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The Rise of Momentaries

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SUMMARY

This paper explains the customer issues momentary interruptions cause and how the efforts to reduce sustained outages on the lateral lines exacerbate these momentaries. The recent introduction of outage penalties resulting from unsatisfactory MAIFI indicies has provided utilities an incentive to look for solutions to reduce momentaries on overhead systems. One such solution involves relocating the reclosing activities from the beginning of a feeder line to the tap point of a lateral to localize the impact of momentary interruptions.

While such technology has been available in the market for several years, many utility companies have not used it on their networks mainly because they have not understood the cost benefits. This paper will demonstrate the cost benefits gained from reductions in momentary interruptions using a calculator we developed.

KEYWORDS

Momentary Outage, Sustained Interruption, Persistent Fault, Temporary Fault, Lateral-Reclosing Protection, Blinks, Fuse Blowing, Fuse Saving, SAIFI, $MAIFI_E$

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Pain Caused by Momentary Interruptions

Flickers, blinks, momentary outages or interruptions, regardless of what terms you use, are annoying because these brief power outages lasting less than one minute can cause issues or be a nusance to electricity end users. In fact, regardless of how brief, a momentary outage has the potential to generate a broad range of complaints in an era of sensitive digital technology. Residential customers are irritated, for example, at having to reset clocks, home-security system, and satellite TV systems more often. Retail businesses are equally upset at the hassle, costs, and lost sales that occur when customers walk out the door instead of wait an unknown time for the electronic cash registers to reboot. Pharmacies can take hours to synchronize their rebooted computers with headquarters over their satellite link, and they cannot dispense prescriptions to those who need them while that is happening. Manufacturing plants also incur significant costs caused by lost production and idle workers while product assembly-line controls are reset [1]. Momentaries can affect computer-controlled production processes, such as robotic welding machines, causing scrap and lengthy restart times. Moreover, plastic extrusion machines can require hours of cleanup after a momentary interruption shuts them down, and imagine the mess in high-speed packaging lines when a momentary outage causes the line to hesitate for just one second. All of these situations will lead to customer frustration, financial damage, and a bad reputation for the serving utility.

Fuse-Saving Protection Philsophy Exacebates Momentaries

Based on normal system-protection practices that have been in place for decades, creating momentary outages to minimize sustained outages has been an accepted way to design distribution systems. This design practice is more noticeable now because of the proliferation of electronic devices and appliances [2].

Utilities understand that about 70% of faults are transient in nature, and are caused by temporary events such as squirrels, tree branches and lightning that fault the line but go away as soon as the fault is interrupted. To minimize sustained outages on laterals protected by fuses, a typical utility practice is to design the system so the upstream substation breaker or recloser is set to react faster than the fuse on the initial occurrence of the fault, and then, after interrupting, it will reclose to restore power to the system [3]. For transient faults, the reclose holds and the system is restored. If the fault persists, the upstream protection device, which is set to react slower than the fuse on subsequent reclose operations, allows the fuse to operate and clear the fault on the lateral. This protection practice is known as Fuse-Saving.

The major benefit is the fuse-saving protection strategy avoids blowing lateral fuses for transient faults, and this saves utility companies a truck roll and also saves the customers on the lateral an extended interruption. By using a fuse-saving strategy, no one on the feeder will ever endure a sustained outage for a temporary event. However, one of the major downsides of the fuse-saving strategy is that the entire feeder and every lateral on that feeder is blinked in the effort to save the one lateral fuse from operating, as illustrated in Figure 1 on page 2. All electricity users on the feeder are subjected to a momentary interruption in an effort to try to save one lateral fuse – and that happens every time there is a fault on any lateral.

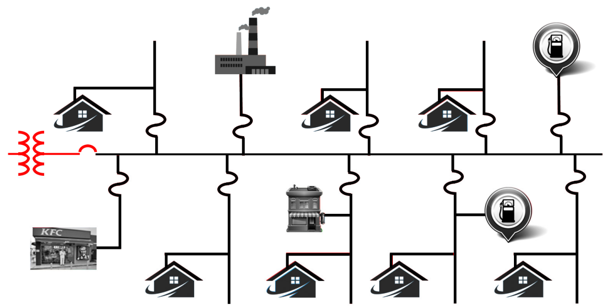

Figure 1: Substation breaker or recloser operates on a lateral transient fault. All customers down the breaker experience a momentary blackout.

