Coordinated Relay Control Strategy for Wildfire Mitigation Without Impacting System Reliability

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***Abstract*—Wildfire ignition risk has become a defining challenge for electric utilities operating in rural and fuel dense environments. Relay controlled ignition mitigation is a readily available method of reducing ignition probability but often incurs reductions in system reliability. The method outlined in this paper details the strategy to get the most ignition reduction without adversely impacting system availability.**

Keywords—Wildfire Mitigation, Relay, Strategy, System Protection, Reclosing Methods, Reliability, Outage Mitigation

I. INTRODUCTION

Wildfire ignition risk has become a defining challenge for electric utilities operating in rural and fuel dense environments. Electricity providers have begun to employ relay-controlled ignition mitigation approaches. These often involve reducing fault clearing time and reclosing attempts, which incur higher outage occurrences.

This paper presents a relay control architecture that minimizes both ignition probability and reliability impacts. This is achieved through a combination of several overlapping strategies, including stacking minimum response delays, high current trip functions, and reduced current limits. By configuring sequential protective relays in radial power systems to use incremental response delays, coordination is preserved while fault duration is minimized. Concurrently, using high current trip functions that are configured to use an independent control command clears high intensity faults even faster. This is achieved by leveraging electromagnetic physics constraints in electrical distribution systems. Rapid fault clearing of high current faults is achieved while lower current faults are cleared significantly faster than traditional reclosing parameters. This approach is simple, effective, flexible, and can be implemented across most distribution systems.

Previous work on fault analysis and atypical fault scenarios [1]-[4] was essential for the development of the initial prototype of this strategy.

II. BACKGROUND

In classic reclosing relay strategies, outages are mitigated by re-energizing a power line after a fault clearing operation up to four times (often called shots). These devices do not usually instantly trip; they have a time-current curve (TCC) timer that allows downstream devices to clear the fault first. This partition greatly reduces power outage scale.

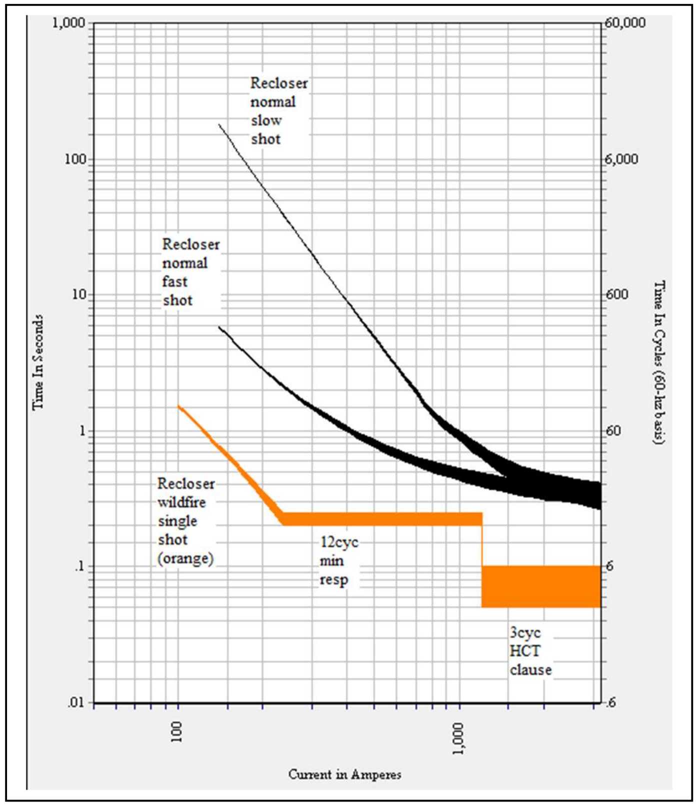

Fig. 1. Time Current Curve (TCC) of a recloser normal fast & slow shot curves (shown in black) compared to the wildfire relay strategy curve (shown in orange) of same recloser.

III. PROPOSED RELAY STRATEGY

This wildfire mitigation strategy uses an optimized approach through deliberate parameter selection. The core function is to create a second control "profile" (sometimes "group" or "mode" depending on manufacturer) that can operate and coordinate with neighboring reclosers in both normal and wildfire mode.

A. Addition of Minimum Response (MR) to Normal Profile

This is done by first adding an incremental Minimum Response (MR) 3-cycle[1] delay to the existing normal profile. For each device in series, the MR increases by an additional 3-cycle[1] increment. Ie, for a circuit with four reclosers, farthest device has a 3-cycle MR, next upstream device has a 6-cycle MR, the 2nd upstream device has a 9-cycle MR, and the feeder controller at the substation has a 12-cycle MR.

