip is determined by breaker settings.</td>
<td>• Increased sensitivity is obtainable through lower minimum trips, providing additional fault sensing, and increased line protection.</td>
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<td>• Centralized system with switches for fault isolation requires 100% reliability of the communication system.</td>
<td>• No communication system is required for immediate fault isolation. Inherent system reliability is improved due to multiple independent devices.</td>
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<td>• Switches are to be opened during periods of de-energized line, or load-break ratings.</td>
<td>• Full maximum fault interrupting ratings provide increased safety.</td>
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<tr>
<td>• Communication system is integral to distribution system and must be fast-responding to isolate faults (those seen by circuit breakers).</td>
<td>• Communication system can be added to supplement the protective system, for data analysis. Communication system polling can be slow as data collection needs vary.</td>
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<tr>
<td>• Communication and sectionalizing equipment costs are required for operation.</td>
<td>• Sectionalizing costs only.</td>
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### Momentary Outages

More than 20 percent of utilities today track momentary operations of “blinks.” Continual process operations, factory automation, and residential demands require new enhancements to the application of distribution equipment. MAIFI and MAIFI\(_E\) statistics are becoming more common indices to measure momentary blinks.

For MAIFI, a customer momentary interruption is defined as each momentary interruption to which the customer is subjected. If a recloser initiates an operating sequence with two reclose intervals, all customers beyond the recloser are interrupted twice. Therefore, MAIFI will calculate this occurrence as two customer momentary interruptions.

A momentary event is defined as one or more momentary interruptions, to one customer within a short time period, required by the interrupting device to restore service. An example of MAIFI\(_E\) is a recloser which trips more than once, but does not sequence to the lockout position. The trip/reclose sequences are all identified as one momentary event for the MAIFI\(_E\) calculation.

DA goals are also addressed in the application of switches or reclosers. Traditional fault protection based on substation device (circuit breaker or recloser) protection and lateral fusing is being replaced with the addition of distribution reclosers to provide fault protection, minimizing substation trips and momentary outages. Extensive flexibility in time-current curves, minimum trip values, and operation sequences result in simple installations to existing systems providing trip coordination.

The application of DA switches without line protection reclosers does not reduce substation device operations. Therefore, the distribution Automation analysis must include the current high quality electrical demands of today’s user and minimize momentary outages.

### System Prioritization

Distribution automation, to date, has focused primarily on communications. Multiple mediums, ranging from power-line carrier, fiber optic, radio or satellite communications, are impressive and continue to improve the transmission of large amounts of data. Communications and the migration toward standard protocols continue to increase DA applications. Included in the large scope of DA, protection issues need to be re-evaluated, not as part of the communication system, but as the driving force to improve system performance. Increased protection results in improved electrical service through reduced affected outage areas, responding to faulted conditions in cycles. With prioritization, the goals are to isolate the smallest segment immediately, and then report the status via communications.
Substation Reclosers and Breaker Operation

Protection on the distribution system is improved when operating the substation breaker versus operating multiple devices in the field. A switch can be placed on the distribution system without any examination of the time-current curves of the device. The application of reclosers requires that time-current curves be examined for proper coordination. While this may appear to benefit the application of switches, improving electrical customer service must be examined in more detail. The switch does not affect breaker trip operations, maintaining the same momentary interruptions on the entire distribution feeder. The substation transformer is exposed to the same thru-fault conditions. The substation recloser or breaker requires the same maintenance costs as before.

Goals should include reducing unnecessary costs on the distribution system by extending transformer life and reducing maintenance costs to improve customer service. An examination of a typical relay curve with typical recloser curves illustrates a reduction in thru-fault times. A thru-fault time for an 8000 Amp fault is reduced by 50 percent per trip operation based upon the typical recloser delayed curve only. Instantaneous tripping on both the relay and recloser may also be used to further limit the thru-fault duration, with the recloser always tripping faster than the relay. The thru-fault reduction requires less service and maintenance for substation transformers.

Momentary Outage Significance

All DA implementations must examine momentary outages as part of the justification for the cost. Seventy-five percent of all faults on the distribution system are recognized as temporary by nature; DA is used to minimize the affected areas subject to momentary outages. For example, consider the effect of MAIFI_E with the use of either a switch or recloser. Recall that MAIFI_E will only look at the event of an automatic restoration of the system independent of the number of actual trips and recloses on the system. Four incidents are reported in the table entitled “Effects of MAIFI_E with Switch and Recloser.”