It may seem logical to create momentary outages for a large number of customers to avoid sustained outages for a few customers, but what is the impact and can it be quantified? In today's sophisticated electronic world, momentary interruptions cost electricity users billions of dollars per year. According to a study done by Lawrence Berkeley National Laboratory in 2004, momentary interruptions cost about $52 billion a year [4] – double the cost of the entire Apollo program that put the first humans on the moon.

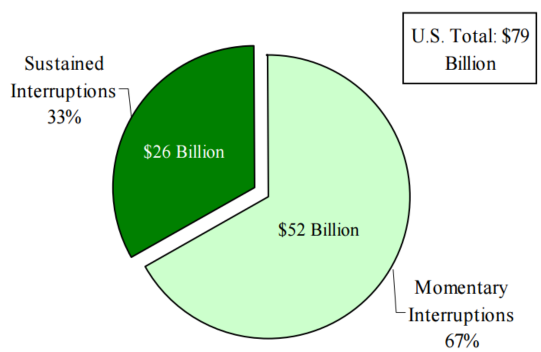

Figure 2: Total Interruptions Cost in the US, 2004

Another problem associated with the fuse-saving philosophy is voltage sags, which can affect sensitive equipment just as much as a blink. Most substation transformers have two to four feeders connected to them. When the breaker for one feeder operates for a fault, it opens and then recloses several times. Each time it recloses, it puts the fault back on the system, causing the voltage to sag on the transformer bus and all the other feeders connected to it see that sag [5]. This is clearly a big deal – because customers on adjacent feeders can also experience sags that cause issues with their equipment similar to what they would experience with a momentary outage.

Lateral-Reclosing Protection Strategy

The recent introduction of outage penalties caused by unsatisfactory MAIFI indicies has provided an incentive for utilities to look for solutions to reduce momentaries on overhead systems [6]. The solution to the problem of the rise in momentaries is a Lateral-Reclosing Protection Strategy. The lateral-reclosing method, as illustrated in Figure 3 on page 3, involves replacing the lateral fuse cutout with a reclosing device that coordinates with the substation circuit breaker to interrupt faults on the laterals without operating the circuit breaker and affecting other customers on the feeder. So for transient faults, the lateral-reclosing device clears the initial fault, and then recloses and restores power to the lateral.

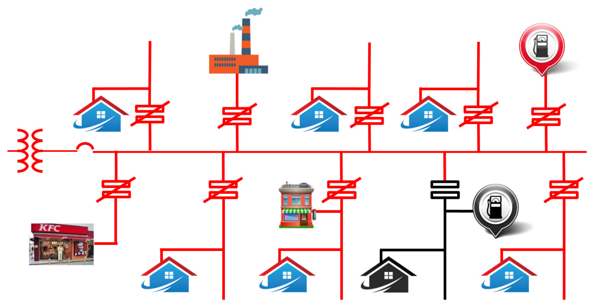

Figure 3: Only customers on the faulted lateral experience a momentary blackout. Customers on the main feeder and other laterals are unaffected.

This strategy provides the best of both worlds because there will be no need for a truck roll, no sustained interruption for the users on the faulted lateral, and no blinking the main line. The lateral-reclosing strategy moves the reclosing closer to the problem so only the faulted lateral will see a blink, not the rest of the feeder.

How to Calculate Lateral-Reclosing Cost Savings

Historically, utilities have been hesitant to take a broad approach to reduce their momentary outages because the industry had not been able to reasonably quantify the cost impact from momentary outages on electricity customers. But this is changing, because regulators are now accepting the consumer outage-cost data as reasonable and are beginning to allow utilities to recover their reliability-improvement expenses in their rates [7]. In some countries, the recent imposition of outage penalties caused by unsatisfactory MAIFI reliability indices has provided an incentive for utilities to investigate solutions for immediate service continuity improvement on overhead systems.

The aforementioned lateral-reclosing strategy is one such solution. While such technology has been available in the market for several years, many utility companies have not used it on their networks mainly because they did not understand the electricity user cost benefits gained from the huge reduction in momentaries that result when adopting the strategy. In the 2015 CIGRE Grid-of-the-Future Symposium, a paper was presented on the interruption costs for different lateral protection strategies using a calculator developed by S&C. Here, to emphasize the impact of the rise of momentaries, it will be demonstrated again how to calculate the significant electricity user interruption cost benefits gained from switching to the lateral-reclosing strategy.