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B. Addition of High Current Trip (HCT) Function

Duplicate this to a "wildfire" profile and disable reclosing. Next add a High Current Trip (HCT) clause that operates in parallel to the normal TCC/MR trip function. Set this HCT to have a set delay of 3-cycles[2] regardless of circuit position. Set this HCT function's pick up to trip when the observed fault current is higher than the next recloser can physically receive. The maximum fault current is defined by the system impedance up to that recloser.

C. Limitations of Mixed Modality in Adjacent Radial Relays

Through this architecture, recloser-recloser coordination remains intact. Depending on system environmental parameters, fuses may not operate, operate in congruence with recloser, or operate independently of the recloser control relay. Normal profile and wildfire profile mode can be mixed on a circuit, but once wildfire profile is set on a given relay all downstream relays must follow suit to retain coordination.

D. Understanding the Coordination Development Thus Far

When these are overlaid functionally, they retain coordination and TCC separation. This can be more intuitively observed in figure 3, where the circuit schematic is displayed.

E. Special Conditions and Caveats

Note[1]: The incremental delay is dependent on recloser operating time. Bench and field testing have verified that the recommended 3-cycle delay is adequate. Each recloser control is subject to sampling frequency, waveform smoothing filters, and clearing time. Total time (T) can be calculated as:

$$T(Fault)=T(Detect)+T(Control\ Timing)+T(Clearing) \quad (1)$$

Observationally, T(Detect) is typically approximately 0.5 cycles (60Hz) dependent on control sampling frequency and processing interval, T(Control Timing) is dependent on delay and TCC settings parameters, and T(Clearing) is typically approximately 1.5 cycles depending on manufacturer. See figure 5 for visualization of this.

Note[2]: Ideally, a wildfire prevention relay strategy could operate faster than any downline fusing (fusing operations are often expulsive). This was field tested and ultimately found to be unrealistic – both relay and fuse consistently operated. This issue is mitigated by the blanket 3-cycle minimum response setting. If the fuse is operating anyway, this addition dramatically reduces outage impact without severely affecting ignition probability. This recommended 3-cycle delay allows small fuses to clear large faults immediately and prevents expulsive functions for small fault magnitudes.

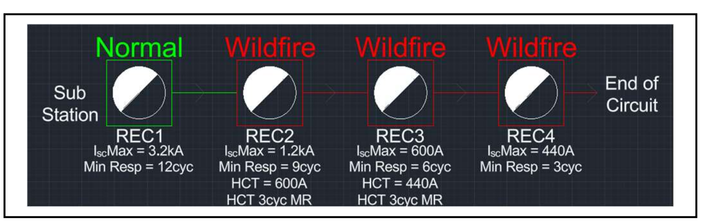

Fig. 2. Example TCC of multiple reclosers in series; mixed profiles are in use and displayed.

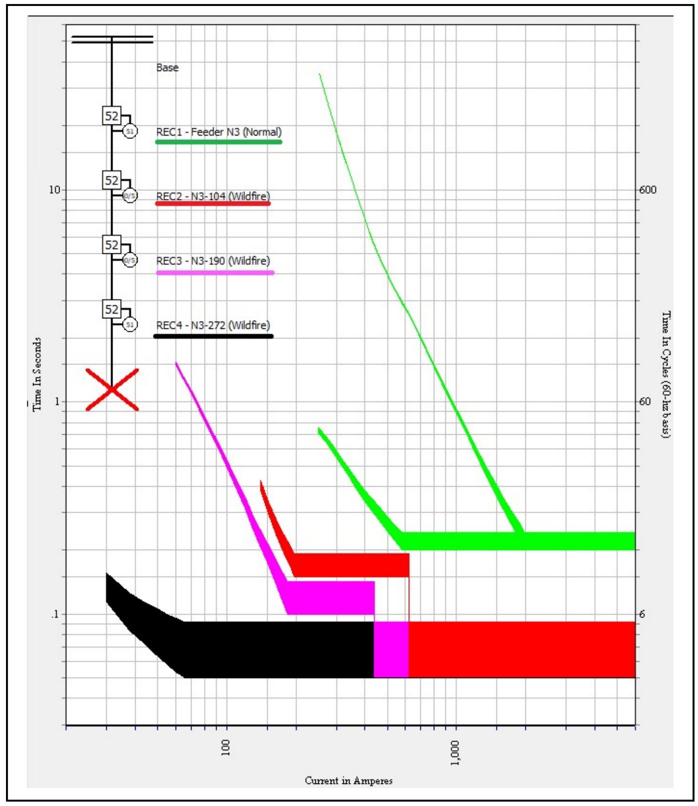

Fig. 3. Example TCC of multiple reclosers in series; mixed profiles are in use and displayed.