Switch application diagram.

Recloser application diagram.
Note that Incident 4 is included for a second fault at F3. The second fault at F3 is based upon the additional exposure at the end of the circuit, the circuit length, additional laterals, tree trimming, etc. While the duration is estimated at 30 seconds for either case, the significance is that the service is restored quickly prior to a traditionally reported outage.

The improvement from a MAIFI_E of 4.00 to 2.33 (42 percent improvement) is directly related to reductions in momentary interruptions for electrical users. The economics of MAIFI_E as it previously related to only presetting digital clocks, or nuisance blinks cannot be ignored. A recent study of 198 large industrial and commercial consumers of electricity quantified the costs of a momentary outage. The survey included detailed descriptions of interrupting costs such as lost production costs, losses due to damage, restart costs and savings. For a momentary outage of one to two seconds (summer afternoon in clear weather), the average total cost was $11,027. The cost does not include residential customers, which on a feeder basis, would increase the $11,027 amount. If a distribution feeder includes only four industrial or commercial customers and is subject to only two momentary outages per year, the total cost is $88,216 per feeder. Again, the cost does not reflect the costs for residential users. There is no doubt that the customer cost of a momentary blink is escalating.

**Minimum Trip Sensitivity**

The use of a recloser on the distribution system increases the ability to sense additional faults. Increased sensitivity and isolation of lower magnitude faults protects distribution line equipment, minimizes conductor burn down, and reduces the likelihood of a temporary fault evolving to a permanent fault.

Comparatively, a switch does not improve the sensitivity of the circuit, relying on the substation device for all protection aspects. The risks not only include the items previously listed, but also by not detecting lower magnitude faults, the faulted area remains energized, providing greater safety concerns for the public.

### Switch vs. Recloser

<table>
<thead>
<tr>
<th>Incident</th>
<th>Momentary Fault</th>
<th>Switch Application</th>
<th>Recloser Application</th>
<th>Duration</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>(Number of Customers Affected)</td>
<td>(Number of Customers Affected)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>F1</td>
<td>1500</td>
<td>1500</td>
<td>30 seconds</td>
</tr>
<tr>
<td>2</td>
<td>F2</td>
<td>1500</td>
<td>1000</td>
<td>30 seconds</td>
</tr>
<tr>
<td>3</td>
<td>F3</td>
<td>1500</td>
<td>500</td>
<td>30 seconds</td>
</tr>
<tr>
<td>4</td>
<td>F3</td>
<td>1500</td>
<td>500</td>
<td>30 seconds</td>
</tr>
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</table>

The above recloser and switch sensitivity diagrams illustrate the basic concept of reach, or sensitivity. Lower magnitude faults on the main fault have an increased ability to be sensed by reclosers, compared to using only the substation devices. Lower magnitude faults on the laterals may be sensed by other protective devices such as reclosers and fuse links. Both phase and ground sensing are increased by 50 percent in the example detecting additional low-level faults.
Communication Reliability

Upon fault detection and isolation, system reconfiguration is required. This may be accomplished by a communication network, automatic decentralized device operation, or a combination of the two. What is the reliability of a communication system? What is the reliability of the communication system during storm conditions? How is the communication system being used for distribution automation? What is an acceptable level for communications during outage reconfiguration? There are more questions than answers, but it is apparent that these questions must be answered prior to using the DA switch philosophy.

System reliability is clearly enhanced when automatic reconfiguration is provided without depending on communications. Decentralized communications is easily obtained with reclosers using a loop scheme. Communications is also a significant contribution to the overall restoration of the circuit, but is not required for immediate reconfiguration after a fault has occurred.

The highest priority for a faulted line is to trip the fault quickly to minimize damage to the distribution equipment, limit fault expansion, and restore electrical service quickly. After the fault is isolated by the closest protection device, the circuit requires quick reconfiguration to maximize service. This is easily accomplished with reclosers on the distribution system without communications.

The following is a typical scenario for reconfiguration of a circuit using switches for a permanent fault at F1.