Calculate Electricity User Interruption Costs

In this approach, the user-interruption costs for the fuse-saving and lateral-reclosing strategy are calculated by summing up the costs attributable to both sustained interruptions and momentary ones. For each type of interruption, the costs attributed to interruptions on laterals and on feeders are calculated separately because of the different input values used for the lateral lines and feeder lines. The following topologies are representative in the model: Urban, Suburban, Exurban (collar counties around a big city), and Rural. The values in Table I on page 4 are typical of the parameters used in the electricity user interruption costs calculation that might apply to each of the topologies. The user base is further segmented into three sectors – Medium and Large C&I, small C&I, and Residential because of the differences in the number of electricity users in each of these sectors and the sector's location on the main feeder.

Table I. Typical Inputs to the Interruption Costs Calculation [9]

Topology	Feeder		Laterals			Other			
	Length, Miles	Faults Per Mile Per Year	Number of Laterals	Average Length, Miles	Faults Per Mile Per Year	Transient Faults %	Fuse-Saving Success Factor	Truck Roll Cost	Installed Cost of Lateral Recloser
Urban	3	0.3	30	0.5	1.0	80%	25%	$500	$2,500
Suburban	5	0.3	25	1.0	1.0	80%	25%	$500	$2,500
Exurban	10	0.4	20	2.5	1.0	80%	50%	$750	$2,500
Rural	20	0.5	20	5.0	1.0	80%	50%	$1000	$2,500

The assumptions made on the user composition and their locations are shown in Table II. Within each sector, the interruption costs are calculated by multiplying the total number of user interruption events that sector experiences with the cost per event type which is obtained from the US Department of Energy's database [8]. This database takes the study data and allows users to customize the calculation for their geography and system parameters. The cost per event type for each user sector is also shown in Table II.

Table II. Distribution of Electricity Users Per Feeder [10]

User Sector	Location	Number of Users Per Feeder	Cost Per Sustained Interruption	Cost Per Momentary Interrution
Medium & Large C&I	Feeder	13	$6,547	$3,332
Small C&I	Feeder	83	$1,021	475
	Lateral	4	$1,021	475
Residential	Lateral	900	$6	$4

An important thing worth noting is that, in the case of fuse-saving strategy, any unsuccessful lateral fuse save attempts closer to the substation turn a momentary interruption on the faulted lateral into a sustained one, so they need to be subtracted from the calculation.

Calculate Reliability Indices

For each protection strategy, $MAIFI_E$ is similarly calculated using the total number of user momentary events obtained in the analysis divided by the total number of customers served, which is 1,000 in this paper.

Calculation Results

Electricity User Interruption Costs:

Annual electricity user interruption costs for the fuse-saving protection strategy compared to the lateral-reclosing protection strategy are listed in Table III on page 5. Note that these cost savings are very significant -- electricity users really benefit when the serving utility uses the lateral-reclosing protection strategy instead of the fuse-saving protection strategy to eliminate unnecessary momentary interruptions. See the "Lateral-Reclosing Savings" column.

Table III. Comparison of Annual Electricity User Interruption Costs -- Fuse-Saving Versus Lateral-Reclosing Protection Strategy [11]

Topology	Electricity User Interruption Costs		Lateral-Reclosing Savings
	Fuse Saving	Lateral-Reclosing	
Urban	$1,107,934	$98,607	$1,009,328
Suburban	$1,847,798	$165,352	$1,682,446
Exurban	$3,853,170	$439,931	$3,413,239
Rural	$7,918,750	$1,092,273	$6,826,478

Reliability Indices:

Besides the electricity user costs savings realized by the lateral-reclosing protection strategy, improvements in key reliability statistics are also realized. The lateral-reclosing protection strategy results in a significant reduction in $MAIFI_E$ compared to the fuse-saving protection strategy because it eliminates the repeated reclosing operations affecting the main feeder and all laterals for any fault on any lateral. $MAIFI_E$ values for the four circuit topologies are shown in Table IV. Significant reductions in $MAIFI_E$ values are listed in the "% Reduction" column.

Table IV. Comparison of Reliability Statistics -- Fuse-Saving Versus Lateral-Reclosing Protection Strategy [12]

Topology	$MAIFI_E$		
	Fuse Saving	Lateral-Reclosing	% Reduction
Urban	4.6	1.1	76%
Suburban	7.6	1.9	75%
Exurban	25.1	5.0	80%
Rural	51.8	11.6	78%

These calculations show that switching from fuse-saving to lateral-reclosing protection strategy on a typical suburban feeder can reduce MAIFI, the index that measures momentaries, by as much as 75%. Decreasing the blinks means improving the customer experience. As an example, one utility company using a lateral-reclosing strategy has already seen electricity user cost savings of $500,000 per feeder per year. So, by eliminating these momentaries, a significant monetary savings is realized by electricity end users.

