Summary Paper for IEEE C37.104 Guide for Automatic Reclosing on AC Distribution & Transmission Lines

PSRC D50 WG

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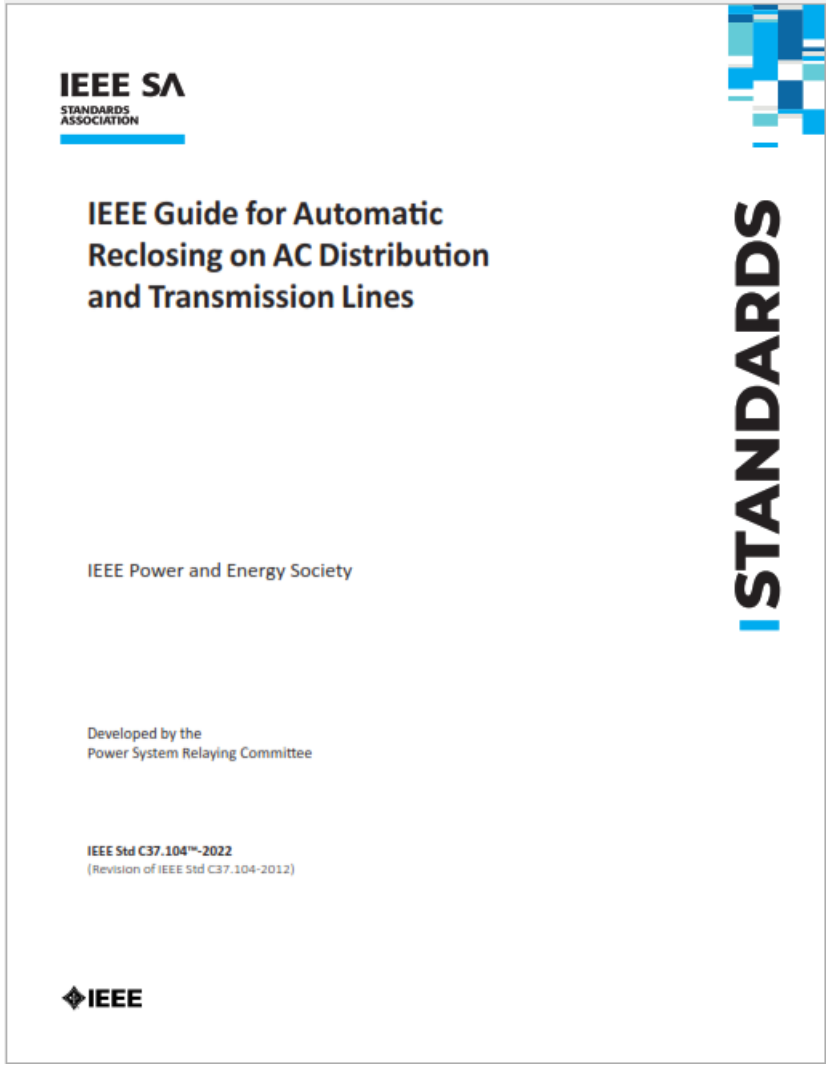
- **Published in 2022, revision of 2012 version**
- **Scope:** This guide documents present practices regarding the application of automatic reclosing control to line circuit breakers or other line interrupting devices. Both transmission and distribution line practices are addressed.
- **Purpose:** The guide describes benefits of automatic reclosing and includes application considerations for proper coordination with other system controls. The guide includes a section on emerging technologies and their application to automatic reclosing.



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Fundamentals & Applications

Basics of Autoreclosing

States of Autoreclosing: Ready state, reclosing in progress state, lockout state, and not ready state

Autoreclosing settings: Number of reclosing attempts, dead time, reset time, and drive to lockout state

Factors to consider:

- Probability of successful reclosing following a trip
- Potential for damage to equipment by autoreclosing into a fault
- Conditions for which autoreclosing is blocked
- Time-delayed or high-speed autoreclosing
- Supervision for autoreclosing
- Consequences of not autoreclosing
- Methods to initiate autoreclosing

Autoreclosing Supervision

- **Autoreclosing supervision serves following purposes**
  - Preventing autoreclosing when systems are out of synchronism
  - Preventing autoreclosing that might cause damage to generators or motors
  - Minimizing the number of unsuccessful autoreclosings
  - Preventing autoreclosing into faulted equipment
  - Helping to maintain system stability