1. The recloser or breaker in the substation detects overcurrent and trips the feeder.
2. The recloser or breaker recloses according to the programmed sequence and continues to trip and reclose until the recloser or breaker sequences to lockout.
3. The entire feeder is without power up to the normally-open Switch Sw3.
4. Communications is required to a central location or between two devices.
5. Communications detects that Switch Sw1 has seen a fault condition.
6. Communications issues a command to open Switch Sw1.
7. Communications detects that Switch Sw2 has not seen a fault condition (Inrush restraint on Switch Sw2).
8. Communications issues a command to open Switch Sw2.
9. Communications issues a command to close the substation recloser or breaker.
10. Communications issues a command to close tie Switch Sw3.

The faulted section is isolated between Switch Sw1 and Switch Sw2. One hundred percent reliable communications is required in steps four through ten to assure quick restoration of the circuit.

The decentralized approach does not require communications for system restoration.

Similarly, using reclosers, the fault F1 is reviewed.

1. Recloser R1 trips on the fault at F1. Note that the substation breaker or recloser does not trip.
2. Recloser R2 changes its operating sequence and trip level based upon loss of voltage.
3. The normally open Recloser R3 closes based upon loss of voltage.
4. Recloser R2 trips only once on the fault current and remains open (lockout).

The faulted section is isolated between Reclosers R1 and R2. No communications are required in steps one to four to assure quick restoration of the circuit. Communications may be used for system restoration or metering, and circuit data during non-critical service restoration periods. Communications is used to enhance the distribution system, not replace it.
Fault Interrupting Capability

Switches have no fault interrupting rating. The impact of this for service restoration and effects on electrical users is often neglected. Most DA switches have fault closing capability. For switches without fault closing capability, however, the up-line device must be opened prior to closing the DA switch.

Fault interruption is vital during both the initial isolation of the faulted area, in order to minimize the momentary disturbances, and circuit restoration. With fault interrupting capabilities, additional safety is available during an inadvertent opening of a DA switch during a fault.

Consider the effects of closing a DA switch into an unexpected faulted area.

Closing Switch Sw1 into an unexpected fault will result in the substation breaker or recloser tripping on the fault, resulting in a momentary outage for all customers. To avoid unnecessary momentary outages, the switches should be replaced by reclosers. Reclosers provide fault-closing and prevent momentary outages through fault interruption.

Sectionalizing Criteria

The primary application for sectionalizing equipment is the ability to sectionalize areas based upon connected MVA. Many utilities segment the distribution feeder into 3-5 MVA sections to provide a “backbone” system. If each section is included as part of the protective system, the choice between recloser and switch is clear. The recloser will be responsible for its own 3-5 MVA section, acting as the substation breaker or recloser for a small feeder.

Switch vs. Recloser

Each recloser provides its own tripping of both temporary and permanent faults. When combined with a loop scheme, a recloser is also able to automatically reconfigure the feeder. This backbone system allows support of auxiliary feeders and common interrogation.

Switches in Distribution Automation

Applications for switches may be used to further segment the distribution feeder to smaller MVA sections. By using a 1 MVA segment, additional switches may be used in combination with reclosers.

A 1 MVA section is accomplished with the inclusion of DA switches. DA switches include traditional single function switches or may include new functionality in a recloser to be used for this application.

The capability of reclosers to include a “switch mode” presents one option. This option includes the ability to disable fault tripping, provide DA switching, and targeting. Simple circuit configurations can be easily accomplished by changing the functionality from “recloser mode” to “switch mode” through supervisory or local control. The economic benefits include reduced purchase costs, minimized training costs, lower inventory costs, and reduced operational costs.
For example, a radial feeder with a switch as the open tie point is evaluated. Due to system growth on the feeder, the tie point moves on the distribution system to provide a 3-5 MVA section for fault isolation. This is accomplished by reconfiguring the existing switch to function as a recloser, while an additional switch is added for the new tie position. For DA applications, the reconfiguration of a recloser to switch mode may be required based upon climate changes, load balancing, live line work, maintenance, etc.

Cooper Power Systems Leads in Distribution Automation

The decentralized intelligence approach toward distribution automation results in significant advantages over centralized intelligence. Historically, momentary disturbances have been neglected in reliability analysis. Today, changing electrical demands result in a momentary outage that can have the same effect as a sustained outage.

The economic evaluation of momentary outages indicates that the cost of purchasing a recloser is negligible for application with industrial and commercial facilities. Economic justification analysis for reliability continues to escalate, including measurement of momentary outages.

Cooper Power Systems is strongly committed to improving the reliability of the electric power industry. Technological advances, including the newest microprocessor-based controls and solid insulation NOVA distribution switchgear products represent our investment in the future.