IV. Field Validation

These settings profiles were tested and developed for several years.

A. Comparisons of Observed Faults in Different Modes

The faults in this section were pulled from real-world conditions with confirmed causes via the recloser controls. Figure 4 shows the sample circuit that is referred to in associated Table I. The table compares the proposed wildfire relay strategy, typical Hot Line Tag (HLT) fire mitigation strategy, and classic "normal" mode which involves multiple reclosing attempts.

The ignition risk is often nuanced, but is a function of fault current intensity and duration. As such, it can be compared using a per unit comparison where classic 4-shot normal procedure is set as the reference value.

$$Ignition\ Risk\ (Proxy) = \sum T{*}I^2\ (active) \,/\, \sum T{*}I^2\ (normal) \quad (2)$$

Where T = fault clear time & I = fault current magnitude

B. Oscillography Breakdown of Relay Logic Response

The oscillography capture in figure 5 is fault clearing of a relay in wildfire profile. This instance is from the 2024 field tests and is a fault caused by high wind slapping the phase wire into the ground wire. This relay did not have the MR functionality, thus tripped nearly instantly. This device functioned correctly and cleared the fault significantly faster than classical methods. Understanding the fault analysis performed by the recloser control is critical to these rapid clear functions.

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Fig. 4. `Reference circuit for visualization of fault log in Table I.

TABLE I.

Field Data of Real-World Faults: Outage Impacts and Ignition Risks				
Settings Mode	*Clearing Device*	*Outage Impact (meters)*	*∑ Fault clear time (cycles, 60Hz)*	*Ignition Risk (Proxy, TI^2)*
Fault #1, bird caused, location N3-78, 1.1kA phase-ground fault magnitude				
1 – WF	Feeder N3	700 meters	15 cycles	0.09
1 – HLT	Feeder N3	700 meters	3 cycles	0.02
1 – Classic	Feeder N3	700 meters	166 cycles	1.00
Fault #2, bird caused, location N3-325, 260A phase-ground fault current magnitude				
3 – WF	N3-273	20 meters	6 cycles	0.06
3 – HLT	Feeder N3	700 meters	3 cycles	0.03
3 – Classic	N3-273	20 meters	106 cycles	1.00
Fault #3, failed wire splice, location N3-A87, 226A phase-ground fault current magnitude				
3 – WF	N3-A73	24 meters	6 cycles	0.07
3 – HLT	Feeder N3	700 meters	3 cycles	0.03
3 – Classic	N3-A73	24 meters	86 cycles	1.00

V. Discussion

Wildfire mitigation relay strategies are always a tradeoff between ignition prevention and increased outages. This strategy is no exception, though it is an excellent approach to minimizing both issues. This tactic is easy to implement, heavily leverages existing infrastructure, and simple to understand and use.

A. Consideration of Implementation and Operational Use

Implementing this strategy by changing modes at each control does take some degree of time investment. It was designed with this in mind such that a recloser can sit effectively in this mode throughout wildfire season.

B. Limitations Acknowledge of Aged Relay Controls

Not all reclosing controls can implement minimum response and high current trip parameters – though most are capable. The last device in sequence does not a high current trip clause.

C. Outage Restoration Trip Sensitivity Considerations

In each restoration, closing the relay back in may prove troubling. The inrush and loss of load diversity may be sufficient to re-trip the proposed relay strategy. During field testing, this was mitigated by changing control mode at the open relay to a normal mode with non-reclosing function enabled.

This could, theoretically, cause the next upstream device in fire mode to trip instead, but did not during several dozen instances of field tests performed in 2025. These field tests were conducted during normal outage restoration functions, where closing back in on the wildfire setting caused a subsequent inrush trip. Setting the open relay to a normal mode with non reclose enabled facilitated power restoration without causing the next upstream relay in fire mode to trip.