Supervision Methods

- **Voltage supervision**
  - Helps to ensure that voltages on both sides of a breaker are of a desired magnitude
  - Single-phase or three-phase voltage monitoring with dead-line/dead-bus, live-bus/dead-line, live-bus/live-line, and live-line/dead-bus
- **Synchronism check supervision**
  - In addition to acceptable voltage, verifies that phase angle and slip is within predefined limits
  - Helps reduce impact on the system when breaker is closed
- **Parallel line supervision**
  - Block reclosing when parallel line is out of service with concerns of reclosing out of synchronism

Supervision Methods

- **Transfer trip supervision -** applied to block reclosing
  - For breaker failure operation
  - On lines with transformers/reactors without a breaker
- **Supervision for high-speed reclosing**
  - Supervision may not be necessary as reclosing is fast
  - Follower terminal of leader-follower scheme may be supervised
- **Supervision following automatic load shedding**
  - Autoreclosing is typically blocked when tripping is initiated by load shedding schemes
  - If automatic reclosing is used for restoring loads, supervision using voltage, frequency, time etc. is considered to prevent additional load shed during the restoration process

Autoreclose Blocking

Autoreclosing is generally blocked or driven to lockout for following conditions:

- Manual or SCADA trip of a circuit breaker
  - To maintain operation of breaker in hands of a person opening it
- Voltage unbalance
  - open phase condition on source side
- Breaker failure to trip or close
- Discontinuity in trip circuit is detected
- High fault currents/three-phase faults
- Cumulative operations
- Receipt of transfer trip
  - Failed breaker at a remote station
- Time delayed tripping
- Automatic load shedding
  - UFLS & UVLS
- Out of step tripping
  - Autoreclose could agitate an already disturbed system condition

Autoreclose Blocking

- **Delayed reclose**
  - Reclosing is delayed until the desired condition is met.
  - Reclosing is driven to lock out when desired system condition is not met within a predefined time
- **Stall reclose**
  - Used to prevent reclosing on a permanently sealed trip signal
  - When sync check supervision is used, reclosing is stalled to allow applicable voltages to come within predefined sync check parameters
- **Reclose initiate supervision**
  - Used to initiate reclosing for desired conditions rather than blocking reclosing for undesired conditions
  - With abundance of microprocessor-based relays, this approach is widely used

Application Considerations

- **Lines with underground cables**
  - Faults are often permanent, autoreclosing is typically not attempted
  - Transient overvoltage studies may need to be performed to identify issues
- **Limitation of circuit breakers/interrupting devices**
  - Dielectric strength recovery time is considered
  - Time needed to recharge stored energy mechanism following a trip
- **Autoreclosing on disk type overcurrent relays**
  - Disk not fully resetting during an open interval may lead to loss of coordination
  - Applicable to microprocessor or static relays that emulate electromechanical reset

Application Considerations

- **Lines with automatic sectionalizing**
  - Coordinate autoreclosing of source breaker with sectionalizing schemes is necessary
- **Reclosing on motor loads**
  - Trapped flux in rotor decays with time and produces residual voltage
  - Synch motors with own excitation system could add complication
- **Reclosing near inverter-based resources (IBR)**
  - Coordinate autoreclosing on lines in close vicinity with IBR's ride-through capability
- **Use of substation controller and SCADA**
  - Enable/disable fuse saving scheme during evening and weekend hours.
  - SCADA allows operator to enable/disable autoreclosing based on weather conditions