Conclusion

This paper concludes that the lateral-reclosing protection strategy will significantly reduce the electricity user costs associated with momentary interruptions caused by the fuse-saving strategy. Barriers to justifying using a lateral-reclosing strategy, which include an inability to calculate the savings to be able to justify the additional cost of adding lateral-reclosing and not having a cost-effective device to use, have been removed.

In addition, although the serving utilities do not directly bear the electricity user interruption costs, there are strong societal and regulatory reasons now to take immediate actions to minimize these momentary interruptions [13]. An affordable modern cutout-mounted recloser, which is simple to install without requiring routine maintenance, helps utilities succeed in their efforts to reduce momentaries and can provide a significant impact in just a few months.

Lastly, note that the interruption costs presented in this paper are per feeder. The improvements can be especially significant when utilities multiply the costs by their number of feeders [14].

BIBLIOGRAPHY

[1] T. Qualheim. “Utility Industry Targets Growing Concern: Momentary Outages” (Electric Light & Power. June 2015. http://www.elp.com/articles/powergrid_international/print/volume-20/issue-6/features/utility-industry-targets-growing-concern-momentary-outages.html)

[2] Petergorough Utilities Group. “Momentary Outages on the Power System”. (Electric Utility News. August 2012. http://www.peterboroughutilities.ca/Electric/Electric_Utility_News/Momentary_Outages_on_the_Power_System.htm)

[3] T. Qualheim. “Utility Industry Targets Growing Concern: Momentary Outages” (Electric Light & Power. June 2015. http://www.elp.com/articles/powergrid_international/print/volume-20/issue-6/features/utility-industry-targets-growing-concern-momentary-outages.html)

[4] K.H.LaCommare, J.H.Eto. “Understanding the Cost of Power Interruptions to U.S. Electricity Consumers” (LBNL-55718, Lawrence Berkeley National Laboratory Electricity Market and Policy Group Publications. September 2004. Page xii. https://emp.lbl.gov/sites/all/files/lbnl-55718.pdf)

[5] T. Qualheim. “Utility Industry Targets Growing Concern: Momentary Outages” (Electric Light & Power. June 2015. http://www.elp.com/articles/powergrid_international/print/volume-20/issue-6/features/utility-industry-targets-growing-concern-momentary-outages.html)

[6] X.Chen, C.J.Cook, P.J.Fahey. “Interruption Costs for Different Lateral Protection Strategies” (CIGRE US National Committee 2015 Grid of the Future Symposium, October 2015. Page 2.http://cigre.wpengine.com/wp-content/uploads/2015/10/Chen.pdf)

[7] T. Qualheim. “Utility Industry Targets Growing Concern: Momentary Outages” (Electric Light & Power. June 2015. http://www.elp.com/articles/powergrid_international/print/volume-20/issue-6/features/utility-industry-targets-growing-concern-momentary-outages.html)

[8] Interruption Cost Estimate Calculator of U.S. Department of Energy. (http://www.icecalculator.com/1/index.asp)

[9][10] X.Chen, C.J.Cook, P.J.Fahey. “Interruption Costs for Different Lateral Protection Strategies” (CIGRE US National Committee 2015 Grid of the Future Symposium, October 2015. Page 3.http://cigre.wpengine.com/wp-content/uploads/2015/10/Chen.pdf)

[11] X.Chen, C.J.Cook, P.J.Fahey. “Interruption Costs for Different Lateral Protection Strategies” (CIGRE US National Committee 2015 Grid of the Future Symposium, October 2015. Page 5.http://cigre.wpengine.com/wp-content/uploads/2015/10/Chen.pdf)

[12] X.Chen, C.J.Cook, P.J.Fahey. “Interruption Costs for Different Lateral Protection Strategies”
(CIGRE US National Committee 2015 Grid of the Future Symposium, October 2015. Page 6.http://cigre.wpengine.com/wp-content/uploads/2015/10/Chen.pdf)

[13][14] X.Chen, C.J.Cook, P.J.Fahey. “Interruption Costs for Different Lateral Protection Strategies”
(CIGRE US National Committee 2015 Grid of the Future Symposium, October 2015. Page 6.http://cigre.wpengine.com/wp-content/uploads/2015/10/Chen.pdf)