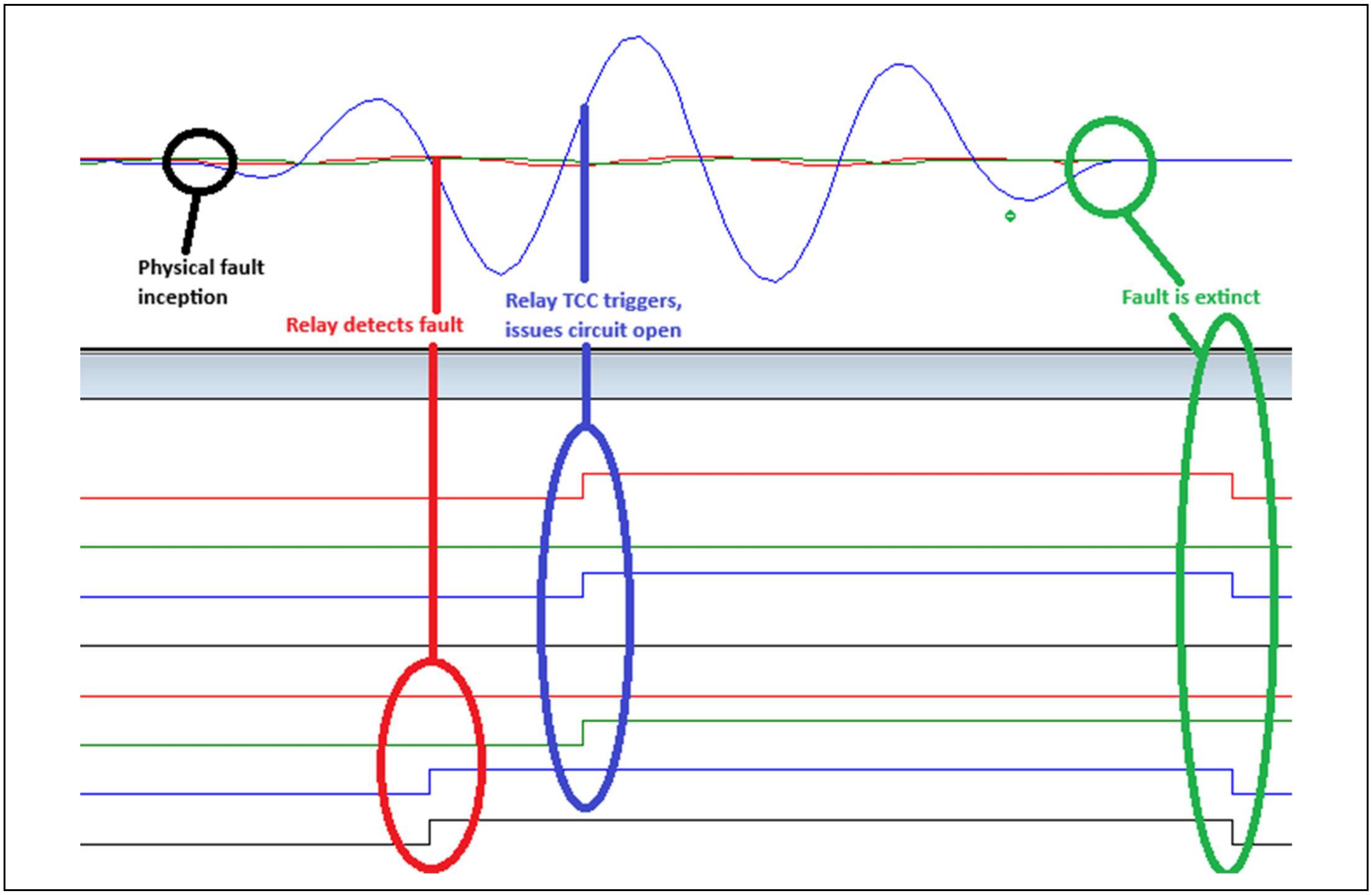

Fig. 5. Oscillography capture of wind caused 1kA phase-ground fault clear.

VI. Conclusion

This proposed wildfire mitigation relay strategy substantially reduces ignition risk without significantly impacting reliability indices. Adaptation is highly feasible for most microprocessor based recloser control relays.

This field of study is evolving quickly as the wildfire frequency and severity continues to compound each year. There are further improvements that can be layered elegantly to operate congruently with this strategy, such as high impedance fault detection algorithms, dropped conductor detection via loss of load without related fault, and physical pole displacement observation hardware. These are all excellent approaches but are less widely applicable without advanced grid awareness and system infrastructure.

VII. Disclaimers

This relay mitigation strategy was developed and tested independently by the author. Since this tactic version was implemented in field for 2025 wildfire season there have been other entities encountered using similar strategies. The author's design of this method began in 2023 and was first tested in 2024's wildfire season. It was refined to this version, deployed, and proved widely effective in all desired attributes in 2025. It is not proprietary; it is a method shared freely with the intent of reducing overall environmental impacts from electric utility operations.

Furthermore, many of the original design components gathered in 2023 were pulled from utility wildfire control methods and publicly available incident reports. This includes utilities from both the Pacific Northwest and Canada. Their contributions and shared experiences were critical to the development of the initial prototype of this relay strategy.

This paper was written without the use of Artificial Intelligence (AI). The author does refer to Open Source's ChatGPT AI to identify possible data sources, check for understanding, and review phrasing cohesiveness.

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