Autoreclosing on Distribution Lines

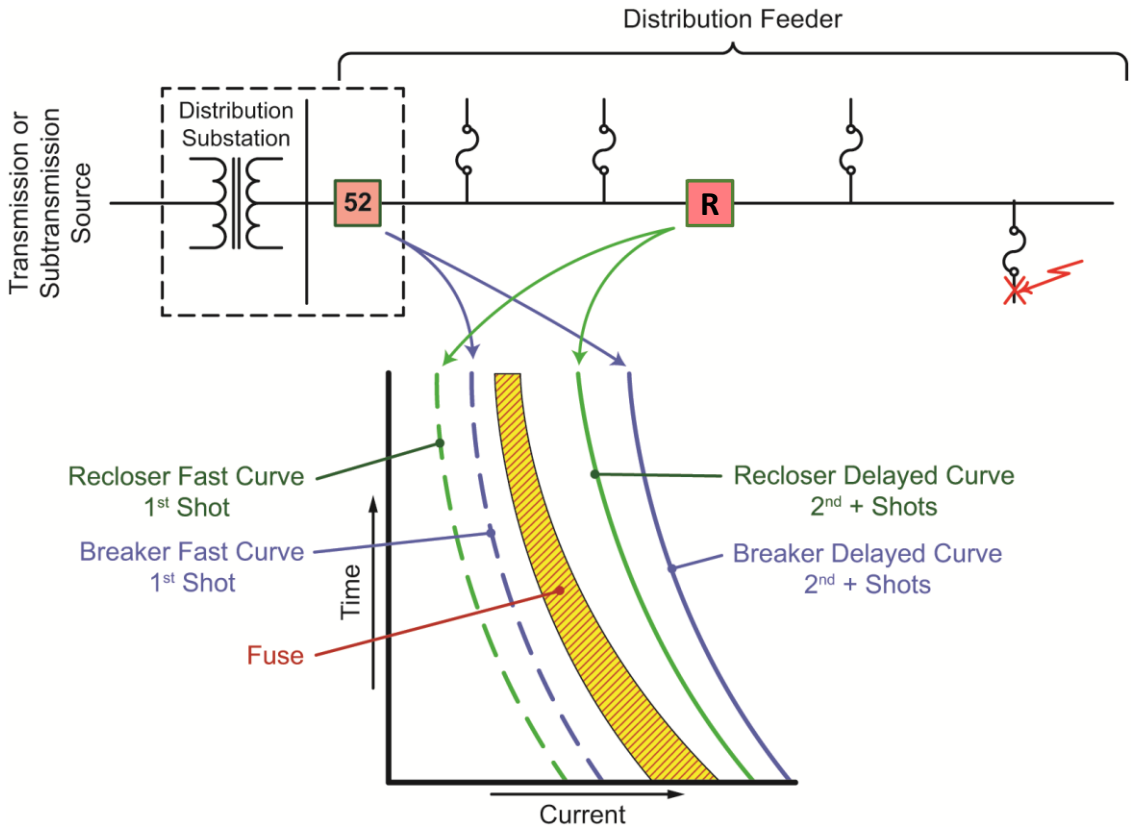
Coordination Practices

- **Sectionalizing schemes**
  - Sectionalizer coordinated with automatic recloser isolates faulted line sections
  - Sectionalizer does not interrupt fault current, operates by counting number of operations of upstream interrupting device
- **Sequence coordination**
  - Control function included in electronic recloser or microprocessor-based relay
  - Used when two fault interrupting devices are used in series
- **Fuse blowing schemes**
  - Used to reduce the impact of a fault on the total feeder by allowing a fuse time to interrupt a fault tap/lateral
  - Source breaker overcurrent protection is set for a time delayed operation

Coordination Practices

Fuse saving schemes

- Used to prevent permanent outages for temporary faults beyond tap fuses
- Utilizes fast overcurrent elements set to clear faults beyond tap fuses
- After one or two operations on the fast tripping curve, the next trip of a source breaker is set for delayed tripping allowing the fuse to operate.



Application Considerations

- **Distributed Energy Resources (DERs)**
  - Needs special consideration and studies
  - Coordination is needed with DER tripping times and ride-through capability
  - IEEE Std 1547 requires DER to cease to energize/trip within 2 seconds of loss of source
  - Communication-aided protection package may be necessary
- **Shunt capacitors**
  - Impact of trapped charge is considered
- **Transformer load tap changers**
  - Reclosing a feeder breaker from a transformer during a tap change operation may expose LTC components to a damage

Autoreclosing on Transmission Lines

Autoreclosing Methods

- **High-speed autoreclosing**
  - Provides fast restoration of power to tapped customers, can help maintain system stability, system capacity and integrity
  - Factors to consider: dissipation of ionized path, clearing time from each terminal, large motor load, turbine-generator shafts, system stability
- **Time delayed autoreclosing**
  - Used where restrictions exist or following a high-speed reclosing
  - Dead time ranges from a second to tens of seconds
  - System stability, breaker duty, coordination with sectionalizing scheme etc. are considered

Autoreclosing Methods

- **Single-shot and multiple-shot autoreclosing**
  - Autoreclosing on EHV systems is predominately single-shot

- **Single-phase tripping and autoreclosing**
  - May be beneficial to improve system stability margins
  - Requires complex protection & control scheme
  - Typical autoreclose times vary from half a second to two seconds and depends on duration of secondary arc current

Application Considerations

- **Turbine-generator considerations**
  - Unsuccessful autoreclose attempt for close-in faults to generating plant may cause accelerated torsional fatigue to generator-turbine shaft
- **Coordination with fast valving**
  - Coordinating autoreclose with fast valving schemes help maintain system stability
- **Synchronism check settings**
  - limit settings for slip, voltage magnitude difference, and phase angle difference

Application Considerations

- **Multiple-breaker line terminations**
  - Benefits of reclosing relay per line versus breaker
- **Leader-follower autoreclosing**
  - Most used scheme - Considerations for autoreclose supervision, line terminating in multiple breakers are provided
- **Weak or strong source to test the line**
  - Weaker terminal is typically used to minimize stress on equipment, system etc.
  - Stronger source may be used on lines with tapped load

Application Considerations

- **Series compensated lines**
  - System stability, single-phase/three-phase tripping, communication means, short-circuit levels etc. determine autoreclosing philosophy

- **Transformer considerations**
  - Lines terminating in a transformer and transformers tapped on lines are discussed

- **Interfacing with automatic sectionalizing schemes**
  - Coordination between source breaker autoreclosing and sectionalizing scheme is necessary for proper operation

New Technologies & Special Considerations

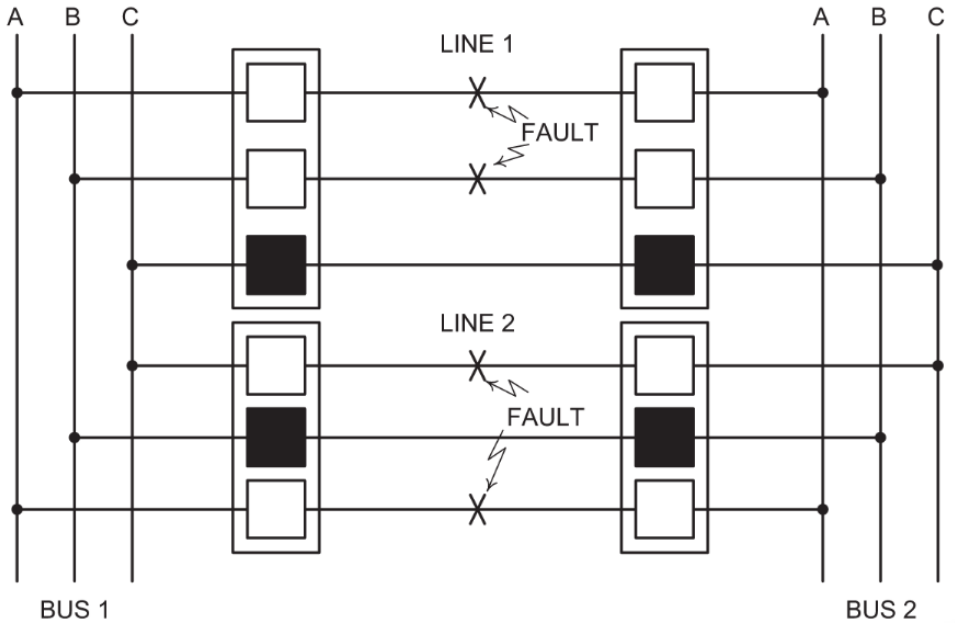
New Technologies

- **Ethernet based applications**
  - With the advent of IEC 61850, DNP, IEEE Std 1851, etc., Ethernet based protection & control schemes are gaining attention
  - Allows to change logic in real time based on equipment/system conditions
- **Application of point-on-wave**
  - Recloses each pole at optimum moment to reduce overvoltages/stress to equipment
- **Application of pulse closing**
  - Applied in medium voltage systems, produces a minor loop or pulse of current which is analyzed to determine if fault is present
  - Initiated by a rapid, single-phase, controlled POW close-open operation resulting in pulse of current for duration between ¼ and ½ cycle

Special Considerations

Fault location supervision for mixed/hybrid lines

- Autoreclosing is desirable for temporary faults on overhead section of a hybrid line
- Synchronized phasor measurements and travelling wave-based fault location algorithms could be used to detect if a fault is on overhead or underground section



Multi-phase tripping & autoreclosing

- Having two healthy phases in-service during a disturbance may help maintain system stability
- Goal is to keep as many phases as possible connected to maximize system stability

Summary

Summary

- The revised C37.104 guide
  - Describes benefits of automatic reclosing
  - Includes application considerations for proper coordination with other system controls
  - Presents generally accepted industry practices for application of autoreclosing on both distribution and transmission lines
  - Contains a number of figures, tables, and graphs which aid in the understanding of autoreclosing concepts